EXHIBIT D.5.1
WIND TURBINE SPECIFICATIONS

1.0 REQUIRED FEATURES

1.1 All available OEM turbine upgrade and enhancement options available at the time of TSA execution, including but not limited to software, controller parameters, blade attachments, and power curve enhancements.

1.2 "Cold weather package" that allows for turbine operation to at least minus 30 degrees C (-30°C).

1.3 Lockable tower door keyed alike.

1.4 No exterior light fixtures attached to the tower.

1.5 Internal tower lighting located at each tower deck, along the full length of the tower ladder, within the nacelle and at control cabinet locations to fully illuminate the work areas.

1.6 240 VAC electrical receptacles at all tower deck locations, NEMA 10-30 or 14-50 size.

1.7 120 VAC and 240 VAC electrical receptacles in the nacelle and tower entry platform areas.

1.8 Steel cable safety system centrally located on the tower ladder and secured at base and tensioned.

1.9 Electric motor platform lift (3S or equivalent) if available for specific turbine model, otherwise Power Climber 100 percent load relief continuous loop type climb assist with remote control for start, stop, load control and integrated power supply. All equipment shall be permanently attached to the turbine or ladder system except for a remote control device.

1.10 Tool/equipment hoist located at the yaw deck or within the nacelle and extends its reach to the tower entry deck level or exterior ground level.

1.11 Capacitors shall be used in place of batteries in electric motor pitch systems if available from the turbine manufacturer.

1.12 Blades shall have an external nameplate or markings along with hub slot position number.

1.13 Main bearings supplied by SKF, Timken or FAG/Schaeffler, or Owner approved equivalent.

1.14 Gearbox meeting IEC 61400-4 CDV international standard "Design Requirements for Wind Turbine Gearboxes".

1.15 Gearbox oil water content less than 200 ppm and particulate to the ISO 4406 cleanliness standard of -/16-13 at Wind Turbine final factory acceptance test.

1.16 Hydraulic oil water content less than 500 ppm and required to meet cleanliness levels of 21/19/16 according to ISO 4406: 1999 at Wind Turbine final factory acceptance test.

1.17 Gearbox oil filtration package with a 10-micron full flow filter and 3-micron kidney loop filter or equivalent to meet the cleanliness standards in the preceding section.

1.18 Gearbox oil particle counter manufactured by Poseidon Systems capable of being integrated into the SCADA or CBM system.

1.19 Ceramic generator bearings or grounding system that eliminates all static discharge through the bearings.

1.20 A backup mechanical anemometer with an ultrasonic anemometer as the primary supply. The controls shall be wired to transfer upon failure of the ultrasonic unit.

1.21 One mechanical wind vane resistant to ice fall damage.

1.22 Liquid applied blade leading edge erosion protection. Erosion protection shall be from blade mid-point to the blade tip and shall be applied at a thickness recommended by the coating manufacturer, but not less than 12 mils. The coating shall fully protect the pre-coated blade surface for a minimum of 10 years.

1.23 Transformer – Up tower transformer room shall have arc flash and access protection systems. The access door shall have a hasp and lock keyed alike.

1.24 Zero voltage ride-through

1.25 Reactive power capability when tower is off-line (if available from manufacturer)

1.26 Central Automatic Greasing System

(1) Pre-filled greasing units shall be provided that are permanently, externally, and non-intrusively mounted at the locations listed below in each turbine. The units shall be pump driven and capable of mixing the grease to prevent separation. Units in the hub shall be supplied with spring loaded pump units.

(a) Main bearings (3pt mount turbines only)

(b) Generator bearings

(c) Yaw bearing (if greasing is required)

(d) Yaw gear teeth

(e) Pitch bearing

(f) Pitch gear teeth (if applicable)

(2) Each pump shall provide at minimum a pump failure alarm signal capable of being integrated into the SCADA or CBM system.

(3) All lines and cables shall be oil and grease resistant, cold weather flexible, and routed in existing trays or routes that are clear of all walkways and maintenance points.

(4) Grease catch units shall be provided that are permanently, externally, and non-intrusively mounted on the yaw gear in each turbine.

1.27 Condition Based Monitoring System

(1) Hardware

Sensors shall be permanently, externally, and non-intrusively mounted at the following locations. Additional sensors shall be added as needed to provide a comprehensive diagnostic system. A list with exact sensor locations and sensor specifications shall be provided.

(a) Main Bearing – 1 sensor per bearing.

(b) Gearbox – 3 sensors to detect low, intermediate, and high-speed shafts.

(c) Generator – 2 sensors, drive, and non-drive end bearings.

(d) Drive train – 1 Proximity Induction sensor.

(e) The data collection / signal processing unit shall be installed in a serviceable location in the nacelle and connected via the turbine network to the server.

(f) All cables shall be oil and grease resistant, cold weather flexible, and routed in existing trays, conduit or routes.

(2) Server and Software

A rack mounted server shall be installed in the turbine SCADA rack and meet the following requirements:

(a) Windows Server latest version with SQL database.

(b) Ability to communicate with other servers and backup devices via Modbus TCP, OPC-UA, PI, or similar protocols.

(c) Capable of quickly running the provided analysis software.

(d) Capable of storing 1 year of data.

(e) Unrestricted access to Windows Server and SQL server without user count-based licensing.

(f) Any connection to Company network shall be in accordance with Company Cybersecurity standards and policies.

(g) Analysis software shall be pre-installed and meet the following requirements:

1. Unrestricted access and configuration ability without individual user licensing. This shall include the ability to modify, add, and delete all configurable points such as gearbox models, bearing frequencies, sensor parameters, alarm points, etc.

2. High level display to view all turbines' status on 1 page.

3. Detailed display for each turbine.

4. Record data at least once per day.

5. Access to all raw data.

(3) Monitoring Service

(a) 2 years of full fault monitoring, analysis, and evaluation service shall be included, and all materials covered under the turbine warranty. Provide next business day alarm response reports with specific fault locations and recommended corrective actions. Phone and/or webcast conferences shall be used to discuss results when necessary, during normal business hours, Monday through Friday excluding Holidays. Conferences shall not be expected to last more than 15 minutes each.

(b) Provide a monthly summary report detailing activity for the previous month.

(c) All data obtained shall remain the property of Owner.

2.0 MINIMUM SCADA FEATURES

2.1 Owner Enterprise network standards require a dedicated room for network, security, and IT hardware. Space shall meet the requirements of Owner Technology Communications Construction Requirements & Infrastructure Standards. If possible, Wind turbine operation and control shall be from a central server located in the O&M building SCADA room. Server rack shall be an open-air rack. A remote operator station shall be connected and placed in the O&M building break room. Network architecture or servers that require dongle authentication shall be capable of authentication within a virtual session such as RDP or VNC.

2.2 Main control server with 3-year minimum data storage and access to live and historical data via OPC-UA protocol or equivalent and ODBC.

2.3 Remote access server

2.4 Single display with 4 channel KVM switch

2.5 GPS time sync server

2.6 Backup UPS power supply

2.7 All applicable software licenses without individual user licensing

2.8 Unrestricted access and configuration ability to all hardware, servers, software and control logic. This shall include the ability to modify, add, and delete all configurable points.

2.9 Automatic backup software

2.10 Software to modify SCADA screens.

2.11 Microsoft Office Excel on each server with lifetime license

2.12 Substation monitoring screen(s) integrated with the SCADA system. Display all alarms and statuses along with a 1-line overview of breaker position and MWs, volts, amps, and VARs at all metered locations. For clarification purposes, metered locations include relays or other equipment that monitors the listed values.

2.13 Remote alarm notification capable of sending emails.

2.14 Power curtailment at the substation level over full output range.

2.15 Analog signal capability with local/remote selection for power and voltage/VAR control.

2.16 Actual possible power signal the value of which is based on actual on-site wind speed.

2.17 Power ramp rate control

2.18 Substation level VAR control

2.19 Substation level voltage control

2.20 Substation capacitor and reactor bank control

2.21 Frequency control

2.22 Line droop compensation

2.23 Aviation light monitoring and failure alarm integrated with the SCADA.

2.24 Met mast interface module

3.0 SUBMITTALS

3.1 All Turbine Supplier commissioning and testing procedures, checklists, inspection reports, punch lists and other records related to wind turbine assembly, inspection, commissioning and testing shall be submitted to Owner.

3.2 Turbine Supplier, Contractor and Subcontractor(s) commissioning and testing procedures, checklists, inspection reports, punch lists and other records related to wind turbine assembly, inspection, commissioning and testing shall be submitted to Owner.

3.3 Subcomponent list of drivetrain major components down to bearing level, which includes, but not limited to, make, model, and serial number of each subcomponent.

3.4 Recommended spare parts list.

3.5 One full electronic detailed and comprehensive set of turbine electrical schematics, control system wiring diagrams, mechanical (fluids) schematics, and turbine operation and maintenance manual.

3.6 One full electronic detailed and comprehensive set of schematic diagrams of SCADA electrical schematics and control wiring diagrams.

3.7 Complete turbine alarm list and associated warning and alarm limit set points.

3.8 As-built data report for all serialized components including, but not limited to, make, model, part number, serial number.

3.9 Gearbox oil analysis report including ISO particle counts, contaminates, additives and water levels which includes the limits of values acceptable to the turbine and oil manufacturers shall be submitted to Owner.

3.10 Pictures of all punch list items before and after the repairs are completed shall be submitted to Owner.

3.11 The final resolution of all component damage noted on component inspection receiving reports shall be documented. This documentation shall include, but not be limited to, inspection reports, repair procedures and before and after pictures.

3.12 See Exhibit A.5 (*Submittal Requirements*) for additional information.

Exhibit D.5.2
PV Module Technical Requirements and Guidelines

Rev A, 20240428

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1. Introduction

Xcel Energy ("Company") has set minimum requirements for the technical specifications, third-party diligence, and quality assurance for PV modules ("modules") used in Company acquired projects. These requirements are designed to help assure the long-term safety, reliability, and performance of the acquired assets.

These requirements are split into the following sections:

- **Products and manufacturing** – minimum standards for modules and their manufacturing.
- **Technical diligence** – module testing and manufacturing audits required in advance of production.
- **Quality assurance** – module inspection, testing and manufacturing oversight required during and after production.

These requirements apply to **crystalline silicon-based modules** with the following variations:

- PERC, TOPCon and HJT technology-based modules.
- Mono- and bi-facial modules.
- Full size and cut-cell modules.

Thin film-based modules (First Solar only) are not considered. If First Solar thin-film modules are proposed, please consult with your representative at Company for the appropriate requirements and guidelines.

Why is quality important?

These requirements and guidelines apply the basic principle that long-term module reliability and performance is determined by the quality of materials used in a module and the quality of the manufacturing process used to assemble them.

2. Purpose

The purpose of this document is for Company to set clear minimum requirements for the technical specifications, diligence, and quality assurance of modules, but also to provide project developers with sufficient information to plan for and satisfy these requirements.

This document is not intended to provide the details, direction or guidance for specific module types or manufacturers. As a project progresses the specifics should be defined together with Company, the selected manufacturer(s) and independent engineers or advisers hired to work on behalf of Company.

These requirements will impact your supply agreement(s) for modules!

It should be noted that to meet the requirements and guidelines described in this document, appropriate terms and language must be included in your module supply agreement for the project. It is therefore important that a supply agreement is not concluded before negotiating the terms necessary to meet these requirements. Company can assist in this process.

3. Product Requirements

3. 1. Performance and Physical Specifications

- The manufacturer must produce and deliver modules that are compliant with the manufacturers' technical datasheet. The datasheet should form the contractually binding technical specification for the module. Any reference on the datasheet to specifications being subject to unilateral change by the manufacturer should be removed prior to the datasheet being incorporated into a supply agreement.
- The technical datasheet must include all specifications that impact the factory-gate performance of the module under real field conditions including at minimum:
    - Nominal output power, efficiency, current and voltage under standard test conditions.
    - Nominal output power tolerance (positive only).
    - Output power under varying irradiance and operating temperatures.
    - Temperature coefficients.
    - Bifacial coefficient for bifacial modules together with any applicable (+/-) tolerance.
    - Maximum system voltage
- The technical datasheet should also specify the major physical attributes of the module:
    - Size and weight.
    - Cable lengths, connector type and specification (including connector compatibility).
    - Maximum certified and warranted wind and snow loads.
    - Maximum certified and warranted hail resistance (by maximum hail size).
- It must be ensured that the design loads (wind, snow, and hail) for any project are not expected to exceed the certified and warranted loads of the module (after applying a minimum 1.75x safety factor and considering the exact module mounting configuration to be used). Results of physical load tests conducted out on the exact same module type and construction should be obtained to verify that these requirements can be met without any module damage or power loss. The total physical deflection of the module while under test may not exceed 1 inch (25mm). A mounting compatibility letter should also be obtained from the manufacturer confirming that the modules are certified and warranted when installed and operated according to the above.
- A third party validated .PAN file must be provided for the module type(s) being sourced. This file must have been generated based on testing modules with the same or similar bill of materials ("BOM") that will be used in the project (at minimum the type of cell and glass used in the test modules must be the same as those in the modules delivered to the project).

- A third-party PAN file test report must be obtained from the manufacturer. The testing should have been conducted by a reputable, independent testing agency. The third-party reported PAN file values should match those in the PAN file provided by the manufacturer.
- Modules shall be IEC or UL 61215 certified up to a hail size of **25mm** [for Module use in low hail risk regions], **45mm** [for Module use in medium hail risk regions] and/or **55mm** [for Module use in high hail risk regions].
- Ultra-large format Modules are not approved by the Company. The Company considers Modules to be ultra-large format if they are wider than 1.2m or heavier than 34kg.

3. 2. Material Specifications

- The materials used to assemble the modules (BOM) must be declared in advance by the manufacturer and be described in all unique combinations the manufacturer intends to use them (especially if multiple material combinations may be used for the same module type).
- The modules should be manufactured using only the declared BOM combinations. The declared BOM combinations should include the front superstrate, rear substrate, encapsulant, solar cells, solar cell interconnect ribbons, soldering flux, junction box, junction box pottant, bypass diode, cables and connectors, frame, and frame sealant. Each material should include the supplier's name, the material type, a unique part or material identifier and the physical origin of the material.
- Evidence to validate that the module type and the declared BOM combination meet the certification requirements described in Section 3.3 must be provided. This is validated by accessing copies of the Certificates as well as the Constructional Data Forms (CDFs) produced by the certifying agencies.
- It is recommended that the manufacturer provide a Material Safety Data Sheet (MSDS) for the modules as well as toxicity test reports per the Federal TCLP and/or California Title 22 TTLS/STLC.
- The valid installation, operating and maintenance manual for the modules must be incorporated and referenced in the supply contract. The manual should be reviewed to ensure that no inadvertent loss of warranty coverage will occur due to the manner of install, operation, and maintenance (O&M) deployed in the field.
- Each module should be permanently labeled with a unique ID number to ensure traceability and identification of the module throughout its' operational life.

3. 3. Certification Requirements

The following certification requirements apply:

Standard	Title	Application
Modules		
UL 61215:Ed.2-2021	PV Module Design Qualification and Type Approval	North America
UL 61730:Ed.2-2022	PV Module Safety Qualification	North America
IEC 61701:2020	Salt Mist Corrosion Testing	Marine/coastal applications only *
IEC 60068-2-68	Environmental Testing – Dust and Sand	Desert applications only
IEC 62716:2013	Ammonia corrosion testing	Agricultural applications only
IEC 62979:2017	Bypass Diode Thermal Runaway Test (I & V based @90°C)	High temperature, hard-shaded applications only
IEC 63126:2020 MQT 18	Bypass Diode Thermal Test (1.4 x I_{sc}, temp. levels 1 and 2)	High temperature, hard-shaded applications only

Module Packaging		
IEC 62759:2022	Transportation Testing (for the module packaging)	Global
Factories		
ISO 9001:2015	Quality Management System	Global
ISO 14001:2015	Environmental Management System	Global
ISO 45001:2018	Occupational Health & Safety Management System	Global

* Junction box and connectors must be marine grade

3. 4. Warranty Requirements

- The modules should be provided with a product workmanship warranty with a term of at least 10 years and a power warranty that has a term of at least 25 years with a maximum allowable power loss of 0.5% per year (after year 1).
- Warranties should include a typical serial defect clause requiring all modules to be repaired or replaced within or beyond the warranty period if more than a reasonable percentage (maximum 10%) of modules across a project are known to be defective.
- For bifacial modules, it is recommended that the power warranty covers power degradation for both the front and rear side of the modules.

3. 5. Preventing Forced Labor

- The manufacturer should have a code of conduct (or similar policy) that commits the manufacturer to avoid the use of forced labor conditions at their manufacturing facilities as well as their equipment, material, and component suppliers, including but not limited to the silicon supply chain including wafers, ingots, and polysilicon.
- The manufacturer should have a robust supply chain documentation program providing traceability of materials including but not limited to the silicon supply chain including wafers, ingots, and polysilicon, and that such documentation is freely available to review and includes relevant information including manufacturer name, location/date of production, and unique and traceable lot identification.

4. Manufacturing Requirements

4. 1. Build Requirements

The following requirements apply to the general condition of modules supplied:

- Modules should be new build only and subject to the quality assurance requirements described in this standard; modules from stock or inventory that cannot be subject to these standards should not be accepted.
- Modules that have been repaired or re-worked should not be accepted unless such repair or rework takes place prior to module lamination. Rework specifically prohibited includes removal or replacement of cells, encapsulants, back-sheets, glass, frames, or junction box after initial assembly.

4. 2. Factory Requirements

The following requirements apply to the locations used to manufacture the modules being supplied:

- The specific factories and workshops to be used to manufacture the modules should be declared in advance by the manufacturer. The same factories and workshops must be subject to the technical diligence and quality assurance requirements of this document.
- Any change to the factories and workshops to be used – either in advance of or during production - may only take place if the new factory and/or workshops meet the technical diligence and quality assurance requirements of this document.

4. 3. Process Requirements

The following basic requirements apply to the process used to manufacture the modules being supplied:

- All finished modules must be subject to electro-luminescence (EL) imaging as part of outgoing quality control (OQC) at the factory. Company may require the EL images for all modules be stored in a database of quality related data for the project (each image identified by module serial number).
- EL imaging should be undertaken with sufficient resolution to reliably identify and display any latent cell defects that may impact module performance and reliability. Digital files must be retained with sufficient image resolution. Images must be clearly focused and sufficiently contrasted.
- All finished modules must be subject to flash testing using an AAA-grade flash tester which is regularly calibrated, including use of modules which have been calibrated within the past twelve (12) months by an internationally recognized calibration laboratory.
- Flash testing should be conducted at standard test conditions (STC) according to IEC 61215-2:2016 MQT 6.1 and for bifacial modules according to IEC 60904-1 and -2 (Measurement of Current-Voltage Characterization of Bifacial Photovoltaic Devices). The flash test data recorded for each Module should be made available. Company may require that the flash data for all modules be stored in a database of quality related data for the project.
- The flash test data shall include the module serial number and associated STC power (W), open circuit voltage (V), short circuit current (A), maximum power voltage (V), maximum power current (A). The

flash test data for the front-side of all modules should be provided by the manufacturer. Rear-side flash test data for bifacial modules must be provided in addition and include a statistically significant sample of rear-side flash test data that is representative of the modules shipped to the project. The measurement accuracy of each flash tested parameter should also be stated.

⚠ **Any modules which do not meet the electrical or mechanical specifications according to the technical datasheet should be rejected.**

5. Technical Diligence Requirements

5. 1. Extended Durability Testing

- The module type with the declared BOM combination(s) should have been (or be) subject to Extended Durability Testing at an independent ISO 17025 accredited test lab specialized in testing PV modules. The testing protocol must be CSA/ANSI C450 compliant.
- Modules may be tested by labs such as PVEL through the latest revision of their Product Qualification Program (PQP) or an equivalent extended duration testing program at another recognized third-party test lab. The manufacturing of the modules used for testing should be witnessed by an independent third party to verify the materials used match the declared BOM combination(s).
- Test results may be available off-the-shelf in which case new testing is not required. Repeat testing is also not required if the same module type and declared BOM combination(s) are used in multiple projects.
- Power degradation after any individual extended durability test sequence shall not exceed 5% (applied to both front and back of the modules for bifacial modules) and there should be no drop in the bifacial coefficient (for bifacial modules). Power degradation after LID testing should not exceed 1% and power degradation after LeTID testing should not exceed 2%.

5. 2. Pre-Production Factory Audit

A pre-production audit of the factories and individual workshop(s) to be used to produce modules should be conducted. The following requirements apply to the pre-production audit:

- The audit should assess the manufacturers' compliance to their own manufacturing standards and assess any potential risk to the safety, reliability, and performance of the modules.
- An independent Factory Auditor specialized in conducting such compliance and risk assessment audits should be used. The Auditor must be sponsored by the buyer and not by the manufacturer.
- The module type to be purchased, or equivalent, should be in production at the time of the audit to ensure relevance of the results.
- The audit shall assess the following areas within module production:
    - Factory management including supply chain, production and quality
    - Conformance to module certification
    - Incoming inspection, storage, use and control of materials (IQC)
    - All module assembly processes, related process controls (IPQC) and documentation

- All module inspection and testing processes, controls, and documentation (OQC)
- Equipment maintenance and calibration; finished goods management

⚠ **The manufacturer is expected to correct any audit non-compliances or mitigate any identified risks before production start for the project, adopt such improvements in the standard operating procedure for the project and maintain them during production for the project.**

6. Quality Assurance Requirements

6. 1. Production Supervision

The production of modules should be overseen in-factory by independent Factory Inspectors hired to work on behalf of the buyer. The goal of production supervision is to ensure that the manufacturer maintains compliance to their standard operating procedures and any improvements made as a result of the pre-production factory audit. It must take place during production of modules for buyer. The basic production supervision requirements are as follows:

- Production supervision should oversee incoming quality controls, conformance to the declared BOM combination(s), equipment maintenance and calibration, all major material, process, production and environmental controls and all the major outgoing quality controls such as flash testing, EL imaging, visual inspection, and safety testing.
- The Factory Inspector must have the right to enter the factory at any time during production of modules for the buyer. Production supervision should be conducted at a frequency no less than one randomly selected instance per week covering approximately **20%** of the total volume of product.

⚠ **Any significant deviations in processes or procedures, which may negatively impact the safety, reliability, and performance of the modules, must be identified, and promptly reported. The manufacturer should then quarantine any potentially non-compliant modules for further inspection. Any defective modules must be replaced before shipment.**

6. 2. Pre-Shipment Inspection

Modules should be sampled from finished goods at the factory and subject to repeat inspection by the Factory Inspector. The goal of pre-shipment inspection is to identify overt or latent defects in the finished modules before shipment. The pre-shipment inspection requirements are as follows:

- Production should be split into reasonably sized batches in the range of **5 to 10 MW** (depending on the size of the project) to ensure inspections are conducted at least weekly during production.
- Modules for re-inspection should be sampled according to ISO 2859 rules by applying the following:
  - General Inspection Level **II**
  - AQL for critical defects of **0** (defects impacting safety)
  - AQL for major defects of **0.65** (defects impacting performance and reliability)
  - AQL for minor defects of **4.0** (defects not impacting safety, performance, or reliability)
- The AQLs should be applied in aggregate to all methods of inspection.

- The sampled modules should be subject to repeat visual inspection, EL-imaging, and flash testing under the direct supervision of the Factory Inspector. The inspection criteria to be applied should be defined upfront in the supply contract. The front- and rear-side of bifacial modules should be repeat flash tested for all modules subject to pre-shipment inspection.
- All modules from the batch being inspected should be held at the factory and not be released for shipment until the pre-shipment inspection has been completed and shown to meet the AQL standards defined above.

⚠ **Any defects which are identified that negatively impact the safety, reliability, and performance of the modules, must be promptly reported. The manufacturer should replace any modules identified with critical or major defects before shipment of the batch.**

6. 3. Pre-Shipment Testing

Modules should also be sampled from production for pre-shipment testing at the manufacturers' in-house lab. They should be sampled from the same batches of modules subject to pre-shipment inspection. The *minimum* testing requirements are as follows:

- The modules should undergo the following tests:
  - Wet leakage testing
  - Gel content testing
  - Peel strength testing
  - Light Induced Degradation (LID)
  - Potential Induced Degradation (PID)
- A minimum of two (2) modules should be subject to each test. Each test should be conducted on samples extracted from each batch produced. The tests should be repeated for each BOM combination used in a batch of modules.
- Power degradation after the LID and PID tests shall not exceed 1 and 5% respectively (applied to both front and back of the modules for bifacial modules) and there should be no drop in the bifacial coefficient (for bifacial modules). The manufacturers standard acceptance criteria should be applied to the wet leakage, gel content and peel strength tests.

⚠ **Power loss that exceeds 5%, or other obvious defects, should immediately be reported. The manufacturer should identify root-cause, the population of modules affected by the defect(s) and provide suitable remedy.**

6. 4. Container Loading and Packaging Inspection

Container loading and packaging inspection should be conducted to make sure that packaged modules are in good, acceptable condition ready for international shipment from the factory.

6. 5. Post-Shipment Inspection

Modules should be sampled from containers delivered to the buyer and subject to repeat inspection by a Field Inspector. The goal of post-shipment inspection is to identify overt or latent defects in the finished modules after shipment, especially those that may have been caused or become apparent during shipping. The post-shipment inspection requirements are as follows:

- Modules for post-shipment inspection should be sampled from individual containers according to ISO 2859 rules by applying the following:
  - General Inspection Level **S4**
  - AQL for critical defects of **0** (defects impacting safety)
  - AQL for major defects of **1.5** (defects impacting performance and reliability)
  - AQL for minor defects of **4.0** (defects not impacting safety, performance, or reliability)
- The AQLs should be applied in aggregate to all methods of inspection.
- The sampled modules should be subject to repeat visual inspection and EL-imaging. The same inspection criteria applied at the factory should be used.
- The buyer may elect not to inspect modules from every container, but a **minimum of 20%** of all containers should be inspected.

EXHIBIT D.5.3
BESS Technology Specifications

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This Exhibit forms an integral part of the Agreement for the [Project Name] ("Project") between NSP (the "Buyer") and [Supplier Name] (the "Supplier"). The parties intend that terms appearing in initial capital letters, but not otherwise defined herein, have the meaning defined elsewhere in the Agreement. The following sections provide project specific technical specifications and standards for the Project.

1.0 Battery System Specifications

Batteries

Requirement	Description
General	• Buyer shall reserve the right to attend factory witness testing of battery cell and module manufacturing, and/or Battery Energy Storage System ("BESS") balance of system integration and testing. • Batteries will have completed independently verified cycle testing prior to consideration, with guaranteed use- and calendar-based degradation comparable (within 10 %) to its peer Tier 1 battery suppliers. • Replacement modules of the same design or of a directly compatible design will be readily available from the manufacturer for a minimum of 10 years such that rack modifications are not required.

Thermal Management

Requirement	Description
General	• Thermal management systems shall be provided to ensure equipment OEMs recommended environmental conditions are met at all times. • Thermal management equipment and systems shall be heavy-duty, industrial grade design, construction, and installation designed to provide a minimum 20-year life expectancy. • Design calculations shall include air conditioning load calculations, heating load calculations, ventilation calculations, psychometric calculations, and pressure drop calculations.
Design Requirements	• Cooling equipment capacity shall be sized based on end-of-life battery state-of-health (70-80%) heat dissipation coincident with maximum design ambient heat gain. • ASHRAE design requirements as specified in Project Requirements. • High efficiency filtration (80%, MERV 13) is required for HVAC units that provide a mixture of outside air and return air. For 100% recirculation style units only 30%, MERV 7 filters may be provided. • Open loop HVAC systems should be designed to operate in economizer (free cooling) mode whenever outdoor air temperature is within specified supply air temperature range. • Filter banks shall have differential pressure transmitters to monitor filter loading. • Heating calculations shall include a minimum 10% margin on capacity. Cooling calculations shall include a minimum 15% margin on sensible and latent capacity. • Thermal management equipment shall be arranged to provide for maximum efficiency of operation and to provide easy access for performing routine maintenance.

	• System design shall be headered such that each HVAC unit is able to provide conditioned air to the entire space within a fire partition. • Equipment redundancy shall be provided such that failure of a single unit does not result in loss of more than 50% cooling capacity. • The thermal management control system shall monitor any equipment failures resulting in loss of cooling capacity. Diminished cooling capacity shall be interlocked with the Site Controller to limit battery charging/discharging rate as necessary to avoid cooling system overload. Battery state of health should be taken into consideration when developing charge/discharge rate limit. • The thermal management systems shall interface with fire protection systems, in accordance with NFPA, other applicable codes, and the results of UL9540A.
Testing	• After installation, HVAC systems, if utilized, shall be functionally tested by NEBB-certified technicians to verify proper operation. • All temperature data points recorded in site data historian shall be functionally verified for proper operation.

Fire Detection and Suppression

Requirement	Description
General	• **Fire and heat detection, suppression, management, isolation, etc. shall be as needed to satisfy UL9540/9540a certification and NFPA 855 approvals.** • Supplier should specify the detection method(s) integrated into the ESS enclosure. This can include but not limited to off-gas, ionizing, laser, aspiration, and/or heat-based detection systems. • System to include all components, connections, programming and equipment to provide a complete, automatic fire protection and detection system including, but not limited to, fire alarm panels / modules, detection devices, annunciation devices, suppression piping and / or agents, as needed. • Supplier is encouraged to provide optional / add-on equipment if available for the given solution. Fire suppression methods that are included or available with the proposed solution (including water-based sprinklers) should be presented with optional pricing made available to the Owner.
Enclosure Fire Rating	1 hour, or per requirements of UL9540/9540, NFPA 855 or other.
Deflagration Panels	Deflagration systems shall be based on gas production demonstrated in UL9540A and shall meet either NFPA 68 or 69 and other local code as necessary. If NFPA 68 is used, then calculations demonstrating that the venting is adequate for the gas production measured in the UL9540A shall be provided. Similarly, if active venting per NFPA 69 is used, calculations demonstrating that the LEL is maintained below 25% shall be provided.
Heat / Smoke / Gas Detectors	Heat, smoke, and gas detectors shall be part of fire detection system to meet NFPA 72 and other applicable codes and standards.
Active Venting	Integrated into controls (with a gas specific sensor), with option to be activated manually, and with provision for natural ventilation when power is not available.
Clean Agent	Clean Agent systems, if utilized, shall be in accordance with the prevailing versions of NFPA 2001 and NFPA 855. A clean agent fire suppression system shall be FM200, NOVEC 1230, or equal. CO_2 systems are not acceptable.

Fire Detection and Alarm	• Each independent fire detection system shall be designed to provide fire detection and annunciation in each of the areas affected. • Each detection control panel shall continuously monitor its detection systems for fire or trouble condition and activate the appropriate fire or trouble alarm(s). These detection and alarm functions shall be performed independently of any other plant equipment or facility. • Fire detection or fire alarms at any enclosed BESS system shall shut down the affected BESS equipment, and the PCS unit associated with the affected BESS in order to prevent possible supply of additional energy to the affected unit. • All fire system wiring installed above ground shall be installed in ridged metallic conduit. All fire system wiring shall be installed in dedicated raceways, above and below ground.
Addressable Fire Alarm Panels / Modules	• Local control Fire Alarm Control Panels ("FACP") shall be furnished and installed to monitor distributed sensors and control units. • Main fire panel shall remotely transmit and annunciate all Fire, Trouble and Supervisory conditions to the facility EMS, and to a manned location as designated by Owner if required per applicable codes, standards, and local requirements • Each local control panel shall be named and identifiable and be capable of operation as a stand-alone system with its own internal secondary power via battery backup. Each remote device shall be addressable and communicate to local panel via signaling line circuit ("SLC") circuit. • The addressable local control panel(s) shall monitor and annunciate; alarms, trouble, and supervisory signals for each of the fire protection and detection devices and systems. The panel shall be of modular construction and in accessible location. • The panel for each clean agent or pre-action sprinkler system shall also continuously monitor the systems to ensure the availability and proper operation of each system and to annunciate distinctly supervisory and trouble alarms. • Provision shall be made for extending the FACP to all planned BESS augmentation units over the lifetime of the project. • Each local control panel shall continuously monitor its associated fire suppression and/or detection system(s) for fire alarms, supervisory signals, and circuit trouble signals. • Auxiliary shutdown functions, where required, shall be designed, furnished, and installed, as a minimum, per applicable codes, standards, and local requirements. • Fire protection wiring shall include surge protection, per applicable codes, standards, and local requirements. • Upon receipt of any fire alarm signal the local alarm panel shall activate interior and exterior fire alarm horns/strobes.

Testing	• Vendor's representative shall coordinate and provide final testing for fire and suppression systems. Vendor shall be responsible for costs associated with initial testing as well as costs to correct deficiencies and retest. • Vendor shall notify Owner and Authorities Having Jurisdiction ("AHJ") (if required) at least 5 days in advance of beginning of each test. Final acceptance shall be determined by the Owner. • Documentation of the inspections and tests shall be maintained by Vendor and furnished to Owner. Defects found by these inspections and tests shall be re-inspected following repair by the same method and technique which originally identified the defect. Acceptance shall be based on identical acceptance criteria. Inspection and tests shall be in accordance with NFPA as a minimum. All parties necessary to sign off on test shall be obtained.

2.0 Balance of System Specifications

PCS

	Description
General	• The PCS shall consist of inverters, medium voltage transformers, protection, thermal management and isolation devices, close-coupled as a complete skid-mounted assembly. A combination PCS/MVT skid is also acceptable. • Contractor shall ensure the inverter and transformer design are adequate to perform the intended functions specified herein, and with utility operating requirements. • Contractor shall ensure the selected inverter is optimized to maximize power and energy generation for the environmental design requirements specified in this document. • Active power (MWac) output shall be rated in accordance with the following design conditions: o For ambient temperatures up to the Annual Cooling Design Temperature and DC voltages within the manufacturer-rated range, the inverters shall be capable of continuous operation without any de-rate in output. The manufacturer shall provide the de-rating curves for both temperature and voltage outside of the specified range. o For ambient temperatures up to the Extreme Annual Dry Bulb Temperature and DC voltages within the manufacturer-rated range, the inverters shall be capable of continuous operation at unity power factor at the POI without any de-rate in output. A gradual de-rate will be experienced in case the conditions exceed its rated DC voltage or the Annual Cooling Design Temperature. The manufacturer shall provide the de-rating curves for both temperature and voltage. • Apparent power (MVA) output shall be rated in accordance with the following design condition: o For ambient temperatures up to the Extreme Annual Dry Bulb Temperature and DC voltages within the manufacturer-rated range, inverters shall be capable of operating continuously at reactive power requirements specified in the project technical description can be maintained at the project POI, without any de-rate in output power (this may be a greater or lesser than the power factor stated, in order to overcome losses and effect in medium voltage equipment and connecting lines. • Current harmonics: in accordance with IEEE 1547, <5% THD as a system. • Inverter shall be designed to Applicable Codes, including IEEE-1547 and FCC Part 15 Sub Part B Class A standards.

	• Inverters shall be programmed in accordance with the requirements of the Interconnection Agreement and within the permissible range of the inverter control parameters. • Inverter shall have voltage and frequency ride-through capabilities that are in accordance with IEEE 1547, NERC Reliability Guidelines on BPS Connected Inverter-Based Resources (2018), 1547SA and in accordance with the requirements of the Interconnection Agreement. • Provisions to be provided to allow for unit removal and replacement. • Inverter shall be compatible with the SCADA System described below and should have the option for remote control of real power output. This shall be accomplished by Owner's EMS through an on-site RTU. • Buyer shall reserve the right to attend factory witness testing of PCS. • Inverter shall provide ground alarms for the ungrounded DC bus and collection system. • Inverter shall provide DC disconnecting means required in NEC code.

Medium Voltage Transformers (MVT)

	Description
General	The Contractor will be responsible for the design, engineering, procurement, shipping, and installation of the MV Power transformers. Bidders shall ensure the PCS proposed is compatible with transformer specifications outlined below: • Primary voltage: as shown in project description, with elbow arrestors. • Secondary Voltage: The secondary voltage shall match the output AC voltage of the inverter(s). • High efficiency: 99% minimum at 100% of nameplate MVA rating. • Oil level, pressure/vacuum and oil temperature gauges. Oil level gauge, oil temperature and pressure instruments to be furnished with alarm contacts. • Compartmental pad-mount design, dead front, loop feed conforming to IEEE/ANSI C57.12 series standards for the type (liquid-filled or dry-type) and MVA rating of the transformer proposed. • The design shall provide minimum clear working space in front of transformers conforming to NEC Table 110-34(A). The equipment shall also conform to all applicable standards of ANSI, NEMA, UL, NEC, NESC, and IEEE C57.12. • Design life: 25 years from Substantial Completion • Ratings: 4.8 MVA or as required by the inverter configuration to equal or exceed the MVA rating of the inverter(s). Impedance 7% plus/minus 7.5% (or as required by the inverter manufacturer), cooling class = ONAN/KNAN or better.

	• BIL ratings: Transformer 150 kV primary (high side) accessories and bushings, 30 kV secondary (low side). High side winding shall have a BIL of 150 kV. • Temperature ratings: 65 °C average winding rise/65°C top oil rise/85°C hot spot rise. Peaking transformers may be utilized. • Ambient temperatures: Maximum 50°C, average 40°C, minimum -12°C or according to the Site. • Aluminum or copper windings. • Hook stick, load-break disconnect switch externally accessible. • Overcurrent protection via current limiting fuse/expulsion fuse pair (or VFI) and current limiting fuse up to 2.75MVA, and via provided switchgear for > 2.75 MVA. • Insulating fluid shall contain less than 1 PPM PCBs and the nameplate shall be marked accordingly. Secondary containment of transformer insulating fluid, if required, shall be provided and designed in compliance with all applicable environmental regulations. • Buyer shall reserve the right to attend factory witness testing of MV step-up transformers. • Electrical cable to the substation shall be run in an underground system. Features shall include: • Drain valve with oil and dissolved gas analysis sampling provisions on the exterior of the transformer main tank. • Automatic pressure-relief valve. • The Facility layout design to accommodate the installation of oil containment, ensuring that the insulating oil (mineral, vegetable or other) within the units doesn't leave the site. Oil containment is required for this site and should be communicated and documented in the site SPCC Plan. • Oil level sight glass. • NEMA 2-hole ground terminal pads. • Surge arrestors shall be provided on one set of medium voltage bushings of the last transformer of each radial feeder and shall be connected by a copper ground bus to ground pads at base level. Surge arrestor class shall be dictated by the short-circuit study. Alternatively, surge protectors may be installed on the first and last transformers on the chain. • Steel divider between MV and LV compartments. • The secondary compartment door catches shall be caught at the three points and the handle shall be capable of being padlocked, and a penta-head bolt shall provide additional means of securing the door. The penta-head bolt shall be spring loaded to hold it in a retracted position unless threaded into the nut. The handle shall not be capable of being padlocked

	until the penta-head bolt is seated. The high voltage compartment shall be secured in place with one or more captive penta-head bolts. • Both compartment doors shall be equipped with stops for holding each door in a minimum 90° position. The stops shall be captive to prevent loss of the device and for convenience. Each door shall include a factory-installed flexible ground conductor connecting the door to the compartment. • Lifting lugs and corresponding lifting plan.

EMS Specifications

	Description
General	The EMS controller (computer and software) shall manage system operation and shall include, but not be limited to, the following: • Inverter controller interface • Rack and Master BMS • Controls for battery charging, discharging, balancing and SOC • System-level and component-specific alarms for out of specification conditions and malfunctions • Instantaneous and automated remote-shutdown capability • Communication interface with customer systems • HMI terminals in the battery enclosure and in the control room Management of any software versions • Cyber Security management of the BESS • Data exchange with the BESS The EMS shall provide remote and autonomous operation of the BESS. The EMS shall also be able to dispatch the BESS using a remote SCADA system, ISO and Owner dispatch. All modes of operation and setpoints shall be remotely adjustable. The controls shall: • Allow changes in settings and control modes • Have access to all the system data (at least, but not limited to, the system's instantaneous power, current, voltage, etc.) and have ability to dispatch real and reactive power commands The EMS must provide the following data acquisition capabilities: • Ability to remotely access and monitor the data as well as have a minimum storage capacity for the duration of the proposed warranty (minimum) up to the life of the Project • Data points shall have the ability be recorded at a maximum of 1-second intervals, if required by warranty the sampling interval shall

<table>
<tr><td></td><td>be reduced, with the capability for instantaneous collection and visualization of data</td></tr>
<tr><td>EMS Backup Power/UPS</td><td>Minimum 2-hour duration, based on connected equipment load, or longer as required for safety systems by the locality AHJ.</td></tr>
<tr><td>Site Controller</td><td>• The Site Controller shall coordinate with the PCS and BMS to perform the functions specified in this section.
• The Site Controller shall interface with the Owner’s remote dispatch system. Contractor may coordinate revisions to the Owner’s existing SCADA remote interface gateway or may furnish a new gateway. The remote interface gateway shall be a SEL RTAC 3530 or equal. Communication with Owner’s remote dispatch system shall utilize DNP3 Ethernet protocol.
• The Site Controller shall aggregate the operation of the individual Power Conversion Systems such that the BESS may be remotely operated as if a single asset. The Site Controller shall include a data historian function able to store a minimum of 1 month of required BESS operating data locally. The Site Controller shall include a local HMI station and shall be located in a separate control enclosure.
The Site Controller hardware and application software shall be of proven technology and shall have been installed in similar applications for a minimum of one year.</td></tr>
<tr><td>SCADA Interface</td><td>• The BESS control system mode selection shall be possible locally via the site controller HMI or via the remote SCADA system.
• The Site Controller shall locally store the data points listed at a collection interval of once per second.
• The Site Controller shall aggregate the rack / string level data listed, and transmit to the remote dispatch system via SCADA RTAC at a two second intervals.
• The SCADA interface must be fully capable of communicating with all required Owner energy management systems.
• Full list of required SCADA control points and data points to be transmitted from/to remote dispatch to be provided during detailed design. At a minimum this interface should be planned to collect and concentrate all points necessary for O&M purposes such as transformer alarms.
• The BMS shall monitor the data points listed in the following table at an interval of at least once per second.
• The BMS shall monitor all data points required and store data a minimum of 24 hours of before and after any ESS alarm or event (or longer, if required by the battery OEM) for root cause / postmortem analysis and warranty claim disposition. Data points shall also be transmitted to the Site Controller / Historian for long term data storage and retrieval.
<table><tr><td rowspan="2">System Level</td><td>Fault Status</td></tr><tr><td>Alarm Status</td></tr></table></td></tr>
</table>

		System Current
		System Voltage
	Power Conversion System / ESS Sub-arrays or blocks	Fault Status, from each PCS and DC:DC Converter
		Alarm Status, from each PCS and DC:DC Converter
		System Current, from each PCS and DC:DC Converter
		System Voltage, from each PCS and DC:DC Converter

Telecommunications Network

	Description
General	• Contractor's scope includes design, equipment, and installation of a complete local area network to allow monitoring of the BESS facility from a remote location. • System and subsystems provided by Contractor shall be designed and configured for unmanned operation of the facility. • Communication connections to the remote System Operator shall connect serially via DNP 3.0 or Modbus TCP, via a plant SEL RTAC or similar. • Network media internal to equipment enclosures may be implemented via CAT 6 cables for distances up to 300 feet. • Terminations to equipment shall be made using prefabricated patch cables. CAT 6 cables exiting equipment shall first terminate on a patch panel. • Fiber installed underground on the premises shall be installed in conduit. Bends and risers extending above ground shall be metallic conduit. • Fiber installed in buildings or enclosures may be routed in inner-duct supported in instrument and control trays. • Network communications leaving the project site shall be implemented using fiber optic cable installed in HDPE or similar underground conduit following regional practices for telecommunications installations.

5.0 Codes and Standards

Contractor shall design and manufacture all equipment in accordance with ANSI standards. All documents, drawings, instruction manuals and test certificates shall use English units.

All Work connected with the supply of the Project shall be in accordance with the requirements of the appropriate ANSI/IEEE standards and including any Applicable Law and a proposed Change In Law of any Governmental Authority, which proposal was in existence prior to the Execution Date but not yet made effective; but only if such proposal has been published to the public by the applicable Governmental Authority and only if those proposals are required by the applicable Governmental Authority prior to issuance of relevant permits. Where no ANSI/IEEE standard exists, the Project shall comply with recognized standards (including IEC) and design practices. If the requirements of this specification conflict with any of the above standards or practices, this specification shall apply. Based on the location of the Project, Contractor is required to determine any applicable codes pertaining to the applicable Governmental Authority.

The revisions of the following standards adopted or proposed and published to the public as of Execution Date, and required by the applicable Governmental Authority prior to issuance of relevant permits, shall apply, as applicable. All of the below will be followed based on adopted versions at Execution Date:

General

ANSI C2	National Electrical Safety Code
NFPA 1	Fire Code
IFC	International Fire Code 2021 (chapters 9 and 12)
IEEE 979	Guide for Substation Fire Protection
NFPA 13	Standard for the Installation of Sprinkler Systems
NFPA 70, CSA C22.1	US National Electrical Code Canadian Electric Code
NFPA 72	National Fire Alarm and Signaling Code
IBC	International Building Code
ASHRAE 169	Climatic Data for Building Design Standards
ASCE 7	Minimum Design Loads
ACI 318	Building Code Requirements for Structural Concrete
ANSI S1.4-2014	Specification for Sound Level Meters

BESS

UL/CAN 9540	Standard for Energy Storage Systems and Equipment, 2020 Edition
UL 9540 A	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 4th Edition

UL 1642	Standard for Lithium Batteries (Cells)
UL 1741, C22.2 No. 107.1	Standard for Inverters, Converters, Controllers and Interconnection System Equipment
IEEE 1547-2018	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
NFPA 855	Standard for the Installation of Stationary Energy Storage Systems (2020 Edition)
UL/CAN 1973	Battery system
UL 50E, CAN/CSA-C22.2 No. 60529	ESS Enclosure

Arc Flash

IEEE 1584-2018	AC Arc Flash Calculations Guide for Performing Arc-Flash Hazard Calculations
IEEE ESW 2007/NFPA 70E 2015 Annex D	DC Arc Flash Calculations IEEE Electrical Safety Workshop 2007 Maximum Power Transfer Method (implemented in software in SKM Powertools or ETAP) or another approved method

Transformers and Reactors

IEEE C57	Standards Collection: Distribution, Power, and Regulating Transformers. Note: The items below are all included where applicable by the reference above. [NEMA TR-1 Transformers, Regulators, and Reactors]
ASTM D6871	Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus
ASTM D3487	Standard Specification for Mineral Insulating Oil used in Electrical Apparatus.

Arrestors

IEEE C62	Standards Collection: Guides for Surge Protection
IEEE C62.11	IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits
NEMA LA 1	Surge Arresters
IEEE C37	Standards Collection: Circuit Breakers, Switchgear, Relays, Substations, and Fuses

IEEE C37.37	IEEE Standard Loading Guide for AC High Voltage Switches (in excess of 1000 Volts)
NEMA SG 6	Fuses
IEEE C37.46	Specifications for Power Fuses and Fuse Disconnection Switches
IEEE C37.47	Specifications for Distribution Fuse Disconnecting Switches
NEMA FU 1	Low Voltage Cartridge Fuses
IEEE C62	Standards Collection: Guides for Surge Protection
IEEE C62.11	IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits
NEMA LA 1	Surge Arresters
IEEE C37	Standards Collection: Circuit Breakers, Switchgear, Relays, Substations, and Fuses
IEEE C37.37	IEEE Standard Loading Guide for AC High Voltage Switches (in excess of 1000 Volts)
NEMA SG 6	Fuses
IEEE C37.46	Specifications for Power Fuses and Fuse Disconnection Switches
IEEE C37.47	Specifications for Distribution Fuse Disconnecting Switches
NEMA FU 1	Low Voltage Cartridge Fuses

Protection

IEEE C37.91	IEEE Guide for Protecting Power Transformers
IEEE C37.99	Guide for Protection of Shunt Power Capacitors
IEEE C37.90	IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.90.1	IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
IEEE C37.234	Guide for Protective Relay Applications to Power System Buses
IEEE 242	Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
IEEE 141	Recommended Practice for Electric Power Distribution for Industrial Plants
IEC 255-5	Electric Relays. Part 5: Insulation Tests for Electric Relays

IEC 255-22	Electric Relays. Part 22: Electrical Disturbance Tests for Measuring Relays and Protection Equipment
NERC Reliability Standards	PRC-002-2, PRC-019-2, PRC-023-2, PRC-024-2, PRC-025-2, PRC-026-1, PRC-027-1

Control Equipment

ANSI/IPC D30OG	Printed Board Dimensions and Tolerances
ANSI/IPC A610B	Acceptability of Printed Boards

Instrument Transformers

IEEE C57.13	IEEE Standard Requirements for Instrument Transformers
IEEE C57.13.2	IEEE Standard Conformance Test Procedures for Instrument Transformers

Harmonics

IEEE 1547	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE 519	Standard for Harmonic Control in Electric Power Systems
IEEE 80	Guide for Safety in AC Substation Grounding
IEEE 693	IEEE Recommended Practice for Seismic Design of Substations

Grounding

IEEE 80	Guide for Safety in AC Substation Grounding

Seismic

IEEE 693	IEEE Recommended Practice for Seismic Design of Substations.

Xcel Energy®		ESP 7.970W01
Energy Supply Projects Policy System		**Revision: 1.8**
TITLE:	Drawing Deliverable Standards (PSCo, NSP, SPS)	Page 1 of 15

Revision History

Date	Revision Number	Change
12-16-08	1.0	New
7-10-09	1.1	Updated Logo
7-15-10	1.2	Review for 2010 Audit, Minor formatting changes made
10-11-11	1.3	Modified for capital project requirements
3-27-14	1.4	- Revised for 2014 Audit. Minor formatting changes made. - Revised Section 1.2 – Added O&M Manual Deliverable information.
8-18-15	1.5	Consolidated Regional Drawing Deliverable Standard WI's into one applicable for all Operating Regions.
6.15-18	1.6	Triannual Review complete, removed names replaced with titles, cleaned up regional references, linked TitleBlock standards,
5-8-20	1.7	Revised to include 3D Model naming guidelines and ProjectWise storage.
11-24-21	1.8	Changed font style to Consolas in 1.7.4.1 and 1.7.4.2

1.0 REQUIREMENTS

1.1 GENERAL

The Energy Supply Projects (ESP) of Xcel Energy are responsible for all engineering and design standards, including drawings and specifications for Xcel Energy Power Generation facilities throughout company's three operating regions as defined below:

1.1.1 **Public Service Company of Colorado (PSCo) Operating region**: PSCo Power Plants located within the state of Colorado.

1.1.2 **Northern States Power (NSP) Operating region:** NSP Power Plants located within the states of Minnesota, Wisconsin, South Dakota, and North Dakota.

1.1.3 **Southwestern Public Service Company (SPS) Operating region:** SPS Power Plants located in the states of Texas and New Mexico.

The EDDS department within ESP is responsible for setting and administering drawings and applicable standards for company owned generation facilities.

1.2 Existing Drawing Checkout: - The Architectural/Engineering (A/E) firm or Vendor shall request from EDDS department for drawings needed for revision or changes using the Engineering Document Services (EDS) Media Request form or via e-mail to the respective EDS e-mail address (reference EEC 7.955 Engineering Document Management). The A/E firm or Vendor shall clearly list the drawings needed and any CAD files required. EDDS will perform a verification of the information on the Media Request form including status of the requested drawing (CAD or Manual) and check out the electronic drawing file(s) to the A/E firm or Vendor submitted request. If the drawing is manual, ESP Design Staff will convert the drawing to electronic format (CAD/Tif Hybrid) for modification. Once EDS has completed checkout, a copy of the requested CAD files shall be placed on the project SharePoint Site and released for work to the A/E firm or Vendor. It is the A/E firm's or Vendor's responsibility to maintain the integrity and availability of the original electronic drawing file(s).

A redraw of an existing drawing shall only be done if it is faster to recreate the drawing versus making the revisions. If a drawing is redrawn, ALL information including existing revisions shall be carried over to the new file. This shall include, at minimum, latest three revision triangles as shown on the existing drawing as well as revision descriptions in the revision block. Both the existing original drawing and the new redrawn original drawing shall be sent to EDDS.

1.3 **New Drawing Request/Checkout:** - A/E firm or Vendor shall contact (ESP) EDDS department for all new drawing requests. EDDS shall provide the following to the A/E firm or Vendor for all new drawings, according to the Regional Plant Operating requirements:

- Unique drawing numbers
- Standard Drawing Borders

Please contact the Regional Design Supervisors within EDDS for the Standard Drawing Border requirements.

In order to assign the new drawing number, Design Supervisors will need the A/E firm or Vendor to provide the following information:

- Plant
- Unit Number
- Plant System and Sub-system Code where applicable
- Discipline Category
- Drawing Type

Once the above information is received, Design Supervisors will coordinate with EDS to assign all new drawing numbers and properly reserve the drawing numbers in ProjectWise. Once reserved, Design supervisors shall communicate all new drawing numbers to the A/E firm or vendor via e-mail through the respective EDS e-mail address. All new drawings shall be identified as new.

1.4 **DRAWING ISSUE PACKAGE:**

When outside A/E firms or Vendors issue drawings, the following items shall constitute an issued package and shall not be considered complete unless all the deliverables are included, without exception. At time of issue, EDS shall be included on all transmittals and shall receive all items included in a drawing issue package. All drawing issue packages shall consist of the following items:

PDF of each Manual – One (1) unsecured pdf copy of all equipment manuals such as original equipment manufacturer (OEM), operation & maintenance, instruction and/or installation manuals. All final manuals must conform to, and include, all construction As-Built information.

Hard Copy of each Manual – Company's plant or project manager will identify quantity of required equipment manuals such as OEM operation & maintenance, instruction and/or installation manuals. All final manuals must include all construction As-Built information.

Hard Copy Original Record Drawings: (See Requirements per Operating Region

below)

- **PSCo Operating Region:** – No hard copy record drawing required, PDF/electronic are sufficient.

- **NSP Operating Region:** – No hard copy record drawing required, PDF/electronic are sufficient.

- **SPS Operating Region:** – No hard copy record drawing required, PDF/electronic are sufficient.

Image File of Drawing Being Issued – An unsecured image files of the official record drawings shall be provided. The image files shall be created electronically from the native file, if possible. The image files shall be the correct drawing size, clear, legible, and shall not be rotated and match the Hard Copy Original Record Drawing exactly. If this image files are not of the acceptable quality, the drawing issue package will be rejected and the A/E firm or Vendor will be asked to provide quality images with no additional charge to Xcel Energy. This requirement shall also apply include record drawings submitted for As-Built. Record drawings issued for construction shall be stamped by a licensed Professional Engineer (P.E.) in the state where the project is located. See 1.5 DRAWING FILE FORMATS for acceptable image file format.

CAD File – CAD files, shall be provided on all initial drawing issues for checking of drawing compliance, as well as final "As-Built" issues. Each CAD drawing shall have its own separate CAD Drawing file and shall not combine multiple drawings into one CAD drawing File. Each CAD file(s) shall correspond to the current revision of the official record drawing being issued. If the drawing requires further revisions, a copy of the current CAD file of the final/latest drawing shall be made and provided. See **"FORMATS"** for acceptable CAD file formats. Below are the requirements that must be included in the CAD file:

- ✓ Initials/Signatures typed in the titleblock of all originators, checkers, approvals, etc. This includes the titleblock as well as the revision block.
- ✓ Detailed descriptive reason of the revision in the revision block.
- ✓ All CAD drawings shall be drawn in such a manner that distances, radiuses, angles, areas & volumes may be correctly derived from the CAD file entities or elements & dimensions. If the production drawing (Cad file) is developed from 3D Model file(s), the 3D Model should be transmitted with the production drawing for use in verifying the above listed measurements.
- ✓ Clouds shall be placed around all the areas where the drawing was changed.
- ✓ Provided CAD files shall include all associated CAD references and 3D models used in the design. All Cad files and 3D models shall be in native format used to

create the drawing files. Acceptable formats are MicroStation (.dgn) and AutoCAD (.dwg).

- ✓ All seed files associated with 3D model and CAD files.
- ✓ All CAD drawings shall include any customized fonts, plot styles, pen tables and any other custom drawing features used on the provided drawings.

If drawings, 3D models, seed files, or borders are referenced in the working drawing, then they should be submitted with all associated CAD files used in the design and shall be included as part of the Drawing Issue Package. Drawings should not be bound prior to submitting to Xcel Energy.

Transmittal – One (1) transmittal shall be provided for every drawing issue. The transmittal shall include the following:

- ✓ If applicable, the name of the Project Manager for the project which the drawings are being issued.
- ✓ The A/E firm or Vendor's Project Manager
- ✓ The A/E firm or Vendor's Administrative person who created the transmittal
- ✓ EDDS personnel
- ✓ The recipients of the drawings being issued
- ✓ Clear and concise description of what the drawings are being issued for (Preliminary, Bid Issue, Construction, Not to be Used for Construction, Demolition Sketch, As-Built), any specific instructions, or information pertinent to the drawings
- ✓ All drawings shall be collated to match the transmittal, if issued hard copy.

Design Services Review of AE Firm or Vendor Submitted Drawings: – Upon transmittal of a drawing package by an A/E firm or Vendor, Design Staff shall review the package for compliance with ESP Design/Drafting standards. This review shall be performed in parallel to any Engineering review of the drawing package. All comments shall be forwarded to the Project Manager or Project Lead to be incorporated along with any Engineering comments and returned to the A/E firm or Vendor for correction and revision.

When all the drawings are agreed upon as complete, and are in As-Built or final status, the "DDI Import Form" (reference Attachment A) for the Xcel specific operating Region shall be completed by the A/E firm or Vendor. This shall be completed at the end of the project or may be deemed necessary by the Project Manager at any time during the project. This information is required so Xcel ESP can easily import drawing information into Xcel Energy's drawing management system. Drawing information entered on the DDI Import Form shall be as descriptive as possible. The A/E firm or Vendor is responsible for adding this information relating to all columns and rows

within the spreadsheet (examples can be provided if requested).

1.5 DRAWING FILE FORMATS:

During the project, PDF image files and/or CAD files may be requested. The following are acceptable electronic files to be delivered to ESP. The A/E firm or Vendor shall inquire of the DS and EDS departments as to current versions being used by ESP. All other formats shall be approved by ESP prior to being used and/or As-Built submitted.

Acceptable CAD File Formats:

DWG – AutoCAD 2018 - all files in Native Format
DGN – Bentley MicroStation V8i - all files in Native Format

Acceptable Image File Formats:

PDF – Adobe Acrobat Format Unsecured, electronically searchable, not a hard copy scanned document)

Acceptable GIS Data File Formats:

Shapefiles/KMZ – All spatial data provided in native GIS file formats in addition to a KMZ file

1.6 FILE NAMING

1.6.1 PSCo File Naming: All new engineering drawings shall be drawn in CAD and shall have a unique PSCo drawing number assigned. EDDS will provide this unique number to the A/E firm or Vendor. All file names shall be identical to the assigned drawing number. The A/E firm or Vendor shall not change or alter any part of the drawing number/file names received from EDDS. No two (2) drawings will be assigned the same PSCo drawing number. The A/E firm or Vendor shall formally request from EDDS these assigned numbers.

1.6.2 NSP File Naming: All new engineering drawings shall be drawn in CAD and shall have a unique NSP drawing number assigned. EDS will provide this unique series number. All file names shall be identical to the assigned drawing number. The A/E firm or Vendor shall not change or alter any part of the drawing number/file names received from EDS. No two (2) drawings will be assigned the same NSP drawing number. The A/E firm or Vendor shall formally request from EDS these assigned series numbers.

1.6.3 **SPS File Naming:** All new engineering drawings shall be drawn in CAD and shall have a unique SPS drawing number assigned. EDDS will provide this unique number. All file names shall be identical to the assigned drawing number. The A/E firm or Vendor shall not change or alter any part of the drawing number/file names received from EDDS. No two (2) drawings will be assigned the same SPS drawing number, even if the drawing prefixes (referring to dwg size) differ. The A/E firm or Vendor shall formally request from EDDS these assigned numbers.

1.6.4 **3D Model File Naming**

1.6.4.1 PSCo

1.6.4.1.1 File name should always begin with MOD followed by the System Number, and then a discipline alpha designator of S, M, or E.

1.6.4.1.2 Example: MODMCANM-01.DGN for a mechanical model for the Air Cooled Condenser System.

- MOD – Designates file type
- MCAN – Designates System/Subsystem
- M – Designates discipline
- 01 – Sequential Number (if necessary)

1.6.4.1.3 Stored in ProjectWise under \PLANT\CO\(PLANT MNEMONIC)\CAD\MODELS folder

1.6.4.2 NSP

1.6.4.2.1 File name should always begin with MOD or PCL, followed by plant three letter mnemonic, three-digit unit code, three letter system code (if applicable), and discipline code followed by sequential model number

1.6.4.2.2 Example: MOD-SHC-100-CCL-E001.DGN

1.6.4.2.3 Stored in ProjectWise under \PLANT\(STATE)\(PLANT MNEMONIC)\CAD\MODELS folder

1.6.4.3 SPS

1.6.4.3.1 File name should always begin with P3D, followed by the two-digit plant code (PP), two-digit unit code (UU), three-digit system code (SSS), discipline/category identifier (M-Mechanical, S-Structural, C-Civil, E-Electrical, EQ-equipment, CCD-Controls), and a sequential model number (XXX).

1.6.4.3.2 Example: P3D-PPUU-SSS-MXXX (P3D-PN00-457-M0001.DGN)

1.6.4.3.3 Stored in ProjectWise under \PLANT\(STATE)\(PLANT MNEMONIC)\CAD\UNIT X\SUPPORT folder

1.6.4.4 KMZ File Naming

1.6.4.4.1 File name should begin with KMZ followed by three letter wind farm mnemonic.

1.6.4.4.2 Example: KMZ-BS1

1.6.4.4.3 Stored in ProjectWise under same folder as regional 3D models

1.6.4.5 Metadata for ProjectWise

1.6.4.5.1 File Name

1.6.4.5.2 MFR Drawing No. (if applicable)

1.6.4.5.3 Rev Date (last date touched by Xcel or received from AE firm)

1.6.4.5.4 File Type

1.6.4.5.5 Drawing Title: System name or description for model

1.7 DRAFTING STANDARDS

1.7.1 Standard Drawing Templates: Drawings created will use standard templates/seed files to setup the drawing. A/E firms or Vendors shall contact the appropriate Regional Supervisors for the standard templates/seed files.

1.7.2 TitleBlock and Revision Attributes: All checked and approved names/initials with complete dates shall be typed on all revisions and titleblocks on the electronic CAD files. A/E firms or Vendors shall contact the appropriate Regional Design Supervisors for the TitleBlock standards.
NSP TitleBlock
PSCO TitleBlock
SPS TitleBlock

1.7.3 Drawing Scale: All drawings shall be drawn full scale in Model space and plotted in Paperspace with the titleblock inserted at a scale of 1:1.

1.7.4 Standard Text Fonts: Only standard AutoCAD and MicroStation text font styles shall be used.

1.7.4.1 AutoCAD standard text shall be text style “ARIAL” except for electrical drawings. Electrical Drawings shall use text Style “CONSOLAS”

1.7.4.2 MicroStation standard text shall be text style “ARIAL” except for electrical drawings. Electrical Drawings shall use text Style “CONSOLAS”

1.7.5 Standard Text Height:

1.7.5.1 PSCo Drawings:

- 3/32” (.100”) shall be the Standard Text Height for PSCo C, D, or E-Size drawings.
- 1/8” (.125”) shall be used for all sub-titles that require Medium-Height Bold Text such as Equipment Specifications or Designations, Titles for Notes and Highlighted Text.
- 5/32” (.150”) – shall be used for all Prominent Titles that require Large-Height Bold Text such as Equipment Titles, Detail Titles, Section Titles, Plan or Elevation View Titles, etc.
- 5/64” (.08”) - shall be used when space limitations on the drawing require deviation from the Standard Text Height. In this case the Standard Text Height for the entire drawing will be .08 consistent throughout the drawing ; subtitles and equipment designations will be .100” and Bold text, Prominent Titles will be .125 and Bold text.
- 5/64” (.08”) shall be the Standard Text Height for PSCo A or B-Size drawings.

1.7.5.2 NSP Drawings:

- 3/32” (.100”) shall be the Standard Text Height for NSP A, B, or C-Size drawings.
- 1/8” (.125”) shall be the Standard Text Height for NSP D or E-Size drawings.
- 5/32” (.150”) – shall be used for all Prominent Titles that require Large-Height Bold Text such as Equipment Titles, Detail Titles, Section Titles, Plan or Elevation View Titles, etc.

1.7.5.3 SPS Drawings:

- 3/32” (.100”) shall be the Standard Text Height for all SPS A, B, C, or D-size drawings.

1.7.6 Drawing Units:

1.7.6.1 AutoCAD drawing units shall be Decimal, Engineering, Architectural, and Fractional. Use the appropriate drawing units for the type of drawing that is being created.

1.7.6.2 All MicroStation CAD files shall have the following working units:
Master Unit = FT, Label = '; Sub-units = IN, Label = ".
Coordinate Readout: Master Units, Accuracy: 0.12
Angles – Format: DD.DDDD, Mode: Conventional, Accuracy: 0.123

1.7.6.3 Land Surveys & Topographic drawings shall have the following Drawing Units:
Master Unit = FT, Label = '; Sub-units = IN, Label = ".
Coordinate Readout: Master Units, Accuracy: 0.12
Angles – Format: DD MM SS, Mode: Bearing, Accuracy: 0

1.7.7 Dimensions:

1.7.7.1 All drawings shall have dimension units shown in feet, inches, and fractions of inches with the exception of civil engineering drawings. Civil engineering drawings shall be dimensioned in feet and hundredths of a foot.

1.7.7.2 Dimensions on drawings shall be associative and shall not be exploded or dropped. Never override the default measurement on a dimension unless it is a hybrid drawing with an image file.

1.7.7.3 Dimension Precision shall be set to 0'-0 1/128" or 0'-0 1/256".

1.7.7.4 Dimension text shall be the same size as all other text on the drawing and shall be configured to plot the same width as all other Standard text on the drawing. (See section 1.7.5 – Standard Text Height).

1.7.7.5 Dimension text shall be placed above the dimension line and centered between the extension lines except when the text will not fit. Then move text to the right or left.

1.7.7.6 Dimension, extension, and leader lines shall not cross each other unless absolutely necessary. A dimension line shall not be broken. Extension lines or leader lines shall not run through a dimension nor

shall they be broken except where they pass through or are adjacent to arrowheads.

1.7.7.7 Sufficient dimensions shall be shown in the view that clearly define the size, shape, and position of the component. Dimensions shall be given as to minimize the need to calculate, scale, or assume any dimension during the construction or fabrication process.

1.7.7.8 Place dimension lines across the top of an object and along the left side. If additional dimensions are required to clearly dimension an object, they can be placed along the bottom and right side of an object.

1.7.8 Sections & Details:

1.7.8.1 PSCo Drawings: Sections and Elevations shall be labeled with Alpha characters. Details shall be labeled with Numeric characters.

1.7.8.2 NSP Drawings: Sections and Elevations shall be labeled with Alpha characters. Details shall be labeled with Numeric characters.

1.7.8.3 SPS Drawings: Sections and Elevations shall be labeled with Numeric characters. Details shall be labeled with Alpha characters.

1.7.9 Drawing Notes:

1.7.9.1 General notes affecting all the sheets per that drawing number shall be placed on the first sheet and always be placed in the upper right hand corner of the drawing. They may serve any of several purposes; it may be a note that would become repetitive if placed at each point of application, a note that applies to the drawing in general, or a lengthy note that would occupy excessive space on the drawing.

1.7.9.2 All notes shall be equally spaced with a space equivalent to the one line of text between each note. Note text shall be indented from the note number.

1.7.9.3 General notes shall be presented in a sequence that corresponds to the construction process.

1.7.9.4 Local notes are placed on the drawing, normally outside the outline of the affected object and as near as practicable to the affected region

of the object. Information presented in these notes normally applies to a particular portion of the overall drawing.

1.7.10 North Arrow:

1.7.10.1 North arrows shall always be located in the upper left hand corner of all plan views.

1.7.10.2 The north arrow should never be positioned pointing down.

1.7.11 Symbology:

1.7.11.1 Symbols and nomenclature used to create the drawings shall conform to the existing nomenclature sheets established for that particular plant, or with Xcel Energy's standard symbology sheets.

- Mechanical – Reference Mechanical Symbology & Nomenclature sheets.
- Instrumentation - Reference Instrumentation Symbology & Nomenclature sheets.
- Electrical – Reference Electrical Symbology & Nomenclature sheets.

1.7.12 Drawing Revisions:

1.7.12.1 When revising existing drawings, use existing layers/levels and colors.

1.7.12.2 Revisions shall be made by modifying the latest electronic version of that particular drawing.

1.7.12.3 Drawing revisions shall be clouded, being careful not to cross any text, dimensions, or notes. Clouds will be erased with the next revision, and the new changes will be clouded.

1.7.12.4 All revisions formally transmitted shall be routed and reviewed by appropriate ESP assigned personnel. All drawings formally transmitted "Issued for Comments" shall have an alpha character as a revision. Once all comments have been reviewed, addressed, and incorporated by the proper personnel, the drawings are ready to be

transmitted for "Issued for Construction" and shall have numeric revisions starting with revision 0.

1.7.12.5 When drawings are being "Issued for Construction," all previous preliminary revisions are removed from the revision block and shall only show Revision 0. All "Issued for Construction (IFC)" drawing shall be P. E. certified. If major design changes are made to the IFC drawings, AE firms shall revise recertify the current version of the IFC drawings and submitted to the Company for record, prior to the As-build drawing process.

1.7.12.6 Drawing revisions will be made by adding, deleting, crossing out the information, or by redrawing the drawing. The revision status is identified by a numeric revision number beginning with the number 0 (zero), and used in sequential order. Revisions to drawings shall be consistent with the original workmanship.

1.7.12.7 Once all drawing changes are As-Built and the drawing status is "Issue For Record," the revision block shall have "Issue For Record" typed into the description along with the Project Name, and Project Number. Official P. E. certified record drawings my need to be resubmitted if major design changes are made to the drawings (see section 1.7.12.5. When issuing drawings as "Issue For Record," there shall be no clouds on the drawings; only a revision triangle shall be used to identify the As-Built changes unless clouds are specifically requested. All signatures/initials shall be typed in the electronic CAD file so they may be kept electronically.

ATTACHMENT A

DDI FORM

Xcel Energy®

Energy Supply - Engineering & Construction Dept.

Drawing and Instruction Manual Submittal Form

Plant / Substation / Transmission-Line:
Plant Name Here
City State

Todays Date:

Consultant / Vendor Name & Address:

Consultant / Vendor Project Transmittal #
Xcel Project #
Maximo Work Order #
Submitted Date:

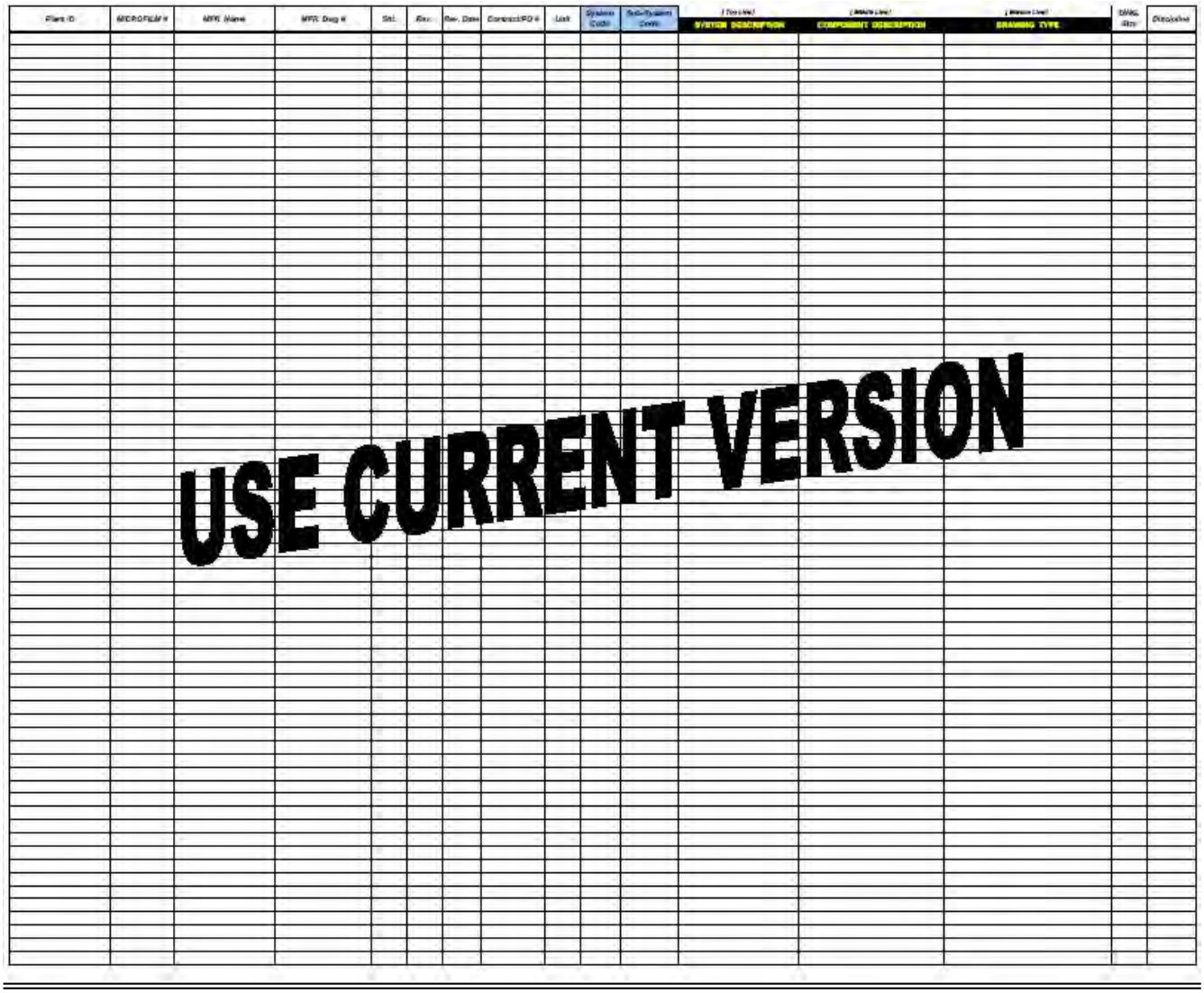
USE CURRENT VERSION

Submitted B Phone #: Mobile #:
Xcel Energy TS Coordnator: Phone #: Mobile #:

Project Title \ Description:

Comments \ Instructions:

Attached Files Created On: Delivery Method: Total Drawings: 0
Total Manuals: 0


USE CURRENT VERSION

Xcel Energy®		EEC 7.970W01
Energy Supply Engineering & Construction Policy System		**Revision: 1.5**
TITLE:	Drawing Deliverable Standards attachment (NSP) Title Block Standard (Referenced from 1.7.2.2)	Page 1 of 6

1.7.2.2 TITLEBLOCKS

Standard title blocks are created and shall be used on all Xcel drawings and shall not be altered. The Design Services Manager shall approve any changes required prior to being used.

Drawing Sizes

NSP, Architectural Engineering firms, or Consultants drawings are considered domestic, and are prefixed by an "N", and an identifier corresponding to the physical size of the end product. This identifier has a direct relationship to better known international standard sizes.
Vendor or Manufactured originated drawings and manuals are prefixed with "**NX**"

(Example) "NX-12345-1-1. Vendor prefixes have no relationship to the drawing size.

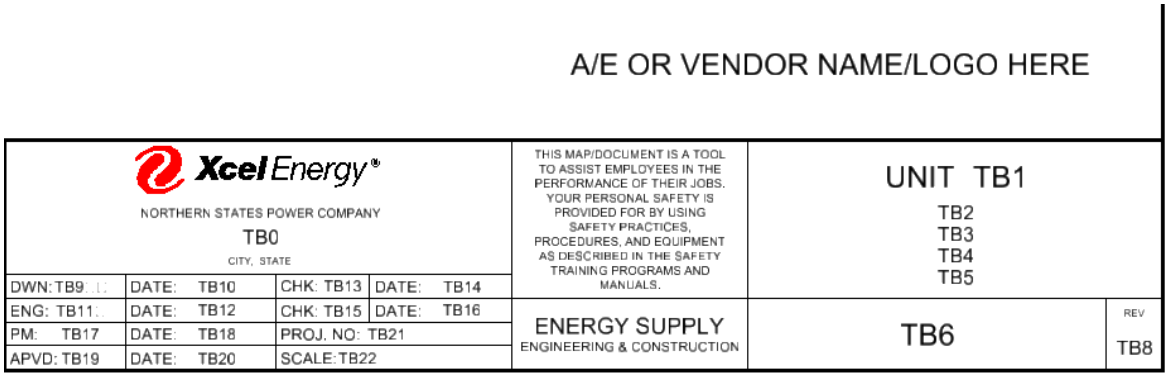
PREFIX		SIZE(Height x Width)	NSP FILE SIZE CODE
NL	=	11 X 8.5	A
ND	=	11 X 17	B
NQ	=	17 X 22	C
NH	=	22 X 34	D (preferred size for P&ID's and Schematics)
NF	=	34 X 44	E (preferred size for GA, Site, UG Utilities)
NX	=	Vendor Only Various	A thru E

* **Obsolete** Industry Standard, do not use with new drawings, except to add to an existing series of that size.

***NE/DE**	=	11 X 34	D
***B**	=	18 X 27	C
***A**	=	24 X 36	E
***E**	=	34 X 48	E
***AA**	=	30 X 42	E

Borders: Shall be scaled to 1:1 only.
Do Not Re-name Borders block name or tag set.
Do Not Reference Borders into drawings.
The **lower left corner** of all drawing borders will reside at **XY="0,0"**, unless a UTM or USDS coordinate system is used.

Key Elements of Drawing Titleblock Information



The following information shall be input into all NSP plant project title blocks. It is the responsibility of the A/E firm's or Vendor's drafter/designer to include the correct information on the title block.

TB0 – PLANT NAME

This is the plant name for which the drawing content is to be located.

TB1 – UNIT#

This is the unit number for which the drawing content is to be located. If the drawing(s) relate to more than one unit, then the number (UNIT 0) zero is entered representing all units.

TB2 – SYSTEM

The system the drawing pertains to shall be input on this line. For example, if the project is for dust suppression, then DUST SUPPRESSION is entered. For a new instrument air compressor, INSTRUMENT AIR is entered.

TB3 – EQUIPMENT DESCRIPTION

The equipment the drawing pertains to shall be input on this line. For example above, for a new instrument air compressor, INSTRUMENT AIR COMPRESSOR would be entered.

TB4 – FURTHER DESCRIPTION

This is used if further equipment description is needed. If this is not needed, then this line is blank.

TB5 – DRAWING TYPE

This is the type of drawing. For example, if it is a wiring or connection diagram, then WIRING DIAGRAM is entered. If it is plan and sections, PLAN & SECTIONS is entered.

TB6 – DRAWING NUMBER

This is the NSP Drawing number. Xcel Energy's EDS Dept. assigns ALL drawing numbers. Architectural Engineers (AE's) to follow **example** "NH-200000-1-1" (First NH-is the prefix for "D" size followed by a 6 digit series number, then followed by a dash and sheet number if needed).

TB8 – CURRENT REVISION NUMBER

This is the current revision of the drawing. Revisions Issued for Comment or Review prior to Revision 0 shall use an alpha character. Drawings Issued for Construction or Record shall be numeric and start with Revison 0.

TB9 – DRAWN BY

This is the initial of the person who created the drawing. Two (2) or three (3) initials are required.

TB10 – DATE DRAWN

This is the date the drawing was created. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB11 – ENGINEERED BY

This is the engineer or designer who designed the system or worked on the drawing. Two (2) or three (3) initials are required.

TB12 – DATE ENGINEERED

This is the date the drawing was engineered or designed. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB13 – DRAFTING CHECKED BY

This is the initials of the person who checked the drafting of the drawing. Two (2) or three (3) initials are required.

TB14 – DATE DRAFTING CHECKED

This is the date the drafting was checked. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB15 – ENGINEERING CHECKED BY

This is the initials of the person who checked the engineering. Two (2) or three (3) initials are required.

TB16 – DATE ENGINEERING CHECKED

This is the date the engineering was checked. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB17 – PROJECT MANAGER (If Applicable)

This is the initials of the person who was the Project Manager. Two (2) or three (3)

initials are required.

TB18 – DATE PROJECT MANAGER (If Applicable)

This is the date the Project Manager approved the drawing. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB19 – DRAWING APPROVED BY

This is the initials of the person who approved the drawing. Two (2) or three (3) initials are required.

TB20 – DATE APPROVED

This is the date of the person who approved the drawing. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB21 – XCEL PROJECT NUMBER

This is the Xcel Energy project number assigned to the NSP project. This field will not change with revisions of the drawing.

TB22 – DRAWING SCALE

This is the scale of the drawing. Drawings that are drawn to scale will indicate the scale, (for example, 3” = 1’-0”). Drawings that are not drawn to scale will indicate the scale as NONE. If multiple scales are used on a drawing, the field shall read AS NOTED.

TB23 – OPERATING COMPANY

This relates to the Minnesota/Wisconsin/South and North Dakota operating regional company; NORTHERN STATES POWER COMPANY.

TB24 – OPERATING STATE

This relates to the City and State location of which the work is being performed at.

PROFESSIONAL ENGINEERS SEAL SECTION
This section is reserved for the Professional Engineer's Seal or Professional Architect's Seal. This section may be turned off by layer/level or the layer/level can be frozen if using a seal in lieu of the Minnesota engineering verbiage or the work takes place in another state.

Key Elements of Drawing (Revision) Block Information

NO.
This is the current revision of the drawing.

REVISION
This is a short, clear, and concise description of the revision. Abbreviations can be used. However, they need to be clear and easily understood. Multiple lines can be used if required. Occasionally, a drawing revision will have a new project number for which the revision was created. The new project number will be incorporated in the revision description. If the drawing was redrawn on CAD then this shall be the first item noted in the revision description.

ZONE
D-size and E-Size drawings are subdivided into zones. The zones are indicated by alphabetical and numerical entries along the border. The revision zone shall be entered with the alphabetical designation first, followed by a "dash", followed by the numerical designation corresponding with the area of the drawing that was revised. If there are multiple areas of the drawing that were revised, this field may be left blank.

DATE
This is the date the drawing was revised. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

BY
This is the initials of who made the revision to the drawing. Two (2) or three (3) initials are required.

CHK
This is the initials of the person who checked the revision to the drawing. Two (2) or three (3) initials are required.

ENG
This is the engineer or designer who designed the system or worked on the drawing revision. This can also be the person who approves the revision. Two (2) or three (3) initials are required.

Xcel Energy®		EEC 7.970W01
Energy Supply Engineering & Construction Policy System		**Revision: 1.5**
TITLE:	Drawing Deliverable Standards attachment (NSP) Title Block Standard (Referenced from 1.7.2.2)	Page 6 of 6

Key Elements of Drawing (Reference) Block Information

DRAWING NUMBER
This is the drawing number of the drawing being referenced.

MANUFACTURER
This is the manufacturer, vendor, or Company name of the drawing being referenced.

DRAWING TITLE
This is the title of the drawing being referenced.

1.0 PURPOSE

- This document is the methodology developed by Xcel Energy to state methods used in calculating equipment ratings.

2.0 APPLICABILITY AND RESPONSIBILITIES

- This policy is applicable to all Xcel Energy Transmission facilities, including transmission lines and substations. A facility rating determined from this policy shall respect the most limiting applicable equipment rating of the individual equipment that comprises that facility.

3.0 APPROVERS

Name	Title
Benson, Ian R	AVP*TRANS STRAT & PLNG
Craig, Byron R	DIRECTOR*SUBS/TRANS ENG & DES
Hargreaves, Roger D	DIRECTOR*SR SYSTEM OPERATIONS

4.0 VERSION HISTORY

Date	Version Number	Change
04/19/2007	1.0	• Was written as rev. 3 in document
07/08/2009	4.0	• Clarify transmission to substation jumper ratings • AAC and ACAR conductor temperature maximum updates
07/01/2010	5.0	• Removed Appendices • Condensed descriptions • Provided clarity to Transmission Line Emergency Ratings
07/01/2011	5.1	• Added CAPX IEEE 738 assumptions • Modified winter season for NSP • Removed solar heat gain assumption for indoor conductors
08/31/2012	6.0	• Revised to Comply with FAC-008 • Replaced Dynamic Line Ratings with Ambient-Adjusted Ratings • Added Operational Guidelines
08/01/2013	6.1	• Removed NSP and SPS Unnecessary Assumptions • Added Current Split Methodology • Minor Rewording for Clarification
11/01/2014	7.0	• Added Strain Bus Rating Cases • Added Conservative Rating • Removed SPP CT Rating Criteria
11/01/2015	8.0	• Relocated Ambient Assumptions to General • Relocated Operational Guidelines to General • Added ACCR Rating • Relocated formulation under Proximity Effect of Conductors section to Supplement • Improved Substation Rating Diagram and removed duplicated information
07/18/2016	9.0	• Fixed Header • Revised Table of Contents • Renamed Section 5 title to avoid using “Purpose” twice • Added Default Ambient Temperature table • Modified ACSS 30 Minute Emergency Rating

9/5/2017	10.0	• Section 6.2 - Clarified split path applicability where there are three or more paths. • Section 6.9 – Added table for altitude adjusted ambient temperatures. • Section 9.2 - Changed NSP Winter Day used for Substation calculations to 90.
12/1/2017	10.1	• Section 4.0 – corrected version number for 9/5/2017 • Section 7.1 – Changed maximum operating temperatures for ACCC and ACCR conductor
9/1/2018	11.0	• Section 6.9 – revised wording to allow for use of altitude adjusted ambient temperatures for all equipment. • Section 7.1 – added ZTACSR conductor to the conductor table.
10/1/2019	12.0	• Section 7.0 – added year to IEEE 738 reference and removed PLS CAD reference. • Section 9.9 – rewrite section on line trap ratings to remove differentiation between epoxy and dry type. • Section 9.16 – added statement to assume 5 amp rating if secondary device rating is unknown.
01/01/2020	13.0	• Table of Contents – renumbered sections in 6.0 General Information • Section 6.3 – removed reference to split path method • Section 6.4 – removed reference to split path method • Section 6.5 – removed – split path method no longer used • Section 9.9 – corrected reference to section 6.8
11/15/2020	14.0	• Section 6.1 – Changed 18 to 24 months

Policy

Xcel Energy

Transmission

Facility Rating Methodology

Version 14.0

November 15, 2020

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5.0 Objective

The objective of this document is to describe the methodologies employed when determining the ratings of transmission facilities on the Xcel Energy Bulk Electric Transmission Systems. The rating methodology includes both Normal and Emergency Ratings. For tables of equipment ratings and example calculations please refer to the Xcel Energy Rating Methodology Supplement. The Supplement is not considered part of the Rating Methodology, because all information pertaining to the method of the calculation is included in the Rating Methodology. The Supplements are in two parts; there are Excel Spreadsheets, which contain tables of calculated ratings, along with word documents explaining the development of the Rating Methodology and example calculations. Xcel Energy is currently developing software to calculate all bulk electric system facility ratings as the primary system. Once the published facility ratings are created with the software, the Supplement tables and example calculations will be secondary.

The Xcel Energy Bulk Electric Transmission Systems includes the combined Northern States Power Company Minnesota and Northern States Power Company Wisconsin (NSPM and NSPW) Transmission System, Public Service Company of Colorado (PSCo) Transmission System, and the Southwestern Public Service (SPS) Transmission Systems.

6.0 General Information

6.1. Updates

Once a revised Facility Rating Methodology has been approved, Xcel Energy will review and update rating information and issue new ratings (if needed) within 24 months.

6.2. Facility Ratings

The Facility Rating shall respect the most limiting applicable Equipment Rating of the individual equipment that comprises that Facility. Ratings of the equipment that comprise the Facility shall be consistent with at least one of the following:

- Ratings provided by equipment manufacturers or obtained from equipment manufacturer specifications such as nameplate rating.
- One or more industry standards developed through an open process such as Institute of Electrical and Electronics Engineers (IEEE) or International Council on Large Electric Systems (CIGRE).
- A practice that has been verified by testing, performance history or engineering analysis. The equipment shall include, but not be limited to, transmission conductors, transformers, relay protective devices, terminal equipment, and series and shunt compensation devices. The rating for each individual piece of equipment considers the (a) Equipment Rating standard(s) used in development of this methodology; (b) Ratings provided by equipment manufacturers or obtained from equipment manufacturer specifications; (c) Ambient conditions (for particular or average conditions or as they vary in real-time); and (d) Operating limitations; in accordance with good utility practice. Operational limitations may result in a de-rating based on good utility practice. The Facility Rating will include both Normal and Emergency Ratings.

Xcel Energy develops a 30-minute emergency facility rating for all Transmission Lines. The emergency rating timeframes available for transformers are published in the Criteria for Power Transformer Loading. IEEE equipment standards have varying time frames for equipment emergency ratings. If the emergency rating developed for a piece of equipment is for a longer duration than that of the reported rating, then the equipment's emergency rating is utilized in determining the Facility's Emergency Rating. For example, it is acceptable to use a switch's four-hour emergency rating

when determining the 30-minute emergency rating of a transmission line. However, when the duration of an emergency rating of a piece of equipment is less than the duration of the rating being reported, then the equipment's normal ratings will be utilized. For example, it is not acceptable to use a switch's 4-hour emergency rating when determining the 8-hour emergency rating for a transformer facility. Instead, the switch's normal continuous rating will be used in determining the 8-hour emergency rating for the transformer facility.

6.3. Transmission Line Facility Ratings

When developing a Transmission Line Facility Rating, the set of equipment that comprises the Facility includes:

a. The transmission line.

b. All of the equipment that is used to operate or disconnect the line and operated as part of the line. This includes, but is not limited to adjacent circuit breakers, disconnect switches, conductor, relays, and meters that as a result of switching could be operated in series with the line.

The Transmission Line Facility Rating is calculated as the minimum rating of the equipment described above.

6.4. Transformer Facility Ratings

When developing a Transformer Facility Rating, the set of equipment that comprises the Facility includes:

a. The transformer equipment.

b. All of the equipment that is used to operate or disconnect the transformer and operated as part of the transformer. This includes, but is not limited to adjacent circuit breakers, disconnect switches, conductor, relays, and meters that as a result of switching could be operated in series with the transformer.

The Transformer Facility Rating is calculated as the minimum rating of the equipment described above.

6.5. SPP, WECC and MRO

Where SPP, WECC and MRO have requirements for facility ratings, the more conservative rating should be used.

6.6. Jointly-Owned Facilities

Equipment ratings on Jointly-Owned facilities will be communicated between the owners. The Jointly-Owned Facility Rating shall equal the most limiting applicable Equipment Rating of the individual piece(s) of equipment that comprise the Jointly-Owned Facility.

In cases where a facility is owned in segments (such as a line terminal being owned by one party and the line conductor by another party), Xcel Energy rates only those portions of the line/terminal/transformer that it owns and provides that information to the owner(s) of the other segment(s). Xcel Energy takes into account rating data provided by the owner(s) of the other segment(s) of the line or transformer, and applies the most limiting rating as the Facility Rating.

6.7. Conservative Ratings

A limited number of pieces of equipment may not have all the information necessary for developing an equipment rating. However, in order to provide system ratings, a conservative rating may be applied to this equipment. The conservative rating for the equipment must be documented in the equipment attributes. Conservative ratings are defined as those, which produce an ampacity on the low end of the possible range for that equipment and are based upon engineering judgment. A Rating Exception Form must be on file for all conservative ratings developed.

6.8. Default Ambient Temperature

Design Ambient Temperature	NSP	PSCo	SPS
Summer Ambient Design Temperature	40 °C 104 °F	40 °C 104 °F	40 °C 104 °F
Winter Ambient Design Temperature (used for winter peaking circuits – these circuits peak at very low temps)	0 °C 32 °F	24 °C 75 °F	27 °C 81 °F

For elevations greater than or equal to 5500 feet in the PSCo region, ambient temperatures in the following table may be used for calculating ampacity of conductors & equipment.

Elevation (feet)	Summer Ambient Design Temperature	Winter Ambient Design Temperature
5500-6000	40°C = 104°F	24°C = 75°F
6001-6500	39°C = 101°F	24°C = 75°F
6501-7000	37°C = 99°F	24°C = 75°F
7001-7500	36°C = 97°F	24°C = 75°F
7501-8000	35°C = 95°F	23°C = 73°F
8001-8500	34°C = 93°F	22°C = 71°F
8501-9000	33°C = 91°F	21°C = 69°F
9001-9500	32°C = 89°F	20°C = 67°F
9501-10000	30°C = 87°F	19°C = 66°F
>10001	29°C = 85°F	18°C = 64°F

The Winter Operating Seasons are:

- December 1 – March 1 for NSPM and NSPW
- November 1 – March 31 for PSCo
- December 1 – March 31 for SPS

Ambient temperature assumptions are used for standards that do not state assumptions.

6.9. Ambient-Adjusted Ratings

Ambient-Adjusted Ratings may be used for real-time operations and near-term planning; however, long-term planning should not rely on Ambient-Adjusted Ratings. Typically, these ratings will rely on weather parameters for ambient temperature but may also be based on wind speed or other ambient-based parameters. In real-time operations, these ambient parameters will be obtained from local meteorological stations or from the weather service in the vicinity of the affected facility. In the case where facilities cross areas of differing weather conditions, the more conservative values will be utilized.

Once the ambient parameters are known, the Ambient-Adjusted Rating for one or more elements of the Facility may be determined by various methods. A few of the common methods are listed but other methods may be used.

- Recalculated Ambient Adjusted Rating tables
- Standalone program utilizing comparable rating calculation
- EMS dynamic rating feature
- Line monitors

If Ambient-Adjusted Ratings are applied to some but not all elements of a Facility, then the normal seasonal ratings are to be used for those elements, which do not have an Ambient-Adjusted Rating when determining the overall Facility rating.

The Ambient-Adjusted Ratings are not to exceed the maximum published facility rating unless a detailed review of relay settings is completed.

6.10. Operational Guidelines

Operating Guidelines may be utilized in cases where recent field verification has identified a potential discrepancy in the assumptions used to determine the rating of an element and the resulting facility de-rate would result in significant risk to the operation of the transmission system. These Operating Guidelines will be temporary, with the assumption that once the resulting remediation project is complete, then the Operating Guideline will be removed and the calculated rating will be implemented.

7.0 Transmission Line Rating Methodology

Xcel Energy uses the IEEE 738-2006 standard for calculating bare overhead conductor ratings. Xcel Energy will use the lesser of the Conductor Maximum Operating Temperature and the Clearance/Hardware thermal limits for conductor operating temperature in the IEEE 738-2006 calculation. The remainder of this section lists assumptions.

7.1. Conductor Maximum Operating Temperature

Xcel Energy adheres to the following table for maximum operating temperature of its conductors. The table shows normal and emergency limits.

Conductor type	Normal (Operating Temperature)	30 Minute Emergency Rating
ACSR*	100 °C	Normal Rating X 110%
ACAR	100 °C	Normal Rating X 110%
AAC	100 °C	Normal Rating X 110%
Cu	95 °C	Normal Rating X 110%
Copper Weld	95 °C	Normal Rating X 110%
ACCC	180 °C	200 °C
ACSS	200 °C	250 °C
SCACAR	100 °C	Normal Rating X 110%
ACCR	210 °C	240 °C
ZTACSR	210 °C	240 °C

*ACSR may be permitted to run at higher temperatures see “General Guidelines when considering up-rating ACSR beyond 100 degrees C” in Rating Methodology Supplement.

7.2. Permitting/Other

Conductor may be rated below the maximum operating temperature listed in section 7.1 for the following reasons:

- Permitted ROW agreements (ex. railroad or waterway crossing).
- Ampacity (ex. NESC clearance limitation).
- EMF calculations.

7.3. Clearance/Hardware Limit

The Clearance/Hardware thermal rating of a transmission line is the maximum temperature, (regardless of the current) which a conductor can attain without violating code-mandated clearances or damaging temperature limited hardware. Short-term limitations due to clearance restrictions will be considered on a case by case basis.

7.4. Remaining Assumptions

Variables	NSP – Assumption	PSCo – Assumption	SPS – Assumption
Conductor properties	Southwire Overhead Conductor Manual 2nd Edition and other various sources	Southwire Overhead Conductor Manual 2nd Edition and other various sources	Southwire Overhead Conductor Manual 2nd Edition and other various sources
Cooling Wind	Maximum of 4 ft/sec @ 90deg to conductor *	Maximum of 4 ft/sec @ 90deg to conductor	Maximum of 6 ft/sec @ 90deg to conductor
Elevation	Actual Elevation (or use default of 1100')	Actual Elevation (or use default of 5200')	Actual Elevation (or use default of 3700')
Emissivity	0.5	0.5	0.5
Absorptivity	0.5	0.5	0.5
Latitude	Actual Latitude (or use default of 43°N)	Actual Latitude (or use default of 40°N)	Actual Latitude (or us default of 35°N)
Summer Day Solar Calc	172	172	172
Winter Day Solar Calc	90	90	90
Time of Day	12:00 PM	12:00 PM	12:00 PM
Orientation of Line	Actual Orientation (or use default of East to West)	East to West	East to West
Atmosphere	Clear	Clear	Clear

***Excludes Buffalo Ridge Wind Rated Lines**

7.5. CAPX Assumptions

CapX2020 is a joint initiative of 11 transmission-owning utilities in Minnesota and the surrounding region to construct region transmission lines. These lines are to be owned jointly as a percentage share in the line. The following assumptions have been agreed upon by the utilities for rating calculations.

Variables	CAPX2020 – Assumption
Conductor properties	Southwire Overhead Conductor Manual 2nd Edition and other various sources
Cooling Wind	2 ft/sec @ 90deg to conductor
Emissivity	0.7
Absorptivity	0.9
Summer Day Solar Calc	July 8th
Winter Day Solar Calc	April 30th
Time of Day	12:00 PM
Orientation of Line	East to West
Atmosphere	Clear

7.6. Buffalo Ridge Wind Rated Lines

A few transmission lines in southwestern Minnesota that provide outlet to wind generators have a rating based on a higher wind speed than is typical throughout the rest of the NSP system. Higher output from the wind generators is only available during the time periods where the wind speed is higher than used in normal transmission line ratings. Thus a higher wind speed was used to rate these lines. The higher wind speed was approved at the time of development by the Design Review Subcommittee of the then existing NERC Reliability Region “Mid-Continent Area Power Pool (MAPP).

The transmission line circuits in the NSP Transmission System with wind ratings are the following 115kV lines: Split Rock-Pipestone and Chanarambie-Pipestone.

7.7. Underground Lines

Underground lines have been and will be rated on an individual basis using engineering analysis. The ratings are developed and based on the soil conditions, conductor type, and installation methods.

Underground cable and the associated terminators are engineered as a system and the ampacity rating is determined for the system. The ampacity rating provided for underground cable and terminator systems shall equal the most limiting element of the system.

8.0 Transmission Line Equipment Rating Methodology

8.1. Line Switches

The line switch ratings are based on the manufacturer's assigned nameplate rating and ACCC designation. The maximum ampacity to operate the switch is based on the IEEE C37.37 loading guide.

8.2. Line Jumpers

The rating methodology for line jumpers is the same as that used as for Xcel Energy's Transmission Lines, which references IEEE STD. 738. The ratings communicated for transmission lines will represent the rating of the line including all jumpers in the line. If the rating of a jumper is the limiting equipment in a line, then the rating of the line will be limited to the jumper rating.

Jumpers between transmission lines and the substation equipment should be rated per the transmission line rating methodology unless restricted by the equipment or hardware that the jumper is attached to.

8.3. Hardware

Hardware for transmission lines is temperature limited and is designed for the operating temperature of the line. The equipment manufacturer provides hardware ratings.

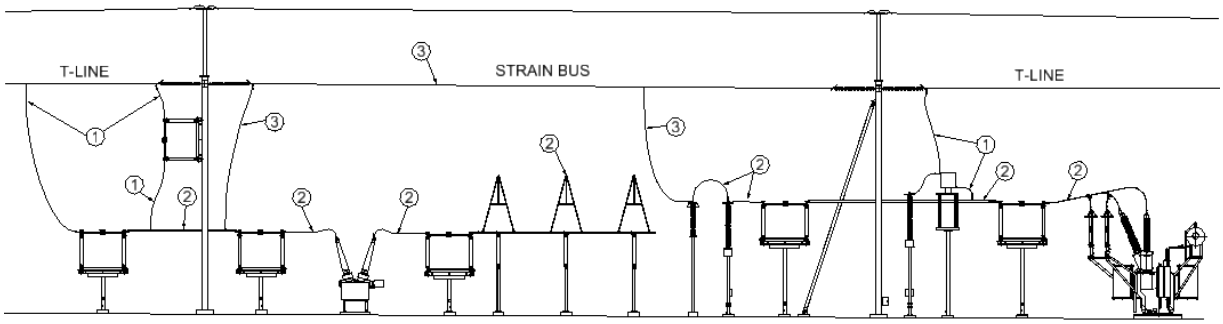
9.0 Transmission Substation Equipment Rating Methodology

Transmission Substations are comprised of several pieces of equipment. Each piece of equipment is identified below along with its ratings methodology.

The following diagrams are to be used as reference for the Substation Equipment Rating Methodology.

9.1. Substation Rating Diagrams

SUBSTATION RATING DIAGRAM



① T-LINE TO SUBSTATION EQUIPMENT - RATE ONLY FLEXIBLE CONDUCTORS PER *TRANSMISSION LINE RATING METHODOLOGY* SECTION;
DERATE CONDUCTORS WHEN CONNECTED DIRECTLY TO:

DEVICES WITH BUSHINGS	-	NORMAL 85°C	EMERGENCY 100°C,
LINE TRAPS	-	NORMAL 135°C	EMERGENCY 135°C,
SWITCHES	-	NORMAL 200°C	EMERGENCY 200°C;

ALL CONDUCTORS' RATINGS SHALL FOLLOW *CONDUCTOR MAXIMUM OPERATING TEMPERATURE* TABLE.

② SUBSTATION OR STRAIN BUS TO TUBE, BUSHING OR EQUIPMENT:

ALL CONDUCTORS	-	NORMAL 85°C	EMERGENCY 100°C

③ REFER TO THE CRITERIA UNDER *BUS CONDUCTORS AND EQUIPMENT JUMPERS* SECTION TO DETERMINE WHETHER SUBSTATION OR TRANSMISSION RATING METHODOLOGY IS APPLICABLE.

9.2. Bus Conductors and Equipment Jumpers

The rating methodology is as outlined in IEEE Standard 605 for tubular bus and IEEE Standard 738 for wire bus and jumpers. Assumptions made for conductors are as follows:

Variables used for Bus Conductor (Tube, Wire & Jumpers) Ampacity Calculations			
Variables	**NSP**	**PSCO**	**SPS**
Summer Ambient Temperature (Deg. C)	See Default Ambient Temperature under General section		
Winter Ambient Temperature (Deg. C)			
Emissivity Outdoors(e)	0.5	0.5	0.5
Emissivity Indoors(e)	0.35	N/A	N/A
Absorptivity (a)	0.5	0.5	0.5
Degrees North Latitude	Actual (or 43)	Actual (or 40)	Actual (or 35)
Time	12	12	12
Atmosphere	Clear	Clear	Clear
Elevation (ft.)	Actual (or 1100)	Actual (or 5900)	Actual (or 3700)
Wind Speed (ft./S) – indoor	0	0	0
Wind Speed (ft./sec.) - enclosed substation	2	2	2
Wind Speed (ft./sec.) - open substation	4	4	6
Wind Direction Factor (deg.)	90	90	90
Azimuth of Conductor (deg.)	90	90	90
Day of the year - Summer (Variable N from IEEE 738)*	172	172	172
Day of the year - Winter (Variable N from IEEE 738)*	90	90	90

*No solar heat gain for indoor conductors

All tube and bare overhead conductors inside the substation will have a normal rating of 85° C and an emergency four hour rating of 100° C. Jumpers between transmission lines and the substation equipment should be rated per the transmission line rating methodology unless restricted by the equipment or hardware that the jumper is attached to. Strain bus consisting of bare overhead conductor may be rated per the Transmission Line Rating Methodology if all of the following are true:

1. The strain bus is considered an extension of the transmission line due to the fact that one end of the strain bus terminates on the transmission line dead-end structure.

2. The strain bus terminations inside the substation are at the same height as or higher than the transmission line termination into the substation or minimum conductor ground clearance greater than 25 feet above surface grade.
3. The strain bus is in an open substation and is expected to be exposed to the same wind speed as the transmission line.
4. Structures and hardware used to install the strain bus are rated for the maximum conductor temperature and tension as outlined by the Transmission Line Rating Methodology.
5. Clearances to ground and other substation equipment can be maintained at maximum sag based on company standards when designed.

Connectors and terminations used on substation conductors will be given a rating equal to that of the conductor to which they are attached. Therefore, the ratings communicated for substation conductors will include the rating of the conductor itself as well as the connectors and terminations connected to it.

9.3. Proximity Effect of Conductors

Conductors spaced less than six inches apart are subject to reductions of capacity due to proximity effect. Xcel Energy has used Engineering Analysis to develop proper ratings for these conductors. Xcel Energy has developed ratings on these conductors based on three sources. “Skin Effect and Proximity Effect in Tubular Conductors”, “Skin Effect in Tubular and Flat Conductors,” and “Bessel Functions for A-C Problems” were used in formulating the calculation.

9.4. Circuit Breakers, Circuit Switchers, and Line-Switchers

The rating methodology is as outlined in ANSI/IEEE C37.010. Breakers pre 1964 utilize a 55 degree C Hot Spot temperature rise and 1964 – present utilize a 65 degree C Hot Spot temperature rise.

9.5. Disconnect Switches

The rating methodology is as outlined in ANSI/IEEE C37.30 and ANSI/IEEE C37.37. Xcel Energy has contacted switch manufacturers about connecting conductors, which will operate at 200ºC to switch pads. The manufacturers have provided test data and

have stated that this will not adversely affect the operation of the switches.

9.6. Transformers

The rating methodology is as outlined in ANSI/IEEE C57.12.00. Loading/rating for loading above transformer nameplate is in accordance with ANSI/IEEE C57.91. The ratings for transformers are determined by the Criteria for Power Transformer Loading.

9.7. Current Transformers (CT's)

The overload capacity of a Current Transformer (CT) is determined by its continuous thermal rating factor (RF). The continuous thermal rating factor is defined in IEEE C37.110. The maximum secondary current of a CT is the rated value of the CT secondary*RF or as limited by other elements in the circuit.

$Itap = Itap_r * RF$

Itap = adjusted rated continuous current of specific CT tap under consideration

$Itap_r$ = rated continuous current of tap

RF = Continuous thermal rating factor (Manufacturer should be consulted for value of continuous current rating factor. Assume 1 if not available.)

9.7.1. Autotransformer neutral winding CTs

CTs on the neutral winding of an autotransformer do not experience the same current flows as the H or X windings. The method of calculating the flow in the common winding uses the following formula:

$$CommonWindingAmps = \frac{TopRating(KVA)}{\sqrt{3} * V_{lowside}(kV)} - \frac{TopRating(KVA)}{\sqrt{3} * V_{highside}(kV)}$$

This formula is applied to find the amperage flowing through the common winding when the transformer is operating at its top rating.

9.8. Power Apparatus Bushings

This section applies to power apparatus bushings as defined by IEEE C57.19.00 that have basic impulse insulation levels of 110 kV and above for use as components of oil-

filled transformers and oil-filled reactors. Bushings supplied with other equipment will be rated using the same methods as the equipment they are attached to.

Bushings can be loaded up to their specified ampere rating. The overload rating of the equipment on which the bushing is installed could be limited by the bushing ampere rating. If the bushing rating cannot be confirmed by name plate or contacting manufacturer, the equipment will be rated at its nameplate rating or calculated rating with no overload. However, if the equipment was specified to have an overload rating, or if the equipment manufacture has documented an overload rating, this overload rating may be used.

9.9. Line Traps

The terms Line Traps and Wave Traps are used interchangeably throughout this document.

The ratings methodology for the wave trap is according to IEEE Std C93.3-2017 The wave trap allows for loadability to change due to ambient temperature and emergency operating conditions. The maximum terminal temperature for a wave trap is 135 degrees C. Altitude derating factors in C93.3-2017 include an elevation adjustment with a lower mean (24 hour) maximum temperature. Line traps should therefore not be ambient adjusted per the elevation table in section 6.8 above.

9.10. Shunt Reactors

The ratings methodology for shunt reactors (oil filled) is according to ANSI/IEEE C57.21. There is no emergency or overload rating for shunt reactors. Shunt reactors may be operated up to 105% of the rated voltage.

9.11. Shunt Capacitors

IEEE standard 18 specifies the technical requirement of individual capacitor units and IEEE 1036 provides the application guidelines for shunt capacitor banks.

9.12. Series Capacitors

All series Capacitors will be rated per manufacture specifications for normal and emergency conditions.

9.13. SVC (Static Var Compensators)

SVC's will be rated per the manufacturers recommended ratings for normal and emergency conditions.

9.14. DC Tie Equipment

DC Tie equipment will be rated per the manufacturers recommended ratings for normal and emergency conditions.

9.15. GIS Equipment

All Gas Insulated Substation (GIS) equipment will be rated per manufacture specifications for normal and emergency conditions.

9.16. Protective Relay & CT Secondary Devices

All secondary devices will be operated within their specified manufacturer limits. If the rating for a secondary device cannot be determined then assume the rating is 5 amps.

Protective relay settings on all equipment in the bulk electric transmission system should be designed and set to permit the emergency loading of equipment per NERC standard PRC-023 where applicable. PRC-023 shall be followed with respect to any settings that may affect facility ratings.

The over-current relays on the transmission lines used for "switch-onto-fault" should be designed and set above the maximum loading of the line.

Over-current relays on transformers should be designed and set above the maximum emergency loading.

Xcel Energy		EPR 5.200
Energy Supply Performance Optimization Policy System		**Revision: 4.3**
TITLE:	Facility Rating and Reporting NERC FAC-008 Compliance Requirements	Page 1 of **4**

1.0 Purpose:

1.1 This policy defines the responsibilities of Performance Optimization to meet certain requirements established by NERC Standard FAC-008. The policy ensures Energy Supply develops and applies a facility rating methodology.

2.0 Applicability:

2.1 This policy applies to all Xcel Energy generating facilities and Energy Supply-owned synchronous condensers connected to the Bulk Electric System. Facility ratings for jointly owned units will be determined by the generating unit operator.

3.0 Responsibilities:

3.1 Performance Optimization, Fleet Engineering management is responsible to:

3.1.1 Compile Normal and Emergency electrical ratings for the generators, transformers, relay protective devices, and terminal equipment, as applicable, for each unit in all regions.

If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.

3.1.2 Determine the most limiting and next most limiting applicable equipment rating of each unit. Identify and document the most limiting and next most limiting component.

3.1.3 Maintain the records required by 5.1, 5.2 for the generating plants.

3.1.4 Review and update ratings data annually. Upon receipt of request to supply facility ratings, Performance Optimization, Fleet Engineering will review and update ratings prior to submittal in accordance with EPR 5.220P01 NERC Facility Rating Methodolgy. Reviews shall include all new facilities, modified facilities, or any changes in operational limitations of in scope equipment.

4.0 Requirements:

4.1 Performance Optimization, Fleet Engineering shall maintain, in an approved document repository, a spreadsheet, by region, of electrical component and unit ratings.

4.1.1 The equipment and unit ratings will include Normal and Emergency ratings, as well as the most limiting component rating.

If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.

4.2 Performance Optimization, Fleet Engineering shall maintain, in an approved document repository, the methodology used to develop the facility ratings. Any superseded portions of the methodology that had been replaced, changed, or revised must be retained for 12 months.

4.3 Performance Optimization, Fleet Engineering shall provide, on request, each facility rating methodology, and rating, to those Reliability Coordinators, Transmission Operators, Transmission Planners, and Planning Coordinators that have responsibility for the area in which the associated facilities are located, within 21 calendar days of receipt of a request.

4.4 Performance Optimization, Fleet Engineering shall respond, within 45 calendar days, in writing, to written comments from those Reliability Coordinators, Transmission Operators, Transmission Planners, and Planning Coordinators that have responsibility for the area in which the associated facilities are located. The response shall indicate whether a change will be made to the facility rating methodology and, if no change the reason why.

4.5 Performance Optimization, Fleet Engineering shall provide its Facility Ratings and the identity of the most limiting equipment to the Reliability Coordinators, Planning Coordinators, Transmission Planners, Transmission Owners, and Transmission Operators as scheduled by these entities.

4.6 Performance Optimization, Fleet Engineering shall provide the identity of the second most limiting equipment and its thermal rating within 30 calendar days of a request from its Reliability Coordinators, Planning Coordinators, Transmission Planners, Transmission Owners, and Transmission Operators.

5.0 Required Records:

5.1 Performance Optimization, Fleet Engineering shall have evidence it provided the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Authority the facility rating methodology and facility ratings requested within 21 calendar days.

5.2 Performance Optimization, Fleet Engineering shall have evidence it responded to comments from the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Authority within 45 calendar days.

5.3 Performance Optimization, Fleet Engineering shall retain the spreadsheet required by section 4.1, and methodology required by section 4.2 in an approved document repository in accordance with the corporate non-nuclear records retention schedule, record class code AUD1040.

6.0 References & Definitions:

6.1 References

6.1.1 EPR 5.220P01 – NERC Facility Rating Methodology procedure found on XpressNet.

6.1.2 Corporate non-nuclear records retention schedule found on XpressNet.

6.2 Definitions

6.2.1 **North American Electric Reliability Corporation (NERC) -**The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.2 **NERC Reliability Standard FAC 008 –** NERC Standard applicable to Facility Ratings

6.2.3 **Bulk Electric System** – As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100kv or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.

7.0 Revision History

Date	Revision	Change
04/02/2007	Draft	Draft for FERC Reliability Standard – FAC 008, 009
04/10/2007	0	
06/07/2007	1	Added requirement to review and update ratings every 12 months or as facilities are added, modified or re-rated. Added reference to EPR-5.220. Added requirement to retain superseded portions of the methodology fro 12 months.
06/21/2007	2	Revised applicability “Facility ratings for jointly owned units will be determined by the generating unit operator.”
11/09/2007	3.0	If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.
09/20/2012	4.0	Revised the policy to align with NERC Standard FAC-008-3 which replaces FAC-008-1 and FAC-009-1. Changed Maintenance Resources to Technical Resources and Compliance. Changed Production Resources to Technical Services in the header. Removed reference to Performance Monitoring.
01/01/13	4.1	Added language to specify that operational limitations be included in the review and reporting.
08/19/2013	4.2	Modified header and footer to reflect current standardized format. Updated author to current responsible employee. Corrected effective and approval dates to reflect the most recent major revision.
10/04/2016	4.2	Completed triennial review. No content change required.
10/07/2019	4.3	Updated department names to reflect current organization. Combined sections 3.1, 3.1 and 3.3 (region-specific) into a single section encompassing all regions. Updated references.

Xcel Energy		EPR 5.201S01
Energy Supply Performance Optimization Policy System		**Revision: 6.0**
TITLE:	Stability Modeling Data Maintenance and Reporting Requirements	Page 1 of **18**

1.0 PURPOSE

1.1 This standard defines responsibilities and requirements to meet certain requirements established by NERC Standards, MOD-025, “Verification and Data Reporting of Generator Real and Reactive Power Capability and Synchronous Condenser Reactive Power Capability”, MOD-026, “Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions”, MOD-027, “ Verification of Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions”, and MOD-032 “Data for Power System Modeling and Analysis”. This standard ensures Energy Supply provides generator steady state and dynamic modeling design data to the Transmission Planners as required.

2.0 APPLICABILITY

2.1 This standard is applicable to all Energy Supply generating facilities including hydro units and synchronous condensers included in the definition of Bulk Electric System.

The following additional qualifiers are applicable to MOD-026 and MOD-027:

2.1.1 In the WECC region, MOD-026 and MOD-027 are applicable to generating or synchronous condenser units >75 MVA and facilities with aggregate rating >75 MVA.

2.1.2 In the MRO and SPP regions, MOD-026 and MOD-027 are applicable to generating or synchronous condenser units >100 MVA and facilities with aggregate ratings >100 MVA.

3.0 RESPONSIBILITIES

3.1 The cognizant Reliability Engineer, and/or Project Manager/Engineer are responsible to:

3.1.1 Notify Fleet Engineering of any proposed modifications to, or new installations of, excitation control system or plant volt/var control function equipment for applicable units. With Fleet Engineering guidance, provide Fleet Engineering with the verified model, documentation, and data for the new or modified excitation control system or plant volt/var control function equipment installed. Data shall be provided within 335 days after the facility being released for Commercial Operation.

3.1.2 Notify Fleet Engineering of any proposed modifications to, or new installations of, turbine/governor and load control or active power/frequency control equipment for applicable units. With Fleet Engineering guidance, provide Fleet Engineering with the verified model, documentation, and data for the new or modified turbine/governor and load control or active power/frequency control equipment installed. Data shall be provided within 335 days after the facility being released for Commercial Operation.

3.1.3 Notify Fleet Engineering of any changes in generator steady state net real or reactive power design ratings, or any changes in design dynamic characteristics resulting from alterations of generator excitation or turbine governor equipment. This notification should be made at least 3 months prior to project installation.

3.2 Reliability Engineering is responsible to provide support to Fleet Engineering in coordinating and performance of testing required to verify modeling of applicable units or facilities.

3.3 Plant Directors or designee are responsible to notify Fleet Engineering when they become aware of any changes in generator steady state net real or reactive power design ratings. Furthermore, any changes in design dynamic characteristics resulting from alterations of generator excitation or turbine governor equipment or control functions that alter the equipment response characteristic.

3.4 Analytics and Practices is responsible to:

3.4.1 Verify and provide Fleet Engineering with Real Power capability of applicable units or facilities within 30 days after verification, as requested during data gathering for Green & White Capacity Ratings.

3.5 Fleet Engineering personnel are responsible to:

3.5.1 Provide overall compliance guidance and support as needed to execute activities and verify timely completion.

3.5.2 Maintain information, provide information upon request, and communicate changes of that Operating Company's power plant steady state and dynamic modeling data to the regional Transmission Planning organization. This information will be maintained and promulgated per the region-specific processes described in Section 4.0 below.

3.5.2.1 Evidence of correspondence with Transmission Planning concerning steady state and dynamic modeling data shall be stored in the appropriate MOD-032 Documentum folder.

3.5.3 Verify and provide the Transmission Planner with Real and Reactive Power capability of applicable units or facilities.

3.5.3.1 Evidence of correspondence with Transmission Planning concerning Real and Reactive Power capability shall be stored in the appropriate MOD-025 Documentum folder.

3.5.4 Verify and provide the Transmission Planner with the generator excitation control system or plant volt/var control function model, including documentation and data for each applicable unit or facility.

3.5.4.1 Evidence of correspondence with Transmission Planning concerning generator excitation control system or plant volt/var control function modeling shall be stored in the appropriate MOD-026 Documentum folder.

3.5.5 Verify and provide the Transmission Planner with the turbine/governor and load control or active power/frequency control model, including documentation and data for each applicable unit or facility.

3.5.5.1 Evidence of correspondence with Transmission Planning concerning the turbine/governor and load control or active power/frequency control modeling shall be stored in the appropriate MOD-027 Documentum folder.

4.0 REQUIREMENTS:

4.1 Regional Performance Optimization personnel shall fulfill their MOD-032 responsibilities as follows:

4.1.1 Northern States Power (NSP), Southwestern Public Service (SPS), Public Service Company of Colorado (PSCO):

4.1.1.1 Fleet Engineering shall maintain a database of generator steady state modeling design data including minimum and maximum net real and reactive power ratings. This database shall be maintained in Documentum and provided to Transmission Planning upon request or when changes are made.

4.1.1.2 Fleet Engineering shall maintain a database of generator design modeling design data. This database shall be maintained in Documentum and provided to Transmission Planning upon request or when changes are made.

4.1.1.3 Fleet Engineering personnel shall provide steady-state, dynamic, and short circuit modeling data to its Transmission Planner and Planning Coordinator (PSCO) or to its Transmission Planner (NSP and SPS) according to their modeling data requirements and reporting procedures. The Xcel Energy Transmission Planner for NSP and SPS submits the modeling data to the Planning Coordinator on behalf of the Generator Owner. For data that has not changed, an email notification confirming the data has not changed is sufficient. Email notifications will be maintained in Documentum.

Data submission schedule in the regions are as follows:

- NSP provides data to Transmission Planner when changes occur.
- PSCO provides data annually.
- SPS provides annual update when data is requested.

Energy Supply supplies the modeling data to the Transmission business area. Transmission submits the final Generator Owner and Transmission Owner data in the correct format to the Planning Coordinator. Transmission fulfils any time-based reporting requirements in the Transmission Planner & Planning Coordinator data reporting procedures.

4.1.1.4 Upon written notification from the Planning Coordinator or Transmission Planner regarding technical concerns with data submitted above, Fleet Engineering will:

4.1.1.4.1 Provided either updated data or an explanation with a technical basis for maintaining the current data.

4.1.1.4.2 Provide the response within 90 calendar days after receipt unless a longer time period is agreed upon by the notifying Planning Coordinator or Transmission Planner.

4.1.1.4.3 Evidence or correspondence will be maintained in Documentum. If no written notification(s) received, a

statement that it has not received written notification regarding technical concerns with the data submitted may be posted to Documentum as evidence.

4.1.1.5 In the NSP region only, the NSP Transmission Planner works with Generator Owner, Resource Planner, and Transmission Owner to resolve any technical concerns with data submitted to either Planning Coordinator or Transmission Planner. NSP Transmission Planner will provide a response to Planning Coordinator within 90 days after receipt that either updated data, or an explanation with a technical basis to keep the data as originally submitted. NSP Transmission Planner will retain the necessary evidence of its responses and provide Energy Supply with access to evidence.

4.2 Performance Optimization Analytics and Practices, Fleet Engineering personnel shall fulfill their MOD-025 responsibilities as follows (Reference Appendix A):

4.2.1 Analytics and Practices shall, when requested during Green & White Sheet Capacity Ratings, verify the Real Power capability of each applicable units or facility in accordance with Attachment 1 of MOD-025. Analytics and Practices shall provide Fleet Engineering a completed Attachment 2 of MOD-025 or a form containing the same information as identified in Attachment 2, within 30 calendar days after either (i) the date the data is recorded for a staged test; or (ii) the date the data is selected for verification using historical operational data.

4.2.2 Fleet Engineering shall verify the Real and Reactive Power capability of each applicable units or facility in accordance with Attachment 1 of MOD-025. Fleet Engineering shall provide the Transmission Planner a completed Attachment 2 of MOD-025 or a form containing the same information as identified in Attachment 2, within 90 calendar days after either (i) the date the data is recorded for a staged test; or (ii) the date the data is selected for verification using historical operational data.

4.3 Performance Optimization, Fleet Engineering personnel shall fulfill their MOD-026 responsibilities as follows (Reference Appendix B – note for all Facilities that meet MOD-026 applicability, a written notification to the Transmission Planner SHALL be made.):

4.3.1 Shall provide for each applicable unit, a verified generator excitation control system or plant volt/var control function model, including documentation and data as specified in 4.5.1.1 to the Transmission Planner in accordance with the periodicity specified in MOD-026 Attachment 1.

4.3.1.1 Each applicable unit's model shall be verified using one or more models acceptable to the Transmission Planner. Each verification shall include the following:

4.3.1.1.1 Documentation demonstrating the applicable unit's model response matches the recorded response for a voltage excursion from either a staged test or a measured system disturbance.

4.3.1.1.2 Manufacturer, model number (if available), and type of the excitation control system including, but not limited to static, AC brushless, DC rotating, and/or the plant volt/var control function (if installed).

4.3.1.1.3 Model structure and data including, but not limited to reactance, time constants, saturation factors, total rotational inertia, or equivalent data for the generator.

4.3.1.1.4 Model structure and data for the excitation control system, including the closed loop voltage regulator if a closed loop voltage regulator is installed or the model structure and data for the plant volt/var control function system.

4.3.1.1.5 Compensation settings (such as droop, line drop, differential compensation), if used.

4.3.1.1.6 Model structure and data for power system stabilizer, if so equipped.

4.3.1.1.7 For newly constructed or purchased wind and solar Facilities, it is recommended to model Voltage Control, Power Factor Control, and VAR control operating modes to avoid future remodeling if Operations changes modes.

4.3.2 Shall provide a written response to the Transmission Planner within 90 calendar days after receiving one of the following items for an applicable unit:

4.3.2.1 Written notification from the Transmission Planner (in accordance with MOD-026, R6) that the excitation control system or plant volt/var control function model is not usable.

4.3.2.2 Written comments from the Transmission Planner identifying technical concerns with the verification documentation related to the excitation control system or plant volt/var control function model.

4.3.2.3 Written comments and supporting evidence from the Transmission Planner indicating that the simulated excitation control system or plant volt/var control function model response did not match the recorded response to a transmission system event.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification.

4.3.3 Shall provide revised model data or plans to perform model verification (in accordance with MOD-026, R2) for an applicable unit to the Transmission Planner within 180 calendar days after making changes to the excitation control system or plant volt/var control function that alter the equipment response characteristic.

4.3.4 Shall provide a written response to the Transmission Planner, within 90 calendar days following receipt of a technically justified unit request from the Transmission Planner to perform a model review of a unit or plant that includes one of the following:

4.3.4.1 Details of plans to verify the model (in accordance with MOD-026, R2).

4.3.4.2 Corrected model data including the source of revised model data such as discovery of manufacturer test values to replace generic model data or updating of data parameters based on an on-site review of the equipment.

4.3.5 Fleet Engineering personnel or their delegate shall create a reminder in eGRC for applicable due date for model verifications or equipment modifications.

4.4 Energy Supply Project's personnel shall fulfill their MOD-026 responsibilities as identified in XES 7.400 and XES 7.405 (Reference Appendix B).

4.5 Performance Optimization, Fleet Engineering personnel shall fulfill their MOD-027 responsibilities as follows (Reference Appendix C – note for all Facilities that meet MOD-027 applicability, a written notification to the Transmission Planner SHALL be made.):

4.5.1 Shall provide for each applicable unit, a verified turbine/governor and load control or active power/frequency control model, including documentation and data as specified in section 4.6.1.1 to the Transmission Planner in accordance with the periodicity specified in MOD-027 Attachment 1.

4.5.1.1 Each applicable unit's model shall be verified using one or more models acceptable to the Transmission Planner. Each verification shall include the following:

4.5.1.2 Documentation comparing the applicable unit's MW model response to the recorded MW response for either:

4.5.1.2.1 A frequency excursion from a system disturbance that meets MOD-027 Attachment 1 Note 1 with the applicable unit on-line.

4.5.1.2.2 A speed governor reference change with the applicable unit on-line.

4.5.1.2.3 A partial load rejection test.

4.5.1.3 Type of governor and load control or active power control/frequency control equipment.

4.5.1.4 A description of the turbine.

4.5.1.5 Model structure and data for turbine/governor and load control or active power/frequency control.

4.5.1.6 Representation of the real power response effects of outer loop controls that would override the governor response if applicable.

4.5.1.7 For newly constructed or purchased wind and solar Facilities, it is recommended to model operating mode as if enabled, regardless of initial operating modes, to avoid future remodeling if Operations changes modes.

4.5.2 Shall provide a written response to the Transmission Planner within 90 calendar days after receiving one of the following items for an applicable unit.

4.5.2.1 Written notification from the Transmission Planner (in accordance with MOD-027, R5) that the turbine/governor and load control or active power/frequency control model is not usable.

4.5.2.2 Written comments from the Transmission Planner identifying technical concerns with the verification documentation related to the turbine/governor and load control or active power/frequency control model.

4.5.2.3 Written comments and supporting evidence from the Transmission Planner indicating that the simulated turbine/governor and load control or active power/frequency control response did not approximate the recorded response for three or more transmission system events.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification (in accordance with MOD-027, R2).

4.5.3 Shall provide revised model data or plans to perform model verification (in accordance with MOD-027, R2) for an applicable unit to the Transmission Planner within 180 calendar days after making changes to the turbine/governor and load control or active power/frequency control system that alter the equipment response characteristic.

4.5.3.1 Changes to items below alter the equipment response characteristic and require 180 calendar days model verification to the Transmission Planner:

4.5.3.1.1 Droop

4.5.3.1.2 Dead band

4.5.3.1.3 Frequency Control Modes: Including changing between Isochronous and Droop Control, changes to any outer loop control contributing to droop response, or disabling/enabling any logic or algorithms contributing to droop response.

4.5.3.2 Fleet Engineering Controls personnel making changes to the control systems that alter frequency response shall coordinate those changes and notifications with Fleet Engineering Electrical personnel.

4.5.4 Fleet Engineering personnel or their delegate shall create a reminder in eGRC for applicable due date for model verifications or equipment modifications.

4.6 Energy Supply Project's personnel shall fulfill their MOD-027 responsibilities as identified in XES 7.400 and XES 7.405 (Reference Appendix C).

5.0 REQUIRED RECORDS

5.1 Fleet Engineering shall maintain evidence of correspondence with Transmission Planning documenting:

5.1.1 Modeling data was provided in response to requests and that Transmission Planning was notified of changes in any steady state or dynamic modeling data.

5.1.2 Real and reactive power verification was provided.

5.1.3 A verified generator excitation control system or plant volt/var control function model, including documentation and data was provided.

5.1.4 A verified turbine/governor and load control or active power/frequency control model, including documentation and data was provided.

6.0 REFERENCES AND DEFINITIONS

6.1 References

6.1.1 Glossary of Terms Used in NERC Reliability Standards

6.1.2 XES 7.405, Screening of Projects for Impact on NERC Compliance Program (found on the Energy Supply Policies web page)

6.1.3 XES 7.400, NERC FAC-002 Coordination of Plans for New Facilities (found on the Energy Supply Policies web page)

6.2 Definitions

6.2.1 North American Electric Reliability Corporation (NERC) – The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.2 Bulk Electric System (BES) – See definition in Glossary of Terms Used in NERC Reliability Standards.

6.2.3 NERC Reliability Standard MOD-025 – NERC Standard applicable to the verification and data reporting of generator real and reactive power capability and synchronous condenser reactive power capability.

6.2.4 NERC Reliability Standard MOD-026 – NERC Standard applicable to the verification of models and data for generator excitation control system or plant volt/var control functions.

6.2.5 NERC Reliability Standard MOD-027 – NERC Standard applicable to the verification of models and data for turbine/governor and load control or active power/frequency control functions.

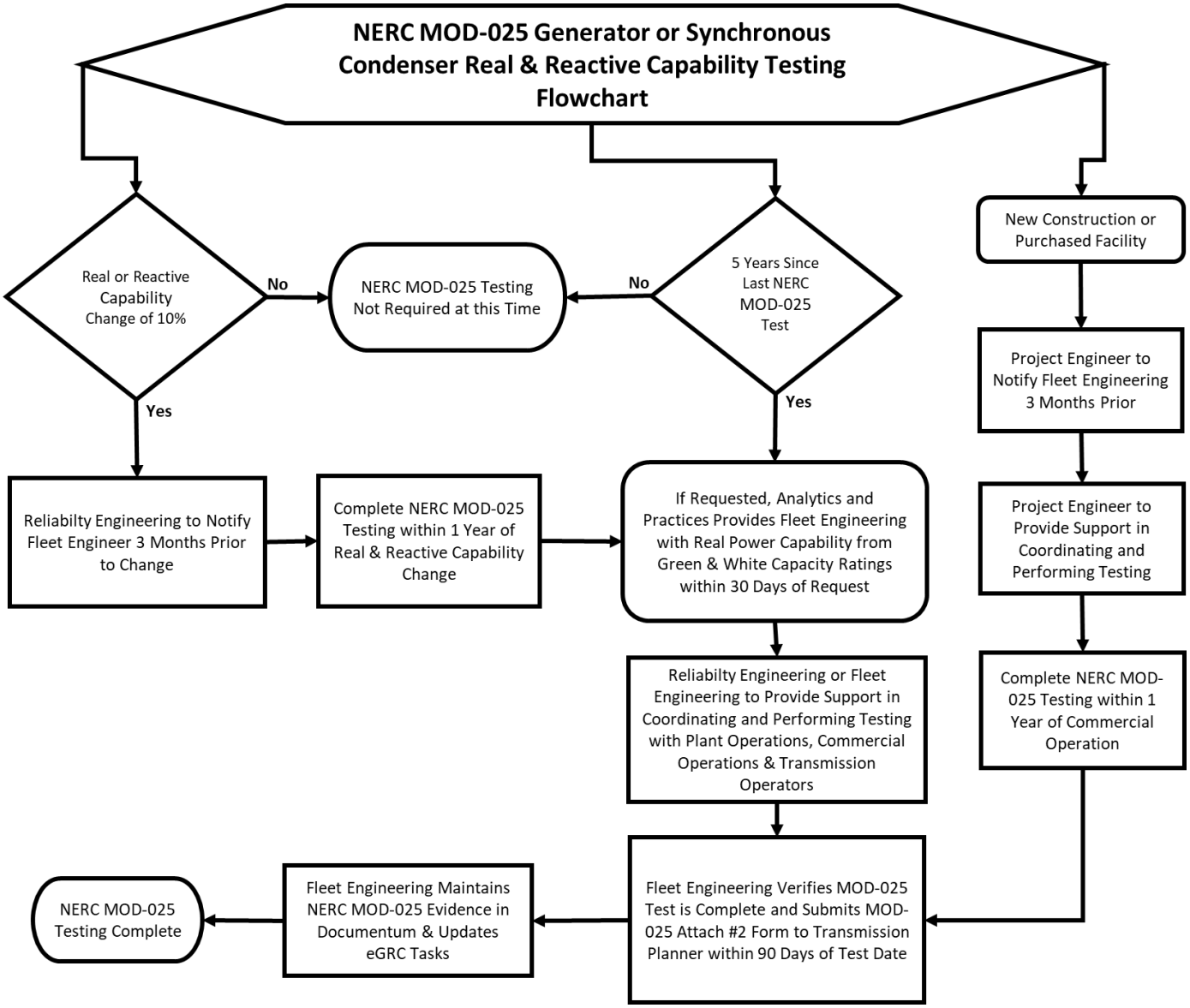
6.2.6 NERC Reliability Standard MOD-032 – NERC Standard applicable to establishing consistent modeling data requirements and reporting.

6.2.7 Transmission Planner - The Transmission Planning role is performed by Xcel Energy for all fleet generation facilities in the MRO, WECC, and SPP service regions.

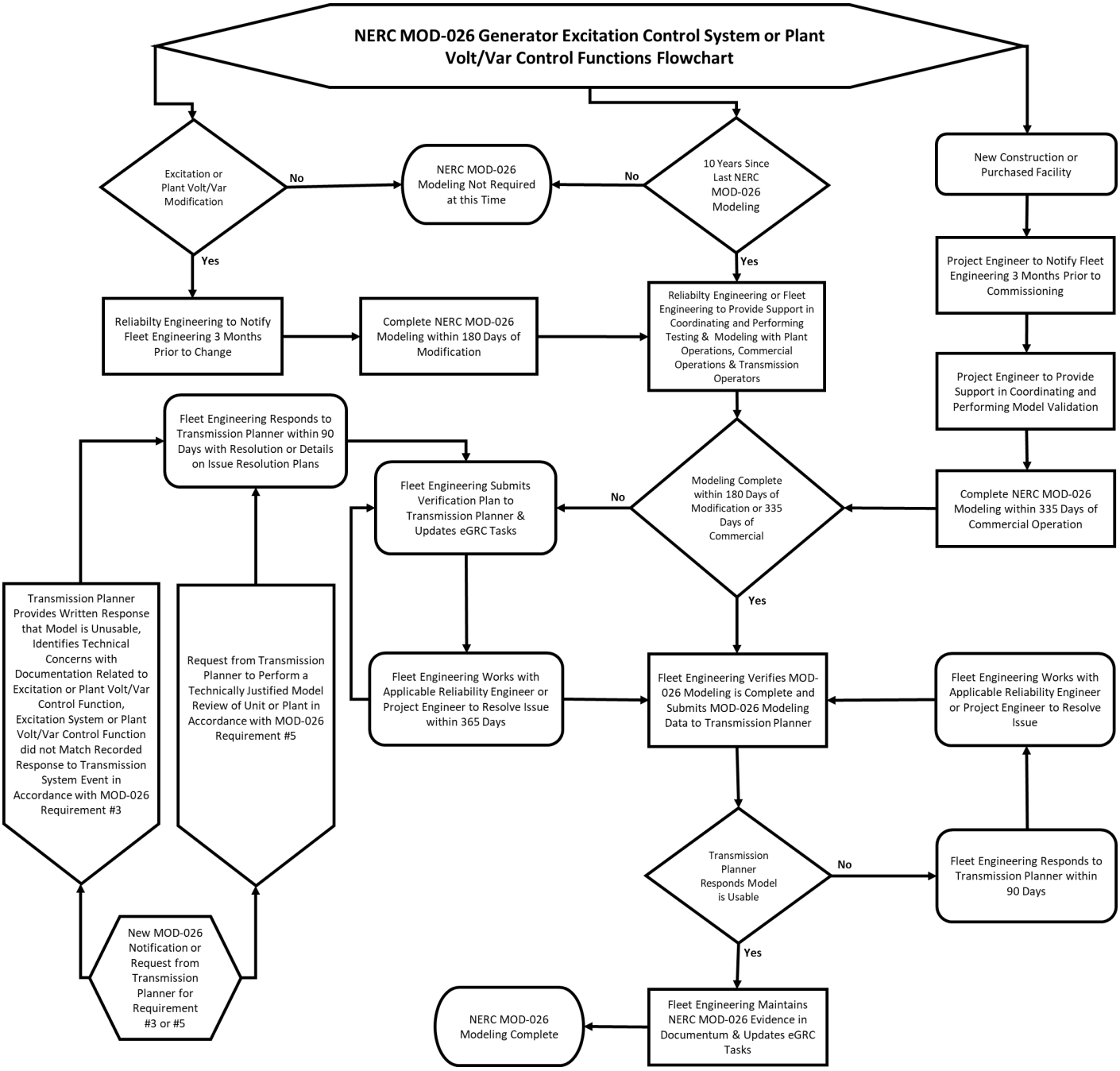
7.0 REVISION HISTORY

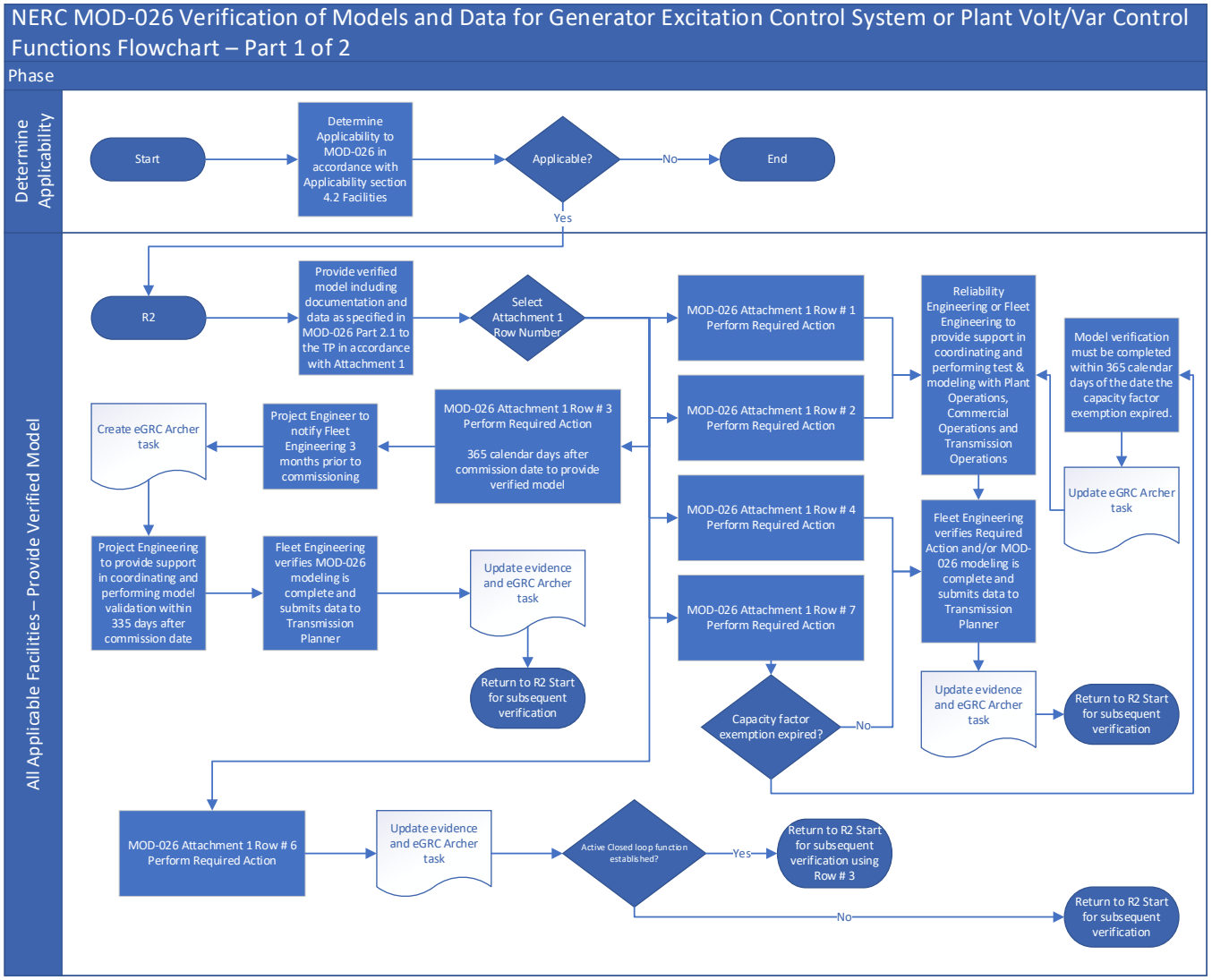
Date	Revision	Change
02/03/2014	1.0	Original Issue, supersedes XES 1.110 Rev 2.2 Stability Modeling Data Maintenance and Reporting Requirements
07/21/2014	2.0	Modified to include MOD-025, MOD-026 and MOD-027
11/22/2016	3.0	Modified to include MOD-032-1 and delete MOD-010 and MOD-012.
02/14/2019	4.0	Improved MOD-032 requirement section 4.1.
8/23/2022	5.0	Triennial Review along with department name changes, added Appendix flowcharts, and eGRC Reminder Tasks.
04/14/2023	6.0	Modified section 4.5.3 to clarify specific examples requiring MOD-027 revised modeling. Clarified reporting requirements to the Transmission Planner in section 4.3 and 4.5. Updated flow Appendix B and Appendix C Flowcharts. Added modeling recommendation for wind and solar Facilities in sections 4.3.1.1.7 and 4.5.1.7.

Appendix A: NERC MOD-025 Flowchart

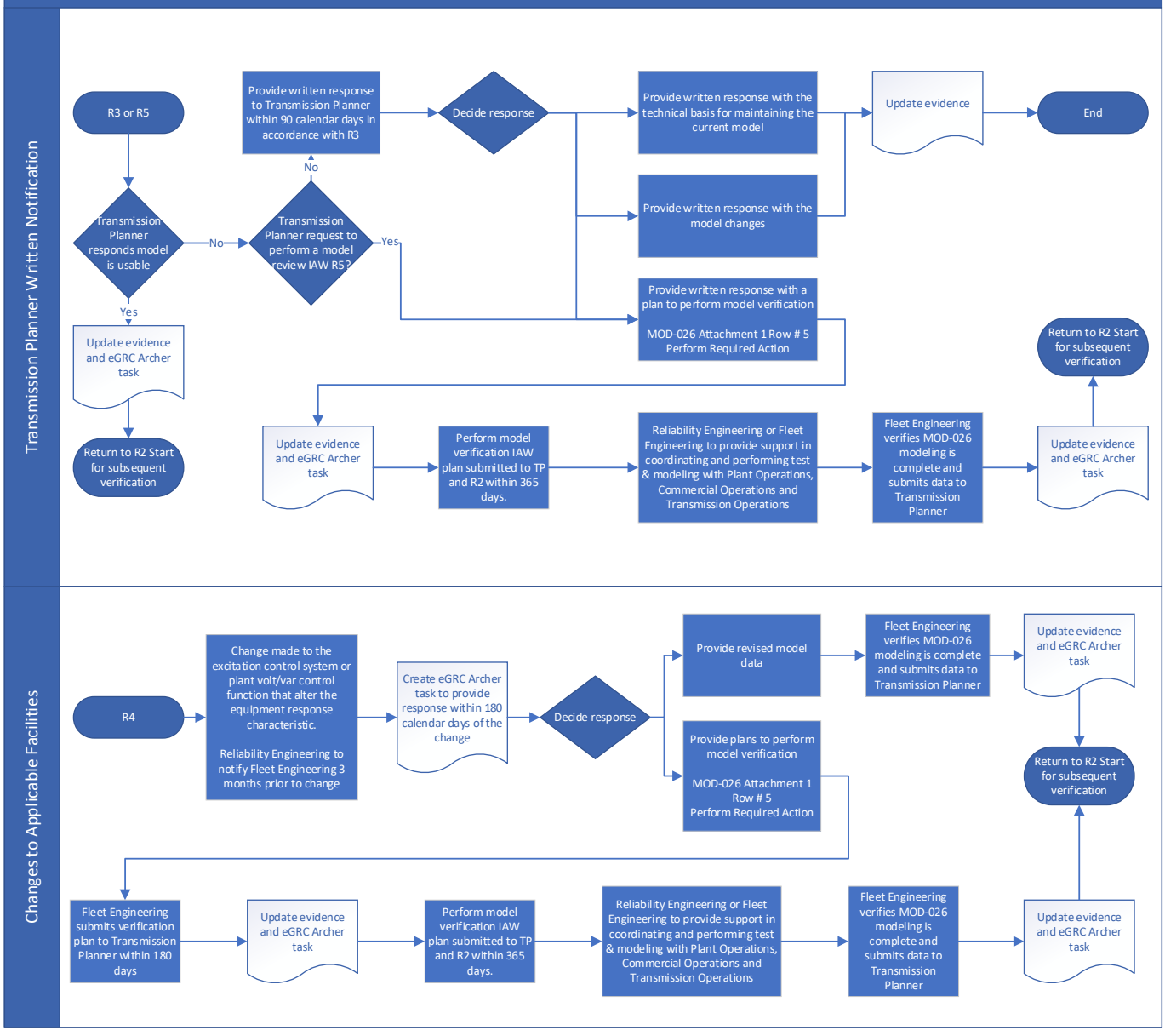


Appendix B: NERC MOD-026 Flowcharts

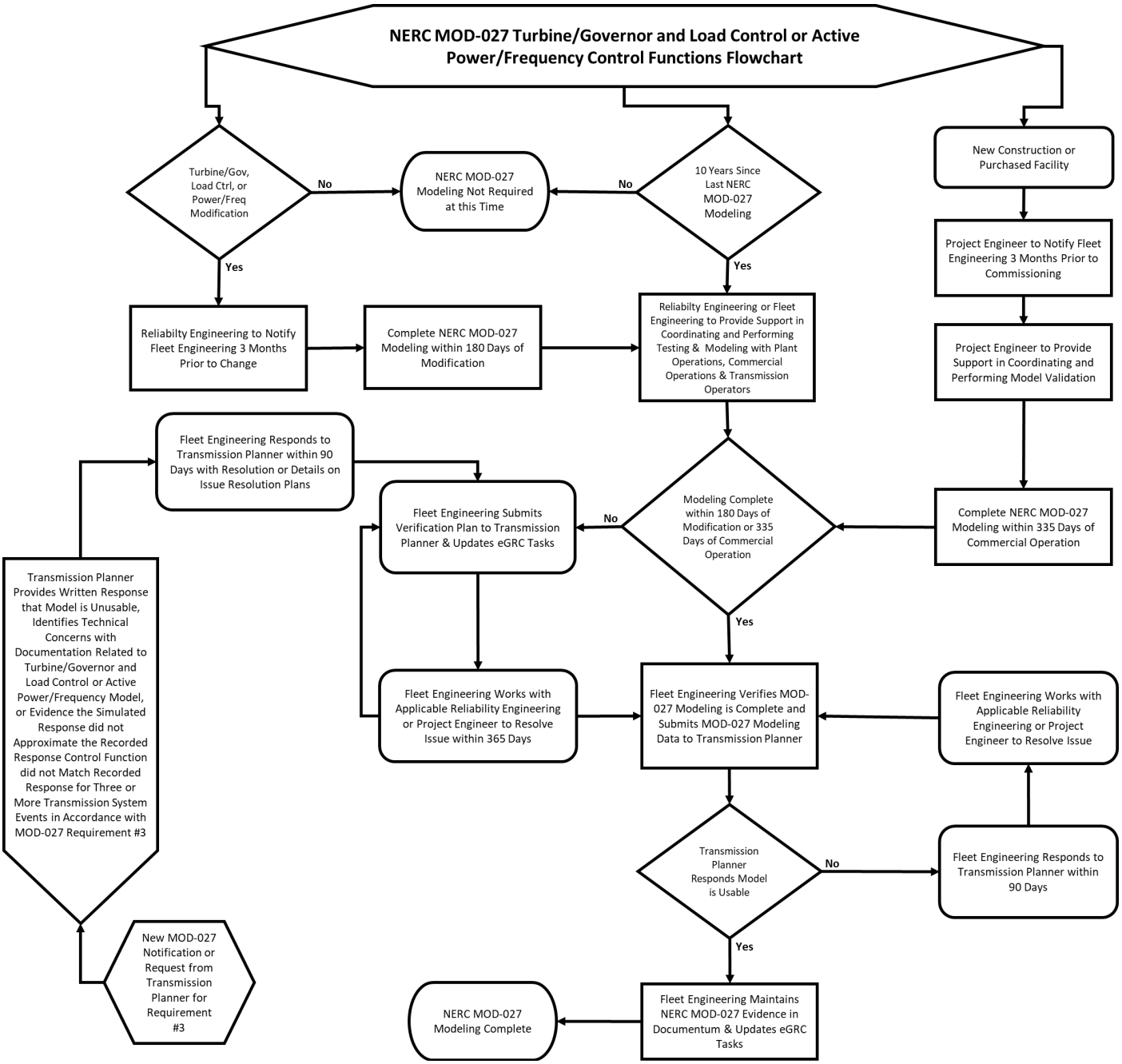



NERC MOD-026 Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions Flowchart – Part 1 of 2
Phase
Determine Applicability
All Applicable Facilities – Provide Verified Model
Start
Determine Applicability to MOD-026 in accordance with Applicability section 4.2 Facilities
Applicable?
No
End
Yes
R2
Provide verified model including documentation and data as specified in MOD-026 Part 2.1 to the TP in accordance with Attachment 1
Select Attachment 1 Row Number
MOD-026 Attachment 1 Row # 1 Perform Required Action
MOD-026 Attachment 1 Row # 2 Perform Required Action
MOD-026 Attachment 1 Row # 3 Perform Required Action
365 calendar days after commission date to provide verified model
MOD-026 Attachment 1 Row # 4 Perform Required Action
MOD-026 Attachment 1 Row # 7 Perform Required Action
Project Engineer to notify Fleet Engineering 3 months prior to commissioning
Create eGRC Archer task
Project Engineering to provide support in coordinating and performing model validation within 335 days after commission date
Fleet Engineering verifies MOD-026 modeling is complete and submits data to Transmission Planner
Update evidence and eGRC Archer task
Return to R2 Start for subsequent verification
Capacity factor exemption expired?
No
Reliability Engineering or Fleet Engineering to provide support in coordinating and performing test & modeling with Plant Operations, Commercial Operations and Transmission Operations
Fleet Engineering verifies Required Action and/or MOD-026 modeling is complete and submits data to Transmission Planner
Update evidence and eGRC Archer task
Return to R2 Start for subsequent verification
Model verification must be completed within 365 calendar days of the date the capacity factor exemption expired.
Update eGRC Archer task
MOD-026 Attachment 1 Row # 6 Perform Required Action
Update evidence and eGRC Archer task
Active Closed loop function established?
Yes
Return to R2 Start for subsequent verification using Row # 3
No
Return to R2 Start for subsequent verification

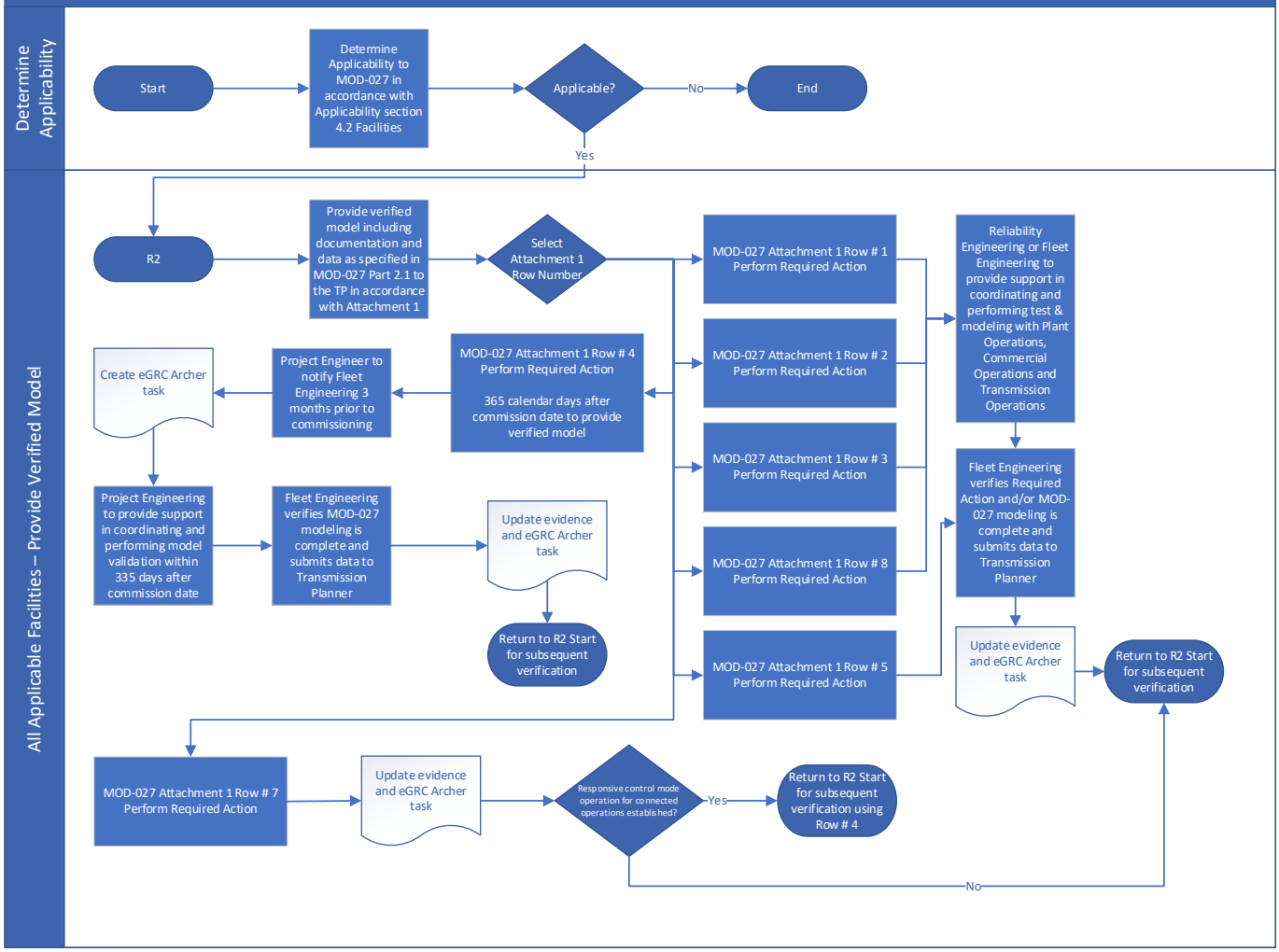
NERC MOD-026 Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions Flowchart – Part 2 of 2



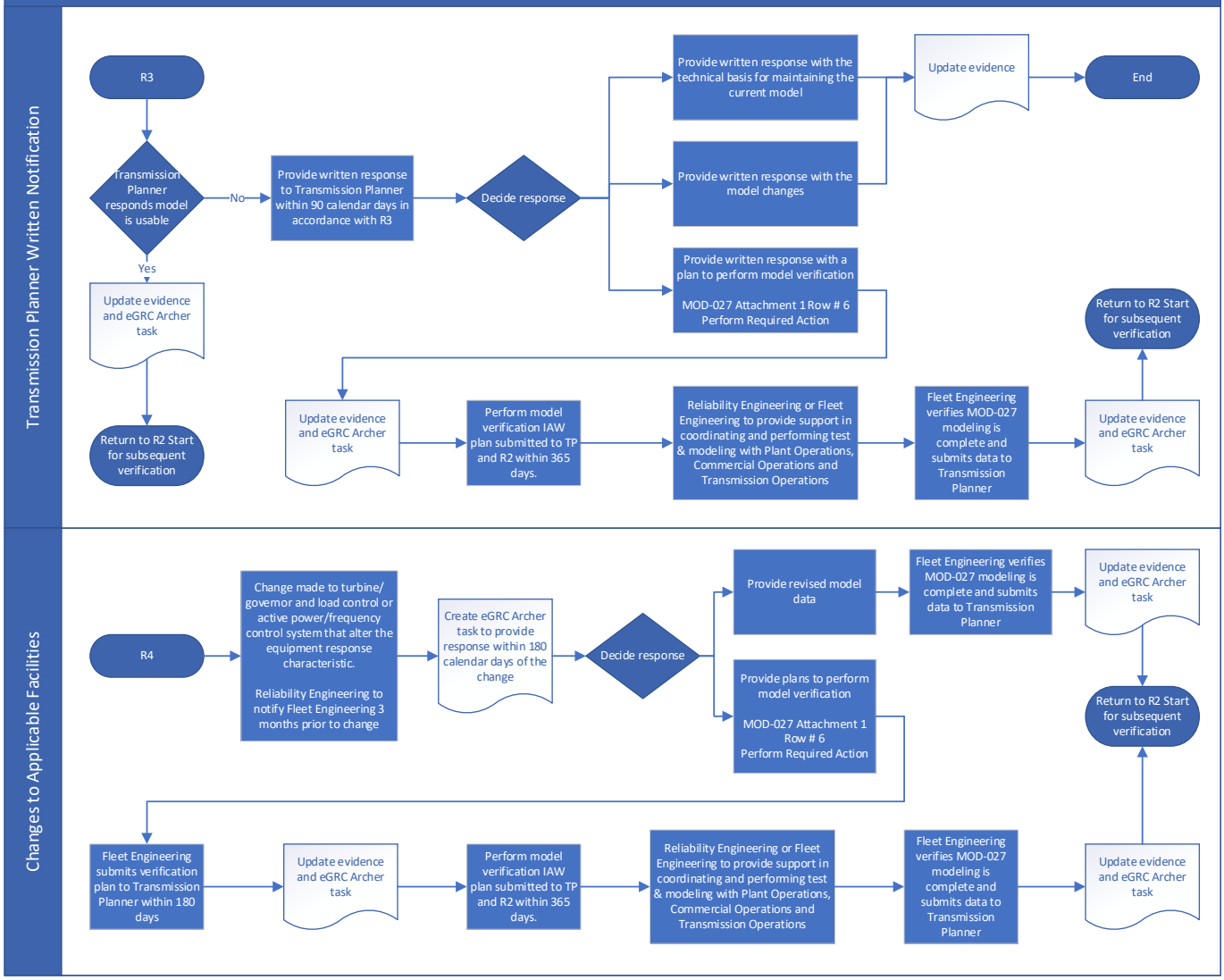
Appendix C: NERC MOD-027 Flowcharts



NERC MOD-027 Verification of Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions Flowchart – Part 1 of 2



NERC MOD-027 Verification of Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions Flowchart – Part 2 of 2



Xcel Energy	EPR 5.202S
Energy Supply Performance Optimization Policy System	**Revision: 3.2**
TITLE: NERC Protection System Coordination, Relay Setting, and Reporting Requirements *Supersedes XES 7.410, "FERC PRC-001 System Protection Coordination"*	Page 1 of **13**

1.0 PURPOSE

1.1 This standard defines responsibilities and requirements to meet certain requirements established by the following NERC Standards:

- PRC-019, "Coordination of Generating Unit or Plant Capabilities, Voltage Regulator Controls, and Protection"
- PRC-024, "Frequency and Voltage Protection Settings for Generating Resources"
- PRC-025, "Generator Relay Loadability"
- PRC-026, “Relay Performance During Stable Power Swings”
- PRC-027, “Coordination of Protection Systems for Performance During Faults”

2.0 APPLICABILITY

2.1 This standard is applicable to all Energy Supply Bulk Electric System (BES) generating facilities. Requirements of the various NERC Standards referenced above may have applicability to Protections Systems at these facilities for:

2.1.1 Generators

2.1.2 Synchronous condensers

2.1.3 Generator step up (GSU) transformers

2.1.4 Energy Supply owned Generator interconnection facilities that connect the GSU transformer to the transmission system.

2.1.5 Main or unit connected auxiliary transformers capable of feeding plant load when the unit is at power

2.1.6 Reserve or startup auxiliary transformers capable of feeding plant load when the unit is at power.

2.1.7 Aggregating systems and individual generating resources at dispersed generation facilities such as wind farms.

3.0 RESPONSIBILITIES

3.1 Performance Optimization Fleet Engineering personnel are responsible for the overall administration of the regional NERC Protection System Coordination and Relay Setting program. These responsibilities include maintaining coordination and settings studies for NERC related protection systems at BES generating facilities as well as performing and documenting all required communications with the other NERC Functional Entities concerning protection system coordination issues as required per Section 4.0 Requirements below.

3.2 The cognizant Performance Optimization Reliability Engineering personnel and/or ES Projects group Project Manager/Engineer are responsible:

3.2.1 To provide written notification to the Performance Optimization Fleet Engineering personnel of the installation of any new or planned installation of any NERC related protection systems; or any changes or planned changes to the existing NERC related protection systems as soon as the information becomes available.

3.2.2 To provide written notification to the Performance Optimization Fleet Engineering personnel of the installation of any new or planned installation of equipment, modification of the existing voltage regulating settings or planned modifications of existing voltage regulating settings at BES generating facilities as soon as the information becomes available.

3.2.3 To provide written notification to the Performance Optimization Fleet Engineering personnel of any change or planned changes in BES generator or synchronous condenser equipment capability as soon as the information becomes available.

3.2.4 To provide written notification to the Performance Optimization Fleet Engineering personnel of generator or synchronous condenser step up transformer, main or unit connected auxiliary transformer, or reserve or startup auxiliary transformer changes or replacements.

3.2.5 To provide an updated notification to Performance Optimization Fleet Engineering when previous notification is no longer valid for the changes described in paragraphs 3.2.1-3.2.4 above

3.2.6 As a result of any of the changes described in paragraphs 3.2.1-3.2.5 above, to work with Performance Optimization Fleet Engineering department to assure

that any required coordination studies are performed, and relay settings are established and communicated to other entities as required per Section 4.0 Requirements below.

4.0 REQUIREMENTS:

4.1 General

4.1.1 A Protection System Coordination and Relay Setting Study shall be developed for any new NERC related Protection System to be installed at a BES generating facility.

4.1.2 A Protection System Coordination and Relay Setting Study shall be developed or revised to address changes in a NERC related Protection System at a BES generating facility. Examples of changes which may necessitate development or revision of a study include, (but are not limited to), relay replacements, relay setpoint changes, excitation limiter and protection settings, or changes in current or voltage sensing devices.

4.1.3 A Protection System Coordination and Relay Setting Study shall be developed or revised to address replacement of generators or synchronous condensers, generator or synchronous condenser step-up transformers, main or unit connected auxiliary transformers, or reserve or startup auxiliary transformers when the replacement device ratings and/or impedance characteristics deviate from those utilized in the existing coordination study of the protection system for the component to be replaced.

4.1.4 For conventional synchronous machines, there should be only one Protection Coordination and Relay Setting study per NERC related Protection System that addresses PRC-027, PRC-019, PRC-024, PRC-025, and PRC-026 requirements applicable to that scheme or unit. This integrated approach will provide for greater clarity and consistency in documentation.

4.1.5 For dispersed generating facilities such as wind farms, the complex topography often requires use of dynamic simulations by vendors to prove compliance with some of the NERC standards. Coordination studies are often performed by architect/engineer firms during construction. As such, a collection of standard specific studies are often performed to address PRC-027, PRC-019, PRC-024, PRC-025, and PRC-026 as required.

4.1.6 Prior to performing a Protection System Coordination and Relay Setting Study, data to be used for generator and/or transformer ratings and impedances shall be verified against equipment test reports or design values for new equipment. The following engineering data should be included in the study for reference of report reviewers:

Generator Parameters
Generator MVA Rating
Generator kV Rating
Generator pf Rating
Generator X_d
Generator X'_d
Generator $X"_d$ (sat)
Generator X_2 (sat)
Gen Neut Gr Tr Ratio
Gen Neut Gr Resistance

GSU Parameters
GSU HV KV rating
GSU High Volt Tap
GSU LV KV Rating
GSU Impedance
GSU BASE MVA Rating
GSU Neutral Reactance
GSU Core Type

System Parameters
Assumed system available fault current

4.1.7 Prior to performing a Protection System Coordination and Relay Setting Study, updated transmission system fault current and impedance data shall be obtained. Updated transmission system fault current and impedance data shall be obtained at least annually or more frequently if significant changes are being implemented or have occurred which are anticipated to have a significant effect (>15% change) on system parameters for the substation associated with the generating unit to be analyzed.

4.1.8 All Protection System Coordination and Relay Setting Studies shall have a second engineering review to ensure adequacy of the developed protection system settings.

4.1.9 All Protection System Coordination and Relay Setting Studies shall be re-validated using updated data on a five-calendar year interval to ensure developed and applied settings remain valid for system and generating plant changes. This five-calendar year interval meets the periodic update requirements of both PRC-019 and PRC-027.

4.1.10 Protection system setting changes that do not affect fault coordination with separate interconnected entities can be processed as minor revisions and do not require review and approval by that separate entity prior to implementation. Nonetheless, a courtesy copy of the minor revision of the coordination study should be forwarded to the interconnected entity for documentation purposes.

Note that this does not eliminate the need for follow-up notifications such as those listed in Section 4.4.3 or 4.4.4 below.

4.2 PRC-027 Requirements

4.2.1 New or revised Protection System Coordination and Relay Setting studies for facilities that connect to the Xcel Energy Transmission System SHALL be provided to Transmission Operations - Protection System Engineering for review.

4.2.2 General requirements 4.1.6, 4.1.7, 4.1.8, and 4.1.9 above must be met to fulfill NERC PRC-027 program requirements for having an established relay setting process to assure accuracy of input data and output results.

4.2.3 For protection system settings applied on BES elements that electrically join the generating plant to equipment owned by a separate NERC functional entity (i.e. - Transmission Owner, Generator Owner, or Distribution Provider), the following PRC-027 requirements apply:

4.2.3.1 The proposed protections settings developed by the Protection System Coordination and Relay Setting study and applied on the BES Element that electrically joins the generating facility to that owned by a separate functional entity shall be provided to that entity for review. Performance Optimization Fleet Engineering should request that the Interconnecting Entity review the relay settings and associated coordination study within 30 days, or a mutually agreed upon timeframe.

4.2.3.2 That separate functional entity will either notify us of any identified coordination issues or will affirm that no coordination issues were identified.

4.2.3.3 When provided with protection system settings from a separate functional entity and applied on the BES element joining our generating facility to their system, the provided settings shall be reviewed within a mutually agreed to timeframe. Any identified coordination issues shall be communicated to that entity or the entity shall be notified that our review did not identify any coordination issues with the proposed settings.

4.2.3.4 Any identified coordination issues identified by the reviews described in 4.2.2.1 or 4.2.2.2 shall be addressed prior to the implementation of the proposed settings.

4.2.3.5 Any protection system settings revisions for protection applied on equipment that electrically joins the generating facility to that owned by a separate functional entity and which result from unforeseen circumstances that arise during implementation or commissioning, misoperation investigations, maintenance activities, or emergency replacements as a result of a protection system failure shall be communicated to the other owner of the electrically joined facility.

4.3 PRC-019 Requirements

4.3.1 Coordination studies for generators and synchronous condensers shall show coordination for the voltage regulating system controls, including in-service limiters and protection functions, with the applicable equipment capabilities and settings of the applicable Protection System devices and functions. Assuming normal automatic voltage regulator control loop and steady-state system operating conditions, the studies should show that:

4.3.1.1 In-service limiters are set to operate before the Protection System of the applicable Facility in order to avoid disconnecting the generator unnecessarily, and

4.3.1.2 The applicable in-service Protection System devices are set to operate to isolate or de-energize equipment in order to limit the extent of damage when operating conditions exceed equipment capabilities or stability limits.

4.3.2 The study described in Section 4.3.1 shall be reviewed and updated at a maximum of every 5 calendar years or within 90 days following the identification or implementation of systems, equipment, or settings changes that will affect the coordination of devices as described in Section 4.3.1. Possible systems, settings, or equipment changes which could affect this coordination include but are not limited to:

4.3.2.1 Voltage regulating settings or equipment changes;

4.3.2.2 Protection System settings or component changes;

4.3.2.3 Generator or synchronous condenser equipment capability changes;

4.3.2.4 Generator or synchronous condenser step up transformer changes.

4.3.3 Section G of NERC Reliability Standard PRC-019, "Coordination of Generating Unit or Plant Capabilities, Voltage Regulator Controls, and Protection" (Reference 6.1.5) provides a technical discussion of methods to show possible required coordination, but all voltage regulator settings, limiters and trips shall be reviewed for coordination with protective relays.

4.4 PRC-024 Requirements

4.4.1 Coordination and Relay Settings Studies shall document that BES generating resource frequency protection is set in accordance with PRC-024 Attachment 1 such that the applicable frequency protection does not cause the generating resource to trip or cease injecting current within the "no trip zone" during a frequency excursion of PRC-024 Attachment 1, subject to the following exceptions:

4.4.1.1 Applicable frequency protection may be set to trip or cease injecting current within a portion of the “no trip zone” for documented and communicated regulatory or equipment limitations in accordance with Requirement R3.

4.4.2 Coordination and Relay Settings Studies shall document that applicable voltage protection is set in accordance with PRC-024 Attachment 2, such that the applicable protection does not cause the generating resource to trip or cease injecting current within the “no trip zone” during a voltage excursion at the high side of the GSU or MPT, subject to the following exceptions: [

4.4.2.1 If the Transmission Planner allows less stringent voltage protection settings than those required to meet PRC-024 Attachment 2, then the Generator Owner may set its protection within the voltage recovery characteristics of a location-specific Transmission Planner’s study. •

4.4.2.2 Applicable voltage protection may be set to trip or cease injecting current during a voltage excursion within a portion of the “no trip zone” for documented and communicated regulatory or equipment limitations in accordance with Requirement R3

4.4.3 If exceptions are applied in frequency protection settings per Section 4.4.1.1 or in voltage protection per Section 4.4.2.2 above because of known regulatory or equipment limitations, or when a previously documented regulatory or

equipment limitation is removed, the change shall be communicated to the Planning Coordinator and Transmission Planner within 30 calendar days of any of the following:

4.4.3.1 Identification of a regulatory or equipment limitation.

4.4.3.2 Repair of the equipment causing the limitation that removes the limitation.

4.4.3.3 Replacement of the equipment causing the limitation that removes the limitation.

4.4.3.4 Creation or adjustment of an equipment limitation caused by the consumption of the cumulative turbine life-time frequency excursion allowance.

4.4.4 Frequency and voltage protection settings established per Sections 4.4.1 and 4.4.2 shall be provided to the Planning Coordinator or Transmission Planner responsible for modeling the unit within 60 calendar days of receipt of a written request for the data or within 60 calendar days of any change of previously requested protection settings unless directed by the Planning Coordinator or Transmission Planner that the reporting of protection setting changes is not required.

4.5 PRC-025 Requirements

4.5.1 Coordination and Relay Settings Studies for BES facilities identified in Section 2.1 above shall document that all settings applied to load-responsive relays are made in accordance with PRC-025-2 Attachment 1 while maintaining reliable fault protection.

4.6 PRC-026 Requirements

4.6.1 For load-responsive protective relay functions as identified in PRC-026, Coordination and Relay Setting Studies for BES generators, transformers and transmission lines shall document applicability of PRC-026 requirements. In general, these requirements only apply to phase distance (21), phase overcurrent (51), out of step tripping (78), and loss of field (40) settings with time delays of less than 15 cycles. See PRC-026 Attachment A.

4.6.2 Within 12 months of notification from the Planning Coordinator of an ES owned BES element pursuant to Requirement R1 of PRC-026, the associated

Protection Coordination and Relay Setting study should be revised to determine and document whether the load responsive relay functions are applied per the criteria of PRC-026 Attachment B. This is only required if such an evaluation has not been performed in the last five years for the load responsive relay in question.

4.6.3 Within 12 months of becoming aware of an ES owned generator, transformer, or transmission line BES element that tripped in response to a stable or unstable power swing due to operation of its protective relays, the associated Protection Coordination and Relay Setting study should be revised to determine and document whether the load responsive relay functions are applied per the criteria of PRC-026 Attachment B.

4.6.4 If the evaluation performed per paragraph 4.6.2 or 4.6.3 above determines that the load responsive relay settings do not meet PRC-026 Appendix B criteria, a formal NERC Corrective Action Plan, CAP, shall be developed within six full calendar months to either:

4.6.4.1 Change settings to meet PRC-026 Attachment B criteria while maintaining dependable fault detection and, if applied, dependable out of step tripping.

Or

4.6.4.2 Modify the Protection System such that it is excluded from applicability to PRC-026 Attachment A criteria while maintaining dependable fault detection and, if applied, dependable out of step tripping.

4.6.5 Any CAP developed per paragraph 4.6.4 shall be implemented as planned. If CAP actions or timetables change, the CAP should be formally updated until all associated actions are complete.

4.7 Implementation Timelines – General Information

4.7.1 A Protection System Coordination and Relay Setting Study shall be developed to address all NERC related Protection Systems at a BES generating facility. All BES units shall have a Protection Coordination and Relay Setting study. Existing studies shall be reviewed and updated as needed per the requirements outlined in this document.

4.7.2 For PRC-026, studies performed in response to Planning Coordinator notifications per paragraph 4.6.2 or upon becoming aware that a BES element tripped because of a protective relay operation in response to a stable or unstable power swing per paragraph 4.6.3 must be completed by the later of 12 months after the notification from the Planning Coordinator, 12 months after awareness of a trip in response to a power swing or January 1, 2020.

4.7.3 For PRC-027, all initial studies for PRC-027 R2 compliance must be completed no later than 6 calendar years after the effective date of PRC-027-1. Based on PRC-027-1 effective date of 4/1/2021, the deadline for initial R2 compliance is 12/31/27.

5.0 REQUIRED RECORDS

5.1 Protection System Coordination and Relay Setting Studies written to address the requirements of this standard SHALL be stored in the regional Protection System Coordination and Relay Setting Study folder in Documentum or other approved regional data repository.

5.2 Copies of correspondence with Transmission Operators, Transmission Planners, Distribution Providers and/or Planning Coordinators concerning these Protection System Coordination and Relay Settings Studies SHALL be stored Documentum or in the regional specific data repository flagged for the applicable PRC-019, PRC-024, PRC-025, PRC-026, or PRC-027 standard. Note that dated sign-off blocks on Protection System Coordination and Relay Setting Study documents may be used as evidence of this communication.

5.3 Any Corrective Action Plan developed per paragraph 4.6.4 or revised Corrective Action Plant per paragraph 4.6.5 SHALL be stored in Documentum or in the regional specific data repository for PRC-026 documentation. The CAP SHALL be retained and available for review for a minimum of 12 months following completion of the implementation of the CAP.

6.0 REFERENCES AND DEFINITIONS

6.1 References

6.1.1 NERC System Protection and Control Subcommittee Technical Reference Document, "Power Plant and Transmission System Protection Coordination," Revision 2 - July 2010. It should be noted that this document does not contain the most up to date information concerning PRC-019, PRC-024, and PRC-025

requirements. The technical bases and guidelines for these specific standards supersede the information contained in the "Power Plant and Transmission System Protection Coordination," Revision 1 - July 2010 document for the affected settings.

6.1.2 IEEE Std C37.102, "IEEE Guide for AC Generator Protection"

6.1.3 IEEE Power System Relay Committee paper, "Coordination of Generator Protection with Generator Excitation Control and Generator Capability"

6.1.4 NERC Reliability Standard PRC-019, "Coordination of Generating Unit or Plant Capabilities, Voltage Regulator Controls, and Protection"

6.1.5 NERC Reliability Standard PRC-024, "Generator Frequency and Voltage Protective Relay Settings"

6.1.6 NERC Reliability Standard PRC-025, "Generator Relay Loadability."

6.1.7 NERC Reliability Standard PRC-025 "Guideline and Technical Basis"

6.1.8 NERC Reliability Standard PRC-026 “Relay Performance During Stable Power Swings”

6.1.9 NERC Reliability Standard PRC-027, “Coordination of Protection Systems for Performance During Faults”

6.2 Definitions

6.2.1 **BES** – Bulk Electric System

6.2.2 **BES Generating Facility** – in general, an individual generator of greater than 75 MVA and that connects to the system at a voltage level > 100 KV or a generating facility that aggregates to greater than 75MVA and that connects to the system at a voltage level >100 KV. See the NERC Glossary of Terms definition of Bulk Electric System for more details

6.2.3 **Frequency and Voltage Protection** **-** Frequency, voltage, and volts per hertz protection (whether provided by relaying or functions within associated control systems) that respond to electrical signals and: (i) directly trip the generating resource(s); or (ii) provide signals to the generating resource(s) to either trip or cease injecting current; and are applied to the following: BES generating resource(s), BES GSU transformer(s), High side of the generator-connected

unit auxiliary transformer (UAT) installed on BES generating resource(s),. Individual dispersed power producing resource(s) identified in the BES Definition, Inclusion I4, or Elements that are designed primarily for the delivery of capacity from the individual dispersed power producing resources identified in the BES Definition, Inclusion I4, to the point where those resources aggregate to greater than 75 MVA.

6.2.4 **GSU** – Generator Step Up

6.2.5 **NERC - North American Electric Reliability Corporation** – The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.6 **NERC related Protection System** – are located at BES generating facilities and consist of the relays, voltage and current sensing devices, DC control circuitry, DC power supply and communication systems used to protect generators, generator step up or main power transformers, synchronous condensers, reactive power sources such as capacitor banks or reactors, Unit Auxiliary or Main Station Auxiliary transformers, Startup or Reserve Station Auxiliary transformers and those portions of dispersed power facility aggregating systems where the power flow aggregates to >75 MVA.

7.0 REVISION HISTORY

Date	Revision	Change
07/21/2014	1.0	Original Issue, supersedes *XES 7.410, "FERC PRC-001 System Protection Coordination"*
05/23/2017	2.0	Revised paragraph 3.2.6 and added paragraph 4.2.3 to clarify that a revised coordination study may be required for changes of the generator and/or GSU, MSA or UST, or RSA or SST transformers. Added section 4.6 to document PRC-026 requirements. Revised section 4.7 to document PRC-026 implementation requirements. Revised section 5.0 to document PRC-026 record retention requirements.
06/05/2018	2.1	Corrected section references for PRC-024.

01/02/2019	2.2	Corrected section 4.5 references to current version of applicable standard, PRC-025-2.
06/09/2020	3.0	Updated department names. Added requirements for PRC-027 including requirements for obtaining up to date input data for the performance of coordination studies and specific requirements for coordination of protection applied on equipment that joins the generating facility to that owned by other NERC functional entities.
06/21/2022	3.1	Updated to reflect minor changes to PRC-024 requirements as delineated in PRC-024-3. Deleted references to PRC-001.
08/01/2023	3.2	Minor revision to paragraph 4.7.3 to correct PRC-027 effective date and implementation requirements based on 6 month COVID extension by FERC Order.

1.0 Purpose:

1.1 This procedure establishes facility ratings to meet certain requirements established by NERC Standard FAC-008. This procedure ensures that Energy Supply develops and applies a facility rating methodology that complies with the NERC Reliability Standards. Energy Supply Technical Services policy EPR 5.200, Facility Rating and Reporting, establishes responsibilities and requirements for utilizing this procedure.

2.0 Applicability:

2.1 This procedure is applicable to all generating facilities including hydro units and Energy Supply-owned synchronous condensers connected to the Bulk Electric System.

2.2 The facility ratings determined from this procedure shall equal the most limiting applicable equipment rating of the individual equipment that comprises the facility.

If Emergency ratings have not been provided by the original equipment manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.

Facility ratings for jointly owned units will be determined by the generating unit operator.

3.0 Responsibilities:

3.1 Performance Optimization Fleet Engineering management is responsible to compile the Normal and Emergency electrical ratings for the generators, transformers, relay protective devices, and terminal equipment, as applicable, for each Bulk Electric System unit.

3.1.1 The point of interconnect between Energy Supply and Xcel Energy Transmission Owners is agreed upon with the Transmission Owner per the XEL-PRO-Facility Rating Coord bet TO and GO.docx.

3.1.2 The point of interconnection between Energy Supply and other Transmission Owners is determined by agreement between the two parties.

4.0 Requirements:

4.1 NERC Facility Rating Methodology

4.1.1 The following methodology is to be used to determine the Facility Rating used for compliance with NERC Standard FAC-008-3.

4.1.2 The facility ratings determined from this procedure shall equal the most limiting applicable equipment rating of the individual equipment that comprises the facility.

4.1.3 To determine the limiting piece of equipment for a facility it is necessary to determine the electrical current (ampere) rating of the following pieces of equipment for conventional generating stations:

- Generator
- Generator Current Transformers
- Generator Disconnect
- Bus or cable conductors that connect the Generator, Generator Breaker (if applicable) and the GSU Transformer.
- Generator Circuit Breaker
- Generator Breaker Current Transformers
- Generator Circuit Breaker Disconnects
- Generator Step-Up (GSU) Transformer – use primary (low voltage) winding current rating for comparison purposes.
- Generator Step-Up Transformer Current Transformers
- Generator Step-Up Transformer Disconnect
- Bus or cable conductors that connect the GSU Transformer or GSU Transformer Disconnect (if applicable) to the Transmission Substation.
- Overcurrent relay minimum pick-up setpoint

4.1.4 The following scope of equipment shall be used for wind farms:

- The combined kVA rating of individual turbines connected to a collector feeder.
- Collector Feeder cable or conductor rating.
- Collector Feeder circuit breaker.
- Collector Feeder circuit breaker disconnects.
- Collector Feeder circuit breaker current transformers.
- Step-Up Transformer
- Step-Up Transformer Disconnects
- Step-Up Transformer Current Transformers
- Conductors that connect the Step-Up Transformer to the Transmission Substation.
- Overcurrent Relay minimum pick-up setpoint.
- Series and Shunt compensation devices

4.1.5 For equipment operating at a voltage other than the generator voltage (or collector feeder voltage for wind farms), for comparison purposes, its current rating shall be adjusted to the equivalent of its rating at the generator (or collector feeder) for the same MVA power level. For example, for a generator rated 10 kV, connected to a generator breaker installed on the high side of the GSU Transformer operating at 100 kV, if the nameplate current rating of the breaker is 1,000 amperes, for the facility rating evaluation, use 100 kV/10 kV times 1,000 amperes = 10,000 amperes.

4.1.6 The rating normally is the manufacturer's nameplate rating. The rating for the nominal generator voltage, normal operating coolant pressure and ambient temperature during summer peak should be used.

4.1.7 For units where the bus or cable does not have a nameplate rating, the current rating of the generator may be substituted.

4.1.8 For bus or conductors in air, use ratings developed based on IEEE 738 for overhead conductors and IEEE 605 for bus. The assumptions used in calculating the ratings are contained in the 'Transmission Line Rating Methodology' and 'Bus Conductors and Equipment Jumpers' sections of Transmission System Policy **XEL-POL-Facility Rating Methodology.doc.** For units with a separate summer and winter rating, the appropriate summer or winter "Normal" current rating should be used. For units with only one seasonal rating, use the appropriate summer "Normal" current rating.

4.1.9 Operating limitations (such as temporary deratings) will be captured in the ratings determination and will be used in finding the most limiting and next most limiting equipment. Temporary operating limitations will be noted as such in the rating documentation.

4.1.10 The identity of the most limiting equipment and the next most limiting equipment shall be identified.

5.0 Required Records:

5.1 Performance Optimization Fleet Engineering shall have evidence it provided the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Coordinator the facility rating methodology requested within 21 calendar days of receipt of a request.

5.2 Performance Optimization Fleet Engineering shall have evidence it responded, in writing, to comments from the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Coordinator within 45 calendar days of receipt of those comments The response shall indicate whether a change will be made to the facility ratings methodology and, if no change will be made to the facility ratings methodology, the reason why.

5.3 Performance Optimization Fleet Engineering shall have evidence it provided the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Coordinator the facility ratings as scheduled by such requesting entities.

5.4 Performance Optimization Fleet Engineering shall have evidence it provided the Reliability Coordinator, Planning Coordinator, Transmission Planner, Transmission Owner, and Transmission Operator with the identity and thermal rating of the next most limiting equipment within 30 calendar days of a request.

6.0 References & Definitions:

6.1 References

6.1.1 EPR 5.200 Facility Ratings and Reporting Policy (found on the XpressNet Energy Supply Performance Optimization Policies Index)

6.1.2 IEEE 738 IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors

6.1.3 IEEE 605 IEEE Guide for Design of Substation Rigid-Bus Structures

6.1.4 XEL-POL-Facility Rating Methodology

6.1.5 XEL-PRO-Facility Rating Coord bet TO and GO.docx

6.2 Definitions

6.2.1 North American Electric Reliability Corporation (NERC) -The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.2 NERC Reliability Standard FAC 008 – NERC Standard applicable to Facility Ratings

6.2.3 Bulk Electric System – See NERC Glossary of Terms for definition: https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

7.0 Revision History

Date	Revision	Change
05/31/2007	Draft	Draft for FERC Reliability Standard – FAC 008, 009
06/07/07	Rev 0	Added reference to EPR – 5.200P
06/21/07	Rev 1	Revised Applicability "Facility ratings for jointly owned units will be determined by the generating unit operator."
9/13/07	Rev 2	Revised Section 3 "producing for an eight (8) hour period for three (3) consecutive days during the summer or winter months at reference ambient conditions as defined in PPT – MC – 01."
11/09/07	Rev 3	If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.
8/15/08	4.0	Administrative change only. Modified numbering to match Documentum version.
10/2/08	5.0	Clarification of capacity terms
6/17/10	6.0	Added generator disconnects, generator breakers (and associated disconnects and CT's), and GSU CT's to the scope of Facility Rating equipment to be evaluated. Added a procedure to evaluate wind farms.
10/01/12	7.0	Revised the procedure to align with NERC Standard FAC-008-3 which replaces FAC-008-1 and FAC-009-1. Changed Maintenance Resources to Technical Resources and Compliance. Changed Production Resources to Technical Services in the header. Removed references to Performance Monitoring.
01/01/13	7.1	Removed Energy Supply specification from section 2.1 and clarified that only Energy Supply-owned synchronous condensers are covered by this policy. Added section to explicitly call out for consideration of operating limitations in section 4 of the methodology.
08/05/2013	7.2	Changed title wording from "determination" to "methodology". Modified header and footer to reflect current standardized format. Updated author to current responsible employee. Corrected effective date to reflect the most recent major revision.
09/15/2014	7.3	Updated section 4.1.8 to included a statement about the assumptions used in calculating the ratings of bus and conductors in air. Added reference to Transmission's facility rating methodology.

Date	Revision	Change
10/10/2016	7.4	Added section 6.1.5 and added sections 3.1.1 and 3.1.2 to the Responsibility section to include policy reference XEL-PRO-Facility Rating Coord bet TO and GO.docx. Added “Series and shunt compensation devices” to wind farm scope section 4.1.4.
10/07/2019	7.5	Changed all references of Technical Resources and Compliance to Performance Optimization Fleet Engineering to reflect department name changes. Added link to the NERC Glossary of Terms for the new definition of Bulk Electric System. Added link to Energy Supply Performance Optimization Policy Index.

1.0 PURPOSE:

This maintenance standard establishes general practices for routine preventative maintenance of batteries and battery chargers utilized at the Company's electric generating plants.

2.0 APPLICABILITY:

2.1 This standard addresses all aspects of routine maintenance and recommended maintenance intervals.

2.2 Xcel Energy Generating Plants have a large variety of battery types and battery applications. This standard is primarily directed toward the maintenance of large strings of flooded cells of either the vented lead acid, lead calcium, lead antimony, or lead selenium type. As such, IEEE Standard 450 – "IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead Acid Batteries for Stationary Applications" provides, in general, the basis for both the content and the frequency of performance of the battery maintenance and testing procedures set forth in this Energy Supply Maintenance Standard. Any deviations between the requirements contained in this standard and the specific IEEE Standard 450 recommendations are within the allowable program considerations discussed in Section 1.2 of IEEE Standard 450. Maintenance activities specific to other types of batteries such as valve regulated lead acid batteries that are used in these applications in power plants have also been included in the program. Proper functioning of battery chargers is validated by observing that the battery charger maintains connected batteries in a fully charged condition by its ability to maintain a proper float voltage on the battery.

For batteries and battery chargers serving as part of a NERC PRC-005 related Protection System, the maintenance activities and maximum allowable intervals of this standard meet or are more restrictive than the NERC Standard PRC-005 for minimum maintenance activities and maximum maintenance intervals for batteries and battery chargers. NERC PRC-005 related batteries and chargers SHALL be maintained per this standard and are on a time-based maintenance program with intervals not to exceed the PRC-005 specified maintenance intervals for unmonitored components.

2.3 This standard applies to batteries and battery chargers used in the following applications:

2.3.1 24 V, 48 V, 125 V or 250 VDC Station Service Batteries

2.3.2 UPS batteries

2.4 Some provisions of this document may be applicable to other battery types and applications. Compliance with this standard for these additional battery types and

applications is at the discretion of the power plant for non-NERC PRC-005 related batteries.

3.0 RESPONSIBILITIES:

3.1 Performance Optimization is responsible for assigning a Fleet Engineering staff member in each region to serve as the Battery Maintenance subject matter expert, (SME)

3.2 The facility director and Performance Optimization management should collaborate and designate an individual to serve as a Site Electrical Maintenance Coordinator, (Site EMC), for each site. The Site EMC responsibilities will, in part, include administration of the requirements identified in Section 4.0 below.

Most frequently the Site EMC will be the electrical Performance Optimization Reliability Engineer assigned to the site. Alternatively, if there is not an electrical Performance Optimization Reliability Engineer assigned to the site, a Maintenance Planner, Operations Support Manager, Station Electrician, or a Performance Optimization Fleet Engineer may be assigned to fulfill this role.

4.0 REQUIREMENTS:

The following maintenance and testing activities are identified for implementation of the battery maintenance program and shall be used by plant management, engineering, operations, and maintenance personnel to assure reliable operations of station DC systems:

4.1 Monthly Inspections:

4.1.1 Plant electrical staff or other knowledgeable battery technician shall perform a monthly inspection of applicable batteries.

4.1.2 The above work should be performed per Performance Optimization Maintenance Procedure, “Battery – Monthly Testing”. This procedure should be set up in the work and asset management program to be performed on each applicable station battery on a monthly basis. A copy of the procedure is available in Energy Supply Policy/Procedure Toolbox.

4.2 Quarterly Inspections

4.2.1 In addition to the monthly inspections, plant personnel or other knowledgeable battery technician shall also perform a quarterly inspection of applicable batteries.

The above work should be performed per Performance Optimization Maintenance Procedure, "Battery – Quarterly Testing". This procedure should be set up in the work and asset management program to be performed on each applicable station battery on a quarterly basis. A copy of the procedure is available in Energy Supply Policy/Procedure Toolbox.

4.3 Annual Inspections:

4.3.1 In addition to the monthly and quarterly battery inspection requirements, plant electrical staff or other knowledgeable battery technicians shall perform a detailed annual inspection of applicable batteries.

4.3.2 The above work should be performed per Performance Optimization Maintenance Procedure, "Battery – Annual Testing". This procedure should be set up in the work and asset management program to be performed on each applicable station battery on an annual basis. A copy of the procedure is available in Energy Supply Policy/Procedure Toolbox.

4.4 Battery Capacity Tests

4.4.1 Plant electrical staff or knowledgeable battery technicians shall perform a battery capacity test at no longer than a 6-calendar year interval for Vented Lead Acid batteries or a 3-calendar year interval for Valve Regulated Lead Acid batteries.

4.4.2 The above work should be performed per Performance Optimization Maintenance Procedure, "Battery – Capacity Testing." This procedure should be set up in the work and asset management program to be performed on each applicable station battery on an interval not to exceed that identified in Section 4.4.1 for that type of battery. A copy of the procedure is available in Energy Supply Policy/Procedure Toolbox. As battery capacity tests frequently require a plant outage, plants should consider their typical maintenance outage interval when establishing the interval for the performance of battery capacity tests associated with a given unit.

4.5 For newly acquired plants, the following grace period is established to bring the facility's battery maintenance program into alignment with this Standard:

4.5.1 The newly acquired plant's NERC related battery system(s) SHALL have a Monthly and Quarterly Inspection performed per the procedures referenced in Sections 4.1 and 4.2 above within three months of assuming ownership of the facility.

4.5.2 The newly acquired plant's NERC related battery systems SHALL have an Annual Inspection performed per the procedure referenced in Section 4.3 above within the first year of assuming ownership of the facility.

4.5.3 The newly acquired plant's NERC related battery system(s) SHALL have a Capacity Test performed per the procedure referenced in Section 4.4 above no later than the sooner of the end of first scheduled maintenance outage or within two years of assuming ownership of the facility unless test records are available from the previous owner's testing program to justify a later test date.

4.6 For batteries and battery chargers serving as part of a NERC PRC-005 related Protection System, the work and asset management shall call for the use of the Monthly, Quarterly, Annual, and Capacity Procedures or approved equivalent forms.

4.7 Plants shall maintain a listing of NERC PRC-005 related batteries and associated battery acceptance criteria. This Battery Acceptance Criteria document shall be kept current.

4.8 Identify any subsequent Work and Asset Management Work Orders issued to address and track any Unresolved Maintenance Issues.

5.0 REQUIRED RECORDS

5.1 The plant shall maintain copies of monthly and quarterly inspection data sheets in the plant maintenance files for at least 3 years. For NERC PRC-005 related batteries, the plant shall maintain copies of monthly and quarterly inspection data sheets for the longer of three years or since the last NERC Compliance audit.

5.2 The plant shall maintain copies of annual inspection completed procedure and data sheets in the plant maintenance files for at least 5 years. For NERC PRC-005 related batteries, the plant shall maintain completed copies of the annual inspection procedure and data sheets for the longer of five years or since the last NERC Compliance audit.

5.3 The plant shall maintain copies of battery capacity procedure and test data sheets in the plant maintenance files for the life of the battery or three years, whichever is longer. For NERC PRC-005 related batteries, the plant shall maintain completed copies of the completed capacity test procedure and data sheets for the longer of the life of the battery or since the last NERC Compliance audit.

6.0 DEFINITIONS & REFERENCES

6.1 Definitions

6.1.1 **Battery Monthly Inspection** – A documented routine inspection of a battery and its charger that should be performed once each month of the year. If scheduling or resource issues prevent completion of a monthly inspection in each calendar month, the reason for the failure to complete the inspection on the normal monthly basis SHALL be documented on the associated Work Order or maintenance procedure and the monthly inspection SHALL be completed within the next calendar month. Technical Rationale for Monthly Inspection Time Allowance: IEEE Standard 450, Section 1.2 allows for some minor program deviations. Furthermore, the Monthly inspection delineated in the associated procedure contains all measurements required on a 4-calendar month interval by the current draft of PRC-005. As such, the one-month time allowance discussed in this paragraph still results in inspections on an interval roughly half of that allowed in the NERC PRC-005 standard. Furthermore, a NERC violation only occurs if a Battery Monthly Inspection is missed for 4 consecutive months

6.1.2 **Battery Quarterly Inspection**– A documented routine inspection of a battery and its charger that should be performed once each quarter of the year. If scheduling or resource issues prevent completion of a quarterly inspection, the reason for the failure to complete the inspection SHALL be documented on the associated Work Order or maintenance procedure and the quarterly inspection SHALL be completed in conjunction with the next monthly inspection.

Technical Rationale for Quarterly Inspection Time Allowance for Vented Lead Acid Batteries: IEEE Standard 450, Section 1.2 allows for some minor program deviations. Furthermore, the Quarterly inspection delineated in the associated procedure contains measurements required for Vented Lead Acid batteries on an 18-calendar month interval by the current revision of PRC-005. As such, the additional one-month time allowance discussed in the above paragraph still results in inspections on a not to exceed 4-month interval which is over 4 times as frequent at the 18-calendar month interval allowed in NERC PRC-005 standard. As such, a NERC violation only occurs if a Battery Quarterly Inspection is missed for 6 consecutive quarters for a Vented Lead Acid Battery and then only if the Annual Inspection for the associated battery was also missed.

Technical Rationale for Quarterly Inspection Time Allowance for Valve Regulated Lead Acid Batteries: The Quarterly inspection delineated in the associated procedure contains measurements required for Valve Regulated Lead Acid

batteries on a 6-calendar month interval by the current version of PRC-005. As such, the additional one-month time allowance discussed in the above paragraph still results in inspections on a not to exceed 4-month interval which is still more frequent than the 6-calendar month allowed in the NERC PRC-005 standard. As such, a NERC violation only occurs if a Battery Quarterly Inspection is missed for 2 consecutive quarters for a Valve Regulated Lead Acid Battery.

6.1.3 **Battery Annual Inspection** – A documented and detailed inspection of a battery and its charger that should be performed on a one-year interval. If scheduling or resource issues prevent completion of the annual inspection within 12 calendar months of its last completion, the reason for the failure to complete the inspection within the normal annual basis SHALL be documented on the associated Work Order or maintenance procedure and the annual inspection SHALL be completed within the next six calendar months. Technical Rationale for Annual Inspection Time Allowance: IEEE Standard 450, Section 1.2 allows for some minor program deviations. Furthermore, the Annual inspection delineated in the associated procedure contains measurements required on an 18-calendar month interval by the current version of PRC-005. As such, the additional six-month time allowance discussed in this paragraph results in inspections on an interval equivalent to the 18-calendar month allowed in the NERC PRC-005 standard.

6.1.4 **Unresolved Maintenance Issue** – a deficiency identified during a maintenance activity that causes the component to not meet the intended performance, cannot be corrected during the maintenance interval, and requires follow-up corrective action.

6.1.5 **Additional Definitions** – see IEEE Standard 450 for definitions and further descriptions of battery terms used in this standard or associated maintenance procedures.

6.2 References

6.2.1 IEEE Standard 450 – “IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead Acid Batteries for Stationary Applications. “

6.2.2 NERC Standard PRC-005

6.2.3 Energy Supply Policy/Procedure Toolbox.

REVISION HISTORY

Date	Revision	Change
8/1/05	0	Original Issue
3/12/07	0	Guideline rewritten into a standard
3/26/07	1.1	Clarified requirements for reading cell voltages only on a quarterly basis during performance of monthly inspections. See paragraph 4.1.1.
3/13/08	1.2	Expanded on definitions of monthly and annual inspections to allow for flexibility in scheduling.
4/7/08	1.3	Removed quarterly testing requirements from description of monthly inspection and added a stand-alone quarterly inspection requirement.
11/6/08	1.4	Removed inspection detailed guidelines from paragraphs 4.1.1, 4.2.1, 4.3.1 and 4.4.1 of the standards as this information is provided in the respective inspection and test procedures.
9/24/09	1.5	Revised paragraph 2.0 to clarify that IEEE Standard 450 serves as the primary basis of the Energy Supply Battery Maintenance program. Clarified maximum allowable interval for performance of battery capacity tests in paragraph in paragraph 4.4, and in Paragraph 6.0, eliminated definitions and instead referred to IEEE Standard 450 definitions and added IEEE Standard 450 as a reference.
1/26/2010	1.6	Reinstated definitions of monthly, quarterly, and annual inspections at section 6.0 to allow flexibility in scheduling.
05/24/2012	1.7	Updated hyperlinks.
08/26/2012	1.8	Updated hyperlinks, changed department names to reflect current organization.
11/21/2012	2.0	Major Revision to establish and document program alignment with pending PRC-005-2 requirements and to address change in NERC definition to include battery chargers as part of the DC Supply element of a Protection System.
03/02/2015	2.1	Reformatted to comply with XES 1.100P01 'Configuration Management for ES Policies and Procedures'. Minor grammatical revisions and clarification that monitoring attributes are not utilized to extend maintenance intervals.

Date	Revision	Change
02/09/2016	2.2	Changed references from revision-specific to non-revision specific NERC standard PRC-005.
03/13/2017	2.3	Changed Maximo to generic “work and asset management”
09/14/2018	2.4	Updated hyperlinks. Changed “Maximo” to “Work and Asset Management” in section 4.8.
01/24/2022	3.0	Triennial review - Minor change to reflect current department names for the existing responsibilities
5/3/2023	3.1	Updated Links to the Electrical Maintenance Index

1.0 PURPOSE:

1.1 This standard establishes general practices for routine preventative maintenance of Protection Systems and Sudden Pressure Relaying utilized at the Company's electric generating plants.

2.0 APPLICABILITY:

2.1 Included in the scope of this standard are Protection Systems and Sudden Pressure Relaying that protect generators, transformers, switchgear, and the individual loads fed from the circuit breakers on a medium voltage or low voltage bus. The standard addresses all aspects of routine maintenance as well as recommended testing and maintenance intervals. Note that Protection Systems and Sudden Pressure Relaying for generators, generator step-up transformers, generator interconnection facilities, main or unit connected auxiliary transformers, reserve or startup auxiliary transformers, and generator bus connected excitation transformers at Bulk Electrical System (BES) plants or Protection Systems for facilities used in aggregating dispersed BES generation from the point where those resources aggregate to greater than 75 MVA to a common point of connection at 100 kV or above, must be maintained per this standard to meet NERC Standard PRC-005, "Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance," requirements.

2.2 Energy Supply does not utilize Automatic Reclosing and as such, maintenance of Automatic Reclosing components is not addressed in this standard. Furthermore, Energy Supply has no RAS, UVLS or UFLS systems and therefore maintenance of those systems is not addressed.

2.3 The maintenance activities and associated maximum maintenance intervals established within this policy are based on those contained in the current version of NERC Standard PRC-005 and associated documents as they exist at the time of the approval of this standard.

2.4 For NERC Standard PRC-005 related schemes all Relays, Voltage and Current Sensing Devices, Associated Control Circuitry Protection System Component Types, as well as Sudden Pressure Relaying, are maintained per a time-based maintenance program with intervals not to exceed the PRC-005 specified maintenance intervals for unmonitored components.

2.5 For NERC Standard PRC-005 related schemes, Communication Protection System Components maintained per this Energy Supply program are maintained per a time-based maintenance program for continuously monitored Communication Protection Systems with intervals not to exceed the PRC-005 specified maintenance intervals for monitored communication components. All present Communication Protection System Components alarm to an operator for communication system failure.

2.6 For NERC Standard PRC-005 related schemes, Battery and Battery Charger Protection System Components are maintained per EPR 5.704S.

3.0 RESPONSIBILITIES:

3.1 Performance Optimization is responsible for assigning a Fleet Engineering staff member in each region to serve as the Protection System Maintenance subject matter expert, (PSM-SME) .

3.2 The facility director and Performance Optimization management should collaborate and designate an individual to serve as a Site Electrical Maintenance Coordinator, (Site EMC), for each site. The Site EMC responsibilities will, in part, include administration of the requirements identified in Section 4.0 below.

Most frequently the Site EMC will be the electrical Performance Optimization Reliability Engineer assigned to the site. Alternatively, if there is not an electrical Performance Optimization Reliability Engineer assigned to the site, a Maintenance Planner, Operations Support Manager, Station Electrician, or a Performance Optimization Fleet Engineer may be assigned to fulfill this role.

4.0 REQUIREMENTS:

The following maintenance and testing activities are identified for implementation of the Protection System maintenance program and shall be used to assure reliable operation and performance of the protection systems:

4.1 Development and Management of the Site Protection System Maintenance Program.

4.1.1 The Site EMC and PSM-SME should work together to identify all protective relays, voltage and current sensing devices (PTs and CTs/DC shunts), communications systems, and associated control circuitry used in Protection Systems and Sudden Pressure Relaying on a site and to group these devices into protective schemes for the purposes of scheduling and performing maintenance.

4.1.2 For NERC PRC-005 Related Protection Systems and Sudden Pressure Relaying, the PSM-SME SHALL develop scheme specific Protection System maintenance procedures. These procedures SHALL

4.1.2.1 Clearly identify all relays, voltage and current sensing devices, communications systems, associated control circuitry trip paths and Sudden Pressure relaying to be tested in conjunction with the maintenance of that particular NERC PRC-005 Related Protection System.

4.1.2.2 Provide adequate guidance to assure that the maintenance activities specified in paragraph 4.2.2 below are performed for each component type utilized within that particular protection system scheme and so that completion is documented for compliance evidence.

4.1.2.3 Identify any subsequent work and asset management system Work Orders issued to address and track any Unresolved Maintenance Issues - issues identified but not corrected during the performance of the procedure

4.1.2.4 Be reviewed and updated as necessary by the PSM-SME following any protection system modifications.

4.1.3 The PSM-SME is responsible for maintaining documentation of the desired setpoints of all protective relays and to have this information available for technician reference during maintenance. The PSM-SME should strive to develop consistent setpoint documentation at all plants. Consistency in the methods of setpoint documentation will make maintenance much easier for the technicians who travel from site to site to perform relay calibration.

4.1.4 The Site EMC shall ensure that plant protective system component maintenance and testing as described in this standard is performed within the intervals established in Table 1, “Maximum Allowed Protection System Maintenance Intervals.”

4.1.4.1 Under no circumstance shall the period between tests of any particular device exceed the timeframe prescribed in Table 1, except that maintenance and testing of a device may be completed any time within a calendar year (i.e., the interval is based on calendar years and not anniversary dates).

4.1.4.2 The plant overhaul schedule should be taken into consideration when scheduling protection system maintenance and testing.

4.1.4.3 Equipment outages may be required to maintain and test certain devices; therefore, equipment outage schedules should be considered when scheduling protection system maintenance and testing.

4.1.4.4 In scheduling the maintenance and testing activities, priority should be driven by the criticality of the equipment, the cleanliness of the environment, the type of relay involved (electromechanical, solid state, or microprocessor based), and past maintenance history. While prioritization of scheduling may be appropriate, in no event shall the period between maintenance and testing of a specific device exceed the applicable interval set out in Table 1.

4.1.5 Once all of the protective relay schemes have been identified and appropriate maintenance intervals have been identified for each of the individual schemes, the Site EMC should assure this information is entered into the work and asset management system PM program so that protective relay maintenance of all protective relay schemes will be automatically scheduled to be performed on a recurring basis.

4.1.5.1 For NERC PRC-005 Related Protection Systems and Sudden Pressure Relaying, the work and asset management system PM shall call for the performance of the scheme specific procedures developed per Section 4.1.2 above.

4.1.6 The Site EMC is responsible for onsite coordination of protection system maintenance activities.

4.1.7 Periodically, the PSM-SME and the Site EMC should review as found vs. as left test data recorded during performance of maintenance. Based on the findings of this review, they may elect to lengthen or shorten the maintenance interval assigned to a particular scheme. However, for NERC PRC-005 related protection and sudden pressure relaying systems, the interval cannot be extended beyond that specified on Table 1.

4.2 Performance of Protection System Maintenance

4.2.1 **Effective Program Start Dates.** For compliance purposes, the relay maintenance program effective start date for all component types other than sudden pressure relaying is 4/1/2015 which is the original effective date of

PRC-005-2. For sudden pressure relaying the effective program start date is 1/1/2016 which is the original effective date of PRC-005-6. See NERC Implementation Plans for detailed phased in requirements.

4.2.1.1 For those protection systems for which maintenance activities meeting the requirements of paragraph 4.2.2 were performed prior to 4/1/2015, initial maintenance may be scheduled based on the last completion date and the appropriate Table 1 maximum allowed interval.

4.2.1.2 For newly installed or modified Protection Systems, initial maintenance should be scheduled based on the final commission/acceptance test date and the appropriate Table 1 maximum allowed interval.

4.2.2 **Maintenance Activities.** The following maintenance activities should be performed for the various component types making up a Protection System. For PRC-005 related schemes, these maintenance activities must be performed to meet the maintenance activity requirements of PRC-005.

4.2.2.1 Maintenance Activities for Electromechanical Protective Relays

Perform the following as appropriate:

- Perform and record a single point, as found calibration check of the device prior to cleaning or adjusting the relay.
- Clean, inspect, and adjust the relay as necessary.
- Perform an as left calibration check of the device. For time overcurrent relays, this as left check should be at a minimum of three points on the time characteristic curve.
- Verify that the relay output contacts will act to trip the associated circuit breaker or actuate any associated lockout device.
- Verify the relay as left settings are as specified

4.2.2.2 Maintenance Activities for Analog Electronic Protective Relays

Perform the following as appropriate:

- Perform and record a single point as found calibration check of the device. The results of this initial test should be recorded.

- If the results of the as found test or relay self test were acceptable, the technician need not perform any as left testing. If the results of the initial test were unacceptable, the technician should adjust the relay and perform as left testing. If performed, the results of the as left testing should be recorded.

- Verify that the relay output contacts will act to trip the associated circuit breaker or actuate any associated lockout device.

- Verify the as left relay settings are as specified

4.2.2.3 Maintenance Activities for Microprocessor Based Protective Relays

Perform the following as appropriate:

- Verify that the relay output contacts will act to trip the associated circuit breaker or actuate any associated lockout device.

- Verify proper functioning of the input analog/digital converters.

- Verify proper response to relay inputs critical to Protection System performance.

- Verify the as left relay settings are as specified.

4.2.2.4 Maintenance Activities for Current Transformers (CTs) and DC shunts

A CT/Shunt Verification Test should be performed at the interval listed in Table 1. Acceptable methods of CT Verification include:

- CT Feedback (Saturation) Test

- CT/Shunt Load Check Test

- CT/Shunt Comparison Test

4.2.2.5 Maintenance Activities for Potential Transformers (PTs)

A PT Verification Test should be performed at the interval listed in Table 1. Acceptable methods of PT Verification include:

- Turns Ratio Test

- Phase Comparison Test

- PT Comparison Test

4.2.2.6 Maintenance Activities for Associated Control Circuitry

4.2.2.6.1 For NERC PRC-005 related schemes, control circuitry between the protective relay output contacts and the trip coil(s) of the interrupting device(s) actuated by the protection system must be tested. This includes actuation of lockout devices and auxiliary tripping relays and verifying that each trip coil can trip the associated circuit breaker.

4.2.2.6.2 When testing control circuits, it is not necessary to test each individual path completely from the relay all the way to the trip coils of the interrupting device. However, each segment must be functionally tested and overlap of testing will assure functionality of the entire circuit. For example, if several different protective relays can cause a lockout device to actuate and that lockout in turn actuates a circuit breaker trip coil, it is only necessary to prove that each individual relay can actuate the lockout and only once prove that the lockout can actuate the breaker trip coil.

4.2.2.6.3 For NERC PRC-005 related schemes, testing of associated control circuitry SHALL be performed and documented using the scheme specific testing procedures discussed in Sections 4.1.2 and 4.1.5.1 above.

4.2.2.7 Maintenance Activities for Batteries and Battery Chargers Associated with Protection Systems

4.2.2.7.1 Batteries have many critical functions at power plants beyond those served in protection systems. Furthermore, maintenance of batteries is vastly different in scope and process than that for other protection system devices. As such, requirements for the maintenance and testing of battery and charger systems is provided for in a separate stand alone document, EPR 5.704S, “Battery Maintenance Standard”

4.2.2.7.2 The Site EMC SHALL assure that batteries and chargers associated with NERC PRC-005 Related Protection Systems are maintained per EPR 5.704S.

4.2.2.8 Maintenance Activities for Protection System Communication Systems

4.2.2.8.1 Verify that the communications system meets performance criteria pertinent to the communications technology applied (e.g. signal level, reflected power, or data error rate)

For Fiber Optic Systems perform the following:

- Perform equipment alarm function test back to station DCS
- Single end testing utilizes the local relay and looped back communication equipment to verify local scheme functionally.

4.2.2.8.2 The trips via the communications shall be maintained per the DC Control Circuitry maintenance requirements at an interval of 6 years. This includes verification of communication system inputs and outputs that are essential to proper functioning of the protection system.

4.2.2.8.3 In lieu of the above, Protection System Communication Systems, if present, at the interface between power plants and the substation may be maintained per the Substation/Transmission Protection System Maintenance Program for communication systems.

4.2.2.8.4 Synchronized and Non-synchronized end to end protective system testing shall be done in coordination of the authority on the other end of the communication line.

4.2.2.9 Maintenance Activities for Sudden Pressure Relaying

4.2.2.9.1 Sudden Pressure Relaying should be performed at the interval listed in Table 1 and verify:

- The pressure or flow sensing mechanism is operable.
- Electrical operation of associated electromechanical lockout devices.

- Functionality of all associated paths of the trip circuits inclusive of all auxiliary relays through the trip coil(s) of the circuit breakers or other interrupting devices.

4.2.2.9.2 For NERC PRC-005 related schemes, testing of Sudden Pressure Relaying SHALL be performed and documented using the scheme specific testing procedures discussed in Sections 4.1.2 and 4.1.5.1 above.

4.3 Implementation Schedule for Newly Acquired Plants

For Protection Systems acquired through acquisition or merger process there will be a transition period from the previous entity's program to Xcel Energy Supply's program. PRC-005 related protection systems reviews SHALL be completed before commercial operation begins under Xcel Energy's control. The initial performance of all the maintenance activities required by Section 4.2 must be completed no later than the sooner of the end of first scheduled maintenance outage or within two years of assuming ownership of the facility. However, if test records are available from the previous owner's testing program and the requirements of Section 4.2 are met; the first scheduled maintenance may be based on the completion date of those records.

For batteries, see Section 4.5 of EPR 5.704S 'Battery Maintenance Standard (NERC)'

5.0 REQUIRED RECORDS

5.1 The PSM-SME and Site EMC SHALL have a method to identify all protective relay schemes and to document the individual relays, CTs, and PTs making up a particular scheme. Note that scheme specific procedures can be used to fulfill this requirement.

5.2 The PSM-SME SHALL maintain documentation of the desired setpoints of all protective relays and baseline CT, DC shunt and PT verification test data.

5.3 For every protective relay, voltage and current sensing device, calibration or testing history should be maintained in the program maintenance files for the last three test intervals. For NERC PRC-005 Related Protection Systems, calibration and/or test history SHALL be maintained at least for the last 2 completed test intervals

5.4 For NERC PRC-005 Related Protection Systems and Sudden Pressure Relaying, the Site EMC SHALL maintain the last 2 completed scheme specific maintenance procedures in the program maintenance files

6.0 DEFINITIONS & REFERENCES

6.1 Definitions

6.1.1 **As Found Relay Setting** – a check of a relay setpoint that is taken prior to performing any cleaning, adjustment, or maintenance on a relay.

6.1.2 **As Left Relay Setting** – a check of a relay setpoint that is taken after all cleaning, adjustment, and maintenance has been completed on a relay.

6.1.3 **Automatic Reclosing –** Includes the following Components:

- Reclosing relay
- Supervisory relay(s) or function(s) – relay(s) or function(s) that perform voltage and/or sync check functions that enable or disable operation of the reclosing relay
- Voltage sensing devices associated with the supervisory relay(s) or function(s)
- Control circuitry associated with the reclosing relay or supervisory relay(s) or function(s)

Automatic Reclosing is not installed or used in Energy Supply owned facilities.

6.1.4 **Bulk Electric System (BES) Plants –** plants which connect to the transmission system at voltages ≥ 100 KV at the point of interconnection and are either individual units sized at >20 MVA or aggregate site size of > 75 MVA. Additionally any units used for black start restoration, regardless of the size or the voltage at which they connect to the system are included in the BES. See NERC BES definition for BES classification of dispersed generating assets such as wind or solar farms.

6.1.5 **Communication Systems** – Communication Systems in Protection Systems are typically defined as relays at remote ends of transmission lines communicating via various mediums in order to transmit data such as current values and trip signals. Communication Systems types such as Carrier and Tone, are not used with Protection Systems maintained by Energy Supply Power Plants. Digital Equipment type Communication Systems are occasionally used. Digital Equipment is typically defined as follows:

6.1.5.1 Digital Equipment types self monitor channel integrity and will alarm back to the control center through DCS equipment notifying of channel issues or problems.

6.1.5.2 Communication Processors that act as a RTU (remote terminal unit) to communicate relay status are not applicable to this standard as long as no digital bits are passed between relays for protection functions.

6.1.6 **Current Transformer (CT)** – an instrument transformer that has its primary winding in series with the current to be measured and which produces a small signal current in its secondary winding that is proportional to the current in its primary winding. This secondary current is used to provide inputs to protective relaying and/or metering that requires a current signal to operate.

6.1.7 **CT/DC shunt Verification Test** – any type of test or observation that provides some level of assurance that a CT or DC shunt is functioning properly. The verification test should include the CT secondary wiring or shunt MV signal wiring between the relay panel and the location of the CT or DC shunt. Some possible methods of verifying proper CT/DC Shunt function include:

6.1.7.1 Performance of a CT Feedback test (Saturation Test) – an offline test in which a voltage is impressed on a CT and current is measured and compared to previous test data. This test can detect developing problems with the CT or with the wiring that interconnects the CT to the meter or relay that it feeds. The CT is considered acceptable if the excitation current is within +/- 50% of the baseline value for a given input voltage.

6.1.7.2 Performance of CT/DC shunt load checks – observation of secondary currents on in service CTs or millivolt signals from DC shunts to verify currents are as expected for a given load. A three-phase set of CT's is considered acceptable if the current from each CT is within +/- 5% of the average of the set of CT's. A DC shunt is considered acceptable if within 5% of the anticipated value for the given operating point for the DC circuit being monitored.

6.1.7.3 CT/Shunt Comparison Test – For CTs, a comparison of the outputs of 2 separate CTs monitoring the same current. This may be accomplished by observing current, Volt-ampere, watt, or VAR indications fed from two separate sets of CTs. The CT is considered acceptable if the current from the CT is within +/- 5% of the CT to which it is being compared. For DC shunts, comparison of the output of a DC shunt to current measured by use of a DC clamp on ammeter and is acceptable if within 5%

6.1.8 **Electromechanical Relay** – any relay that relies on interaction of electromagnetic forces and moving parts such as springs, disks, or pneumatic diaphragms to establish the relay setpoint. Electromechanical relays often have tight mechanical clearances and rely on low friction jewel bearings to allow movement of the relay disk. As such, these relays are quite sensitive to the presence of coal dust and other environmental factors. Relays located in dusty or dirty areas will require more frequent maintenance than similar relays located in cleaner environments. Electromechanical relays also make use of magnets whose magnetic properties degrade over time resulting in setpoint drift that necessitates periodic re-calibration of the relay. For the above reasons, electromechanical relays require more frequent maintenance than do electronic or microprocessor based relays.

6.1.9 **(Analog) Electronic Relay** – a relay whose setpoint is controlled by analog electronics such that there are no moving parts involved in establishing the setpoint. These relays are much less affected by dust and dirt and exhibit significantly less setpoint drift than do electromechanical relays. Electronic or solid state relays require less frequent and less extensive maintenance then do electromechanical relays.

6.1.10 **Microprocessor Based Relay** - a relay that uses digital electronics and has a programmable microprocessor to control trip and alarm features. These devices are equipped with alarming self check features that are constantly monitoring relay performance and condition. As such, microprocessor relays are highly reliable and require much less frequent and extensive maintenance than either electromechanical or analog electronic relays.

6.1.11 **NERC PRC-005 Related Protection Systems–** protection system relays, communication systems, associated trip circuits and instrument transformers which protect and act to trip generator, generator step up transformer, generator interconnection facilities, main or unit connected auxiliary transformers, reserve or startup auxiliary transformers at BES plants, or Protection Systems for facilities used in aggregating dispersed BES generation from the point where those resources aggregate to greater than 75 MVA to a common point of connection at 100 kV or above.

6.1.12 **Potential Transformer (PT)** – an instrument transformer that is intended to have its primary winding connected in parallel with a power circuit such that the small voltage signal induced in the secondary is proportional to the voltage on the power circuit and primary winding of the transformer. The secondary winding voltage signal is then used in metering and relays.

6.1.13 **Protection System -** NERC's official definition of a Protection System is:

- Protective relays which respond to electrical quantities,
- Communications systems necessary for correct operation of protective functions
- Voltage and current sensing devices providing inputs to protective relays,
- Station dc supply associated with protective functions (including batteries, battery chargers, and non-battery-based dc supply), and
- Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices

6.1.14 **PT Verification Test -** any type of test or observation that provides some level of assurance that a PT is functioning properly. The verification test should include the PT secondary wiring between the relay panel and the location of the PT. Some possible methods of verifying proper PT function include:

6.1.14.1 Turns Ratio Test. A turns ratio test is performed by injecting a voltage into one of the windings and the resultant output is measured on the other winding. The test is acceptable if resultant voltage is within +/- 2% of expected values.

6.1.14.2 Phase Comparison Test. A test where each of the phase outputs of a set of PT's is compared to the average of the set. A three-phase set of PT's is considered acceptable if the voltage from each PT is within +/- 5% of the average of the set of PT's.

6.1.14.3 Comparison Test – comparison of the outputs of 2 separate PTs monitoring the same current. This may be accomplished by observing current, Volt-ampere, watt, or VAR indications fed from two separate sets of PTs. The PT is considered acceptable if the voltage from the PT is within +/- 5% of the PT to which it is being compared.

6.1.15 **Scheme** – a grouping of protective relays applied together to protect a device such as a generator, transformer, bus, or load. Typically, all relays in a relaying scheme will require many of the same isolation points and equipment outages in order to perform maintenance or calibration of the relay. As such, maintenance of protective relaying is planned and scheduled on the basis of protective schemes rather than by individual relays.

6.1.16 **Sudden Pressure Relaying** – A system that trips an interrupting device(s) to isolate the equipment it is monitoring and includes the following components:

- Fault pressure relay – a mechanical relay or device that detects rapid changes in gas pressure, oil pressure, or oil flow that are indicative of faults within liquid filled, wire-wound equipment
- Control circuitry associated with a fault pressure relay

6.2 References

6.2.1 PRC-005-6, "Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance"

6.2.2 NERC Supplementary Reference and FAQ, “PRC-005-6 Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance and Testing - October 2015.”

6.2.3 NERC Implementation Plan, “Project 2007-17.4 FERC Order Directive 803 PRC-005-6”

6.2.4 EPR 5.704S Battery Maintenance Standard (found on the Energy Supply Performance Optimization Policies web page)

7.0 REVISION HISTORY

Date	Revision	Change
8/1/05	0	Original Issue
3/12/07	0	Revised into a standard
3/20/07	1	Revised Table A Plant identifiers to Coal/RDF and Gas/CT/Hydro
5/21/08	1.1	Corrected policy number in heading on Appendix A and reference to Appendix A in ¶4.4
11/17/08	2.0	Reformatted numbering of section 4.2 and provided for alternative methods of current and potential transformer verification. Added paragraph 4.2.1 to clarify program start date
6/1/09	2.1	Added definition of microprocessor based relay and delineated requirements for microprocessor vs. analog electronic relays in paragraphs 4.2.3 and 4.2.4 and Table A. Added further clarification of the bases of Table A intervals in paragraph 4.1.3
7/21/10	2.2	Added sentence to paragraph 4.2.1 to clarify intent of requirements for scheduling of initial maintenance necessary to fulfill program initiation requirements
11/21/2012	3.0	Major Rewrite to meet requirements of pending NERC standard PRC-005-2. Significant changes include: -change in title to clarify scope of standard is for Protection Systems rather than just protective relays. -moved program bases description up to Section 2.0. Establish draft PRC-005-2 materials as the basis for the program. -changed departmental references from “Maintenance Resources” to “Technical Resources & Compliance” to reflect organizational changes. -added paragraphs 4.1.2, 4.1.5.1, and 5.3 to discuss new requirements for scheme specific testing procedures for NERC PRC-005 Related Protection Systems -added paragraph 4.2.2.6 and modified Table A to Table 1 and provided greater clarity for requirements for testing of associated control circuits. -added paragraph 4.2.2.7 to recognize and emphasize that batteries and battery chargers are part of a protection system but are maintained per requirements delineated in EPR 5.704S, Battery Maintenance Standard. -added paragraph 4.2.2.8 to recognize that Communication Systems are part of protection systems but to document that

Date	Revision	Change
		they are not utilized within Protection Systems maintained by Energy Supply
03/26/2013	3.1	– Removed Supersedes EPR 5.714G from title block – Removed references to PRC-005-2 and made all references to PRC-005 throughout document – Added UAT/RAT and SU transformers back in section 2.0 – Updated section 2.0 applicability for a communication device maintenance program, defining types and monitoring statuses. – 4.1.2.4 added for updating procedures for changes in relaying – 4.1.5.1 added 'of' for clarification in the statement 'for the performance of' – 4.2.2 the statement 'requirements required by' was changed to 'requirements of PRC-005' – Completely rewrote 4.2.2.8 and added subsections for fiber optic communication systems in all regions – Updates to section 4.3 for acquired plants – Added 6.1.14 definition of a communication system – Updated Section 6.2 references – Updated Table 1 to include communication systems
05/07/2013	3.2	– Added wording in section 2.0 that was inadvertently deleted in previous revision.
11/04/2013	3.3	– Added wording to address generator interconnection facilities in the following sections: Section 2.0, new definition 6.1.8, modified definition 6.1.10, and Table 1
08/03/2015	3.4	– Revised section 2.0 to more accurately describe in scope protection systems at dispersed BES generation facilities per PRC-005-2(i) applicability – Deleted section 4.4 which referenced a non-existent specification for performance of relay testing by vendor personnel
02/09/2016	4.0	– Major re-write to address requirements of NERC standard PRC-005-6, including adding Automatic Reclosing and Sudden Pressure Relaying.
11/07/2016	4.1	– Minor re-write to include: ▪ use of the generic term "voltage and current sensing device" instead of "instrument transformer" or "CTs/PTs" and to include DC shunt testing for new AVR systems

Date	Revision	Change
		which have Protection System trips derived from DC shunt signals for generator field current. ▪ Re-organization of Table A to clarify applicability for dispersed generation assets. ▪ Deletion of references to Maximo and addition of generic term “work and asset management system”. ▪ Clarified in applicability that ES does not have RAS, UFLS or UVLS systems.
3/20/2020	5.0	– Update department names to reflect current organization. – Updated references – Updated paragraph 4.2.1 to reflect effective program start dates for PRC-005-2 and PRC-005-6 phased in maintenance programs per the associated NERC Implementation Plans. – Clarified responsibilities of the Site Electrical Maintenance Coordinator and the Protection System Maintenance Subject Matter Expert
5/3/2023	5.1	– Updated link to Performance Optimization Policy

Table 1 – Maximum Allowed Protection System Maintenance Intervals

Relay Application	Environment	Device Type	Maximum Allowed Maintenance Interval*
Generator, Generator Interconnection Facility, and Dispersed Gen Aggregating Facility Protective Relays	All	Electromechanical or Electronic (Analog)	6 years
	All	Microprocessor based	6 years
GSU, MSA RSA/Startup Transformer Relays	All	Electromechanical or Electronic (Analog)	6 years
	All	Microprocessor based	6 years
MV & LV Switchgear Protection Relays	All	Electromechanical or Electronic (Analog)	6 years
	All	Microprocessor based	12 years
Voltage and Current Sensing Devices	All	Current	12 years
	All	Potential	12 years
Communication Systems	All	Communications	12 years
Associated Control Circuits	All	Trip Paths	6 years
Sudden Pressure Relaying	All	Pressure and Flow Sensor, Associated Lockout Devices and Control Circuits	6 years

*Maximum allowed interval is based on calendar years.

1.0 PURPOSE

1.1 To reduce the vulnerability of cyber-attack, specific requirements for cyber-security administration, monitoring, protection, and oversight are applied to cyber assets within electric generating facilities.

1.2 This policy implements cyber-security requirements of the NERC Critical Infrastructure Protection (CIP) reliability and compliance program, standard CIP-003-8, "Cyber-Security – Security Management Controls" applicable to facilities designated at the low impact level. In addition, selected principles as recommended by the National Institute of Standards and Technology (NIST) are included, such as: isolation of mission-critical systems from public access; a clear delineation of logical security boundaries; use of a protected, layered architecture; least privilege access control, information protection, and operation under the assumption that any external network connection is insecure.

1.3 This document does not supersede any of the Xcel Energy corporate policies. The intent of this policy is to expand upon those expectations and address them on an Energy Supply level. In the event that an issue is not addressed in this document, the Enterprise Information Security and Technology Standards should be consulted.

2.0 APPLICABILITY

2.1 This policy applies to all Xcel Energy Bulk Electric System (BES) generating facilities that meet the following conditions:

2.1.1 Are identified as CIP regulated at the low impact level under the corporate program for BES Cyber System Identification and Categorization [CIP-002-5.1a] as shown in Attachment 1.

2.1.2 Contain BES Cyber Systems (BCSs) that provide named reliability operating services. For Energy Supply, these services are in the following categories: Dynamic Response to BES conditions; Controlling Frequency; Controlling Voltage; Monitoring and Control; Restoration of the BES; and Situational Awareness [CIP-002-5.1a].

2.1.3 Utilizes microprocessor-based data acquisition systems that collect or store potentially sensitive or proprietary information. This includes but is not limited to unit and equipment operating status, production and consumption rates and environmental data.

2.2 Facilities regulated by the U.S. Nuclear Regulatory Commission are exempt from this policy.

3.0 RESPONSIBILITIES

3.1 The Manager of Fleet Engineering is responsible for designating a Regional System Administrator for each operating region (SPS, PSCo, and NSP).

3.2 Plant Network Delegates

3.2.1 Complete the Plant Network Inspection Checklist in compliance with this policy, and coordinate responses and approval with Regional System Administrators.

3.2.2 Assist with local network issues

3.3 Regional System Administrators

3.3.1 Develop, maintain, and document a Plant Network Security Plan and review with Plant Network Delegates

3.3.2 Limit BCS access to those staff who need access to perform their jobs; the type and level granted shall be the minimum level required to perform the assigned work. Username and Password authentication shall be used for all access to any device on a BCS plant network. For these systems, the default manufacturer's password shall be changed to unique and strong passwords, where technically feasible. If a unique login is not technically feasible or will prevent an individual from being able to perform their job responsibilities in a reasonable manner a documented exception will be required.

3.3.3 Firewall administration, including final approval and implementation of rule sets and changes to them, as justified by business need.

3.3.4 Documenting the business justification and approval for rules not being logged or turned off

3.3.5 Compliance review and approval of the Plant Network Security Plan and Plant Network Inspection Checklist every 15 months.

- This is done by reviewing the Plant Network Security Plan and Plant Network Inspection Checklist and moving them to the "released" state in ProjectWise

3.3.6 Investigation and disposition of suspected cyber-security incidents, notification of the Enterprise Command Center (ECC) if indicated and submitting required forms in SharePoint.

3.3.7 Logical access to each plant BCS network shall be managed by the Regional System Administrator, who shall review and approve the rule change form submitted by the Plant Network Delegate where applicable.

3.4 Energy Supply CIP Senior Consultant is responsible for:

3.4.1 Review and update of this policy as necessary or at a minimum every 15 calendar months.

3.4.2 Update e-Learning course: “Plant Network Security Policies” as necessary or at a minimum every 15 months

3.4.3 Review administrator access for Regional System Administrators as necessary or at a minimum every 15 months

3.4.4 Administration of storage repositories

3.4.5 Updating and maintaining SharePoint Processes

- Energy Supply Firewall Change Request Form and Workflow
- Energy Supply Smart Key Request Form and Workflow

3.5 Plant Managers and Directors are responsible to provide equipment, software, and facility resources as needed to support requirements of this policy.

3.6 Plant improvement projects Project Initiators are responsible to plan for cyber-security compliance at the project initiation stage and incorporate cyber-security implementation tasks required to comply with this policy into the project cost and schedule prior to funding and approval. Project planning for cyber-security shall employ the Enterprise Project Management (EPM) system, in accordance with policy “Screening of Projects for Impact on NERC Compliance Program (XES 7.405)”.

4.0 CIP-003-8 REQUIREMENTS

4.1 **Requirement - Cyber Security Awareness**: Each Responsible Entity shall reinforce, at least once every 15 calendar months, cyber security practices (which may include associated physical security practices).

4.2 Energy Supply’s Cyber Security Awareness Program

4.2.1 In accordance with “XEL-PRO-CIP Training and Awareness Program” all Xcel Energy employees and contractors are required to compete the Enterprise Security Awareness course (LPN L0015C-008)

- The Enterprise Security Awareness course covers the four areas that make up Enterprise Security: Cyber Security, Physical Security, Enterprise Resilience and Security Governance and Risk Services. It includes scenarios that cover the security habits that are the responsibility of every Xcel Energy employee and contractor.

4.2.2 In addition to the Enterprise e-Learning course Energy Supply has a supplemental e-Learning course: Energy Supply Cyber Security Policies (LPN R4835C-002) that identifies policies specific to energy supply and reinforces cyber security awareness principles.

- All Regional Systems Administrators, Plant Network Delegates, and their management supporting execution of this policy shall maintain current completion status.

4.3 **Requirement - Physical Security Controls**: Each Responsible Entity shall control physical access, based on need as determined by the Responsible Entity, to (1) the asset or the locations of the low impact BES Cyber Systems within the asset, and (2) the Cyber Asset(s), as specified by the Responsible Entity, that provide electronic access control(s) implemented for Section 3.1, if any.

4.4 **Energy Supply's Physical Security Program**

4.4.1 Adherence to the "XEL-PRO-CIP Physical Security of Low Impact BES Cyber Systems" policy is required to ensure adequate physical security at BES plants.

4.4.2 XES 4.200 Power Plant Physical Security Policy addresses escorting requirements and expectations.

4.4.3 XES 4.210 Electronic Lock & Key Policy requires that electronic locks and keys have been implemented at all the plant physical security perimeters as well as substations and other critical areas.

4.5 **Requirement - Electronic Access Controls**: For each asset containing low impact BES Cyber System(s) identified pursuant to CIP-002, the Responsible Entity shall implement electronic access controls to:

4.5.1 Permit only necessary inbound and outbound electronic access as determined by the Responsible Entity for any communications that are:

- i. between a low impact BES Cyber System(s) and a Cyber Asset(s) outside the asset containing low impact BES Cyber System(s);

- ii. using a routable protocol when entering or leaving the asset containing the low impact BES Cyber System(s); and

- iii. not used for time-sensitive protection or control functions between intelligent electronic devices (e.g., communications using protocol IEC TR61850-90-5 R-GOOSE).

4.5.2 Authenticate all Dial-up Connectivity, if any, that provides access to low impact BES Cyber System(s), per Cyber Asset capability.

4.6 Energy Supply's Electronic Access Controls Program

4.6.1 Electronic Access Controls are addressed in EPR 4.200P01 Energy Supply Electronic Access Controls Procedure

4.6.2 Use of dial-up connections to plant networks is strictly prohibited

4.7 **Requirement 1.2.4 - Cyber-Security Incident Response:** Each Responsible Entity shall have one or more Cyber Security Incident response plan(s), either by asset or group of assets, which shall include:

4.7.1 Identification, classification, and response to Cyber Security Incidents;

4.7.2 Determination of whether an identified Cyber Security Incident is a Reportable Cyber Security Incident and subsequent notification to the Electricity Information Sharing and Analysis Center (E-ISAC), unless prohibited by law;

4.7.3 Identification of the roles and responsibilities for Cyber Security Incident response by groups or individuals;

4.7.4 Incident handling for Cyber Security Incidents;

4.7.5 Testing the Cyber Security Incident response plan(s) at least once every 36 calendar months by: (1) responding to an actual Reportable Cyber Security Incident; (2) using a drill or tabletop exercise of a Reportable Cyber Security Incident; or (3) using an operational exercise of a Reportable Cyber Security Incident; and

4.7.6 Updating the Cyber Security Incident response plan(s), if needed, within 180 calendar days after completion of a Cyber Security Incident response plan(s) test or actual Reportable Cyber Security Incident.

4.8 Energy Supply's Cyber-Security Incident Response Program

4.8.1 All suspected cyber-security incidents shall be reported to the Regional System Administrators or delegate immediately upon suspicion of anomalous activity.

Anomalous activity is that which remains unexplained after normal plant investigation, and includes the unexpected:

- loss of execution of system functions;
- loss of network connections;
- detection of new, unauthorized external connections;
- unauthorized system access,
- antivirus / malware alerts; or
- general abnormal activity.

4.8.2 The Cyber Security Incident Investigation and Reporting Procedure should be reference when dealing with a cyber security incident.

4.8.3 If the cyber incident is suspected to be of malicious intent, and not the result of an error or equipment failure, the Regional Systems Administrator shall engage the Enterprise Command Center (ECC) 612-370-3700 and lead or assist in the subsequent investigation and mitigating actions. Incident responses shall be documented using the "XEL-FRM-Cyber Security Incident Investigation Form" and uploaded to the Cyber Incident Response SharePoint Site.

4.8.4 Energy Supply shall participate in a cyber-security incident response drill at least once every 36 calendar months as led by the involved corporate team.

- Energy Supply participates in GridEx every other year
- In years where GridEx is not scheduled a tabletop drill with the ECC takes place
- Lessons learned will be documented and if response is needed will be assigned a priority and be addressed within 180 days

4.9 Requirement 1.2.5 - Transient Cyber Asset and Removable Media Malicious Code Risk Mitigation: Each Responsible Entity shall implement, except under CIP Exceptional Circumstances, one or more plan(s) to achieve the objective of mitigating

the risk of the introduction of malicious code to low impact BES Cyber Systems through the use of Transient Cyber Assets or Removable Media. The plan(s) shall include:

4.9.1 For Transient Cyber Asset(s) managed by the Responsible Entity, if any, the use of one or a combination of the following in an ongoing or on-demand manner (per Transient Cyber Asset capability):

- Antivirus software, including manual or managed updates of signatures or patterns;
- Application whitelisting; or
- Other method(s) to mitigate the introduction of malicious code.

4.9.2 For Transient Cyber Asset(s) managed by a party other than the Responsible Entity, if any: Use one or a combination of the following prior to connecting the Transient Cyber Asset to a low impact BES Cyber System (per Transient Cyber Asset capability):

- Review of antivirus update level;
- Review of antivirus update process used by the party;
- Review of application whitelisting used by the party;
- Review use of live operating system and software executable only from read-only media;
- Review of system hardening used by the party; or
- Other method(s) to mitigate the introduction of malicious code.

4.9.3 For any method used pursuant to above, Responsible Entities shall determine whether any additional mitigation actions are necessary and implement such actions prior to connecting the Transient Cyber Asset.

4.9.4 For Removable Media, the use of each of the following:

- Method(s) to detect malicious code on Removable Media using a Cyber Asset other than a BES Cyber System; and

- Mitigation of the threat of detected malicious code on the Removable Media prior to connecting Removable Media to a low impact BES Cyber System.

4.10 Energy Supply's Transient Cyber Asset & Removable Media Program

4.10.1 XES 4.220 Transient Cyber Asset & Removable Media Policy should be referenced when considering the use of Transient Cyber Assets and Removable Media.

4.11 **Requirement 1.2.6 - Declaring and responding to CIP Exceptional Circumstances**

4.11.1 Processes to invoke special procedures in the event of a CIP Exceptional Circumstance

4.11.2 Processes to allow for exceptions to policy that do not violate CIP requirements

4.12 Energy Supply's CIP Exceptional Circumstances Program:

4.12.1 Energy Supply follows the XEL-PRO-CIP Exceptional Circumstances procedure to review and document situations that may warrant suspension or delay in implementing certain compliance requirements as allowed by CIP standards.

4.13 **Requirement 2 - Cyber Security Plan:**

4.13.1 Each Responsible Entity with at least one asset identified in CIP-002 containing low impact BES Cyber Systems shall implement one or more documented cyber security plan(s) for its low impact BES Cyber Systems that include the sections in CIP-003-8 Attachment 1.

4.14 **Energy Supply's Cyber Security Plan Program:**

4.14.1 Adherence to the enterprise XEL-POL-CIP Cyber Security Policy. Energy Supply follows the enterprise document and corporate cyber security plan.

4.14.2 In addition to the corporate cyber security plan, Energy Supply maintains Plant Network Security Plans

- Details of these plans and contents can be found in EPR 4.200P01 Electronic Access Controls Procedure

4.15 **Requirement 3 – CIP Senior Manager:** Each Responsible Entity shall identify a CIP Senior Manager by name and document any change within 30 calendar days of the change.

4.15.1 The CIP Senior Manager is Jamey Sample and evidence is on file XEL-EVD-CIP Senior Manager Communication

4.16 Requirement 4 – CIP Senior Manager Approval Delegation: The Responsible Entity shall implement a documented process to delegate authority, unless no delegations are used. Where allowed by the CIP Standards, the CIP Senior Manager may delegate authority for specific actions to a delegate or delegates. These delegations shall be documented, including the name or title of the delegate, the specific actions delegated, and the date of the delegation; approved by the CIP Senior Manager; and updated within 30 days of any change to the delegation. Delegation changes do not need to be reinstated with a change to the delegator.

4.16.1 Adherence to the XEL-PRO-CIP Delegation of Authority Procedure will be observed for the Delegation of Authority for Energy Supply

- Evidence of delegation can be found in XEL-FRM-CIP-Delegation of Authority.docx

5.0 Additional Security Practices

5.1 Internal Connectivity: Plant control networks containing cyber assets with generation capacity that exceeds 1500 MW in a single interconnection will be evaluated for a higher classification. Reasonable effort is made in order to maintain a low classification including but not limited to sectionalizing.

5.2 Remote Station Control: plant control networks shall not control more than one other BES facility, remote from the facility. Remote plant controls shall be isolated from the host plant network.

5.3 Operating System and Application Whitelisting: BCS servers should be configured so that only those programs that are needed for operation and are trusted are installed.

5.4 Operating Systems, Applications and Hardware: Plant networks should have supported operating systems and software that is supported by the involved manufacturers to provide current antivirus and malware signatures and operational patches. A plant improvement project request should be submitted using the project request system if any plant network equipment is no longer supported by the vendor and requires upgrade in order to maintain current cyber-security protections.

5.5 Patch Management and virus/malware definitions: Regional System Administrators or delegate shall update patch and virus/malware definitions for BCS networks, in accordance with instructions provided by systems vendors. A description of patch activity completed each year and reference to instructions used for BCS patches shall be documented per the EPR 4.200A03 Plant Network Inspection Checklist. If virus and patch updates cannot be maintained on a current basis, exceptions shall be documented with justification on the inspection checklist.

5.6 Information Security: All outputs of this policy (Plant Network Security Plan, inspection checklists, suspected cyber-security incident response form, firewall ruleset changes) shall be controlled in accordance with the corporate program for Confidential and Confidential Restricted Information Protection.

5.7 Password Storage: Username and passwords for BES Cyber Assets should be documented and stored in central secure repository. Examples include:

5.7.1 Physical documentation and stored in a secure location

5.7.2 Electronic documentation – stored in a locked file in ProjectWise CIP repository

6.0 RECORDS

6.1 An EPR 4.200A01 Plant Network Security Plan, will be stored in the corresponding Plant's "EPR-4.200 Plant Security Plan" ProjectWise folder.

6.2 EPR 4.200A02 Access Control Process Form will be stored in SharePoint with the corresponding completed form and approval records.

6.3 An EPR 4.200A03 Plant Network Inspection Checklist, will be stored in the corresponding Plant's "EPR-4.200 Plant Security Plan" ProjectWise folder.

6.4 If a plant does not have routable connectivity, an EPR 4.200A04 Non-routable Connectivity Attestation Form must be completed and uploaded into the corresponding Plant's "EPR-4.200 Plant Security Plan" ProjectWise folder and moved into the "released" state

6.5 Electronic Key Requests Forms and approvals are stored in SharePoint

6.6 XEL-FRM-Cyber Security Incident Investigation Form" should be uploaded to the Cyber Incident Response SharePoint Site.

6.7 List of BES Plant & Plant Network Delegates - Live list can be found on Energy Supply NERC CIP SharePoint Site – "Plant Network Contact List

6.8 Version History: Retired versions of documents (This Policy, Plant Network Security Plans, Plant Network Inspection Checklist, etc.) will be filed in an "Archive" folder in the same repository application the current document resides.

7.0 DEFINITIONS

7.1 **Bulk Electric System (BES) Generators:** All units connected to the grid at 100kv or greater and have a gross nameplate rating greater than 20Mva; and dispersed generation facilities with multiple units that have an aggregate gross nameplate rating greater than 75Mva connected to a common bus and connected to the grid at greater than 100 kV. In depth BES definition with inclusion and exclusions can be found on the NERC website.

7.2 **National Institute of Standards and Technology (NIST) Cyber-Security Guides:** Engineering Principles for Information Technology Security, NIST Special Publication 800-27; NIST Special Publication 800-82, Guide to Industrial Control Systems Security; and NIST-Guidelines on Firewalls and Firewall Policy.

7.3 **BES Cyber Assets (BCAs):** Programmable electronic devices essential to the reliable operation of a BES plant, including the hardware, software, and data in those devices. A BCA is a device that if rendered unavailable, degraded or misused, would create a generation outage or de-rate within 15 minutes.

7.4 **Low Impact BES CIP Assets:** In general, facilities larger than 20MVA and less than 1500MW. More detailed information on inclusions and exclusions can be found in CIP-002-5.1a Cyber Security — BES Cyber System Categorization

7.5 **Cyber-Security Incident:** Any malicious act or suspicious event that: Compromises, or was an attempt to compromise, the Electronic Security Perimeter or Physical Security Perimeter, or, Disrupts, or was an attempt to disrupt, the operation of a BES Cyber System. [NERC Glossary]

7.6 **Transient Cyber Asset (TCA):** a cyber asset that is: capable of transmitting or transferring executable code, not included in a BES Cyber System, and directly connected (e.g. using Ethernet, serial, Universal Serial Bus, or wireless including near field or Bluetooth communication) for 30 consecutive calendar days or less to a BES Cyber Asset

7.7 **Removable Media:** storage media that: are not Cyber Assets, are capable of transferring executable code, can be used to store, copy, move or access date, and are directly connected for 30 consecutive calendar days or less to a BES Cyber Asset.

7.8 **Regional System Administrator:** The Fleet Engineering lead for network security monitoring and technical support assigned in each of the three Xcel operating regions: NSP, PSCo, and SPS.

8.0 REVISION HISTORY

Date	Revision	Change
04/12/2013	1.0	Original Issue Supersedes ESO 4.200 to align accountabilities with re-organization. Included best practice security requirements from various sources, including FERC Order and NIST, in preparation step to begin alignment with expected future cyber-security requirements. Detailed requirements moved from this policy to supporting plant cyber-security plan template EPR 4.200_A01.
04/27/2015	1.1	Implementation phase is complete. Deleted note regarding implementation plan in section 1.2. Deleted section 5.0 'Implementation Plan' in its entirety.
09/29/2015	2.0	Updated formatting to comply with XES 1.100P01 Configuration Management for ES Policies and Procedures. Sections re-ordered to improve readability. Revision to align with CIP version 6 requirements and/or Internal Audit Observations as follows: • Revised EPR 4.200A01 Plant Network Cyber-Security Plan Template to document system access and type as required in new NERC terms of LERCs, LEAPs, and BROS; • Added EPR 4.200A02 ES Firewall Rule Change Request to document Energy Supply firewall rule changes; • Added EPR 4.200A03 Annual Plant Network Cyber-Security Inspection Checklist to document patch management instructions and activities; • Added EPR 4.200A04 Energy Supply Cyber-Security Incident Response Checklist to document potential cyber-security incidents and notification of required parties if indicated; and • Added EPR 4.200A05 Modem Session Log to document modem sessions. • Updated definition section to align with NERC terms.

Date	Revision	Change
04/11/2017	3.0	• Minor clarifications for accuracy to NERC Standard verbiage. • Changed Annual references to 15 calendar months. • Removed reference to Work Orders in section 4.11 due to move from SAP to Maximo. Added reference to corporate Physical Security Policy and Corporate Awareness Program. Updated formatting to comply with XES 1.100P01 Configuration Management for ES Policies and Procedures. Sections re-ordered to improve readability. Revision to align with CIP version 6 requirements and/or Internal Audit Observations as follows: • Revised EPR 4.200A01 Plant Network Cyber-Security Plan Template to document system access and type as required in new NERC terms of LERCs, LEAPs, and BROS; • Added EPR 4.200A02 ES Firewall Rule Change Request to document Energy Supply firewall rule changes; • Added EPR 4.200A03 Annual Plant Network Cyber-Security Inspection Checklist to document patch management instructions and activities; • Added EPR 4.200A04 Energy Supply Cyber-Security Incident Response Checklist to document potential cyber-security incidents and notification of required parties if indicated; and • Added EPR 4.200A05 Modem Session Log to document modem sessions. • Updated definition section to align with NERC terms.
07/03/2018	4.0	• Revisions to address the new NERC Standard version CIP-003-7. • Removed LERC and LEAP references and definitions, as they are no longer NERC defined terms. • Modified or removed references as necessary to how they are actually being completed. • Updated SOC to Cyber Defense Center • Removed language relating to dial-up and modem commitments • Updated Architecture Diagram • Minor clarifications for accuracy to NERC Standard verbiage. • Changed Annual references to 15 calendar months. • Removed reference to Work Orders in section 4.11 due to move from SAP to Maximo. • Added reference to corporate Physical Security Policy and Corporate Awareness Program.
10/10/2019	5.0	• Updated all CIP version references to CIP 003-8 • Updated architecture of document to capture all responsibilities in one section • Updated CIP requirement for clarity as to what the requirements are and what process is in place to meet these requirements • Added section on Transient Cyber Assets and removable media
2/26/2020	5.1	• Added to Section 4.4 following GridEx about SOC incident number • Added references to XES 4.210 Electronic Lock & Key Policy (Section 4.2) and XES 4.220 Transient Cyber Asset and Removable Media Policy (Section 4.5) • Replaced “Exception Form” with “Authorization Form” • Added Attachment 1 – Plant Designee list • Moved document repository references into new Section 8.0 and update all links
1/4/2022	6.0	• Created EPR 4.200P01 Electronic Access Controls • Updated references of the CDC to the ECC • Updated Cyber Security Incident Response to follow ECC procedure and form • Updated Attachments and numbers to reflect the use of SharePoint Forms and workflows

Xcel Energy

Guideline for Inverter Based Renewable Generation (IBRG)

Power Quality Measurements and Reports

Rev. A: 5-13-21, Brent R. Lease

Background:

This document replaced the prior "Guideline for Wind Farm Power Quality Measurements and Report Rev. B, dated 6-8-16". This document is intended to apply to Inverter based renewable generation (IBRG) facilities including Wind, Solar and Battery Storage generation facilities.

IBRG facilities produce power that is typically supplied to or interconnected with a Utility Distribution system (*typically 12,470 Volt to 34,500 Volt Distribution line*), or a Utility Transmission system *(typically 69,000V to 345,000V transmission line*). Large IBRG sites will generally supply power onto the utility transmission system.

In order to supply power to end users and also to utility owned equipment (*example – transformers in substations*) that does not include high levels of harmonic currents that can adversely affect electrical equipment (*cause higher levels of losses or heating in equipment, or cause resonant conditions with accompanying high over-voltages*), power quality measurements are required upon completion of a IBRG project as a part of the commissioning of the facility.

It is also possible that the utility, at the point of interconnection with the IBRG facility already contains high levels of harmonic voltage distortion where the IBRG connects to the utility (*PCC or Point of Common Coupling).* This is known as "Utility background voltage distortion".

IBRG Interconnect Agreement:

The interconnect agreement between the utility and the IBRG facility will typically include Power Quality requirements that reference meeting IEEE standard 519 *(IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems)* to avoid:

- Excessive Voltage Flicker
- Excessive Sinusoidal Current Distortion
- Excessive Sinusoidal Voltage Distortion

IEEE 519 places obligations on both the Utility (to not have high levels of sinusoidal voltage distortion that can negatively affect the users equipment), and the user (or in our case, IBRG power plant) to not cause high levels of harmonic currents to flow on the utilities system that can affect the utility or users of electricity that the utility serves.

Applying IEEE 519 to an IBRG site:

IEEE 519 is written primarily for the more common and traditional application of a utility supplying power to an end user of electricity. The end user would most commonly be purchasing power from the utility at their voltage utilization level (such as 120V, 240V, or 480V) or less commonly at a Distribution level voltage (such as 12,470V to 34,500V).

As the voltage that the power is supplied at increases, IEEE 519 allowable limits on harmonic voltages and harmonic currrents become increasingly restrictive. As an example, if the utility is supplying power at less than 1000V, the maximum total harmonic distortion of the utility voltage waveform is 8%. When the utility connection is at a voltage higher than 161,000V, the maximum total harmonic voltage distortion drops to 1.5% (see Table 1, IEEE standard 519).

IEEE 519 is a recommendation, not a requirement, and it is recommended that it be used as a tool to aid in resolving or avoiding serious harmonic issues affecting equipment. IEEE 519 is meant to be applied to steady state conditions only, not transient conditions.

Because IEEE 519 was not written for the application of a IBRG power plant supplying power onto a Utility transmission system, there are areas where we recommend deviating from IEEE 519 or allowing higher limits than IEEE 519 recommends. These areas include:

1. IEEE standard 519 (*section 5.1 – Recommended harmonic voltage limits*) requires that voltages measured be "line to neutral" voltages at the point of common coupling. ***We require that instead at the point of common coupling (transmission line interconnect) and at the 34,500V collection voltage level that voltages be measured from "line to line" only.*** Reasons for this include:

- Transmission and Distribution lines are 3 wire systems (*no neutral wire, but typically does contain a ground wire*). Power from the wind farm is supplied to the phase conductors (*3 wire system*), there is no neutral wire from the IBRG at the point of common coupling. Current is normally intended to return on the phase conductors only (with the exception of a fault returning on a ground conductor), and IEEE 519 standard applies to steady state (*not transient or fault*) conditions.
- All loads on a transmission system (items such as transmission lines, transformers at adjoining substations) draw steady state power from line to line (not line to neutral or line to ground).
- Balanced three phase harmonic voltages (and other triplen harmonics – 9^{th}, 15^{th}, 21^{st}, etc.) that exist between line and neutral on a transformer cancel each other out when added together to calculate line to line voltages (i.e. will not appear on line to line voltage readings and do not affect other equipment drawing power from a line to line source).

2. IEEE Standard 519 (Table 1 – Harmonic Voltage Distortion Limits). ***Where it can be demonstrated that harmonic voltage distortion limits under steady state conditions have no adverse effects on the wind farm or the utility transmission equipment, it is recommended that the harmonic voltage distortion limits not be strictly adhered to.*** Reasons for this include:

- Harmonic measurements at prior Xcel inverter-based wind generation sites indicated that under the steady state condition of the wind farm being lightly loaded (*power production from the wind farm was low*) that the voltage distortion exceeded IEEE 519 recommended limits. The actual amount of harmonic currents that flowed, however, was very low, and well within the ratings of the main power transformer, and the other equipment connected to it.
- At prior Xcel inverter-based wind generation sites as the amount of power being produced by the wind farm increased, the total harmonic voltage distortion at the point of common coupling decreased, and ultimately fell within the IEEE 519 recommended limits.
- End users of electricity typically connect to the utility at the distribution level or utilization level of voltage. Transformers used to step down to these voltages have the effect of filtering out / reducing the level of harmonic voltages transmitted from the transmission system.

3. IEEE Standard 519 (Table 2, Table 3 – Harmonic Current Distortion Limits). ***Where it can be demonstrated that harmonic current distortion limits under steady state conditions have no adverse effects on the IBRG equipment or the utility transmission equipment, it is recommended that the harmonic current distortion limits not be strictly adhered to.*** Reasons for this include:

- Harmonic measurements at prior Xcel inverter-based wind generation sites indicated that under the steady state condition of the wind farm being lightly loaded (*power production from the wind farm was low*) that the current distortion exceeded IEEE 519 recommended limits. The actual amount of harmonic currents that flowed, however, was very low, and well within the ratings of the main power transformer, and the other equipment connected to it.
- At prior inverter-based wind generation sites as the amount of power being produced by the wind farm increased, the harmonic current distortion at the point of common coupling decreased, and ultimately fell within the IEEE 519 recommended limits as the power production increased.
- IEEE standard C57.12.00 under usual service conditions allows for .05 per unit harmonic factor of the current (*THD current = 5% of the transformer nameplate amp rating before you must consider derating the transformer*). This means that when the transformer is fully loaded, it is capable of having up to 5% total harmonic currents flowing before any de-rate of the transformer is required.
- At prior wind generation sites, the current rating of the main power transformers (sinusoidal, harmonic, or combination of the two) never exceeds the ratings of the main power transformer.

Power Quality Measurements when commissioning an Inverter Based Renewable Generation (IBRG) site:

References:

1. IEEE standard 519-2014 (IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems).
2. IEEE standard C57.12.00-2010 (IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers).
3. IEEE standard C57.110-2008 (IEEE Recommended practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Non-sinusoidal Load Currents).
4. Xcel Energy - Guideline for Inverter Based Renewable Generation (IBRG) Power Quality Measurements and Report - Rev. A

Voltage and Current Measurement Locations:

1. PCC - Point of Common Coupling bus.
    a. Measurements to be made nearest to PCC that voltage transformers (VT or CCVT's) and current transformers are available for connecting to. Measurements are required at only one of the locations identified below (*location nearest the PCC*).
        i. At the PCC
        ii. At the switching substation (remote from collection substation / location of main power transformers).
        iii. At the IBRG collection substation, location of main power transformers.
2. IBRG medium voltage collection bus. If collection system bus voltage varies from 34,500V, replace 34,500V with the correct voltage.
    a. Voltage measurements at each 34,500V Bus (tie between buses open).
    b. Current measurements at 34,500V connection to each main power transformer.

Voltage Measurements:

1. PCC - Point of Common coupling bus.
    a. Line to Line Voltage (*line to ground voltages are not measured / recorded*).
        i. Phase A to Phase B
        ii. Phase B to Phase C
        iii. Phase C to Phase A
    b. Voltage Recording
        i. 1^{st} (fundamental – 60 Hz) to 50^{th} harmonic of fundamental (3000 Hz)
        ii. Odd and Even Harmonics
        iii. Voltage Amplitude
        iv. Voltage Phase displacement from fundamental
    c. Voltage Waveform Snapshot
        i. All main power transformers disconnected (*background / utility voltage*)

ii. IBRG facility at low level of power production, all main power transformers in service.
iii. IBRG facility near full power production, all main power transformers in service.

2. Each IBRG medium voltage collection bus.
    a. Line to Line
        i. Phase A to Phase B
        ii. Phase B to Phase C
        iii. Phase C to Phase A
    b. Voltages
        i. 1st (fundamental – 60 Hz) to 50th harmonic of fundamental (3000 Hz)
        ii. Odd and Even Harmonics
        iii. Voltage Amplitude
        iv. Voltage Phase displacement from fundamental

Current Measurements:

1. PCC - Point of Common coupling bus.
    a. Phase and Neutral / Ground Currents
        i. Phase A
        ii. Phase B
        iii. Phase C
        iv. Neutral Current (current returning to transformer neutral via ground connection).
    b. Phase Currents
        i. 1st (fundamental – 60 Hz) to 50th harmonic of fundamental (3000 Hz)
        ii. Odd and Even Harmonics
        iii. Amplitude
        iv. Phase displacement from fundamental
    c. Neutral / Ground Current
        i. Low wind condition, clamp on ammeter, record value
        ii. High wind condition, clamp on ammeter, record value
    d. Current Waveform Snapshots
        v. Phase A, B, C currents
        vi. Wind farm at low level of power production.
        vii. Wind farm near full power production.
2. Each 34,500V Collection bus.
    a. Phase and Neutral / Ground Currents
        i. Phase A
        ii. Phase B
        iii. Phase C

iv. Neutral Current (*current returning to transformer neutral via ground connection*).

b. Phase Currents
   i. 1st (fundamental – 60 Hz) to 50th harmonic of fundamental (3000 Hz)
   ii. Odd and Even Harmonics
   iii. Amplitude
   iv. Phase displacement from fundamental
c. Ground Current
   i. Low wind condition, clamp on ammeter, record value
   ii. High wind condition, clamp on ammeter, record value
d. Current Waveform Snapshots
   i. Phase A, B, C currents
   ii. Wind farm at low level of power production.
   iii. Wind farm near full power production.

Voltage and Current Measurement Duration:

Once the facility is capable of at least 95% of the inverters and their associated power sources (wind generator, solar panel, battery) being in service, measurement / recording of the voltage and currents can begin.

It is anticipated that two weeks of recordings should provide the typical steady state conditions that the IBRG facility will experience (*i.e. conditions from very low level or no output to full or near full output of the site)* If two weeks (14 days) are insufficient to encounter and record output from low to near full, additional days of measurement shall be added as needed.

Power Quality Report:

Upon completion of the power quality measurements, the data shall be analyzed using IEEE 519 standards as a guideline, and a report submitted to Xcel Energy.

The report should include:

1. Executive Summary
2. Interpretation of Data including:
   a. Steady State Fundamental and Harmonic Voltage Content
      i. Background (Utility Voltage Distortion) at the Point of Common Coupling / PCC
      ii. Fundamental and Harmonic Voltages (PCC and collection bus -typically 34,500V)
      iii. Voltage Waveform Snapshots (PCC and collection bus -typically 34,500V)
      iv. Low levels of power production
      v. High level of power production
   b. Steady State Fundamental and Harmonic Current Content
      i. Fundamental and Harmonic Currents (PCC and collection bus -typically 34,500V)

ii. Current Waveform Snapshots (PCC and collection bus -typically 34,500V)
iii. Low levels of power production
iv. High level of power production
v. Neutral current measurements
vi. Harmonic currents flowing through the main power transformer at varying production levels relative to C57.12.00 and the transformer nameplate capacity.

c. Voltage Flicker at the Point of Common Coupling

3. Conclusions and Recommendations
4. Appendix
   a. Site one line diagrams identifying all locations (Voltage Transformers (VT) or CCVT locations, Current Transformer (CT) locations) where measurement data was obtained.
   b. Data files from Power Quality recorder.
   c. Spread sheets containing the calculated short time and very short time harmonic measurements.
   d. Spread sheet containing the statistical evaluation of the short time and very short time harmonic measurements (See IEEE 519 section 4 – Harmonic Measurements).

EXHIBIT E.5
APLIC GUIDANCE

The following exhibits are included in Exhibit E.5:

- Exhibit E.5.1 – Suggested Practices for Avian Protection on Power Lines 2006
- Exhibit E.5.2 – Reducing Avian Collisions with Power Lines 2012

Suggested Practices for Avian Protection On Power Lines:

The State of the Art in 2006

Avian Power Line Interaction Committee

PIER FINAL PROJECT REPORT CEC-500-2006-022

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The State of the Art in 2006

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Prepared by

Avian Power Line Interaction Committee

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Additional copies of this book may be obtained through:

the Avian Power Line Interaction Committee
www.aplic.org

the Edison Electric Institute
www.eei.org

and

the California Energy Commission
www.energy.ca.gov

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ABSTRACT

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PURPOSE AND USE OF THE PUBLICATION

In the early 1970s, an investigation of reported shootings and poisonings of eagles in Wyoming and other western states led to evidence that eagles were also being electrocuted on power lines. Since then, the utility industry, wildlife resource agencies, conservation groups, and manufacturers of avian protection products have worked together to understand the causes of raptor electrocutions and to develop and implement solutions to the problem. Those efforts have improved our understanding of the biological factors that attract raptors and other birds to power lines, and the circumstances that lead to avian electrocutions.

This publication, *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006*, summarizes the history and success of over three decades of work. It springs from three previous editions of *Suggested Practices for Raptor Protection on Power Lines*, and has been expanded and updated to assist those concerned with complying with federal laws protecting and enhancing avian populations, and maintaining the reliability of electric power networks.

THE ISSUE

Discoveries of large numbers of electrocuted raptors in the early 1970s prompted utilities and government agencies to initiate efforts to identify the causes of and develop solutions to this problem. Literature from the 1980s and 1990s continued to document electrocutions of raptors throughout the world. Now, reports of electrocutions of birds other than raptors are appearing in the literature and the impacts of avian interactions on power reliability are becoming more evident.

REGULATIONS AND COMPLIANCE

Three federal laws in the United States protect almost all native avian species and prohibit "taking," or killing, them. The Migratory Bird Treat Act protects over 800 species of native, North American migratory birds. The Bald and Golden Eagle Protection Act provides additional protection to both bald and golden eagles. The Endangered Species Act applies to species that are federally listed as threatened or endangered. Utilities should work with the U.S. Fish and Wildlife Service and their state resource agency(ies) to identify permits and procedures that may be required for nest management, carcass salvage, or other bird management purposes.

BIOLOGICAL ASPECTS OF AVIAN ELECTROCUTION

Bird electrocutions on power lines result from three interacting elements: biology, environment, and engineering. The biological and environmental components that influence electrocution risk include body size, habitat, prey, behavior, age, season, and weather.

Of the 31 species of diurnal raptors and 19 species of owls that regularly breed in North America, 29 have been reported as electrocution victims. Electrocutions have also been reported in over 30 non-raptor North American species, including crows, ravens, magpies, jays, storks, herons, pelicans, gulls, woodpeckers, sparrows, kingbirds, thrushes, starlings, pigeons, and others.

SUGGESTED PRACTICES: POWER LINE DESIGN AND AVIAN SAFETY

Avian electrocutions typically occur on power lines with voltages less than 60 kilovolts (kV). Electrocution can occur when a bird simultaneously contacts electrical equipment either phase-to-phase or phase-to-ground. The separation between energized and/or grounded parts influences the electrocution risk of a structure. Electrocution can occur where horizontal separation is less than the wrist-to-wrist (flesh-to-flesh) distance of a bird's wingspan or where vertical separation is less than a bird's length from head-to-foot (flesh-to-flesh). In this document, 150 cm

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(60 in) of horizontal separation and 100 cm (40 in) of vertical separation are recommended for eagles. Utilities may choose to adopt these recommendations or modify their design standards based on the species and conditions at issue.

Single-phase, two-phase, or three-phase configurations constructed of wood, concrete, metal, fiberglass, or other materials can pose avian electrocution risks if avian-safe separation is lacking. In particular, structures with transformers, other exposed, energized equipment account for a disproportionate number of avian electrocutions.

Both avian-safe new construction and retrofitted existing structures should be used to reduce avian electrocution risk. The principles of *isolation* and *insulation* should be considered when designing or retrofitting structures. *Isolation* refers to providing adequate separation to accommodate avian use of structures and should be employed where new construction warrants avian-safe design. *Insulation* refers to covering exposed energized or grounded parts to prevent avian contact. Although equipment that is covered with specifically-designed avian protection materials can prevent bird mortality, it should not be considered in addition to separation for avian protection.

PERCHING, ROOSTING, AND NESTING OF BIRDS ON POWER LINE STRUCTURES

In habitats where natural nest substrates are scarce, utility structures can provide nesting sites for raptors and other birds. Likewise, many birds use power poles and lines for perching, roosting, or hunting.

Bird nests on utility structures can reduce power reliability. Nest management, including the design and installation of platforms on or near power structures, can enhance nesting while minimizing the risk of electrocution, equipment damage, and loss of service. Utilities are encouraged to collect data on bird-related outages to quantify the impacts of birds on power systems, and to develop measures for preventing bird mortalities and their associated outages.

DEVELOPING AN AVIAN PROTECTION PLAN

In 2005, the Avian Power Line Interaction Committee and the U.S. Fish and Wildlife Service announced their jointly developed Avian Protection Plan Guidelines (Guidelines) that are intended to help utilities craft their own avian protection plans (APPs) for managing avian/power line issues. An APP should provide the framework necessary for implementing a program to reduce bird mortalities, document utility actions, and improve service reliability. It may include the following elements: corporate policy, training, permit compliance, construction design standards, nest management, avian reporting systems, assessment methodology, mortality reduction options, habitat enhancement options, quality control, public awareness, and key resources. The Guidelines present a comprehensive overview of these elements. Although each utility's APP will be different, the overall goal of reducing avian mortality is the same. An APP should be a "living document" that is modified over time to improve its effectiveness.

FOREWORD

Avian interactions with power lines—including electrocutions, collisions, and nest construction—have been documented since the early 1900s when electric utilities began constructing power lines in rural areas. However, it was not until the early 1970s that biologists, engineers, resource agencies, and conservationists began to identify the extent of the problem and address it. Those early researchers and authors are to be commended for tackling a contentious issue and building a foundation of credibility and cooperation that continues today.

The U.S. Fish and Wildlife Service (USFWS) and the Avian Power Line Interaction Committee (APLIC) have a long history of working together on avian/power line issues. These efforts began in 1989 with an ad-hoc group that addressed whooping crane collisions with power lines in the Rocky Mountains. They continued with the release of Avian Protection Plan Guidelines (Guidelines) in April 2005, and have now produced this 2006 edition of *Suggested Practices*.

In 1975, the first edition of *Suggested Practices for Raptor Protection on Power Lines* had 4½ pages of text and 15 exhibit drawings. It summarized, "…studies conducted in the western United States document electrocution losses of egrets, herons, crows, ravens, wild turkeys and raptors, with 90% of the electrocution victims being golden eagles." The document concluded, "this loss of eagles is significant, but pesticide contamination, loss of habitat and illegal shooting remain the most threatening problems to raptors in general." The theme of reducing raptor electrocutions on power lines with an emphasis on "eagle-safe" designs was followed through the 1975, 1981 and 1996 editions.

Electric utilities have recognized that the interactions of migratory birds with electrical facilities may create operational risks, health and safety concerns, and avian injuries or mortalities. The USFWS understands these issues and is also responsible for conserving and protecting North American trust resources[1] under laws and regulations that include the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, and Endangered Species Act. In the 2006 edition of *Suggested Practices*, APLIC and the USFWS have expanded the focus of avian/power line issues from raptors to include other protected

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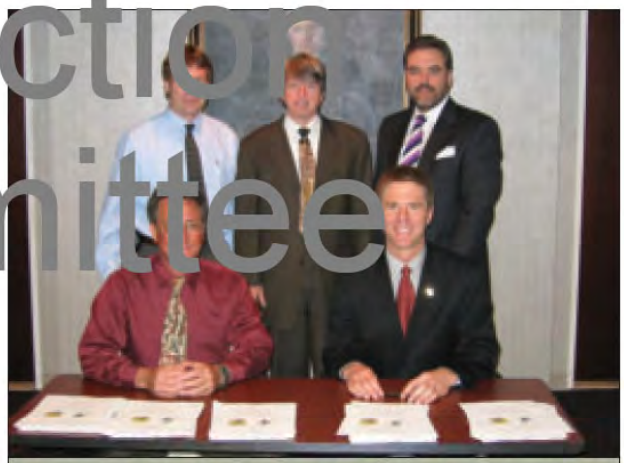

Signing of Avian Protection Plan Guidelines, April 2005. Pictured left to right: top – Jim Burruss (PacifiCorp), John Holt (National Rural Electric Cooperative Association), Quin Shea (Edison Electric Institute); bottom – Jim Lindsay (Florida Power and Light), Paul Schmidt (U.S. Fish and Wildlife Service).

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[1] Trust resources are wildlife, such as migratory birds, that are held in the public trust and managed and protected by federal and state agencies.

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migratory birds such as waterbirds, songbirds, and ravens and crows (corvids).

With this edition of *Suggested Practices* and the voluntary Guidelines, utilities have a "tool box" of the latest technology and science for tailoring an Avian Protection Plan (APP) that meets specific utility needs while conserving migratory birds. The 2006 edition of *Suggested Practices* represents a significant update from the 1996 edition.

APLIC and the USFWS hope you will use this edition of *Suggested Practices* along with the Guidelines to help utilities improve system reliability, implement APPs, and conserve migratory birds.

Paul Schmidt
USFWS, Assistant Director
Migratory Bird Programs

Jim Burruss
APLIC, Immediate Past Chairman

Jim Lindsay
APLIC, Chairman

Avian Power Line Interaction Committee

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Avian Power Line Interaction Committee

THIS PUBLICATION IS DEDICATED TO THE MEMORY OF

Morley Nelson

(1917 – 2005)

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"A man born with the heart and soul of an eagle"

Morley Nelson devoted his life to [illegible] raptor conservation, educating the public about their importance. He accomplished this through his personal zeal for working with raptors and his cinematography skills. Morley's achievements include award-winning films on raptors, the establishment of the Snake River Birds of Prey National Conservation Area, raptor rehabilitation, public lectures that helped educate Americans about the importance of raptors, and research that formed the foundation of recommendations made to the electric utility industry for reducing raptor electrocutions.

A master falconer, Nelson raised public awareness about birds of prey through dozens of movies and TV specials starring his eagles, hawks and falcons—including seven films for Disney. His love of raptors began when he was a boy growing up on a farm in North Dakota. Moving to Boise after serving in World War II, he began his [illegible] conservation efforts along with rehabilitating and training birds.

Morley's raptor/power line research became the focus for cooperation among conservation groups, resource agencies and electric utility companies. His legacy of pooling knowledge and resources for raptor conservation reflected in this document.

To foster the memory of Morley, APLIC will periodically present its *Morley Nelson Award* to an individual who makes significant contributions to raptor conservation. The individual must demonstrate a long-term commitment to natural resources, a consistent history of investigating or managing the natural resource issues faced by the electric utility industry, and success in developing innovative solutions.

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CHAPTER 1

Introduction

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IN THIS CHAPTER Purpose and Scope — Organization of this Document

This book presents engineers, biologists, utility planners, and the public with a comprehensive resource for addressing avian electrocutions at electric power facilities.[2] It outlines the importance of the issue, describes methods for avoiding or mitigating electrocution problems, and highlights management options and cooperative partnerships.

PURPOSE AND SCOPE

In the early 1970s, an investigation of reported shootings and poisonings of golden eagles in Wyoming and other western states led to evidence that eagles were also being electrocuted on power lines (Olendorff et al. 1981). Since then, the utility industry, wildlife resource agencies, conservation groups, and manufacturers of avian protection products have worked together to understand the causes of raptor electrocutions and to develop ways of preventing them. Those efforts have improved our understanding of the biological reasons why raptors and other birds can be attracted to power lines, and the power line configurations that lead to avian electrocutions.

This publication, *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006*, summarizes the history and achievements of over three decades of work. It succeeds three previous editions and has been expanded and updated to assist those concerned with complying with federal laws, protecting and enhancing avian populations, and maintaining the reliability of electric power networks.

Early attempts to understand the engineering aspects of raptor electrocution led to the first edition of *Suggested Practices* (Miller et al. 1975). The 1975 edition was followed by the 1981 edition (Olendorff et al. 1981), which explored the biological and electrical aspects of electrocution, provided guidance for reducing bird mortalities, and contained a comprehensive annotated bibliography. The 1996 edition (APLIC 1996) expanded and refined recommendations for power line structure designs and modifications for protecting raptors, included updated research

[2] This book focuses on avian electrocutions, not collisions. Readers seeking information about the collision of birds with power lines may consult *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994* (Avian Power Line Interaction Committee [APLIC] 1994) or the current edition of this manual.

results, and illustrated the effectiveness of cooperative efforts.

Although raptors remain a focal point of electrocution issues, utilities have found that many other birds also interact with electrical structures, and can reduce power reliability. Accordingly, this 2006 edition of *Suggested Practices* expands upon prior editions by addressing additional avian species. This edition also reflects utility efforts to improve configuration designs and to evaluate the effectiveness of various retrofitting options. The 2006 edition includes the following additions or updates:

- A new chapter on regulations and permits related to migratory birds,
- Biological perspectives and information on electrocution risks for non-raptor avian species, including perching birds, corvids,[3] and songbirds,
- Consideration of the National Electric Safety Code (NESC) relative to suggested practices,
- An overview of electrocution risks and mitigation measures associated with steel and concrete poles,
- Updated recommendations for post-mounted configurations,
- A discussion of perch discouragers and their proper use,
- An overview of new avian protection devices as well as their uses and installation[4],
- A review of bird-related outages,
- An updated bibliography and literature review (Appendix A),
- An appendix containing the voluntary Avian Protection Plan Guidelines (Guidelines) developed by APLIC and the United States Fish and Wildlife Service (USFWS) in 2005, as well as suggestions for developing and implementing an Avian Protection Plan (APP).

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ORGANIZATION OF THIS DOCUMENT

This book is intended for use by electric utilities, resource agencies and scientists worldwide. International literature is included, but it is primarily focused on North America. A brief synopsis of each chapter is listed below:

Chapter 2: The Issue
Defines the avian electrocution problem, traces its history, and reviews the latest research on avian electrocutions and their prevention.

Chapter 3: Regulations and Compliance
Reviews the major federal laws related to migratory birds and identifies potential permit requirements.

Chapter 4: Biological Aspects of Avian Electrocution
Describes the range of avian/power line interactions and discusses the biological and environmental factors that influence avian electrocutions.

Chapter 5: Suggested Practices: Power Line Design and Avian Safety
Presents the reader with the background necessary to understand avian electrocutions from an engineering perspective, i.e., the design and construction of power facilities. Suggests ways to retrofit existing facilities and design new facilities to prevent or minimize avian electrocution risk.

[3] The corvid family includes crows, ravens, magpies, and jays.

[4] See the APLIC website (www.aplic.org) for a current list of avian protection product manufacturers.

Chapter 6: Perching, Roosting, and Nesting of Birds on Power Line Structures
Explores the benefits of power lines to raptors and other birds and proposes strategies for relocating nests or providing alternative nesting sites that minimize electrocution risk while maintaining safe and reliable electrical service. Discusses the use of devices intended to discourage perching versus modifying structures to be avian-safe. Provides an overview of [illegible] voltages and their impacts on reliability and operating costs.

Chapter 7: Developing an Avian Protection Plan
Presents the elements of an APP and provides guidance for APP implementation.

For literature citations from the text and additional useful references, see the Appendix A Literature Cited and Bibliography section. Appendix B contains a history of early agency actions that addressed the electrocution issue; Appendix C Avian Protection Plan Guidelines; Appendix D Glossary; and Appendix E a list of acro[illegible]

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CHAPTER 2

The Issue

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IN THIS CHAPTER

Early Reports
Suggested Practices: 1975, 1981, and 1996
Electrocution Issues to Date
The Outlook

This chapter defines the avian electrocution issue, traces its history, reviews the literature, introduces the latest research, and discusses approaches to solving the problem. Particular emphasis is placed on studies completed since the previous edition of *Suggested Practices* (1996). This chapter also includes an overview of the avian electrocution issue in other countries.

Raptors (birds of prey) are ecologically important and sensitive to toxic substances, habitat alteration and destruction, and persecution by humans. Inadvertent human-raptor interactions occur where humans and raptors interact. The biological importance and environmental sensitivity of raptors have led to substantial academic and public interest in these birds and to the problem of electrocution. This has resulted in better protection and management for raptors and their habitats.

The electrocution issue began with raptors because their size, hunting strategy, and nesting preferences make them particularly vulnerable. However, decades of research have found that other species also incorporate utility structures into their lifecycles. The interaction caused by perching, roosting, loafing, and nesting birds can result in electrocutions or power outages, each of which is receiving more attention from utilities, wildlife resource agencies, and the public.

In the United States, the federal government provides protection for migratory birds through several laws (see Chapter 3). Prominent among these are the Bald and Golden Eagle Protection Act (BGEPA) (16 U.S.C. 668–668C), the Migratory Bird Treaty Act (MBTA) (16 U.S.C. 703–712), and the Endangered Species Act (ESA) (16 U.S.C. 1531–1543). *Taking*[5] a bird protected by these laws can result in fines and/or imprisonment. Because electrocutions of protected birds on power lines are considered *takes* under the law, many utilities have acted

[5] In 50 CFR 10.12, *take* means "to pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to pursue, hunt, shoot, wound, kill, trap, capture or collect."

voluntarily and a few under duress to reduce electrocution mortality.

Another major impetus for action is the impact on the electric power network. Bird-caused outages reduce power reliability and increase power delivery costs (See Bird-Related Outages, Chapter 6). Some outages may impact only a few customers temporarily, yet they can still affect a utility's service reliability and customer guarantees. Larger outages can have dramatic consequences. For example, in 2004, several birds nested in insulators resulted in power outages at the Los Angeles International Airport which caused flight delays and threatened airport security. Wildlife-related outages in California alone are estimated to cost from millions to billions of dollars each year (Hunting 2002; Steiger 2003; Energy and Environmental Economics, Inc. 2005). In a culture that depends upon electronic devices, power outages can cause inconveniences to residential customers, mortal risks to those who need electricity for heat or life support systems, and major production losses for industrial and commercial customers.

The impact of electrocution on raptor populations, and avian populations in general, is poorly understood. Newton (1979:212) summarized the difficulties in addressing population impacts on raptors:

> *The importance of different mortality causes is also poorly understood, partly because it is hard to find a sample that is representative of the whole population, and partly because of the operation of pre-disposing causes. Starvation, predation and disease are all recorded as causing deaths of raptors, as are various accidents and collisions, electrocution, shooting, trapping and poisoning. The [banding] recoveries and post-mortem analyses which provide most information are inevitably biased towards deaths that occur from human action or around human habitation.*

Both direct and indirect mortality factors must be considered when studying raptor population dynamics. In addition to electrocution, Postivit and Postivit (1987) identified eight other human activities that affect birds of prey: (1) persecution,[6] (2) pesticide use and pollution, (3) agricultural development, (4) logging, (5) dam construction and water management, (6) energy and mineral development, (7) urbanization, and (8) recreation. Kochert and Steenhof (2002) identified the greatest threats to golden eagles *(Aquila chrysaetos)* in the United States and Canada as the adverse impacts of human activity, including collisions, electrocutions, shooting, and poisoning from lead or agricultural pesticides. Other human-related sources of mortality that impact birds in general include window and motor vehicle collisions, predation by domestic and feral cats, and collisions with power lines, communication towers, and wind generation facilities (National Wind Coordinating Committee [NWCC] 2001). Estimates of avian mortality due to these causes run in the millions annually, far greater than the estimated number of birds killed by electrocution (Figure 2.1).[7] Habitat destruction is thought to cause greater reductions in bird and other wildlife populations than any other factor, and is still the most serious long-term threat (Newton 1979; Wilcove et al. 1998; USFWS 2002).

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[6] The term *persecution* was used by Postivit and Postivit (1987) to mean shooting. Persecution could also include poisoning and direct trapping.

[7] Figure 2.1 was generated using estimates of avian mortality from NWCC 2001, Curry and Kerlinger LLC: What Kills Birds? (http://www.currykerlinger.com/birds.htm), and the U.S. Fish and Wildlife Service: Migratory Bird Mortality (http://www.fws.gov/birds/). Avian mortality rates associated with electrocution are presented for various species in Chapter 4. The numbers provided in Figure 2.1 are gross estimates collected using different techniques and levels of accuracy, therefore this graph is intended only to provide a relative perspective of various sources of avian mortality.

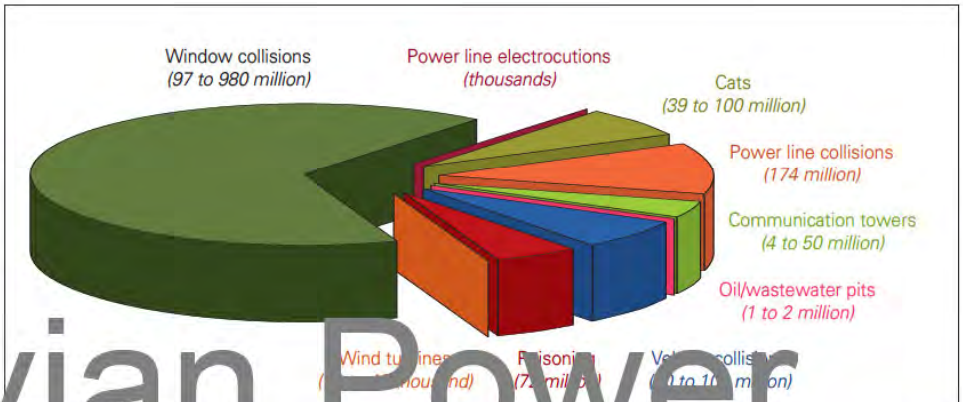

FIGURE 2.1: Comparison of human-caused avian mortality.

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Nevertheless, electrocution on power facilities remains a legitimate concern and a source of mortality that can be reduced. Electrocutions can be minimized through a variety of mitigation measures that include applying "avian-safe"[8] designs to new construction and retrofitting existing lines that pose an electrocution risk. It is in the interest of utility planners, biologists, and engineers to familiarize themselves with the issue and its dimensions, and to plan for and implement measures that identify and rectify existing and potential electrocution problems.

EARLY REPORTS

Before the 1970s, raptor electrocutions had been noted by several researchers (Hallinan 1923; Marshall 1940; Dickey 1937; Benson and Dickinson 1961; Edwards 1969; Coon et al. 1970) although the extent of the problem was not known. Surveys in Wyoming and Colorado during the 1970s found nearly 1,200 eagle mortalities that were due to poisoning, shooting from aircraft, and electrocution. Although most of these eagles had been shot, others had been electrocuted by contact with lines not designed with eagle protection in mind. In northeastern Colorado, 17 golden eagles, 1 red-tailed hawk *(Buteo jamaicensis)*, and 1 great horned owl *(Bubo virginianus)* were found dead—all probably electrocuted, along 5.6 kilometers (km) (3.5 miles [mi]) of line (Olendorff 1972a). Five golden eagles and 4 bald eagles *(Haliaeetus leucocephalus)* were found dead near a power line in Tooele County, Utah. Also, electrocuted eagles were found along a line in Beaver County, Utah (Richardson 1972; Smith and Murphy 1972). Of 60 autopsied golden eagles in Idaho, 55% had been electrocuted (M. Kochert, pers. comm. in Snow 1973). In June of 1974, 37 golden eagles and 1 short-eared owl *(Asio flammeus)* were found dead under a line southwest of Delta, Utah (Benson 1977, 1981). In a review of bald eagle mortality data from 1960 to 1974, 4% of the eagle deaths were attributed to electrocution (total sample size not given) (Meyer 1980). Similar electrocution problems were also noted in

[8] The term *raptor-safe* has been used in previous editions of *Suggested Practices* to identify power poles that are designed or retrofitted to prevent raptor electrocutions. Because this edition of *Suggested Practices* encompasses many avian species, the term *avian-safe* is used.

New Mexico (Denver Post 1974), Oregon (White 1974), Nevada (U.S. Fish and Wildlife Service 1975a), Louisiana (Pendleton 1978), and Idaho (Peacock 1980).

Much of the information from the early 1970s was summarized by Boeker and Nickerson (1975). This 1971 summary documented 37 golden eagle deaths along a power line of just 88 poles in Moffat County, Colorado. Carcasses and skeletons of 416 raptors were found along 24 different 8 k

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SUGGESTED PRACTICES: 1975, 1981, AND 1996

The eagle deaths documented in the western United States during the 1970s raised serious concern about raptors and electric power facilities. Industry, government, and conservation organizations began to work together to identify and solve the problem of raptor electrocution.[9] Agencies initially included the Rural Electrification Administration (REA; now the Rural Utilities Service [RUS]), U.S. Forest Service (USFS), Bureau of Land Management (BLM), USFWS, National Park Service (NPS), and Bureau of Indian Affairs (BIA). The USFWS began searching for lethal lines, while the REA began developing line modification methods to minimize eagle electrocutions. The National Audubon Society and the Edison Electric Institute (EEI) initiated workshops, sought utility participation, raised funds, and began to develop ways to address the problem. In 1972, the REA published a bulletin describing causes of raptor electrocution resulting from certain grounding practices and conductor spacing. This bulletin (61-10) was revised in 1975 and again in 1979 to incorporate research conducted since each earlier edition, including revised inter-phase clearances (Figure 2.2) (U.S. REA 1979).[10] In the 1970s, the

(5 mi) sections of power lines in six western states (Benson 1981). In Utah, U.S. Fish and Wildlife Service (USFWS) employees found the remains of 594 raptors (some dead up to five years) under 36 different distribution lines (spanning approximately 400 km [250 mi]). Of these carcasses, 64 were fresh enough to determine the cause of death: 87.5% had been electrocuted (R. Joseph, pers. comm. in Avian Power Line Interaction Committee [APLIC] 1996).

USFWS also initiated a raptor mortality data bank to track electrocutions.

As data were gathered on the magnitude of raptor electrocution numbers during the early 1970s, regional meetings were held to familiarize industry and agency personnel with the problem. Several electric companies, most notably Idaho Power Company, had retained Morley Nelson[11] of Boise, Idaho, to begin testing the safety of new power line designs and to propose modifications of existing lines. These tests were instrumental in forming the basis for the first definitive work on the subject: *Suggested Practices for Raptor Protection on Power Lines* (Miller et al. 1975). This publication was widely circulated and used by both industry and government (Damon 1975; EEI 1975). For example, the BLM and other agencies began requiring "raptor-safe" construction as a condition of rights-of-way permits on federal land and explicitly stipulated that such actions be consistent with *Suggested Practices* (Olendorff and Kochert 1977).

Field tests of the recommendations contained in the 1975 edition of *Suggested Practices* led to a need for further documentation and evaluation, as some of the recommended dimensions were found inadequate. For

[9] Appendix B presents a history of individual and agency contributions.

[10] REA Bulletin 61-10 was the precursor to the *Suggested Practices* series.

[11] Morley was a cinematographer and pioneer in North American falconry. He filmed trained eagles, hawks, and falcons to study and demonstrate their behavior on a variety of utility pole configurations.

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instance, the suggested 61 centimeters (cm) (24 inches [in]) height of the overhead perch was too high, and needed to be reduced to 41 cm (16 in) to keep birds from landing beneath the perch. New cover-up materials and conductor support schemes were also developed. In the 1981 edition of *Suggested Practices* (Olendorff et al. 1981), earlier recommendations were corrected and updated, and a complete literature review and annotated bibliography were provided. This edition of *Suggested Practices* was adopted (incorporated by reference at 7 CFR 1724.52(a)) by the REA as their standard for raptor protection. *Suggested Practices* continues to be used by the USFWS as a resource for mitigating problems in areas where birds are a concern.

By the mid-1990s, continued progress was being made in reducing raptor electrocution risks. Many utilities had adopted practices participated in raptor enhancement or protection programs (Blue 1996). However, despite these efforts, electrocutions continued in North America and concerns remained over electrocution problems internationally (Lehman 2001). The 1996 edition of *Suggested Practices* refined recommendations from the previous editions, updated the literature review, offered suggestions for cooperative actions among agencies and utilities, and began to identify avian electrocution issues outside of North America.

In the past decade, great strides have been made in preventing avian electrocutions. Many utilities consider avian safety in new construction and continue to retrofit existing poles that pose electrocution risks. There is a growing variety of products and materials manufactured for avian protection (see www.aplic.org). Increased awareness within utilities has improved electrocution reporting and corrective actions. In 2005, APLIC-member utilities were surveyed to obtain information on utility programs, electrocution rates, bird-related outages, and progresses made in avian protection efforts. Of survey respondents (n = 26), most utilities had either an avian protection plan (69%) or policy (77%) (APLIC 2005). Survey respondents were asked to compare their utility's current avian protection efforts to those of 10 and 20 years ago. All utilities surveyed currently retrofit poles for avian protection, however, two decades ago only 31% retrofitted poles for birds. Likewise, the amount of money spent on avian protection efforts has increased substantially. Twenty years ago, half of the utilities surveyed did not have a budget for avian protection; whereas currently all utilities surveyed spend money on avian protection. In addition to expanding their avian protection efforts, many utilities noted that they have

FIGURE 2.2: Golden eagle landing on avian-safe pole. Early research on avian electrocutions and pole modifications focused largely on golden eagles.

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experienced improved relationships with resource agencies. Communication with agencies was considered to be fair by the majority of utilities (45%) 20 years ago, while 58% considered communication good 10 years ago, and 58% reported that they currently have excellent communication with wildlife resource agencies.

ELECTROCUTION ISSUES TO DATE

ELECTROCUTION ISSUES AND PROGRESS IN NORTH AMERICA

Recent literature indicates that electrocution continues to be a cause of mortality for various raptors in North America—particularly eagles and some hawks and owls. Because of increased awareness, new raptor electrocutions are also being documented. The small number of comprehensive field surveys, however, limits the extent of our knowledge of electrocution mortality. Differences in the scope of electrocution studies and the types of data collected make it difficult to compare historic and current information. Additionally, little data exist that quantify the risk of electrocutions relative to other sources of avian mortality. Assessments that use data subsets or incidental reports for extrapolating results based on an estimated number of poles are inaccurate because electrocution risk is not uniformly distributed. Though quite difficult, systematic surveys over large areas can provide more accurate electrocution estimates.

Several recent studies have quantified avian electrocution rates. In a survey of over 70,000 poles in Utah and Wyoming in 2001 and 2002, 547 avian mortalities were found —32% of which were common ravens *(Corvus corax)*, 21% buteos, 19% eagles, 6% passerines/small birds, 4% owls, 2% falcons, 2% waterbirds, and 14% unidentified (Liguori and Burruss 2003). In a survey of 3,120 poles in Colorado, 68 carcasses were discovered, including eagles (53%), hawks (23%), and corvids (7%) (Harness 2001). In a study of 4,090 poles in Montana, golden eagle electrocutions were documented at 4.4% of poles, 20 of which had electrocuted more than one eagle (Schomburg 2003). In Chihuahua, Mexico, studies in 2000 and 2001 documented an average annual electrocution rate of 1 bird per 6.5 concrete poles in non-urban areas (Cartron et al. 2005). In northern California and southern Oregon, confirmed and suspected avian electrocutions were documented at 9% of poles surveyed (n=11,849) in 2004 and 2005 (PacifiCorp, unpubl. data). Of these mortalities, 48% were buteos, 27% owls, 11% eagles, 5% corvids, 5% unidentified raptors, 2% vultures, 1% harriers, and 1% herons.

Studies that have documented electrocutions through incident reports without systematic pole surveys provide conservative estimates of electrocution rates. Harness and Wilson (2001) documented 1,428 raptor electrocutions as a result of mortality records from utilities in the rural western United States from 1986 to 1996. From 1988 to 2003, 210 raptor electrocutions were documented in Nebraska (USFWS/Nebraska unpubl. data). In Montana, 32 golden eagle mortalities were confirmed from 1980 to 1985 (O'Neil 1988). From 1978 to 2004, nearly 800 electrocutions were reported by Alaska utilities to the USFWS (USFWS/Alaska, unpubl. data). Prior to 2000, most electrocutions reported in this database were of bald eagles, which accounted for 83% of reports from 1978 to early 2005. Other birds reported in Alaska include ravens, magpies, crows, owls, gulls, ospreys *(Pandion haliaetus)*, and great blue herons *(Ardea herodias)*.

Bald and golden eagles continue to be a focus of electrocution research in North America, with electrocution accounting for <1% to 25% of eagle deaths in various studies. The U.S. Geological Survey's (USGS)

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National Wildlife Health Laboratory (1985) reported that 9.1% of 1,429 dead bald eagles examined from 1963 to 1984 were electrocuted. In a summary of eagle mortalities from the early 1960s to the mid-1990s, electrocution accounted for 25% of golden eagle and 12% of bald eagle deaths (Franson et al. 1995). Electrocution accounted for 0.5% of deaths in a study of raptor mortality (n=409) in California from 1983 to 1994 (Morishita et al. 1998). Of bald eagles banded in the Yellowstone area (n=[illegible]), 20% died from electrocution or collision with power lines (Harmata et al. 1999). In Florida, 17% of bald eagle mortalities (n=309) from 1963 to 1994 were due to electrocution (Forrester and Spalding 2003). Electrocution also accounted for [illegible]% of eagle mortalities (n=27[illegible]) from a rehabilitation database in Florida from 1988 to 1994 (Forrester and Spalding 2003). Electrocution was the cause of death for 11.5% of bald and golden eagles evaluated (n=[illegible]) from 1987 to 1998 in western Canada (Wayland et al. 2002). Of 61 eagle fatalities in the Diablo Range and Altamont Pass Wind Resource Area, California, from 1994 to 1997, 16% were electrocuted (Hunt et al. 1999). Of birds admitted to the Michigan Department of Natural Resources' (MDNR) Wildlife Disease Laboratory, the number electrocuted was low compared to other causes of death, and most often involved bald eagles, ospreys, and great horned owls (MDNR 2004; T. Cooley, pers. comm.).

The frequency of electrocutions and associated outages has been dramatically reduced in areas where concerted efforts have been made to retrofit or replace hazardous poles. The Klamath Basin of southern Oregon and northern California attracts one of the largest concentrations of wintering raptors in the lower 48 states. In the Butte Valley, an area of the Klamath Basin used extensively by raptors, 90 electrocuted eagles were found between 1986 and 1992 (PacifiCorp, unpubl. data). During the 1990s, extensive pole retrofitting, using recommendations from previous editions of *Suggested Practices*, was completed in this area. Subsequently, in a comprehensive survey of poles in Butte Valley in 2004, only 4 eagle carcasses were found (PacifiCorp, unpubl. data). Likewise, following extensive retrofitting efforts in Worland, Wyoming, the number of eagle electrocutions fell from 49 birds in three years to 1 bird in three years (PacifiCorp, unpubl. data). In the Queen Charlotte Islands of Canada where bird protection was installed on a large proportion of poles, the number of bird-related outages fell from 41 to 16 in two years (BC Hydro 1999). Similarly, in one year following the installation of protective devices on problem circuits in Vermont, animal- and bird-caused outages declined by 56% (Central Vermont Public Service 2002). Electrocution rates of Harris' hawks *(Parabuteo unicinctus)* near nests in Tucson, Arizona, fell from 1.4 electrocutions per nest in 2001 to 0.2 in 2004 (Dwyer 2004).

Mortalities of other raptors, particularly bald eagles, continue to occur in North America. The majority of APLIC-member utilities surveyed in 2005 cited red-tailed hawks as

FIGURE 2.3: Rough-legged hawk perched on insulator.

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one of their most commonly electrocuted species (APLIC 2005). Southern California Edison records indicate that red-tailed hawks constitute about 75% of electrocuted raptors found along their distribution lines (D. Pearson, pers. comm.). Buteos accounted for 21.4% of electrocuted raptors found in Utah and Wyoming (n=547), and included red-tailed hawks (7.5%), Swainson's hawks (5.9%) (*Buteo swainsoni*), ferruginous hawks (1.6%) (*B. regalis*), rough-legged hawks (0.2%) (*B. lagopus*), and unidentified buteos (6.2%) (Ligiguori and Parrish 2003) (Figure 2.3). In a 2004 survey of poles in the Butte Valley of California, buteos accounted for 50% of suspected electrocutions (n=18), 5 of which were red-tailed hawks (PacifiCorp, unpubl. data).

Osprey, a species that the 1996 edition of *Suggested Practices* considered "surprisingly rare" in electrocution records, has greatly increased in population over the past few decades (Saurer et al. 2004). Although records of osprey electrocutions remain infrequent, ospreys are nesting on power poles in growing numbers (USGS 2005; Wisconsin Department of Natural Resources 2003). Consequently, many utilities throughout North America are spending considerable effort on osprey nest management (see Chapter 6).

Pelicans and wading birds, such as herons, egrets, ibises, and storks, have received increased attention from utilities, particularly in the southeastern United States. The lengthy wingspans and heights of these birds put them at risk of electrocution. Like other large birds, they may be electrocuted if they fly into lines mid-span and bridge two conductors. Although waterbirds occur in large concentrations in the southeastern United States and along the Gulf Coast, common and widely distributed species, such as the great blue heron, may be encountered throughout North America.

Although raptor electrocutions typically occur in remote or rural areas, there is a growing awareness of avian electrocutions and outages in urban and suburban locations. In many cases, these interactions involve species that are not protected by the MBTA, i.e. European starlings (*Sturnus vulgaris*), house (English) sparrows (*Passer domesticus*), or rock doves/feral pigeons, *Columba livia*) (Figure 2.4). Regardless of their status, outages caused by these species can result in substantial costs to utilities and their customers. Other protected species—such as jays, crows, ravens, magpies, kingbirds, and woodpeckers—may be common in developed areas and can interact with power lines. In suburban Tucson, Arizona, populations of Harris' hawks have increased and family groups of birds perch or nest on or near power poles. The monk parakeet (*Myiopsitta monachus*), introduced from South America, has presented an increasing problem for utilities in the United

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FIGURE 2.4. Flock of European starlings on power lines.

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States within the last decade. Their large communal nests can cause electrocutions, outages, and fires (see Chapter 6).

Increased awareness of avian electrocutions has led to improved reporting of all birds protected by the MBTA. Of APLIC-member utilities surveyed in 2005 (n=13), 77% currently track electrocutions of all protected species (APLIC 2005). In contrast, ten years ago, most of these utilities only documented electrocutions of eagles, raptors, and other large birds, with only 25% reporting electrocutions of all protected species. Regardless of the species, conducting proactive remedial measures can provide the benefits of reduced mortality and improved reliability.

Since the 1996 edition of *Suggested Practices*, researchers have been trying to identify electrocution risk and to quantify electrocution rates in parts of Mexico (Cartron et al. 2000, 2005, in press; Manzano-Fischer 2004). After numerous electrocuted ravens and raptors were detected under newly constructed distribution lines in northern Mexico in 1999, efforts to address this issue began. Surveys were conducted to assess the scope of the problem and to evaluate possible solutions along lines in northwestern Chihuahua, where the endangered black-tailed prairie dog (*Cynomys ludovicianus*) town complex is North America's remaining (Cartron et al. 2000, 2005). The use of steel-reinforced concrete poles with steel crossarms in this area, coupled with raptor and raven populations attracted to the prairie dog town, increased the electrocution risk. Because the poles and steel crossarms are grounded, birds that perch on them can be electrocuted by touching one conductor (see Chapter 5). In addition, the voltage of distribution lines in Mexico is greater than in the United States, which may create an electrocution risk through arcing. Double dead-end poles pose a particular risk when energized jumper wires are mounted over the crossarms. The problem for raptors such as red-tailed hawks, ferruginous hawks, and golden eagles is greatest during fall and winter and in areas with large prairie dog colonies (Cartron et al. 2005). For the Chihuahuan raven (*Corvus cryptoleucus*), the species most frequently electrocuted in this area, electrocutions occur throughout the year and peak during nesting and after fledging (J-L. Cartron, pers. comm.).

With the added incentive of reducing power outages, Mexico's Federal Utility Company (Comisión Federal de Electricidad; CFE) began to replace conductive steel crossarms with wood crossarms on concrete poles located within the prairie dog town. No dead birds were found at retrofitted concrete poles in a subsequent survey of this area (Cartron et al., in press). In 2002, non-governmental organizations (NGOs), academic institutions, government agencies, and the CFE took part in a workshop, *Avian Electrocutions on Power Lines in Mexico, 1st Workshop*, to address the electrocution problem in Mexico and develop solutions (UNE-SEMARNAT 2002). The workshop was the first meeting of its kind in Mexico, and identified bird electrocutions on distribution lines, collisions with transmission lines, pole construction, and fecal contamination of power lines and optical fiber cable as the main avian related problems.

Although retrofitting of hazardous lines in Chihuahua and Sonora has been implemented, electrocutions still continue along other lines and the extent of the electrocution problem has yet to be determined in other parts of the country (Cartron et al., in press; Manzano-Fischer et al., in press). Agrupación Dodo is currently developing a training manual for CFE maintenance crews. From this they expect to improve data collection on electrocuted birds. All future information will be collected in a national database to help identify problem areas and poles, to support more efficient remedial action.

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The CFE has also begun installing bird flight diverters on some transmission lines in coastal areas to minimize bird collisions, and has installed devices on transmission towers to prevent fecal contamination of insulators by roosting vultures.

In Canada, utilities have documented avian electrocutions and typically retrofit high-risk poles as needed. Manitoba Hydro has surveyed power lines and poles to document bird use and to estimate electrocution and collision mortality rates (G.M. Platt, pers. comm.). ATCO Electric helped fund an extensive study with the University of Alberta (Platt 2005). The goals of this study were to quantify raptor electrocution rates, determine the species affected, and identify pole configurations that present the greatest risk.

Since the 1996 edition of *Suggested Practices* several landmarks regarding avian electrocution have occurred: (1) an electric utility has been prosecuted for avian electrocutions, (2) settlement agreements over avian electrocutions have been reached between utilities and USFWS, (3) Avian Protection Plan Guidelines were collaboratively developed by utilities and USFWS, and (4) the focus of electrocution issues broadened to include non-raptor species. In December 2003, the USFWS prosecuted Moon Lake Electric Association (MLEA) for violations of the MBTA and BGEPA. For the electrocutions of 12 eagles, 4 hawks and 1 owl in Colorado, MLEA was sentenced to three years probation for six violations of the MBTA and seven violations of the BGEPA. In addition, MLEA paid a $50,000 fine, donated $50,000 to raptor conservation efforts, entered into a Memorandum of Understanding (MOU) with the USFWS, and developed a plan to reduce raptor electrocution risk on its facilities. The MLEA case brought heightened attention to raptor electrocution issues from both utilities and agencies. Prior to the MLEA case, fines had been levied against two electric utilities, one in 1993 and the other in 1998, for violations of the MBTA and BGEPA.

In 2005, APLIC and the USFWS published the voluntary Avian Protection Plan Guidelines (Guidelines) to aid utilities in developing programs, policies, and procedures to reduce bird mortality on power lines while enhancing service reliability (see Chapter 7 and Appendix C). Just as the Guidelines were developed in a cooperative manner, the creation of Avian Protection Plans (APPs) by individual utilities is intended to be voluntary but of collaboration with the USFWS and other agencies.

INTERNATIONAL EFFORTS

Workshops

Avian interactions with power lines are global issues. In recent years, awareness of these issues has increased and several international avian conferences have dedicated special sessions to avian/power line interactions. In 1996, the Raptor Research Foundation organized the 2nd *International Conference on Raptors* in Urbino, Italy. This conference was unique because it included a symposium on energy development with presentations on avian electrocutions from South Africa, Spain, Australia, Russia, and Italy. Papers were also presented on power line collisions, and electric and magnetic fields.

In 1998, the *5th World Conference on Birds of Prey and Owls* was held in South Africa and included a session on the impacts of electrical utility structures on raptors. In 2001, the *4th Eurasian Congress on Raptors* was held in Seville, Spain, also with a special session on avian electrocutions. Presentations identified electrocution issues in Mexico, Russia, and Spain. Positive influences from nesting on utility structures were reported in Mongolia and Spain. A field trip was conducted to Doñana National Park where power lines have been retrofitted to prevent electrocutions of Spanish imperial eagles *(Aquila adalberti)*. In

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2003, the *6th World Conference on Birds of Prey and Owls* was held in Hungary where papers on avian electrocutions were presented from the Slovak Republic, Bulgaria, and Hungary.

Addressing the Issue

The challenges faced outside the United States are often disparate. International distribution line construction often includes the use of grounded metal/concrete poles with metal crossarms that present a high electrocution risk to birds and can be difficult to retrofit. Additionally some countries lack the resources to build power lines that minimize electrocution risks to birds, resulting in increased animal contacts and power outages. Like the United States, many countries have programs that range from being reactive to proactive, designed to address electrocutions.

A model program addressing avian electrocutions on power lines exists in South Africa, with a partnership between Eskom, the national electricity supplier, and the Endangered Wildlife Trust (EWT) (C.S. van Rooyen, pers. comm.). The partnership deals specifically with bird collisions, electrocutions, bird pollution and streamers, and nesting-caused electrical outages. The EWT acts as a consultant to the utility, focusing on reducing negative interactions between wildlife and electrical structures by systematically managing avian interaction problems. Eskom staff acts on the EWT's advice to address problems encountered in the course of everyday utility duties. A comprehensive research program is also supported that includes raptor electrocution risk assessments of existing power lines, investigations of faulting mechanisms, and the impacts of power lines on sensitive bird species. Several million dollars are invested annually into Eskom's combined research and mitigation programs. The partnership has also initiated programs in other parts of Africa that assist with impact assessments of new lines in Namibia and Botswana. Environmental personnel from other electrical utilities in the Southern African Development Community are being trained to establish other cooperative management initiatives in Africa.

Retrofitting power lines in Doñana National Park to prevent electrocutions of Spanish imperial eagles is one of Spain's conservation success stories. Between 1991 and 1999, high-risk power line towers were modified, considerably reducing the number of raptor electrocutions. The Spanish Government Ministry of the Environment is currently preparing a Royal Decree to establish protective measures to prevent bird collisions (A.C. Cardenal, pers. comm.). There are 17 local governments in Spain and most have cooperative agreements with their electric companies for reducing the impact of power lines on birds. Recovery plans for endangered species, such as Bonelli's eagle *(Hieraaetus fasciatus)* and bearded vulture *(Gypaetus barbatus)* include measures to mitigate interactions with power lines. Nearby, in the early 1990s, Portugal embarked on a program to deal with large numbers of white storks *(Ciconia ciconia)* on transmission towers by preventing nesting in dangerous areas and encouraging nesting on platforms carefully located on the towers (C. Alonso, pers. comm.).

In 2002 Germany responded to bird electrocutions by passing a Federal Nature Conservation Act to provide avian protection (D.G. Haas, pers. comm.). This regulation states, *"all newly erected power poles and technical structures in the medium voltage range have to be designed to protect birds. Power poles and technical hardware in the medium voltage range that are already in use and pose a high risk to birds are to be retrofitted to exclude electrocution as a threat within the next 10 years."* Raptor-friendly construction standards also have been published by NABU-German Society for Nature Conservation in *Suggested Practices for Bird Protection on Power Lines* (NABU 2002).

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The brochure contains the technical standards necessary for avian-safe construction as well as mitigation measures for medium voltages. Although electrocutions do occur in the United Kingdom (J. Parry-Jones, pers. comm.) and northern Europe (K. Bevanger, pers. com.), less is known about their mitigation efforts.

Eastern European countries are also addressing avian electrocution risks. The State Nature Conservancy of the Slovak Republic is partnering with three Slovakian energy companies to improve mitigation strategies and develop avian-safe configuration standards for new construction (M. Adamec, pers. comm.). The State Nature Conservancy also monitors power lines to help identify areas in need of proactive retrofitting, and is preparing a long-term strategy for Eastern Slovakia to retrofit all medium-voltage structures over the next 10 years. In Hungary, MME BirdLife-Hungary is working with utilities to identify and mitigate problems and to design safer utility configurations (I. Demeter, pers. comm.). Avian electrocution also is acknowledged as a serious problem in Bulgaria, with 50% of the country's poles posing a risk to raptors (S. Stoychev, pers. comm.). The Bulgarian Society for the Protection of Birds/BirdLife Bulgaria (BSPB) is addressing the issue. The BSPB is working with some of the Bulgarian electric companies, providing information on rare species' breeding and foraging grounds, migration routes, and possible solutions to reducing electrocution problems. Protective devices are being deployed as part of a pilot project to determine their effectiveness in reducing mortality and associated power outages. In 2004, the BSPB also implemented an electrocution study in several "Important Bird Areas" (IBAs).

Less is known about avian electrocution issues in Russia and Asia. In Russia, it has been reported that high-risk power lines exist and eagles have been electrocuted, especially in the Kazakhstan steppes and deserts. One report estimates that 10% of the USSR population of steppe eagles *(Aquila nipalensis)*, primarily juvenile or subadult birds, is electrocuted each year in the northern Caspian areas (V. Moseikin, pers. comm.). Given these reports, it is vital to determine the scope of the problem and develop cooperative strategies with the local power companies. Avian interactions with power lines have also been reported in Australia (B. Brown, pers. comm.) and New Zealand. Although Tasmania Hydro participated in the production of the *Raptors at Risk* electrocution video, little is known about the scope of the problem in Australia.

Except for Israel, the extent of avian electrocutions is relatively unknown in the Middle East. The Israel Birds of Prey Research and Conservation Project, the Israel Electric Corporation, the Israel Nature Reserves and Parks Authority, and the Society for the Protection of Nature in Israel work closely together to address electrocution issues (Shalmon, pers. comm.). Through their efforts, electrocution "hotspots" have been identified and retrofitted, significantly reducing bird electrocutions while improving service reliability. Presently they are developing a Geographic Information System (GIS)-based program to avoid siting future lines in IBAs.

Little information is available about retrofitting efforts in Central and South America, although avian interactions with power lines have been documented in Brazil (P. Américo, pers. comm.).

THE OUTLOOK

Since the first edition of *Suggested Practices* in 1975, there has been considerable progress in identifying electrocution hazards and developing solutions. In the decade since the 1996 edition, utilities and resource agencies have made significant strides in communicating and collaborating on avian/power line issues. A product of this collaboration was the

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development of Avian Protection Plan Guidelines by APLIC and the USFWS in 2005 (Appendix C). The Guidelines, which are intended to help utilities develop their own APPs, focus on reducing bird mortality and improving power system reliability by identifying the key policies and practices to achieve these goals. Voluntary cooperation among electric utilities and agencies has improved communication and will benefit participants through reduced avian mortality and enhanced power reliability.

Avian mortality, particularly raptor mortality, continues to play an important role in federal land management decisions. Avian protection measures are often mandated as part of permitting and licensing requirements by most federal agencies in the United States, including the BLM, USFS and USFWS. In addition, the Federal Energy Regulatory Commission (FERC) routinely includes special articles mandating raptor protection on power lines in licenses for hydroelectric projects (FERC 1999).

Although utilities have worked for several decades to make lines on federal lands safe for raptor use, they now face an interesting challenge in areas with sage-grouse *(Centrocercus spp.)*, prairie chickens *(Tympanuchus spp.)*, mountain plovers *(Charadrius montanus)*, Utah prairie dogs *(Cynomys parvidens)*, and desert tortoises *(Gopherus agassizii)*. In some cases, land management agencies have requested that raptors and corvids be prevented from perching on power lines where these rare or endangered species are found (Figure 2.5). The goal of such efforts is to reduce predation, although the actual impact of raptors hunting from poles on populations of these species has not been adequately studied, quantified or verified. Utilities that attempt to discourage raptors from using portions of a power line, as well as agencies requiring such actions, should be aware of several important points: (1) perch discouragers are intended to move birds from an unsafe location to a safe location and do not *prevent* perching, (2) predation can occur regardless of the presence of a power line, (3) raptors and corvids prey upon mammalian predators of sage-grouse and prairie chickens, and (4) electrocution risk may be increased if perch discouragers are installed on long consecutive spans without providing alternative perch

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FIGURE 2.5: Perch discouragers have been installed on utility poles to prevent raptors or corvids from preying upon sensitive species. However, this is not recommended, as perch discouragers are intended to manage where birds perch, not to entirely prevent perching.

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sites (because this may cause birds to perch on exposed pole-mounted equipment). Utilities and agencies should work together to identify predation risk to sensitive species that results from raptor and corvid use of poles; determine retrofitting methods that are appropriate, effective, and commensurate with the level of risk; and develop best management practices or guidelines.

As the human population grows and energy demands increase, new power lines will inevitably be built. Since overhead power lines will continue to be built in avian habitat, and because perching on power line structures involves some degree of risk, electrocutions will occur in the future. In addition, increasing populations of some avian species in North America, such as bald eagles, ospreys, monk parakeets, and some corvids, present utilities with a growing need to manage avian electrocutions or nests on power poles. Electrocution problems may be most severe on those continents that contain large, expanding human populations (Africa, South America, and Asia) (Bevanger 1994a). Raising global awareness of avian electrocution problems and solutions remains a priority and a challenge for conservation organizations. For utilities, the use of avian-safe designs and construction techniques (see Chapter 5) for distribution systems will help reduce future electrocution problems. Much retrofitting work also remains for existing high-risk lines worldwide.

This 2006 edition of *Suggested Practices* contains a new section on steel and concrete poles. These poles can pose serious electrocution hazards and are increasingly being used worldwide. In addition, a Spanish translation of *Suggested Practices* is intended to provide this resource to those in Spanish-speaking countries. The authors hope that *Suggested Practices* will continue to promote an awareness of avian interactions with power facilities and provide a range of electrocution prevention solutions that can be used throughout the world.

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CHAPTER 3

Regulations and Compliance

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IN THIS CHAPTER Overview of Existing Laws Permits

Three federal laws in the United States protect almost all native avian species and prohibit "taking," or killing, them. The Migratory Bird Treaty Act (MBTA) protects over 800 species of native, North American migratory birds. The Bald and Golden Eagle Protection Act (BGEPA) provides additional protection to both bald and golden eagles. The Endangered Species Act (ESA) applies to species that are federally listed as threatened or endangered. This chapter provides an overview of each of these laws and the permits that may be required for nest management, carcass salvage, or other bird management purposes.

OVERVIEW OF EXISTING LAWS

The **Migratory Bird Treaty Act** of 1918 (MBTA) (16 U.S.C. 703–712), which is administered by United States Fish and Wildlife Service (USFWS), is the legal cornerstone of migratory bird conservation and protection in the United States. The MBTA implements four treaties that provide international protection for migratory birds. It is a strict liability statute meaning that proof of intent is not required in the prosecution of a "taking"[12] violation. Most actions that result in *taking* or possessing (permanently or temporarily) a protected species can be violations.

The MBTA states: "Unless and except as permitted by regulations … it shall be unlawful at any time, by any means, or in any manner to pursue, hunt, take, capture, kill … possess, offer for sale, sell … purchase … ship, export, import … transport or cause to be transported … any migratory bird, any part, nest, or eggs of any such bird, or any product … composed in whole or in part, of any such bird or any part, nest, or egg thereof…"

A 1972 amendment to the MBTA provided legal protection to birds of prey (e.g., eagles, hawks, falcons, owls) and corvids (e.g., crows, ravens). The MBTA currently protects 836 migratory bird species, including waterfowl, shorebirds, seabirds, wading birds, raptors, and songbirds. Generally speaking, the MBTA protects all birds native to North America, and excludes house (English) sparrows *(Passer domesticus)*, European starlings

[12] "Take" in this context means to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect.

(Sturnus vulgaris), rock doves (or common/feral pigeons, *Columba livia*), monk parakeets *(Myiopsitta monachus)*, any other species published in the Federal Register, and non-migratory upland game birds. The list of migratory bird species protected under the MBTA appears in Title 50 of the Code of Federal Regulations part 10.13 (50 CFR 10.13) and is available online at www.access.gpo.gov/nara/cfr/waisidx_03/50cfr10_03.html.

An individual who violates the MBTA by taking a migratory bird may be fined up to $15,000 and/or imprisoned for up to six months for a misdemeanor[13] violation. An individual who knowingly takes any migratory bird with the intent to sell, offer to sell, barter, or offer to barter such bird or who knowingly sells, offers for sale, barters, or offers to barter any migratory bird is subject to a felony violation with fines of up to $250,000 and/or imprisonment for up to two years.

Under the authority of the **Bald and Golden Eagle Protection Act** of 1940 (BGEPA) (16 U.S.C. 668–668d), bald *(Haliaeetus leucocephalus)* and golden *(Aquila chrysaetos)* eagles are given additional legal protection. *Take* under the BGEPA is defined as "to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb." Violators of the act's *take* provision may be fined up to $100,000 and/or imprisoned for up to one year. The BGEPA has additional provisions where, in the case of a second or subsequent conviction, penalties of up to $250,000 and/or two years imprisonment may be imposed.

The **Endangered Species Act** (ESA) (16 U.S.C. 1531–1544) was passed by Congress in 1973 to protect our nation's native plants and animals that were in danger of becoming extinct and to conserve their habitats. Federal agencies are directed to use their authority to conserve listed species, as well as "candidate"[14] species, and to ensure that their actions do not jeopardize the existence of these species. The law is administered by two agencies, (1) the USFWS and (2) the Commerce Department's National Marine Fisheries Service (NMFS). The USFWS has primary responsibility for terrestrial and freshwater organisms, while the NMFS has primary responsibility for marine life. These two agencies work with other agencies to plan or modify federal projects to minimize impacts on listed species and their habitats. Protection is also achieved through partnerships with the states, with federal financial assistance, and a system of incentives that encourage state participation. The USFWS also works with private landowners by providing financial and technical land management assistance for the benefit of listed and other protected species. To obtain a list of all federally listed (threatened and endangered) birds, other federally listed animals and plants, consult 50 CFR parts 17.11 and 17.12. This list is available online at www.fws.gov/endangered/wildlife.html.

Section 9 of the ESA makes it unlawful for a person to take listed species. *Take* under the ESA is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." The regulations define the term "harm" as "an act that actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." Unlike the MBTA and the BGEPA, the ESA authorizes the USFWS to issue permits for "incidental take" (*take* that results from an otherwise legal activity).

Section 10 of the ESA allows for "Habitat

[13] A *misdemeanor* is a crime that is punishable by less than one year imprisonment. A *felony* is a serious crime punishable by incarceration for more than a year.

[14] *Candidate* species are those which may be added to the list of threatened and endangered species in the near future.

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Conservation Plans" for endangered species on private lands or for the maintenance of facilities on private lands. This provision helps private landowners incorporate conservation measures for listed species into their land and/or water development plans. Private landowners who develop and implement approved habitat conservation plans can receive incidental take permits that allow their development to proceed.

In addition to federal regulations, individual states may also have bird-protection regulations. A utility should consult with its respective state resource agency (ies) to determine what regulations apply and if permits are required.

Although the MBTA and BGEPA have no provision for allowing *take*, the USFWS realizes that some birds will be killed even if all reasonable measures to avoid it are used. The USFWS Office of Law Enforcement carries out its mission to protect migratory birds through investigations and enforcement, as well as by fostering relationships with individuals, companies, and industries that have programs to minimize their impacts on migratory birds. Since a *take* cannot be authorized, it is not possible to absolve individuals, companies, or agencies from liability even if they implement avian mortality avoidance or similar conservation measures. However, the Office of Law Enforcement does have enforcement discretion and focuses on those individuals, companies, or agencies that *take* migratory birds without regard for their actions and the law, especially when conservation measures had been developed but had not been implemented.

PERMITS

Federal and/or state permits may be required for activities related to species protected by the MBTA, BGEPA, ESA, or state laws. A utility should consult with resource agencies to determine if permits are required for operational activities that may impact protected avian species. Special Purpose or related permits are required for activities such as nest relocation, temporary possession, depredation, salvage/disposal, and scientific collection. Utilities are encouraged to contact their regional USFWS Migratory Bird Permit Office to identify permit requirements and obtain permit applications (See Avian Protection Plan Guidelines, Appendix C, for contact information). In addition, utilities should obtain information regarding state-required permits from their state's resource agency.

MIGRATORY BIRD PERMITS

USFWS regional offices administer permits for the following types of activities: falconry, raptor propagation, scientific collecting, rehabilitation, conservation education, migratory game bird propagation, salvage, take of depredating birds, taxidermy, and waterfowl sale and disposal. These offices also administer the permits authorized by the BGEPA.

The Division of Migratory Bird Management develops migratory bird permit policy and the permits themselves are issued by the Regional Migratory Bird Permit Offices. The regulations governing migratory bird permits can be found in 50 CFR part 13, General Permit Procedures (www.access.gpo.gov/nara/cfr/waisidx_03/50cfr13_03.html), and 50 CFR part 21, Migratory Bird Permits (www.access.gpo.gov/nara/cfr/waisidx_03/50cfr21_03.html).

In 2003, the USFWS released a memorandum regarding the destruction of nests of species protected under the MBTA (see Appendix C or www.fws.gov/permits/mbpermits/PoliciesHandbooks/MBPM-2.nest.pdf). The memo clarified that the definition of *take* under the MBTA applies to active nests (containing eggs or young). The collection, possession, and transfer of possession of

inactive bird nests are also illegal under the MBTA; however, the destruction of nests that do not contain eggs or birds is not illegal. This, however, **does not** apply to eagles or species listed under ESA, whose active and inactive nests may not be destroyed. The memo also stated that the USFWS may issue permits for the removal of occupied nests when public safety is at risk.

EAGLE PERMITS

Under the BGEPA, the USFWS issues permits to *take*, possess, and transport bald and golden eagles for scientific, educational, Native American religious purposes, depredation, and falconry (golden eagles). No permit authorizes the sale, purchase, barter, trade, importation, or exportation of eagles, eagle feathers, or any of their parts, nests, or eggs. The regulations governing eagle permits can be found in 50 CFR part 13, General Permit Procedures (www.access.gpo.gov/nara/cfr/waisidx_03/50cfr13_03.html) and 50 CFR part 22, Eagle Permits (www.access.gpo.gov/nara/cfr/waisidx_03/50cfr22_03.html).

ESA CONSULTATIONS/ HABITAT CONSERVATION PLANS

When power companies propose to construct power generation or transmission facilities or related equipment on federal lands, they must first consult with the USFWS through Section 7 of the ESA. Before initiating an action, the federal agency owning the land or its non-federal permit applicant (e.g., a power company), must ask the USFWS to provide a list of threatened, endangered, proposed, and candidate species and designated critical habitats that may be present in the project area. The USFWS has developed a handbook describing the consultation process in detail, which is available at www.fws.gov/endangered/consultations.

When non-federal activities (activities not on federal lands and/or lacking a federal nexus such as federal funding or a federal permit) will *take* threatened or endangered species, an Incidental Take Permit (ITP) is required under Section 10 of the ESA. Some states may also have regulations that require permits or conservation plans. Approval of an ITP issued in conjunction with a Habitat Conservation Plan (HCP) requires the Secretary of Interior to find, after an opportunity for public comment, that among other things, the *taking* of ESA protected species will be incidental and that the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such *taking*. An HCP must accompany the application for an ITP. The HCP associated with the permit is to ensure that conservation measures are adequate for avoiding jeopardy to the species. Information about consultations and HCPs can be obtained from the closest USFWS Ecological Services Field Office, generally located in each state. A list of those offices and their phone numbers can be accessed at www.fws.gov/info/pocketguide.

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CHAPTER 4

Biological Aspects of Avian Electrocution

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IN THIS CHAPTER

- Susceptibility of Different Birds to Electrocution
- Factors Influencing Electrocution Risk
- Identifying Evidence of Electrocution
- Scavenging Rates of Carcasses

Minimizing avian electrocutions requires an understanding of the biological, engineering, and environmental factors that influence risk. This chapter identifies the causes of bird electrocutions and focuses on the factors that predispose raptors to electrocution.

Bird electrocutions on power lines result from three interacting elements: biology, environment, and engineering. The biological and environmental components that influence electrocution risk include body size, habitat, prey, behavior, age, season, and weather.

- Body size is one of the most important characteristics that make certain species susceptible to electrocution. Outstretched wings or other body parts that span the distance between energized conductors make electrocution risk much greater for large birds; however, small birds can be electrocuted on closely spaced energized equipment such as transformers.
- Habitat is a key factor influencing avian use of poles. In open areas lacking natural perches, power poles provide sites for hunting, feeding, resting, roosting, or nesting.
- Habitats with abundant prey may also attract predatory birds.
- Territorial, nesting, and other behavioral characteristics may bring multiple birds to a pole, increasing electrocution risk.
- Young birds may be more susceptible to electrocution because they are inexperienced or less agile at taking off and landing on poles.
- Local changes in species distribution and abundance during breeding, migration, or wintering can result in a seasonal variation in electrocution rates.
- Wet weather can increase electrocution risk, as wet feathers are electrically more conductive than dry feathers.
- Finally, configurations with closely spaced energized phase conductors and grounded wires are more readily bridged by birds, causing electrocutions (see Chapter 5).

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Of the 31 species of diurnal raptors and 19 species of owls that regularly breed in North America, 29 have been reported as electrocution victims. Electrocutions have also been reported in over 30 non-raptor North American species, including crows, ravens, magpies, jays, storks, herons, pelicans, gulls, woodpeckers, sparrows, kingbirds, thrushes, starlings, pigeons, and others.

SUSCEPTIBILITY OF DIFFERENT BIRDS TO ELECTROCUTION

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RAPTORS

Accipiters

The three North American accipiters—sharp-shinned hawk *(Accipiter striatus)*, Cooper's hawk *(A. cooperii)*, and northern goshawk *(A. gentilis)*—typically hunt in forested areas. Because natural perches are abundant in these habitats, accipiters are more likely to perch in trees than on the exposed perches provided by electric transmission and distribution facilities. Consequently, forested habitats generally have fewer reported raptor electrocutions than do open habitats (Snyder 1977; Benson 1981). In a survey of over 70,000 power poles in various habitats throughout Utah and Wyoming, no electrocutions were found on the 1,500 poles surveyed in forested areas (PacifiCorp, unpubl. data).

Of 2,711 combined electrocution records from six studies (O'Neil 1988; Harness 1996; Idaho Power Co., unpubl. data; Harness and Wilson 2001; Dwyer 2004; USFWS/Nebraska, unpubl. data), 4 electrocutions were northern goshawks and 4 were Cooper's hawks. Of 40 radio-tagged Cooper's hawks in Arizona, 1 (a male) was electrocuted (Mannan et al. 2004). Northern goshawks accounted for <5% of raptor mortality in both Germany (n=567) and France (n=686) (Bayle 1999). In Spain, goshawks accounted for <10% of electrocutions in several studies: 0.4% of electrocutions documented by Ferrer et al. (1991) (n=233), 1.1% of electrocutions documented by Janss (2000) (n=467), and between 5% and 10% of electrocutions documented by Bayle (1999) (n=282).

Buteos

Buteos comprise the largest non-eagle group of raptors that is electrocuted on power lines. In particular, red-tailed *(Buteo jamaicensis)*, ferruginous *(B. regalis)*, Swainson's *(B. swainsoni)*, and rough-legged *(B. lagopus)* hawks occur in open habitats and commonly perch on power poles and towers (Figure 4.1). Combined electrocution mortality of these four hawks has ranged between 6% and 48% of reported electrocutions in a number of studies (e.g., Ansell and Smith 1980; Peacock 1980; Benson 1981; O'Neil 1988; PacifiCorp, unpubl. data; USFWS/Nebraska, unpubl. data). In

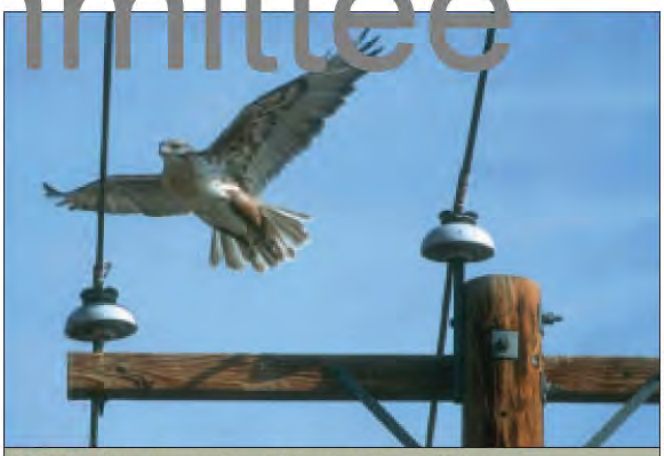

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FIGURE 4.1: Ferruginous hawk taking off from a distribution pole.

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Utah and Wyoming, buteo electrocutions exceeded eagle electrocutions (21% vs. 19%; *n*=547) (Liguori and Burruss 2003). Red-tailed hawks were the most commonly electrocuted buteo in this study (7.5%), followed by Swainson's hawks (5.9%), ferruginous hawks (1.6%), and rough-legged hawks (0.2%). In Nebraska, red-tailed hawks accounted for 11% of electrocutions (*n*=199) from 1988 to 2003 (USFWS/Nebraska, unpubl. data). In addition, rough-legged hawks comprised 10.5% of electrocutions in the dataset. Red-tailed hawks comprised 37% of avian mortalities (*n*=102) in northern California and southern Oregon from 2004 and 2005 (PacifiCorp, unpubl. data). In Chihuahua, Mexico, the red-tailed hawk was the second most frequently electrocuted species (after Chihuahuan raven [*Corvus cryptoleucus*]), accounting for 15% of mortalities (*n*=178) (Cartron et al. 2005).

Although these four buteos comprise a large proportion of electrocuted birds, their mortality rate due to electrocution is low compared to other causes of death and has ranged from 3% to 13% in a number of studies. For example, in an analysis of 163 red-tailed hawk carcasses, 4% died from electrocution (Fraser et al. 1986). Electrocution was the cause of death for 13% of rough-legged hawks (*n*=8), 11% of ferruginous hawks (*n*=9), 3% of Swainson's hawks (*n*=37), and no red-tailed hawks (*n*=31) that were admitted to the Colorado State University Veterinary Teaching Hospital (Wendell et al. 2002). The low overall electrocution rate (3%) of birds in this study (*n*=409) was attributed to two factors: electrocuted birds are unlikely to survive, be detected, and brought to a rehabilitation facility; and, the frequency of electrocutions may be declining due to modification of power poles.

Electrocution records for other buteos are uncommon. Red-shouldered hawk *(Buteo lineatus)* electrocutions have been documented in Florida (J. Lindsay, pers. comm.) and California (M. Best, pers. comm.). Although documented, electrocution of the common black-hawk *(Buteogallus anthracinus)* is rare (Schnell 1980, 1994). The Harris' hawk *(Parabuteo unicinctus)* is a uniquely social raptor that resides in family groups of multiple individuals and commonly uses power poles (Bednarz 1995). Eight cases of electrocution were reported by Whaley (1986) in the Sonoran Desert of southern Arizona, but the author thought the additional electrocutions probably went unreported. In and near Tucson, Arizona, between 1991 and 1994, 63% of Harris' hawk mortalities with known causes (*n*=177) were due to electrocution (Dawson and Mannan 1994). Electrocution was suspected as the cause of death for an additional 44 carcasses. In 2003 and 2004, 75 electrocuted Harris' hawks were found in the metropolitan Tucson area, 29 of which were within 300 meters (m) (1,000 feet [ft]) of a nest (Dwyer 2004). Following the retrofitting of hazardous poles in this area, the electrocution rate per nest fell from 1.4 in 2003 to 0.2 in 2004.

Other Diurnal Raptors

Small diurnal raptors (e.g., American kestrel *(Falco sparverius)*, merlin *(F. columbarius)*, and most sites) with wingspans less than 102 centimeters (cm) (40 inches [in]) generally cannot span the distance between two electric conductors (see Figures 4.11, 4.12 and Table 4.1 for an illustration of avian wingspans). However, electrocution of smaller raptors may be underestimated since they are less noticeable than large birds and because scavengers may consume or remove them before they are found. Small raptors are probably more at risk on poles with transformers or other equipment where only inches of spacing exist between energized and grounded parts. Although uncommon, records of electrocutions do exist for smaller raptors, including Ameri-

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can kestrels (Figure 4.2) (Ellis et al. 1978; Harness and Wilson 2001; Smallwood and Bird 2002; Wendell et al. 2002; Cartron et al. 2005; Idaho Power Co., unpubl. data; USFWS/Nebraska, unpubl. data; PacifiCorp, unpubl. data) and merlins (Bayle 1999). Of avian electrocutions identified by species in the western United States from 1986 to 1996 (n=555), 6 were American kestrels (Harness and Wilson 2001). Likewise, kestrels comprised 1.1% of mortalities in Utah and Wyoming from 2001 to 2002 (n=547) (Liguori and Burruss 2003). Merlins accounted for <5% of raptor mortalities in France (n=686) (Bayle 1999).

Few electrocution records are available for the large falcons. Despite their size and frequent use of power poles, electrocutions of peregrine *(F. peregrinus)* and prairie falcons *(F. mexicanus)* are rare. Two prairie falcons were documented out of 547 electrocutions in Utah and Wyoming from 2001 to 2002 (Liguori and Burruss 2003). Prior to this, very few prairie falcon electrocutions had been documented (Benson 1981; Harness 1991; Harness and Wilson 2001; Idaho Power Company, unpubl. data). Electrocutions of peregrine falcons have been reported by Cade and Sage (Postupalsky 1982), Cade (1985), McLennon and Bresette (1987), Powell et al. (2002), White et al. (2002), and the State of Michigan (2005). Of avian electrocutions in the western United States from 1986 to 1996 (n=555), only 6 were peregrine falcons (Harness and Wilson 2001). Peregrine electrocutions have also occurred in low numbers in other countries, such as France, where <5% of raptor electrocutions (n=686) were peregrines (Bayle 1999) and South Africa, where peregrines accounted for 1.4% of electrocutions (n=147) from 1996 to 1998 (Kruger 2001a). Likewise, in Spain, peregrines have accounted for 0.4%, 0.9%, and <5% of electrocutions (n=233), (n=467)

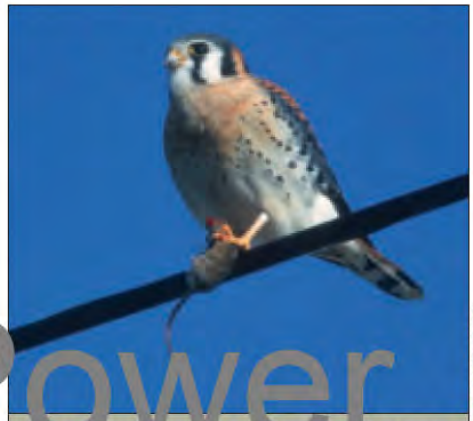

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FIGURE 4.2: American kestrel with prey on wire.

and (n=1,282) in studies conducted by Ferrer et al. (1991), Janss (2000), and Bayle (1999). An electrocution of a fledgling crested caracara *(Caracara cheriway)* from a nest in a substation was documented in Florida (J. Lindsay, pers. comm.). Although aplomado falcons *(F. femoralis)* may nest on power poles, electrocutions in the United States have not been documented. There is one record of a suspected aplomado falcon electrocution in Mexico (G. Montoya, pers. comm.). Records of electrocuted gyrfalcons *(F. rusticolus)* are rare and typically involve escapees of falconry birds rather than wild birds (Hindgren 1980; Harness and Wilson 2001; USFWS/Nebraska, unpubl. data).

Northern harriers *(Circus cyaneus)* are electrocuted infrequently as they rarely perch on poles, but some records exist (Williams and Colson 1989; APLIC 1996). In Germany, the hen harrier *(C. cyaneus)* accounted for <5% of raptor electrocutions (n=567) (Bayle 1999).

Although ospreys *(Pandion haliaetus)* commonly nest on power poles (see Chapter 6), electrocutions of this species are uncommon (Figure 4.3). Of Avian Power Line Interaction Committee (APLIC)-member utilities surveyed

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in 2005, several in the northwest and southeast noted osprey issues, particularly in regard to nest management (APLIC 2005). Poole and Agler (1987) reported that <4% of banded ospreys (n=451) recovered between 1972 and 1984 died from electrocution, collisions with power lines and TV/radio towers, and entanglements with fishing equipment. Of ospreys admitted to wildlife rehabilitation centers in Florida from 1988 to 1995, 9% (n=284) were electrocuted (Forrester and Spalding 2003). Additional osprey electrocution mortalities have been documented by Dunstan (1967, 1968), Yagar (1978), Fulton (1984), Williams and Colson (1989), Munoz-Pulido (1990), Harness (1996), Poole et al. (2002), State of Michigan (2005), and the Idaho Power Company (unpubl. data). In the western United States, 11 electrocutions attributed to species (n=555) from 1986 to 1996 were ospreys (Harness and Wilson 2001). In France, ospreys accounted for <5% of raptor mortalities (n=86) (Bayle 1999).

Osprey populations have increased in parts of their North American range over the past few decades (Sauer et al. 2004). Growing osprey populations in Canada have been attributed to the provision of artificial nest platforms, increased survey efforts, and the ban of DDT (Kirk and Hyslop 1997). In the Willamette Valley of Oregon, where the number of nesting ospreys has more than doubled in six years from the late 1990s to the early 2000s, most nests are located on distribution poles or adjacent nest platforms (Henny et al. 2003; USGS 2003). Osprey populations in the Chesapeake Bay area more than doubled from the 1970s to the mid-1990s as the use of man-made nesting substrates, particularly navigational markers, increased (Watts et al. 2004). In this region, 68% of osprey nests were located on man-made structures during the 1970s, as compared to 93% in the 1990s. Types of man-made structures used during the 1990s included navigational aids (53.5%), nesting platforms (12.1%), duck blinds (9.7%), and other man-made structures (17.6%; including boat houses, chimneys, docks, ships, electrical power poles, bridges, cell phone towers, and pilings). In New Jersey, the number of osprey pairs increased from 68 in 1975 to over 200 in the mid-1980s to 340 in 2001 (Liguori 2005). Many of these nests are located on platforms in coastal marshes.

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FIGURE 4.3: Osprey.

Eagles

The geographic distribution of golden eagles (*Aquila chrysaetos*) electrocutions has ranged dramatically among various studies conducted over the past three decades (Figure 4.4). Electrocution research from the 1970s focused on causes of eagle mortality, which may account for high proportions of golden eagles documented in these studies. For example, golden eagles comprised between 89% and 93% of electrocutions documented by Olendorff (1972a), Smith and Murphy (1972), and Boeker and Nickerson (1975). Recent electrocution studies have documented much smaller proportions of golden eagles. Golden eagles comprised 17% of electrocutions in Utah and Wyoming (n=547) and 5% of electrocutions in Oregon

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FIGURE 4.4: Golden eagle perched on pole top.

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and California (*n*=103) discovered during systematic line surveys investigated electrocutions of all avian species (Liguori and Burruss 2003; PacifiCorp, unpubl. data). Data gathered from utilities in the western United States from 1986 to 1996 documented 748 eagles out of 1,428 electrocution records (Harness and Wilson 2001). Of these eagles, 36% were golden eagles, 16% were bald eagles (*Haliaeetus leucocephalus*), and 48% were unidentified eagles.

Bald eagle electrocutions are less common than golden eagle electrocutions. In Idaho bald eagles comprised 2% (*n*=91) and 5% (*n*=133) of electrocutions (Ansell and Smith 1980; Peacock 1980). In Colorado, 5% of electrocutions (*n*=300) were bald eagles (Boeker 1972). Likewise, bald eagles comprised 5% of all avian electrocutions (*n*=103) documented in Oregon and California in 2004 and 2005 (PacifiCorp, unpubl. data). In Utah and Wyoming, <1% of electrocutions (*n*=547) were bald eagles (Liguori and Burruss 2003). Of bald eagles admitted to wildlife rehabilitation centers in Florida from 1988 to 1994, 6% (*n*=274) were electrocuted (Forrester and Spaulding 2003).

Although electrocution has been documented as a cause of mortality for golden eagles for several decades, the frequency of eagle electrocutions may be declining, likely due to utilities' efforts to prevent electrocutions. From 1980 to 1984, 80% of golden eagles found along power lines in the western United States with known causes of death (*n*=375) died from electrocution (Phillips 1986). From the early 1960s to the mid-1990s, electrocution accounted for 25% of golden eagle deaths in North America (Boeker and Scott 1972). More recently, electrocution was documented as the cause of death in 16% of golden eagles radio-tagged and recovered (*n*=61) from 1994 to 1997 in California (Predatory Bird Research Group 1999). Despite increased detection efforts, the number of eagle electrocutions documented by PacifiCorp (unpubl. data) in western states has declined by 22% from the early 1990s to the early 2000s. Of APLIC-member utilities surveyed in 2005 (*n*=13), only 31% cited eagles as species at issue in their area (APLIC 2005).

Owls

The great horned owl (*Bubo virginianus*) is the most commonly electrocuted owl in North America (Figure 4.5). In the western United States, 95% of electrocuted owl species identified (*n*=91) from 1986 to 1996 were great horned owls (Harness and Wilson 2001). Likewise, great horned owls accounted for 90% of owl electrocutions (*n*=20) in Utah and Wyoming in 2001 and 2002 (Liguori and Burruss 2003). Although great horned owls comprise the majority of owl electrocutions, mortalities of this species are often low in comparison to many diurnal species. Low numbers of great horned owls in electrocution records were reported by Stewart (1969), Houston (1978), Benson (1981), and Harmata (1991). Great horned owls accounted for 4% of mortalities (*n*=113) in

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Idaho between 1972 and 1979 (Ansell and Smith 1980). Some studies have documented higher percentages of great horned owls in electrocution records. For example, of the species identified, great horned owls accounted for 15% of avian electrocutions (n=555) in the western United States from 1986 to 1996 (Harness and Wilson 2001), 20% of electrocutions (n=61) in Montana from 1980 to 1998 (O'Neil 1998), and 33% of electrocutions (n=210) in Nebraska from 1988 to 2003 (USFWS/Nebraska unpubl. data). Of APLIC-member utilities surveyed (n=13), 69% noted electrocution of owls, with 54% specifically listing great horned owls as one of the species most frequently electrocuted in their areas (APLIC 2005). Electrocution was the cause of death in <2% of great horned owl mortalities (n=207) in Saskatchewan (Gilliard 1977). Likewise, 2% of great horned owls admitted to wildlife rehabilitation centers in Florida from 1988 to 1995 (n=174) were electrocuted (Forrester and Spaulding 2003). Electrocutions accounted for 7% of great horned owl mortalities evaluated in Colorado from 1990 to 1994 (n=85) (Wendell et al. 2002) and by the National Wildlife Health Center from 1975 to 1993 (n=132) (Franson and Little 1996).

In North America, the barn owl *(Tyto alba)* is the second most frequently electrocuted owl. Barn owls accounted for 10% of owl electrocutions (n=20) in Utah and Wyoming from 2001 to 2002 (Liguori and Burruss 2003). Barn owl electrocutions have also been documented by Williams and Colson (1989), Harness and Wilson (2001), and USFWS/Nebraska (unpubl. data). In an assessment of barn owls in the northeastern United States, electrocution was noted as a cause of mortality, yet was not considered a population limiting factor (Blodget 1989). In Hawaii, 1% of barn owls evaluated for cause of death from 1992 to 1994 (n=81) was killed by electrocution (Work and Hale 1996). Of barn owls admitted to wildlife rehabilitation centers in Florida from 1988 to 1995, 5% (n=63) were electrocuted (Forrester and Spaulding 2003).

Barn owl electrocutions are not limited to North America. Of marked and recovered barn owls (n=[illegible]) in England, 5.8% died of electrocution (Meek et al. 2003). In a study of barn owl carcasses (n=627) in Britain from 1963 to 1989, electrocution was documented as the cause of death in <1% of birds (Newton et al. 1991). Barn owls comprised <5% of raptor electrocutions in Germany (n=567) and between 5% and 10% of mortalities in France (n=686) (Bayle 1999). In Spain, barn owls comprised 3% of electrocutions (n=233) documented by Ferrer et al. (1991) and <5% of raptor electrocutions (n=1,282) documented by Bayle (1999). In South Africa, barn owls accounted for 6% of electrocutions (n=147) documented from 1996 to 1998 (Kruger 2001a).

FIGURE 4.5: Great horned owl nest on transformer bank.

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Electrocution records of other North American owls are rare. Much like accipiters, many owl species inhabit forested areas and infrequently perch on power poles. No records were found for spotted owl *(Strix occidentalis)*. Barred owl *(S. varia)* electrocutions have been documented on transformer poles in Washington (M. Walters, pers. comm.). In Florida, 1.2% of barred owls admitted to wildlife rehabilitation centers from 1988 to 1995 (*n*=330) were electrocuted (Forrester and Spalding 2003). Bell and Donovan (1990) cite electrocution as a cause of mortality for a great gray owl *(Strix nebulosa)*. Electrocutions of this species are probably uncommon, as <1% of electrocution records (*n*=301) reported for four western states were great gray owls (Harness 1996). Records of other forest owls are also rare, although electrocution has been documented in the eastern screech-owl *(Otus asio)* (APLIC 1996, 2005), western screech-owl *(O. kennicottii)* (Harness 1996; Harness and Wilson 2001; APLIC 2005), and long-eared owl *(Asio otus)* (APLIC 1996). Harness and Wilson (2001) documented western screech-owls among avian species electrocuted (*n*=555) in the western United States from 1986 to 1996. Of eastern screech-owls admitted to wildlife rehabilitation centers in Florida from 1988 to 1995 (*n*=1,320), <1% were electrocuted (Forrester and Spalding 2003). In Germany (*n*=567) and France (*n*=686), <5% of raptor electrocutions were long-eared owls (Bayle 1999). Electrocution records for snowy owls *(Nyctea scandiaca)* are also uncommon (Parmalee 1972; Gillard 1977; Williams and Colson 1989; Parmalee 1992). Smith and Ellis (1989) list electrocution as a cause of death for snowy owls, yet do not quantify electrocution rates for this species. Snowy owls are found primarily in arctic regions lacking utility structures, yet birds that winter in less remote areas of the northern United States and southern Canada may encounter power lines. Electrocution was the cause of death in 5.6% of snowy owls (*n*=71) wintering in Alberta, Canada (Kerlinger and Lein 1988).

Like the snowy owl, the burrowing owl *(Athene cunicularia)* and short-eared owl *(Asio flammeus)* nest and perch on the ground and, consequently, are unlikely to be electrocuted. There are no known electrocution records for the burrowing owl. Electrocution records of short-eared owls are uncommon (Williams and Colson 1989; APLIC 1996; Harness 1997; Harness and Wilson 2001; Carrete et al. 2005). In France, 5% of raptor electrocutions (*n*=686) were short-eared owls (Bayle 1999).

VULTURES/CONDOR

Despite their large size, electrocution records for North American vultures and California condors *(Gymnogyps californianus)* are not as common as buteo and eagle electrocutions. As of 2005, 6% of California condors (*n*=144) that have been released into the wild since 1991 were killed by electrocution (Energy and Environmental Economics, Inc. 2005). Power line collisions have been a greater threat to California condors than electrocutions. Prior to the release of hacked birds, biologists undertook power pole aversion training using unenergized natural snags and simulated power poles (Snyder and Schmitt 2002). If they perch on a simulated power pole, they receive a mild shock.

Electrocutions of vultures are also uncommon, with turkey vultures *(Cathartes aura)* accounting for only 2% of electrocutions (*n*=210) in Nebraska from 1988 to 2003 (USFWS/Nebraska, unpubl. data), 2% of electrocutions (*n*=113) in Arizona from 2003 to 2004 (Dwyer 2004), and 2% of electrocutions (*n*=51) in northern California from 2001 to 2004 (PacifiCorp, unpubl. data). In the western United States, vultures accounted for 1% of electrocutions (*n*=1,428) from 1986 to 1996 (Harness and Wilson

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2001). Hallinan (1922) described turkey vulture electrocutions on three-phase, 13-kV lines with metal crossarms in Florida. In southern Florida, 14 confirmed electrocutions of both turkey and black *(Coragyps atratus)* vultures were documented over a six-year period (J. Lindsay, pers. comm.). Electrocutions of turkey vultures have also been reported in Chihuahua, Mexico (Cartron et al. 2005). Turkey vulture/power line interactions, including electrocutions, were noted by Williams and Colson (1989). Both black and turkey vulture electrocutions were documented in Texas (Harness 1997).

Electrocutions of Old World vultures are much more common. In South Africa, 42% of avian electrocution records from April 1996 to November 2003 (n=1,038) were vultures (C.S. van Rooyen, unpubl. data). The large wingspans (up to 2.7 m [8.9 ft]) of these species, coupled with their behavior of perching together on a pole, accounts for this elevated electrocution risk (C.S. van Rooyen, pers. comm.).

WATERBIRDS

Electrocutions of waterbirds, such as storks, egrets, herons, ibises, pelicans, and gulls, may occur in areas with bird-friendly poles that do not provide sufficient spacing to accommodate their relatively large wingspans and/or heights (see Figures 4.12, 4.13 and Table 4.1). Although avian-safe construction and retrofitting can protect most waterbird species, increased vertical separation may be needed to accommodate their taller heights. Like other birds, waterbirds may be electrocuted as they fly into lines mid-span and touch two conductors (Lano 1927; Pomeroy 1978; PacifiCorp, unpubl. data).

Storks have large wingspans (approx. 1.5 m [5 ft]) and measure approximately 102 cm (40 in) from head to foot. The wood stork *(Mycteria americana)* occurs in the southeastern United States and is currently (2006) listed as endangered under the Endangered Species Act. Wood stork electrocutions may result from power line collisions or from contacts on power poles (Forrester and Spaulding 2003; J. Newman, pers. comm.). Electrocutions of other storks have been documented outside of North America (Pomeroy 1978; Haas 1980; Bevanger 1998; Janss 2000). In Spain, the white stork *(Ciconia ciconia)* was the second most commonly electrocuted species, accounting for 13.3% of mortalities (*n*=279) (Janss and Ferrer 1999). White storks also accounted for 6% of avian electrocutions (*n*=120) in southeastern France (Bayle 1999).

The great blue heron *(Ardea herodias)*, which is commonly found throughout much of sub-arctic North America, has been documented in electrocution records from numerous states (Lano 1927; O'Neil 1988; Harness 1997; Forrester and Spaulding 2003; PacifiCorp, unpubl. data). Great blue herons accounted for 3% of electrocutions (*n*=61) in Montana from 1980 to 1985 (O'Neil 1988). Roseate spoonbill *(Ajaia ajaja)* electrocutions, likely associated with power line collisions, have been identified (Forrester and Spaulding 2003; J. Roberts, pers. comm.). Electrocutions of egrets and herons have been documented outside of North America (Pomeroy 1978). Ciconiiformes, including white stork and cattle egret *(Bubulcus ibis)* accounted for nearly 10% of avian electrocutions (*n*=600) in southwestern Spain from 1990 to 1994 (Janss and Ferrer 2001).

Line investigations and avian surveys near Port Arthur, Texas, revealed that a variety of wading and shoreline birds were killed by electrocution and/or line strikes (J. Roberts, pers. comm.). Roseate spoonbills were impacted more severely than other waterbirds, with over 40 individuals killed in two years. Other birds killed or injured by lines in this area include cattle egrets, snowy egrets *(Egretta thula)*, and neotropic cormorants *(Phalacrocorax brasilianus)*. Preliminary results from an

ongoing study suggest that many of the apparent collision deaths or injuries were juvenile birds with poor flight ability. However, carcass examination has indicated that some of the birds were electrocuted.

Gull electrocutions are uncommon but have been documented (Bevanger 1998). Harness (1997) reported electrocutions of 4 Franklin's gulls *(Larus pipixcan)* in a survey of electrocutions in the western United States from 1986 to 1996. In Alaska, gulls represented 3.4% of mortality records (n=264) from 2000 to 2004 (USFWS Alaska unpublished data). PacifiCorp (unpublished data) has documented gull electrocutions on poles with transformers in the western United States. Dickinson (1957) noted electrocutions of gulls at a landfill in North Carolina. In southeast France, 3% of avian electrocutions (*n*=100) were gulls and terns (Bayle 1999). In addition to both electrocutions and collisions in this same region, 16% were gulls and terns, 43% were herons, and 4% were greater flamingos *(Phoenicopterus ruber)*.

Electrocutions have been reported for both sandhill cranes *(Grus canadensis)* (Harness 1997, Forrester and Spaulding 2003) and whooping cranes *(G. americana)* (Forrester and Spaulding 2003), although these are likely to have occurred as a result of mid-span collisions. Of 15 radio-tagged whooping cranes that died or disappeared between 1993 and 1999, 4.3% were electrocuted as a result of power line collisions (Forrester and Spaulding 2003). Although the North American cranes are not likely to perch on utility structures, grey crowned cranes *(Balearica regulorum)* in South Africa do perch on poles and have been electrocuted (C.S. van Rooyen, pers. comm.).

Electrocutions of brown pelicans *(Pelecanus occidentalis)* have been documented in the United States (Harness 1997; Forrester and Spaulding 2003; APLIC 2005; J. Roberts, pers. comm.). Along the Gulf Coast where large concentrations of brown pelicans occur, numerous electrocutions have been documented (J. Roberts, pers. comm.). These electrocutions occurred when young birds congregated on power lines near fish camps and caused the line to sag, allowing the birds to contact the neutral wire. The neutral wire was removed and there have not been any electrocutions since. In Georgia, an American coot *(Fulica americana)* was found inside a substation, which was suspected to have been electrocuted as a result of contact with equipment (B. Estes, pers. comm.).

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CORVIDS

Not long ago, crows, ravens, and magpies were considered pests for which some states offered bounties. The Migratory Bird Treaty Act (MBTA) of 1918 did not offer protection to corvids and birds of prey until amended in 1972. In recent years, there has been an increasing awareness that corvids are protected under the MBTA, and that they can have considerable impacts on power reliability, particularly in agricultural or suburban areas where their populations are increasing. Corvid electrocutions have received less attention than raptor electrocutions, therefore, less is known about the distribution rates. Because of their large size and frequent use of power poles, ravens are likely electrocuted more often than currently documented. Although corvid mortality is unlikely to have population impacts, their electrocutions and nests can affect power reliability (Figure 4.6).

Corvid electrocutions were reported in 1921, when electrocutions of crows were documented in Florida (Hallinan 1922). Dickinson (1957) noted that crows nested on poles in North Dakota, causing faults on the line, particularly during wet weather.[15] In Montana, common ravens *(Corvus corax)*

[15] Carvings of kingbirds were mounted on the power line to deter the crows from nesting. The discouragers were considered effective, as the crows stopped building nests on the poles.

accounted for 2% of electrocution records (*n*=61) (O'Neil 1988).

Recent studies show an increased number of corvids in electrocution records, possibly due to enhanced reporting, increasing numbers of utility structures and/or increasing populations of some corvid species. Bridges and Lopez (1995), Harness (1997), and Boarman and Heinrich (1999) cite electrocution as a cause of death for the common raven. Common ravens were the most frequently electrocuted species in Utah and Wyoming, occurring in greater numbers than eagles and hawks and accounting for 32% of mortalities (*n*=547) (Liguori and Burruss 2003). American (black-billed) magpies *(Pica hudsonia)* also accounted for 32% of electrocutions documented in this study. Likewise, 25% of mortalities in northern California and southern Oregon from 2004 to 2005 (*n*=103) were magpies (PacifiCorp, unpubl. data). In a survey of 3,120 poles in Colorado, corvids accounted for 7% of mortality (Harness 2003). Of 156 electrocutions in Arizona, 4% were common ravens (Dwyer 2004). Ravens accounted for approximately 40% of electrocution records for one Arizona utility (P. Jelen, pers. comm.). In Chihuahua, Mexico, the Chihuahuan raven was the most frequently electrocuted species, accounting for 39% of mortalities (*n*=178) (Cartron et al. 2005). In Arkansas and Louisiana, reports of American crow *(C. brachyrhynchos)* electrocutions have been rare, although dead crows have been observed in substations on four occasions (J. Roberts, pers. comm.). The deceased crows were found in groups of two to five and the circumstances of the electrocutions have not been determined. Although uncommon, electrocutions of jays have also been documented (PacifiCorp, unpubl. data). Of APLIC-member utilities surveyed that report mortalities of all protected species (*n*=10), 50% listed corvids as birds of issue in their area, and 30% cited crows and ravens as the birds most frequently electrocuted in their area (APLIC 2005).

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FIGURE 4.6: Common raven nest on wishbone configuration.

Corvid electrocutions are not limited to North America (Bevanger 1998). In Spain, common ravens comprised 10% to 25% of electrocutions (*n*=279, Janss and Ferrer 1999; *n*=447, Janss 2000). Common raven and jackdaw *(C. monedula)* together accounted for approximately one-quarter (16% and 10.2%, respectively) of avian mortalities (*n*=60) found in southwestern Spain from 1990 to 1994 (Janss and Ferrer 2001). In southeast France, corvids accounted for 45% of avian electrocutions (*n*=100) (Bayle 1999). Corvid electrocutions are considered fairly common in South Africa (C.S. van Rooyen, pers. comm.).

SONGBIRDS AND OTHER SMALL BIRDS

Although often overlooked, electrocutions of passerines (songbirds) have been documented throughout the 1900s. Electrocution of purple martins *(Progne subis)* flocking on power lines was noted during the early twentieth century (Anderson 1933). Loggerhead shrikes *(Lanius ludovicianus)* were electrocuted in Florida when they attempted to impale prey on tie

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wires (Hallinan 1922). An electrocuted Baltimore oriole (*Icterus galbula*) was reported in Ohio during the 1950s (Dexter 1953). In India, rose-ringed parakeets (*Psittacula krameri*) were electrocuted when they bridged two closely spaced conductors (Dilger 1954). Their habit of climbing poles by clinging to different wires with their feet and bills made them more vulnerable to electrocution than are other small birds. Interestingly, Dilger also noted that large fruit bats, *Pteropus*, were killed on these poles as well.

Reports of songbird electrocutions are becoming more common as utilities, agencies, and the public become increasingly aware of the interactions of small birds with power lines. Records of such electrocutions, often associated with power outages, involve species such as starlings, woodpeckers, jays (not to be confused with Corvids), robins, pigeons, doves, kingbirds, thrushes, shrikes, sparrows, swallows, orioles, and blackbirds (Bevanger 1998; Michigan Dept. Natural Resources 2004; APLIC 2006; PacifiCorp unpubl. data) (Figure 4.7). Although infrequent, some outages result from domestic species or pets not protected by the MBTA (PacifiCorp, unpubl. data).

In some circumstances, songbirds can cause outages when large flocks take off at once, causing lines to gallop or slap together. In Mexico, roosts of purple martins can be so large that they break electrical wires (Brown 1997). Perched flocks of small birds may span from phase to phase or ground, causing an electrical current to pass through multiple individuals. This can result in outages and electrocutions. Individual small birds may not be at risk of conductor-to-conductor contact, yet may be vulnerable to electrocution on transformers or other equipment where separations between energized and grounded hardware are considerably less. On poles where protective coverings have been installed on transformer bushings, arresters, or insulators, insectivorous birds may attempt to glean insects from inside the covers.

MONK PARAKEET

Monk parakeets (*Myiopsitta monachus*) were brought to the United States from South America beginning in the late 1960s to be sold as pets. Escaped birds have since established populations throughout much of the United States and their numbers continue to grow (Pruett-Jones et al. 2005). Monk parakeets build nests in urban and suburban areas in trees and on artificial structures (Figure 4.8; see Chapter 6). Fires and outages can occur when monk parakeet

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FIGURE 4.7: Western kingbird perched on power line.

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FIGURE 4.8: Monk parakeets.

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nesting material comes in contact with energized parts, or from the nesting activity of the birds themselves. Monk parakeets continually maintain their nests and, consequently, individuals have been electrocuted when attempting to weave nesting material (i.e. twigs) into the nest (J. Lindsay, pers. comm.). In addition to posing outage and fire risks, monk parakeet nests on utility structures attract predators and trespassing pet-trade trappers, potentially resulting in electrocutions of both birds and humans (Newman et al. 2004).

FACTORS INFLUENCING ELECTROCUTION RISK

AVIAN USE OF POLES

Raptors, waterbirds and small birds use power poles for hunting, resting, roosting and nesting—particularly in habitats where trees, cliffs or other natural substrates are scarce (Figure 4.9). For waterbirds, power poles and lines can provide sites to perch while drying their feathers. Eagles and other raptors tend to use "preferred poles" that facilitate hunting success. Still-hunting coursers emerge provided suitable habitat for prey is within view. Preferred poles typically provide elevation above the surrounding terrain, a wide field of view, and easy take-off (Boeker 1972; Boeker and Hickey 1975; Nelson and Nelson 1976, 1977; Benson 1981). Where the design of a preferred pole is not avian safe, multiple electrocutions can occur. Researchers have found up to a dozen eagle carcasses or skeletons under a single pole (Dickinson 1957; Benton and Dickinson 1966; Edwards 1969; Olendorff 1972; Nelson and Nelson 1976, 1977; Mansfield 2004).

Benson (1981) confirmed that the height of a perch above the surrounding terrain was important to the frequency of eagle electrocutions. Since pole height generally varies only 1.2 to 3 m (4 to 10 ft), there was no significant difference in the heights of poles with or without electrocuted eagles. However, poles that provided the greatest height above the surrounding terrain, e.g., those on bluffs and knolls, had a higher probability of causing electrocutions.

Habitat diversity plays an important part in pole preference. In one study (Pearson 1979), raptors used poles in heterogeneous environments more often than those in homogeneous environments. In fact, increased habitat diversity is only an indirect cause of increased use. A more direct cause is the increase in prey types and density of prey typical of greater habitat diversity. Eagles and other raptors spend more time hunting in areas that offer a greater chance of a successful capture. It is reasonable to expect that one pole will receive no more use than the next in uniform habitats, other factors notwithstanding (Ansell and Smith 1980). The "preferred pole" concept, therefore, may not apply when addressing an electrocution problem in homogeneous habitats or "preferred areas."

Choice of prey can also influence electrocution risk. Benson (1981) found highly significant differences both in eagle use and

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FIGURE 4.9: In open habitats with few natural alternatives, power poles can provide perching, nesting, hunting, or roosting sites for raptors and other birds.

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eagle mortalities along electric distribution lines in agricultural versus non-agricultural areas in six western states. More use and mortality occurred in native shrublands, primarily because of variations in rabbit distribution and availability. In particular, more golden eagles were electrocuted where cottontails (*Sylvilagus* spp.) occurred than where only jackrabbits (*Lepus* spp.) occurred. In jackrabbit habitat, about 14% of poles had raptor carcasses under them, compared to nearly 37% in cottontail habitat. Where both cottontails and jackrabbits were present, about 2% of poles had raptor carcasses under them. The most lethal 25% of lines studied were in sagebrush-dominated areas where both types of rabbits occurred in large numbers. No correlation was found in the study between rodent population densities and the incidence of raptor electrocutions.

Other studies have also documented a correlation between prey populations and raptor electrocution risk. The attraction of eagles to areas with high rabbit populations and increased electrocution risk was noted by Olendorff (1972a) near the Pawnee National Grassland in Colorado. Kochert (1980) concluded that the incidence of eagle electrocutions in the Snake River Birds of Prey Area in southwestern Idaho was a function of mid-winter eagle density that was in turn strongly related to the density of jackrabbits. The highest densities of jackrabbits in southwestern Idaho occur in native shrublands (Smith and Nydegger 1985); accordingly, more eagles were electrocuted in such habitats.

In the Butte Valley of northern California, irrigated agricultural fields support ground squirrels and other small mammals that, in turn, attract large numbers of raptors. In these habitats, particularly on dead-end poles with transformers lacking avian protection, raptors are at risk of electrocution. Prior to extensive retrofitting efforts in this region, numerous eagles, hawks, and owls had been electrocuted (PacifiCorp, unpubl. data).

Concentrations of wintering raptors, including ferruginous hawks and golden eagles, are attracted to the continent's largest prairie dog complex in Chihuahua, Mexico, where numerous birds had been electrocuted prior to retrofitting efforts (Manzano-Fischer 2004; Cartron et al. 2005).

In Alaska, an abundance of food sources from municipal waste facilities, canneries, and fish cleaning stations attract bald eagles that have been electrocuted on nearby power poles (Hunt 2004).

Research on the proximity of nesting bald eagles to human activity in Florida suggest that fledging eagles from "suburban" nest sites have a higher risk of mortality from human activities, including electrocution, than do their "rural" counterparts (Millsap et al. 2004).

Agricultural areas attract pigeons, blackbirds, and starlings. Large flocks of these birds perching on wires can weigh down conductors, causing lines to gallop when they flash. As with raptors, these smaller species are vulnerable to electrocution on transformer poles, and related outages can disrupt farming activities.

Size

Birds with large wingspans, such as eagles, may straddle the distance between conductors on horizontal crossarms, while tall birds, such as herons or storks, may simultaneously contact different conductors on poles with vertical construction. Golden eagles have large wingspans, ranging from 1.8 to 2.3 m (6 to 7.5 ft) (Figure 4.10, Table 4.1). The height of a golden eagle ranges from 46 to 66 cm (18 to 26 in) from head to foot. Bald eagles are similar in size to golden eagles, with wingspans ranging from 1.7 to 2.4 m (5.5 to 8 ft) and heights ranging from 46 to 71 cm (18 to 28 in). As with most other raptors, female eagles are larger than males.

Because dry feathers provide insulation, birds must typically contact electrical

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equipment with conductive fleshy parts for electrocution to occur. Fleshy parts include the feet, mouth, bill, and the wrists from which the primary feathers originate. For a large golden eagle with a 2.3-m (7.5-ft) wingspan, the distance from the fleshy tip of one wrist to the tip of the other can measure 107 cm (42 in). These distances are important when considering phase-to-phase or phase-to-ground separations of power lines and the susceptibility of eagles to electrocution (see Chapter 5).

The 150-cm (60-in) standard separation between energized and/or grounded parts is intended to allow sufficient clearance for an eagle's wrist-to-wrist span (APLIC 1996; see Chapter 5). Applying this standard will also protect birds with wingspans smaller than eagles, (see Table 4.1 and Figures 4.10, 4.11, 4.12). In areas where eagles do not occur, a standard of 102 cm (40 in) may provide adequate separation for raptors other than eagles. In areas with condors, a 150-cm (60-in) separation may not be adequate. The wingspans of California condors range from 2.5 to 3 m (8.2 to 9.8 ft)[16] and condors measure 120 to 130 cm (46 to 53 in) in height (Snyder and Schmitt 2002; Wheeler 2003). Utilities with condors should consider the large size of this endangered species when designing or retrofitting power lines.

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60 inches"...Where Does It Come From?

The 1981 edition of *Suggested Practices* recommended 150 cm (60 in) of separation to provide adequate space for a large eagle with a wrist-to-wrist distance of 140 cm (54 in). This measurement was calculated by subtracting the lengths of the outer primary feathers (estimated at 46 cm [18 in] each) from the total wingspan of a large, female golden eagle measuring 230 cm (90 in).

In the preparation of the 2006 edition of *Suggested Practices*, the dimensions of numerous bird species were obtained from the literature and from measurements of live birds. This research has raised some interesting questions and has identified the need for further investigation. Measurements of live birds have shown that subtracting primary feather length from total wingspan is not an accurate measure of wrist-to-wrist distance (APLIC, unpubl. data). Although sample sizes are small, the wrist-to-wrist measurements of golden eagles obtained from live birds were much shorter than the 140-cm (54-in) distance identified in previous editions of *Suggested Practices*. Even on birds with wingspans of 200 cm (80 in) or more, wrist-to-wrist measurements were less than 110 cm (43 in). Wrist-to-wrist measurements were much smaller on bald eagles; although bald eagles may have larger wingspans than golden eagles, their primary feathers are longer and account for a greater proportion of the wingspan.

APLIC continues to recommend 150 cm (60 in) horizontal separation for eagle protection in this edition of *Suggested Practices*. This edition also recommends 100 cm (40 in) vertical separation for eagles. However, utilities may choose to implement design standards using different separations based on the species or conditions at issue. To improve avian protection on power lines, APLIC encourages researchers to collect vertical and horizontal flesh-to-flesh separation measurements of large birds. This information will help utilities tailor their avian protection efforts. For example, in areas without eagles or in urban locations, a utility could design power lines to protect large birds such as red-tailed hawks and great horned owls; in areas with California condors, utilities could design structures to accommodate these large birds; and in coastal areas, utilities could consider the tall heights of wading birds when designing lines.

[16] Wrist-to-wrist measurements could not be documented for California condor.

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For tall species, vertical distance can play a role as important as horizontal distance. Because the height (head to foot) can reach up to 66 cm (26 in) for a golden eagle and 71 cm (28 in) for a bald eagle, vertical separation sufficient to accommodate perching eagles is recommended in areas with these species. Long-legged wading birds, such as herons, egrets, ibises, and storks, may also be electrocuted on poles where there is insufficient vertical separation between conductors or conductor and ground. In areas where such species are at risk, vertical separation of 120 cm (48 in) or more may be needed to accommodate the heights of some species.[17] The heights of selected species are provided in Table 4.1 and Figure 4.13.

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TABLE 4.1: Wrist-to-wrist, wingspan, and height measurements for selected birds.*

Species	Wrist-to-wrist cm (in) [sample size][1]	Wingspan cm (in)	Height cm (in) [sample size][§]
Turkey Vulture	58–61 (23–24) [*n*=2]	165–178 (65–70)	36–53 (14–21) [*n*=3]
Black Vulture		137–160 (54–63)	
California Condor		244–300 (98–118)	120–130 (46–53)
Osprey		150–180 (59–71)	
Bald Eagle	79–86 (31–34) [*n*=4]	168–244 (66–96)	46–71 (18–28) [*n*=5]
Harris' Hawk	43 (17) [*n*=1]	104–119 (41–47)	28–43 (11–17) [*n*=2]
Swainson's Hawk	41–58 (16–23) [*n*=2]	132–134 (52–54)	33–41 (13–16) [*n*=2]
Red-tailed Hawk	36–58 (14–23) [*n*=10]	107–142 (42–56)	34–56 (13.5–22) [*n*=9]
Ferruginous Hawk	56 (22) [*n*=1]	135–152 (53–60)	48 (19) [*n*=1]
Rough-legged Hawk		122–142 (48–56)	
Golden Eagle	79–102 (31–40) [*n*=10]	183–229 (72–90)	46–66 (18–26) [*n*=11]
American Kestrel	20–25 (8–10) [*n*=4]	51–61 (20–24)	15–20 (6–8) [*n*=4]
Merlin		53–69 (21–27)	
Peregrine Falcon	33–51 (13–20) [*n*=2]	94–117 (37–46)	28–38 (11–15) [*n*=3]
Prairie Falcon	41 (16) [*n*=1]	91–112 (36–44)	33 (13) [*n*=1]
Barn Owl	38–51 (15–20) [*n*=4]	104–117 (41–46)	25–38 (10–15) [*n*=4]
Great Horned Owl	43–64 (17–25) [*n*=8]	114–130 (45–51)	31–41 (12–16) [*n*=8]

Continued

[17] This distance is based on the height of a great blue heron, approximately 1.2 m (46 in).

TABLE 4.1: Wrist-to-wrist, wingspan, and height measurements for selected birds.* (cont.)

Species	Wrist-to-wrist cm (in) [sample size]†	Wingspan cm (in)	Height cm (in) [sample size]§
Roseate Spoonbill		127 (50)	81 (32)
Wood Stork		155 (61)	102 (40)
White Pelican		244–290 (96–114)	157 (62)
Brown Pelican		203 (80)	130 (51)
Egrets		91–130 (36–51)	51–100 (20–39)
Great Blue Heron		89 (7[illegible])	117 (46)
Other Herons		66–112 (26–44)	46–66 (18–26)
Ibis		91–97 (36–38)	58–64 (23–25)
Cormorants		132–160 (52–63)	
Common Raven		135 (53)	41 (16) [*n*=1]
Chihuahuan Raven		112 (44)	
American Crow		99 (39)	
Magpies		64 (25)	
Jays		48 (19)	
Woodpeckers		31–53 (12–21)	
Blackbirds		38–58 (15–23)	

* Sources: Bohlgard (1988, 1990); Bibley (2000); Wheeler (2003); *Birds of North America* species accounts; City of Lawrence (KS) Prairie Park Nature Center (unpubl. data); Hawk Watch International (unpubl. data); Kansas Department of Wildlife and Parks Milford Nature Center (unpubl. data); Operation WildLife, Inc. (unpubl. data); Oregon Zoo (unpubl. data); PacifiCorp (unpubl. data); Rocky Mountain Raptor Program (unpubl. data); Stone Nature Center (unpubl. data); and Utah Wildlife Rehabilitation (unpubl. data).

† Because wrist-to-wrist and head-to-foot measurements of most species are not typically available in the literature, measurements were obtained from wildlife rehabilitators and handlers as well as from deceased birds. Sample sizes are given for birds that were measured and blanks in this field indicate that these data are currently unavailable. Avian researchers are encouraged to record these measurements when collecting other morphometric data.

§ Height given is from the top of the head to the feet. See also footnote †, above.

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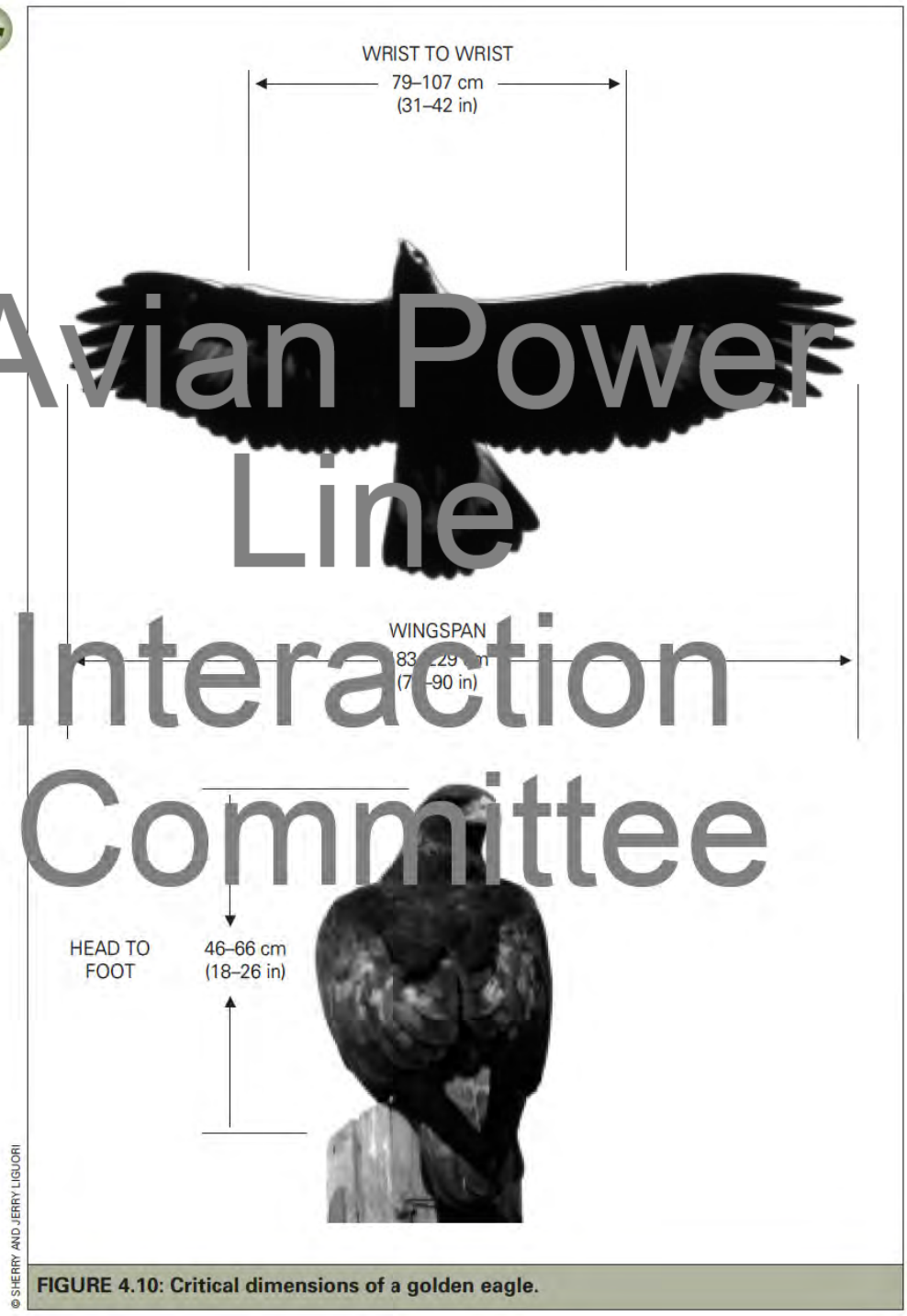

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FIGURE 4.10: Critical dimensions of a golden eagle.

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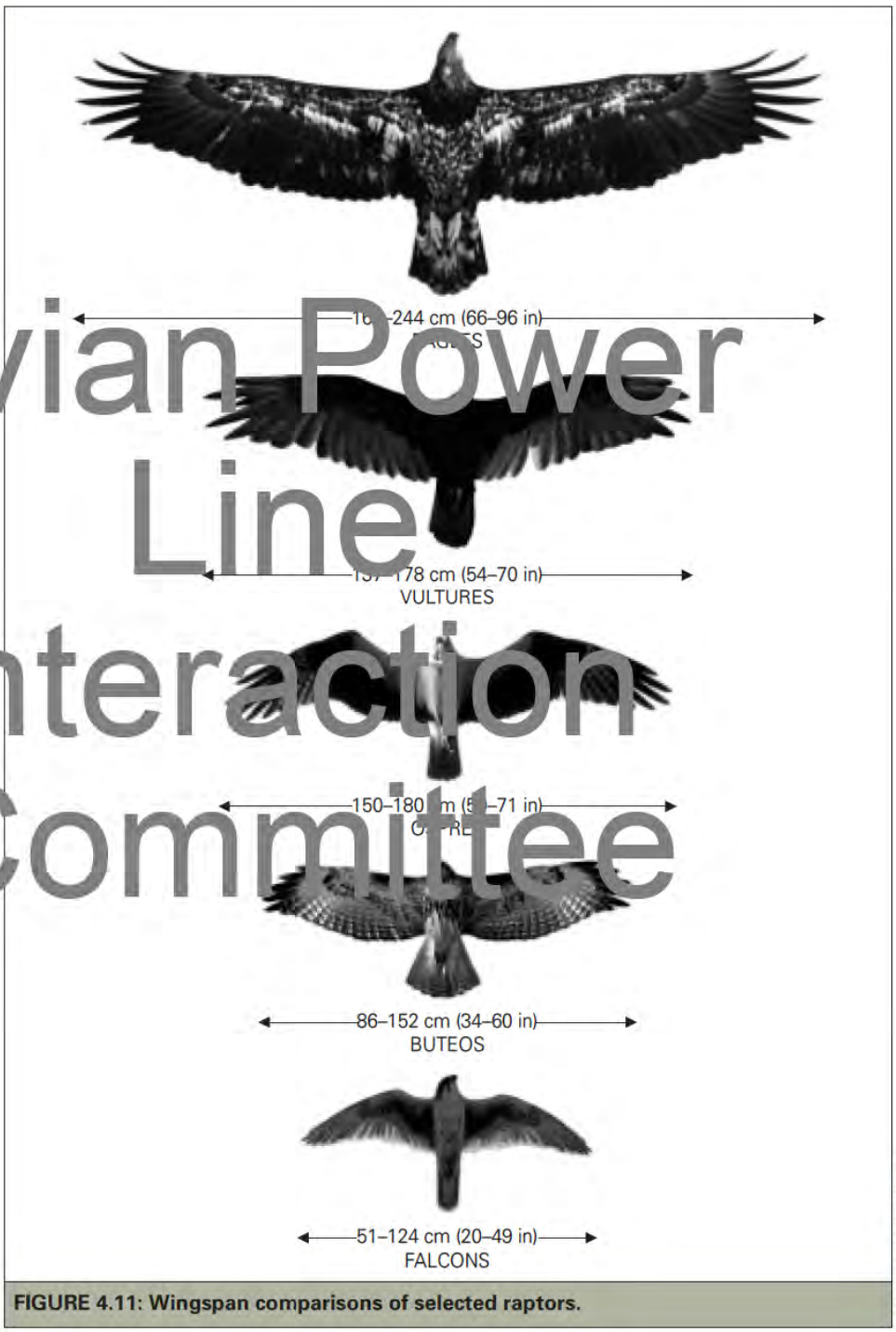

FIGURE 4.11: Wingspan comparisons of selected raptors.

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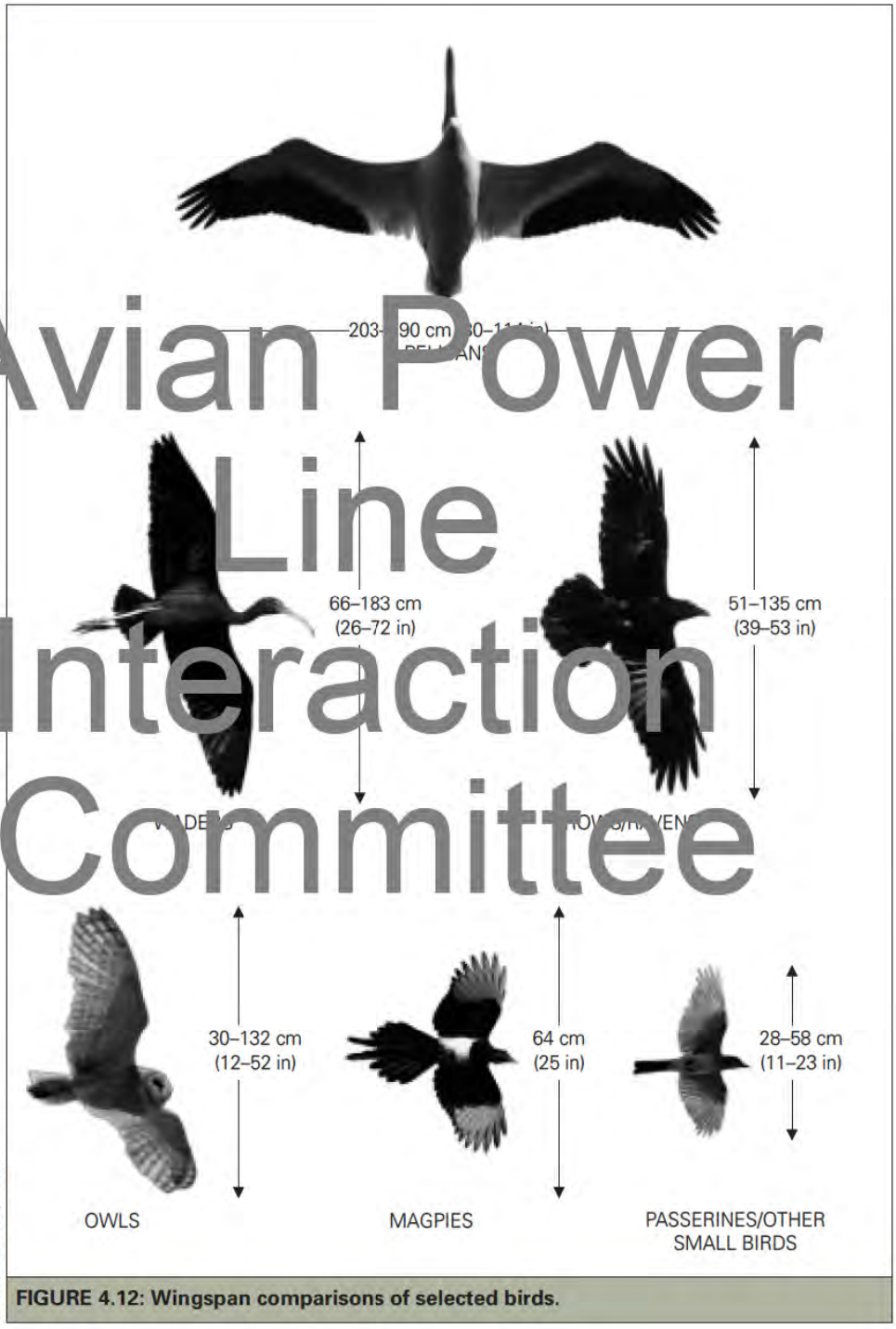

FIGURE 4.12: Wingspan comparisons of selected birds.

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FIGURE 4.13: Height comparisons of perched birds.[18]

[18] Height ranges shown are from various sources and may include both head-to-foot and head-to-tail measurements. See Table 4.1 for additional information on height measurements.

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TABLE 4.2: Percent of juvenile golden eagles in electrocution studies.

Study	Percent juvenile	Sample size
Benson (1981)	94.2%	52
Boeker and Nickerson (1975)	90.0%	419
Schomburg (2003)	87.9%	132
Harness and Wilson (2001)	66%	90
USFWS/Nebraska (unpubl. data)	63%	27

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AGE

Research on golden eagles suggests that juvenile birds may be more susceptible to electrocution than adults (Table 4.2). Birds that nest on power poles may be electrocuted, particularly if the combined wingspans and simultaneous flapping behavior of several young birds cause them to bridge energized phase conductors and/or bridge between conductor and grounded equipment. Post-fledging, juvenile birds may continue to experience increased risk compared to adults because they are less agile at landing on and taking off from poles. Regardless of an electrocuted bird's age, corrective actions to prevent electrocutions remain the same.

Susceptibility of juvenile golden eagles to electrocution involves several factors that one seems more important than experience. Inexperienced birds may be less adept at landing and taking off, which increases their risk. Inexperience may also affect how juvenile birds hunt. Juvenile birds may learn to fly and hunt from a perch, particularly in flat country, where updrafts are less common. Learning to fly involves frequent short flights from perch to perch. The first attempts to hunt involve frequent changes of perches following unsuccessful chases. One juvenile golden eagle was observed making over 20 unsuccessful hunting sorties after cottontails from a distribution pole (Benson 1981). Had the line been unsafe for eagles and weather conditions been poor, the likelihood of electrocution would have been high.

Hundreds of hours of actual observations and analyses of slow-motion, 16-mm movies made by Nelson in the early 1970s demonstrated that juvenile eagles are less adept at maneuvering than adults, especially when landing and taking off (Nelson 1979b, 1980b; Nelson and Nelson 1976, 1977). Trained golden eagles were filmed landing on un-energized, mockup power poles of various configurations in both calm and inclement weather. The eagles did not perch on (energized conductors) and seldom perched on pole-top porcelain insulators that tended to be too small, smooth, or slick for comfortable gripping. Instead, they used pole tops and crossarms that offered firmer footing. When an adult eagle approached a three-wire power pole crossarm, for instance, the bird typically swooped in under the outside wire, swung up between wires with wings folded, and stalled onto the perch. The landing, when made into a headwind, was skilled and graceful, with very little flapping.

Juvenile birds, by contrast, often tried to settle onto a crossarm from above, using outstretched wings to slow their descent. They sometimes approached diagonally, flew to the highest point on the insulator—and tried to land. The birds often slipped off the insulator or tried in mid-flight to change to the crossarm—maneuvers accomplished by much wing flapping that increased their electrocution risk. Sometimes, juvenile birds began corrective action at a distance from the poles, particularly when the approach was too swift or at an improper angle. If they approached parallel to the lines, they often settled down across two conductors or tried to fly up between the conductors, increasing their electrocution risk (Figure 4.14). During landings, juvenile birds contacted the wires of the dummy poles making skin-to-skin contact near the wrists. Occasionally, contact also occurred on downward wing beats during

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FIGURE 4.14 Juvenile golden eagle about to land on a distribution pole that is not avian-safe.

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take-offs. On energized lines, simultaneously touching differing phase wires or a phase and a ground with fleshy parts of the body or with wet feathers can result in electrocution.

Juvenile eagles may rely on poles as hunting perches more than adults. Benson (1981) attributed differences in electrocution risk of adult and juvenile birds to the fact that aerial hunting (as opposed to still-hunting from a perch) was the principal tactic used by adult golden eagles to capture jackrabbits. Catching jackrabbits with any consistency requires experience and tenacity in long, in-flight chases. Young birds find more success in pouncing on cottontails or other prey from stationary perches such as power poles. This increases their exposure to electrocution risk.

Florida has the largest breeding bald eagle population in the lower 48 states, with over 1,000 known nesting pairs (Nesbitt 2003). From 1963 to 1994, 16% of known bald eagle deaths in Florida (n=309) were due to electrocution. Contrary to previously mentioned data for golden eagles, these electrocutions were nearly evenly distributed between adult (55%) and juvenile (45%) birds. Likewise, 45% of known age bald eagle electrocutions in Nebraska (n=22) were juvenile birds (USFWS/Nebraska, unpubl. data).

Overall mortality rates (considering all causes of death) are greater for juvenile birds than for adults. Recoveries of banded golden eagles showed mortality in 50% of the population by an age of 31 months (Harmata 2002). Although age-related differences in electrocution risk are typically poorly understood for species other than eagles, it is likely that juvenile individuals of other species may be at greater risk than adults due to inexperience and overall higher mortality rates. For example, juveniles accounted for 61% of Harris' hawk electrocutions (n=75) in Tucson, Arizona (Dwyer 2004).

SEASONAL PATTERNS

Electrocution risk can vary with season. Many golden eagle mortalities along power lines (nearly 80% in the Benson 1981 study) occur during the winter. Of eagle electrocutions in the western United States with known mortality dates (n=96), 39% occurred from January to March; of eagle

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FIGURE 4.15: Numerous birds perched on a pole can increase electrocution risk. Pictured: common ravens during breeding season.

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carcasses discovered for which the date of mortality was unknown (n=116), 53% were found from January to April (Harness and Wilson 2001). Likewise, the majority (65%) of such mortalities reported during routine utility activities from 2001 to 2004 in the western United States by PacifiCorp (unpubl. data) occurred from December to April. The increased frequency of eagle electrocutions during the winter may be attributed to greater concentrations of these birds in proximity with power lines during the winter months. Likewise, eagles may be attracted to high seasonal prey concentrations that may, coincidentally, occur near non-avian-safe lines. In addition, eagles probably hunt from perches more during the winter than at other times of the year. In Florida, where bald eagles occur year-round, electrocutions occurred during every month of the year (Forrester and Spaulding 2003). However, most occurred from October through April, the period that encompasses the breeding season when eagle abundance is greatest in Florida and when dispersal and migration occur.

Electrocution rates of other species may also increase seasonally due to breeding behavior and the presence of young. Increased raptor electrocutions, particularly of Harris' hawks, corresponded with nesting activity in Tucson, Arizona (Dwyer 2004). Of known electrocution dates for hawks (*n*=119) in the western United States from 1986 to 1996, 57% occurred from July to September (Harness and Wilson 2001). In Chihuahua, Mexico, red-tailed hawk mortality peaked from September to November (Cartron et al. 2005). Similarly, electrocutions of hawks in the western United States from 2001 to 2004 were greatest from July to November, with 16% of annual mortalities occurring between July and August, 24% in September, 11% in October, and 7% in November (PacifiCorp, unpubl. data). These seasonal peaks likely correspond with increases in hawk populations due to dispersal of fledglings during the breeding season and influxes of birds during fall migration. This dataset also showed a slight increase in hawk electrocution mortality during March and April (each with 8% of annual mortality), probably correlated with spring staging.

As with hawks, mortalities of owls in the western United States were greatest in late summer, particularly August and September (Harness and Wilson 2001). Likewise, electrocutions of eagle owls (*Bubo bubo*) in the Italian Alps were greatest during the period of juvenile dispersal in September (Rubolini et al. 2001). In the western United States, owl electrocutions from 2001 to 2004 were greatest during summer and early fall, with June, July, August, and September accounting for 26%, 24%, 7%, and 12%, respectively, of annual mortality (PacifiCorp, unpubl. data).

Electrocutions of other species also exhibit seasonal patterns. Records of corvid electrocutions in the western United States from 2001 to 2004 were greatest from April to August, with highest numbers in June (16%), July (22%), and August (15%) (PacifiCorp, unpubl. data). These months correlated with the local breeding season of these species, particularly the times when nestlings and/or fledglings are present (Figure 4.15). Raven

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electrocutions also peaked in August and September in Chihuahua, Mexico (Cartron et al. 2005). Electrocutions of songbirds in the western United States were correlated with the summer months, as 69% of electrocutions occurred from June to August (PacifiCorp, unpubl. data). The APLIC-member utilities surveyed documented seasonal differences in electrocution rates and noted overall increases during nesting and fall migration (APLIC 2005). In addition, species-specific seasonalities were noted for eagles (winter) and passerines (spring).

BEHAVIOR

Nesting, courtship, and territorial behavior can make raptors and other birds susceptible to electrocution (Figure 4.1; also see Chapter 6). The gregarious social behavior of some birds, such as Harris' hawks or vultures, can also increase electrocution risk as multiple birds perch together on a pole.

Benson (1981) found that nearly 46% of red-tailed hawk electrocutions occurred during courtship and nesting. Most of these birds were adults. Benson also noted that nearly 30% of the hawks electrocuted during the late spring and early summer were fledglings. Dawson and Mannon (1994) reported that 37% of 112 electrocuted Harris' hawks in southern Arizona were birds that had recently fledged. Likewise, Dwyer (2004) found that 63% of electrocuted juvenile Harris' hawks (n=46) were killed within three weeks of fledging. Of raptor and raven electrocutions in Tucson, 79% were within 300 m (1,000 ft) of a nest (n=56) (Dwyer 2004). A young Swainson's hawk was found electrocuted in south-central Washington soon after it fledged (Fitzner 1978), and a fledgling great horned owl was found electrocuted near its nest in Saskatchewan (Gillard 1977). Groups of 2 to 3 common ravens have been electrocuted in Utah and Wyoming, likely due to multiple birds simultaneously spanning conductors (PacifiCorp, unpubl. data).

Several instances of electrocution of birds carrying prey or nest material have been reported. A dangling prey item or stick can help span the gap between phase conductors or between an energized conductor and a grounded conductor, electrocuting a bird returning to the nest (Switzer 1977; Fitzner 1978). A young great horned owl was found electrocuted with a freshly killed snowshoe hare (*Lepus americanus*) lying nearby (Gillard 1977). Similar incidents were noted by Brady (1969) and Hall (1970). In Utah, an electrocuted great horned owl was discovered with four nestling western kingbirds (*Tyrannus verticalis*) in its talons, likely retrieved from a kingbird nest behind the transformer that killed the owl (S. Liguori, pers. obs.). Golden eagles carrying large prey have been electrocuted on otherwise avian-safe poles in Wyoming (PacifiCorp, unpubl. data). Two adult red-tailed hawks were electrocuted at separate nests in Wyoming, possibly while carrying nesting material (Benson 1981). A pair of electrocuted red-tails was found below a pole in Utah, both birds with nesting material in their talons (S. Liguori, pers. obs.). Ospreys have been electrocuted when carrying seaweed (*New York Times* 1951) and barbed wire

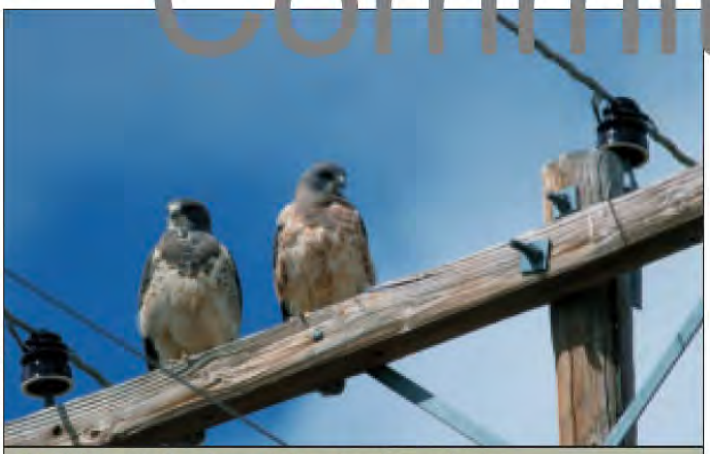

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FIGURE 4.16: Swainson's hawk pair perched on distribution pole.

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(Electric Meter 1953) to their nests. Nests and nestlings can also be destroyed if nesting material lies across conductors, resulting in a flashover and fire (Vanderburgh 1993).

During the nesting period, birds often engage in courtship and territorial defense. In such displays, raptors often lock talons, greatly increasing their effective wingspans. If these activities take place near a power line, the birds can be electrocuted. For example, in Montana, the electrocution of a subadult golden eagle was witnessed during an aggressive encounter with an adult eagle (Schomburg 2003). Benson (1981) documented a pair of electrocuted eagles below a pole, the talons of each bird imbedded in the breast of the other. In Oregon, two electrocuted red-tailed hawks were found below a pole with the foot of the adult imbedded in the chest of the juvenile (S. Liguori, pers. obs.). Aggression between species may also have similar results, e.g., in Wyoming the foot of a great horned owl was found grasping the body of a red-tailed hawk (S. Liguori, pers. obs.). Likewise, in Arizona, a Harris's hawk and red-tailed hawk were electrocuted together during an aggressive encounter (Dawson and Mannan 1994). In areas of Montana where large concentrations of eagles winter, aggressive interactions between birds have led to the electrocution of two birds at once (S. Milodragovich, pers. comm.). In the Northern Cape Province of South Africa, vultures were electrocuted on vertically configured poles when aggressive interactions caused birds to slip off the insulators and fall onto conductors (Kruger et al. 2003).

Raptors and other birds may use power poles to provide protection from the elements. During hot weather in open arid environments, birds seeking shade may perch on power crossarms or perch close to the pole (Figure 4.17). Birds may also use the lower portions of power poles during rain or snow. Although power poles do not appear to offer much protection from the elements, they can provide some cover, particularly in habitats lacking natural shelter.

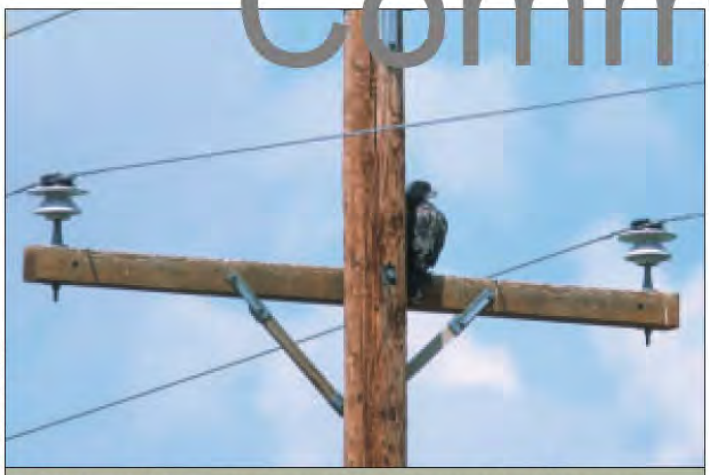

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FIGURE 4.17: Swainson's hawk using power pole for shade.

WEATHER AND THE INFLUENCE OF WET FEATHERS

Inclement weather (particularly rain, snow, and wind) increases the susceptibility of birds to electrocution. Wet feathers increase conductivity, and birds have greater difficulty landing on power poles in high winds. Because dry feathers provide insulation, most electrocutions are caused by simultaneous wing-to-skin, foot-to-skin, or bill-to-skin contact with two energized conductors or a conductor and a ground.

Nelson (1979b, 1980b) conducted experiments to determine the conductivity of a live eagle by attaching electrodes to the skin of the wings and to the toes. Although lethal voltages and currents were not determined, these experiments demonstrated that, at 280 volts (V) and a current of 6.3 milliamperes (mA), the eagle's respiration increased. At 400 to 500 V and a current range of 9 to 12 mA, the eagle convulsed. Wet feathers burned at 5,000 to 7,000 V, but there was no measurable current through a dry feather at 70,000 V. Skin-to-skin contacts were on the order of ten times more dangerous than contacts

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between a wet eagle and two conductors, and about 100 times more dangerous than contacts between conductors and dry feathers. A dry feather is almost as good an insulator as air, but a wet feather has demonstrably greater conductivity. Major conclusions from Nelson (1979b, 1980b) were as follows:

- For voltages of up to 70,000 V and with electrodes at least 17.8 cm (7 in) apart, there is no measurable current flow (no conduction) through a dry feather. There is little or no possibility of electrocution of dry eagles from a wingtip contacts with two electric conductors.
- Wet feathers conduct current more readily than dry ones, and become capable of conducting amperages dangerous to eagles starting at about 5,000 V.
- The hazard to wet birds is much greater than that to dry ones, and is increased even more so when wet birds lose some flight capability and control.

The amount of current conducted through wet feathers also depends on the concentration of salts and minerals in the water. Increased electrolyte content results in increased conductivity. Feather oils further decrease risk because it elicited wing-spreading behavior in the birds studied (Nelson 1979b), presumably to dry the feathers. Although this research was conducted on eagles, it has implications for other species. Birds that spend much of their time in or near water, such as herons, egrets, ibises, storks, pelicans, cormorants, and ospreys, may be at increased risk of electrocution. In addition, wing-spreading behavior commonly exhibited by cormorants or vultures may increase electrocution risk. A utility's Avian Protection Plan (APP) should include design standards appropriate for the species and/or area at issue. However, electrocutions will never be eliminated during wet conditions because feathers and wood can be conductive when wet, potentially causing electrocutions on normally benign poles.

Finally, the direction of the prevailing wind relative to the crossarm can also influence electrocution risk. Poles with crossarms perpendicular to the prevailing wind produced fewer eagle mortalities (Boeker 1972; Nelson and Nelson 1976, 1977). About half as many birds were found below poles with crossarms perpendicular to the wind, when compared to poles with crossarms diagonal or parallel to the wind (Benson 1981). This difference was probably related to the effect of wind on the ability of juvenile eagles to land on poles with exposed energized parts.

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IDENTIFYING EVIDENCE OF ELECTROCUTION

Because not all dead birds below power lines may have died from electrocution, it is important to accurately determine the cause of death so that appropriate action can be taken. In winter surveys of raptor mortality in Montana, Olson (2001) found 126 carcasses along roadsides, 88 of which were submitted for necropsy. Of these birds, only 9% were electrocuted, while the majority (84%) had been shot. The majority of birds found along roadsides that were directly below power poles were also shot, with only 15% electrocuted (Olson 2001).

Evidence of electrocution can include burn marks on the feathers, feet, talons, flesh, or bill. Such burns may be obvious and extensive, or inconspicuous and not visible to the naked eye. Electrocuted birds may also exhibit deformed or damaged talons that appear broken, curled, or incinerated (Olson 2001). In some cases, the feet, toes, or talons are broken off during electrocution (PacifiCorp, unpubl. data). Although most victims of electrocution die, some individuals survive. Of 89 live Harris' hawks that were captured in Arizona, 9% exhibited injuries evident of

electrical shock (Dwyer 2004). Likewise, 20% of Harris' hawk electrocutions documented in Arizona (n=112) were injuries rather than mortalities (Dawson and Mannan 1994).

Evidence of shooting differs from that of electrocution. Birds that have been shot exhibit sheared flight feathers rather than singed feathers (EDM International, Inc. 2004). Other signs of shooting include shattered bones, contusions, hematomas, sprayed or spattered blood, and bullet wounds (Olson 2001).

SCAVENGING RATES OF CARCASSES

Because there have been few large-scale studies that quantify avian electrocution rates, existing data have been used in some cases to extrapolate electrocution rates over large areas. Extrapolation is strongly discouraged, as electrocution risk is not uniformly distributed among all poles in all geographic areas. Carcass scavenging rates obtained from studies of non-raptors have also been used to extrapolate removal rates of electrocuted raptor carcasses. Again, caution should be used as carcass removal rates vary greatly among studies and can be influenced by scavenger populations, habitat, season, observer bias, and carcass species. In particular, raptor carcasses are less likely to be removed by scavengers than carcasses of other species. In a carcass removal study in Colorado and Wyoming, small carcasses were removed within 24 to 48 hours (Deming et al. 2000). In contrast, large birds (i.e. ferruginous hawks, golden eagles, and rough-legged hawks) remained for over two months. Orloff and Flannery (1993) found no scavenging of raptor carcasses (n=14) during a single trial of seven days. Also, Howell and Noone (1992) found that carcasses of larger raptors remained longer than those of smaller raptors. Janss and Ferrer (2001) assumed the scavenging rate of eagles to be considerably lower than that of rabbits. Ellis et al. (1969) noted that, of raptor carcasses found along power lines in Utah (shooting was the primary cause of death), most carcasses had remained intact and were seldom scattered by scavengers. Olson (2001) also found little evidence of scavenging in raptor carcasses below power lines in Montana. Along a power line in Wyoming in 1992, carcasses of electrocuted eagles were removed by researchers, yet there was not a thorough effort to remove all bones and feathers (Harness and Garrett 1999). During a subsequent survey of the line in 1997, scattered, old, bleached bones of 24 carcasses were discovered and assumed to be the remains of the eagles killed several years earlier (Harness and Garrett 1999).[19] Likewise, nearly half of the carcasses found in Utah and Wyoming were old bleached bones or desiccated carcasses, many of which appeared to have been undisturbed (PacifiCorp, unpubl. data). In addition, specific cases of individual carcasses that were not retrieved by researchers after original discovery were found again at the same poles several years later. In the urban area of Tucson, Arizona, most carcasses that were removed were taken by people, rather than scavengers (Dwyer 2004). In a study of carcass removal rates in Chihuahua, Mexico, 25% of raven carcasses (n=72) were removed within one month of their discovery (Cartron et al. 2005). In contrast, 95% of non-raven (raptor) carcasses (n=21) were present after one month, but only 63% remained after two months.

[19] A guide for identifying the remains of various raptor species (EDM International, Inc. 2004) can be obtained at www.energy.ca.gov/pier/final_project_reports/CEC-500-2005-001.html.

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CHAPTER 5

Suggested Practices: Power Line Design and Avian Safety

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IN THIS CHAPTER

Introduction to Electrical Systems
Avian Electrocutions and Power Line Design
Suggested Practices
Summary

This chapter addresses avian electrocution concerns from the engineering perspectives of design, construction, operations, and maintenance. It describes ways of designing new facilities and retrofitting existing facilities to be "avian-safe."

As communities grow, their demand for electricity increases. Additional power lines must be built to supply the additional power. The more miles of power lines there are, the greater the potential for birds to interact with electrical facilities and the inherent hazards. Biologists and planners must have a basic understanding of power systems, power line designs, and related terminology to identify and implement successful solutions to bird electrocutions. This chapter discusses North American power lines, and the designs and configurations that present avian electrocution risks. For further reference, a glossary of terms is provided in Appendix D.

This 2006 edition of *Suggested Practices* supersedes the recommendations incorporated in the 1996 edition and includes updates based on growing field experience and product performance testing. Despite efforts to present "state-of-the-art" recommendations, users of this manual should be aware that many wildlife protection products have not been tested or vetted from an engineering perspective.[20] An IEEE Working Group under project P1656 is writing a guide entitled *Guide for Testing the Electrical, Mechanical, and Durability Performance of Wildlife Protective Devices Installed on Overhead Power Distribution Systems Rated up to 38 kV*. The guide will provide technical guidance for testing wildlife guards and should be available in 2006. Utilities are encouraged to share or publish information regarding avian-safe power line construction and retrofitting experience that can be used to refine future editions of *Suggested Practices*.

[20] However, the recommendations provided in this manual have been field tested by utilities and some results have been published in scientific and engineering journals.

INTRODUCTION TO ELECTRICAL SYSTEMS

DISTINCTIONS BETWEEN TRANSMISSION AND DISTRIBUTION LINES

Power lines are rated and categorized, in part, by the voltage levels to which they are energized. Because the magnitudes of voltage used by the power industry are large, voltage is often specified with the unit of kilovolt (kV) where 1 kV is equal to 1,000 volts (v). Generally, from the point of origin to the end of an electric system, line voltage is used to designate four classes or types of power line (Table 5.1).

TABLE 5.1: Voltage ranges of different power line classes.

Designation	Voltage Range
Generation plant	12 V to 22 kV
Transmission	60 kV to 700+ kV
Distribution	2.4 kV to 60 kV
Utilization	120 V to 600 V

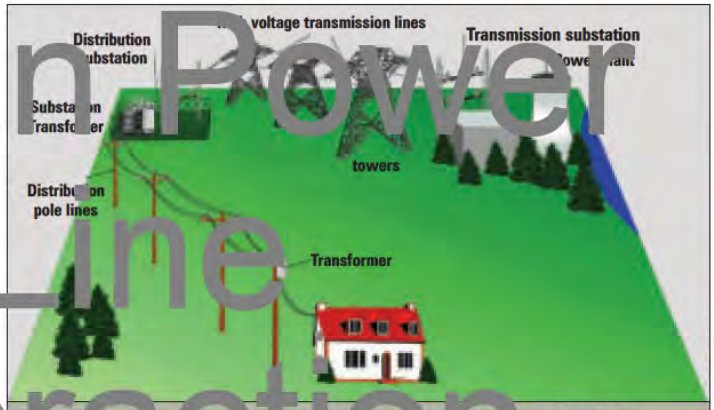

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FIGURE 5.1: Schematic of power system from generation to customer

In addition to the voltage level, power line classification is dependent on the purpose the line serves (as shown in Figure 5.1). This publication is concerned with electrocution hazards the electric distribution and transmission lines may pose to birds. In this manual, lines that are energized at voltages ≥60 kV are considered transmission lines, and lines energized at voltages <60 kV are considered distribution lines, however, this may vary with different utilities. Performance experience indicates that low voltage (secondary) lines—also called *utilization facilities* (≤600 v)—are not often involved in avian electrocutions.

DIRECT CURRENT AND ALTERNATING CURRENT SYSTEMS

Although there are some direct current (DC) power systems where current flows in system conductors in only one direction, most commercial power systems in the United States use alternating current (AC). In AC systems, current flows in system conductors in one direction for 1/120th of a second, going from zero amperes to a peak ampere value and back to zero amperes. It then reverses direction, for another 1/120th of second flows in the opposite direction in system conductors, again going from zero amperes to a peak magnitude and back to zero amperes. It then changes direction again and the cycle repeats. If projected on a graph, the current would appear as a sinusoidal curve as depicted in Figure 5.2, that shows at least two complete cycles of current flow on phases A, B, and C of a three-phase circuit. In the United States, there are 60 such cycles each second (also referred to as 60 hertz). There are more AC systems than DC systems because utilities can transmit large amounts of power over long distances on high voltage transmission lines and can take advantage of the alternating magnetic fields associated with AC systems.

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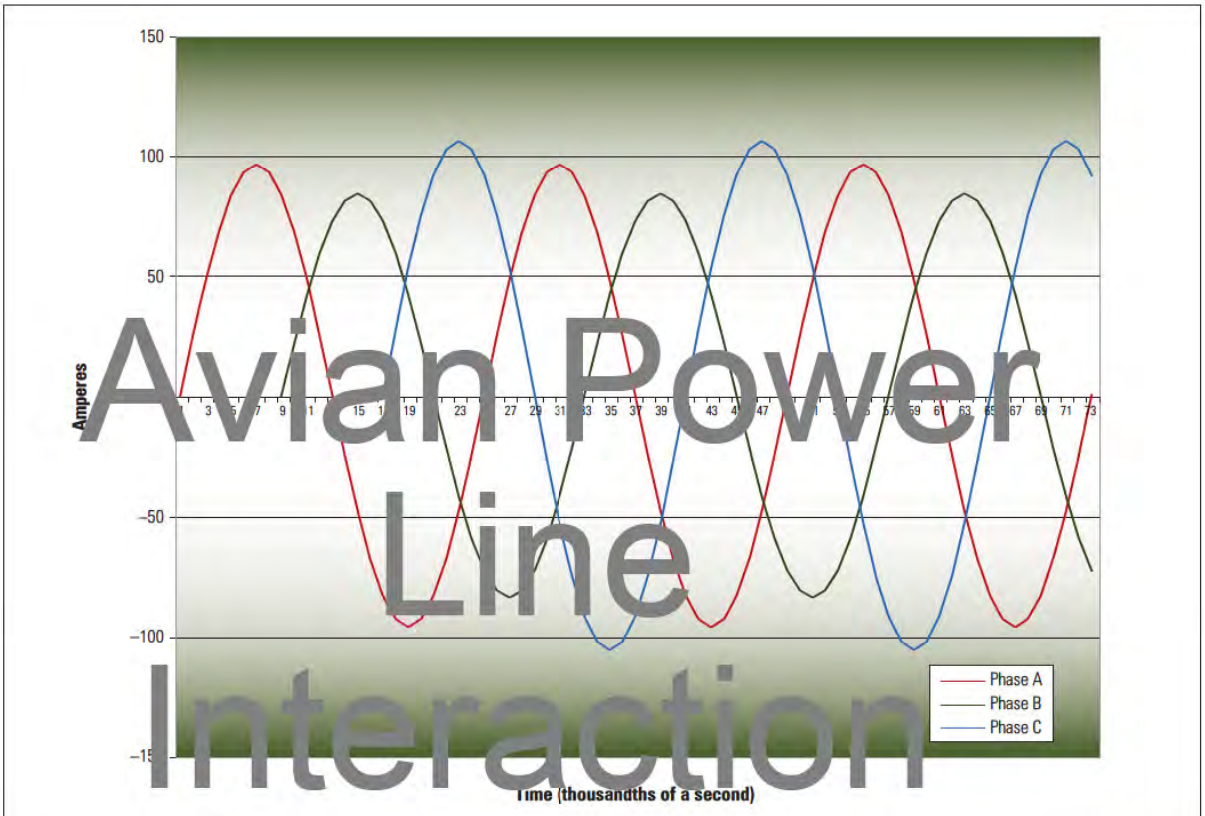

FIGURE 5.2: T ee-ph se current waveform.

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OVERHEAD VERSUS UNDERGROUND

Utilities install facilities either overhead or underground, depending upon numerous factors and concerns. Some key factors include customer needs, terrain and environment restrictions, costs, and code requirements. Cost is a major concern as utilities have a responsibility to serve customers with high quality, reliable electric service at the most reasonable cost possible. Although facilities are installed underground in many areas throughout the country where utilities have found it technically and financially feasible to do so, there are many more areas where utilities have determined that installing facilities underground is not feasible, leaving lines to be installed overhead. If all lines could be installed underground, birds would have little exposure to electrocution hazards and there would be little need for this publication. However, it is neither practical nor feasible to install or convert all overhead lines to underground and it becomes less practical as the voltage of the line increases. The focus of this publication, therefore, is to provide overhead power line designs and modifications that minimize electrocution risk for birds.

SINGLE, TWO, AND THREE-PHASE OVERHEAD SYSTEMS

Most AC commercial overhead power lines utilize some form of support structure from which insulators and electrical conductors are attached. Support structures may consist of preservative-treated wood poles, hollow or lattice steel structures, steel-reinforced concrete poles, or composite poles made from fiberglass or other materials. Insulators are made of porcelain or polymer materials that do not normally conduct electricity. Electrical conductors are usually manufactured from copper or aluminum.

The basic workhorse of the electric utility is the three-phase circuit that consists of structures, as described above, that support at least three electrical phase conductors with or without a neutral (or grounded) conductor. The separate phase conductors are energized at the same voltage level but are electrically 120° out of phase with one another (see Figure 5.3 for a diagram of the three phase voltages and their time relationships). Because of this electrical phase difference, the conductors are called phase conductors. In electrical engineering, the term "phase" has several significant meanings, however, for this publication, it is used to mean an energized electrical conductor with the electrical characteristics described above. Three-phase systems are used for both distribution and transmission lines. One of the primary benefits of three-phase systems is the ability to deliver large amounts of power over long distances. Most electric systems originate as three-phase facilities and,

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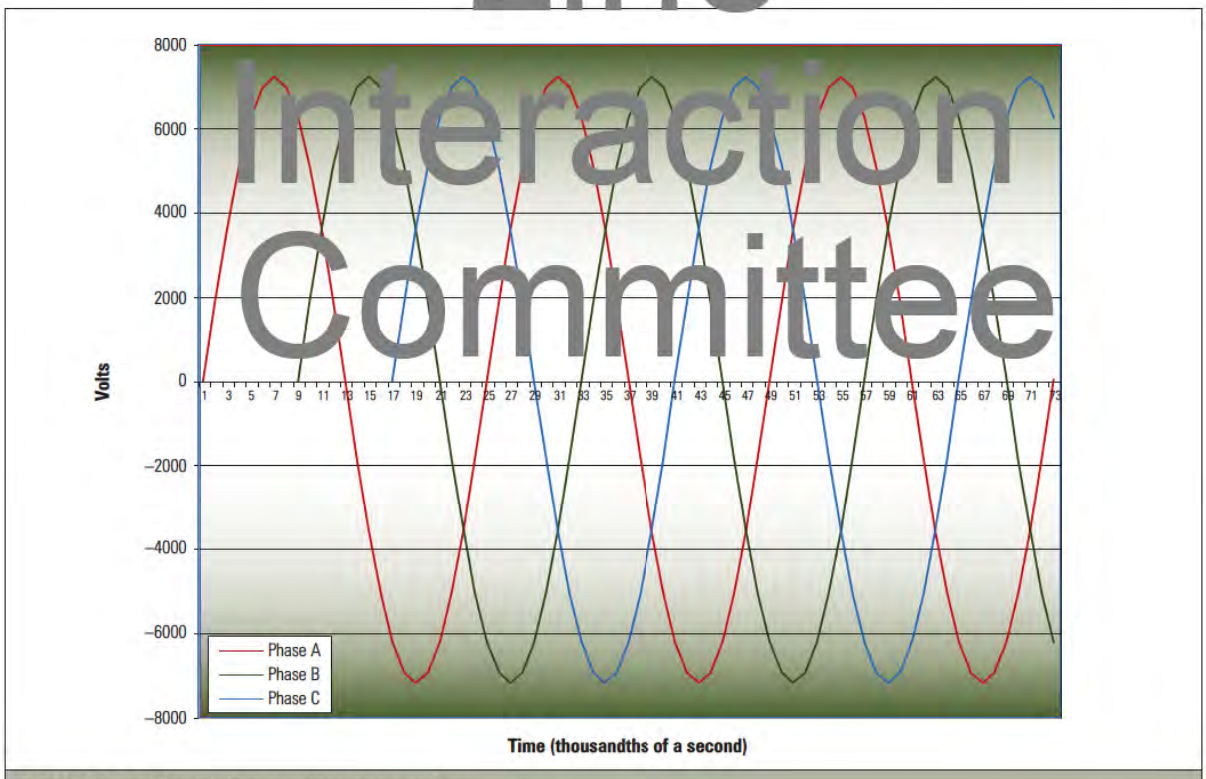

FIGURE 5.3: Three-phase voltage waveform.

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out on the power line route, change from three-phase to two-phase (i.e., V-phase) facilities or to single-phase facilities.

Because of limited rights-of-way (ROW) availability and the need to deliver significant amounts of power, some power line structures may carry several three-phase circuits. In some cases, the structure supports two or more three-phase transmission circuits high on the structure while the lower portion supports several three-phase distribution circuits. Structures could also support low voltage utilization circuits for street lighting or electric service to homes and businesses. Distribution circuits installed on the lower portion of a transmission structure are commonly referred to as "underbuilt" distribution.

Transmission line structures always support at least one three-phase circuit. They have three energized conductors (more if bundled), and may have one or two grounded conductors (usually referred to as *static wires*) installed above the phase conductors for lightning protection. Again, there may be more than one three-phase circuit supported on the same structures.

Distribution line structures may support a variety of conductor configurations. A distribution line could consist of three phase conductors only, or three separate phase conductors and a single neutral (grounded) conductor. The neutral conductor could be the top-most conductor on the supporting structure or it could be placed below or even with the phase conductors. Distribution lines could also consist of two phase conductors alone or two phase conductors and a neutral conductor, again with the neutral conductor being above, below, or even with the phase conductor. A distribution line may also have just a single phase conductor and a neutral conductor with the neutral being above, below, or even with the phase conductor. Most distribution lines throughout the United States have the neutral conductor placed below the phase conductors. The neutral conductor is used to complete the electrical circuit and serves as part of the conducting path for phase current flowing from the customer back to the substation where the circuit originates. The earth itself serves as the other part of the return current path.

AVIAN ELECTROCUTIONS AND POWER LINE DESIGN

Birds can be electrocuted by simultaneously contacting energized and/or grounded structures, conductors, hardware or equipment. Electrocutions may occur because of a combination of biological and electrical design factors. Biological factors are those that influence avian use of poles, such as habitat, prey, and avian species (see Chapter 4). The electrical design factor most crucial to avian electrocutions is the physical separation between energized and/or grounded structures, conductors, hardware, or equipment that can be bridged by birds to complete a circuit. As a general rule, electrocution can occur on structures with the following:

- Phase conductors separated by less than the wrist-to-wrist or head-to-foot (flesh-to-flesh) distance of a bird (see Chapter 4, Size)[21];
- Distance between grounded hardware (e.g., grounded wires, metal braces) and any energized phase conductor that is less than the wrist-to-wrist or head-to-foot (flesh-to-flesh) distance of a bird.

In the 1970s, Morley Nelson evaluated electrocution risk of eagles to identify configurations and voltages that could electrocute birds (Nelson 1979b, 1980b; Nelson and Nelson 1976, 1977; see Chapter 4).

[21] The wrist is the joint toward the middle of the leading edge of a bird's wing. The skin covering the wrist is the outermost fleshy part on the wing.

Because bird feathers provide insulation when dry, contact must typically be made with fleshy parts, such as the skin, feet, or bill. Nelson determined that 150-centimeter (cm) (60-inch [in]) spacing is necessary to accommodate the wrist-to-wrist distance of an eagle. As a result, a 150-cm (60-in) separation has been widely accepted as the standard for eagle protection since the 1975 edition of *Suggested Practices*. Although wingspans can measure up to 2.3 meters (m) (7.5 feet [ft]) for golden eagles (*Aquila chrysaetos*) and 2.4 m (8 ft) for bald eagles (*Haliaeetus leucocephalus*), the distance between fleshy parts (wrist-to-wrist) is less than 150 cm (60 in) for both species (see Chapter 4, Size). Therefore, under dry conditions, a 150-cm (60-in) separation should provide adequate space for an eagle to safely perch. Larger birds such as condors or storks may require special consideration by utilities. Utilities in areas without eagle populations may choose to develop separate species-specific construction standards as may utilities in regions with wet climates or increased air-borne contaminants. A utility's Avian Protection Plan (APP) should identify protected species within the utility's operations area and include design standards appropriate for those species and conditions (see issue set Chapter). An APP should also identify circumstances where avian-safe construction is to be used (i.e., in bird use areas, as part of ROW permit conditions, etc.).

Although avian-safe construction minimizes electrocution risk, electrocutions can never be completely eliminated. Because wet feathers and wet wood are conductive, birds can be electrocuted during wet weather on normally benign poles.

With an understanding of how birds can be electrocuted on power lines, utilities can select designs that are avian-safe and help to avoid and/or mitigate electrical hazards to birds. Voltage, conductor separation, and grounding practices are a particular concern when designing avian-safe structures, however, public safety, governed throughout the United States by the current National Electric Safety Code (NESC), is the primary design consideration. State and local governments also may have codes that govern power line design and construction.[22]

SEPARATIONS

The NESC and the codes of some local jurisdictions dictate power line phase-to-phase separations and the clearances of line components above ground. In accordance with the NESC, both the distance between phase conductors and the distance that conductors are hung above ground is based on the line voltage and the activity that does and could take place in the area of the power line. These code requirements are considered the minimum distances and separations needed to be certain that the facilities will not be harmful to the general public or the line crews that have to operate and maintain them. The code requirements are not intended to provide safety to birds and other animals that come into contact with assemblies at the top of poles and towers.

Distribution lines are built with smaller separations between energized conductors and between energized conductors/hardware and grounded line components than are transmission lines. Consequently, avian electrocution risk is greater on distribution lines.

Transmission conductors are generally spaced 1 to 9.1 m (3 to 30 ft) apart, and are supported on poles or towers that range from 15.2 to 36.6 m (50 to 120 ft) in height. A single transmission tower can accommodate more than one circuit. See Figure 5.4 for examples of transmission structures.

[22] For example, California Public Utility Commission (CPUC) General Order 95 establishes the rules for overhead line construction in California.

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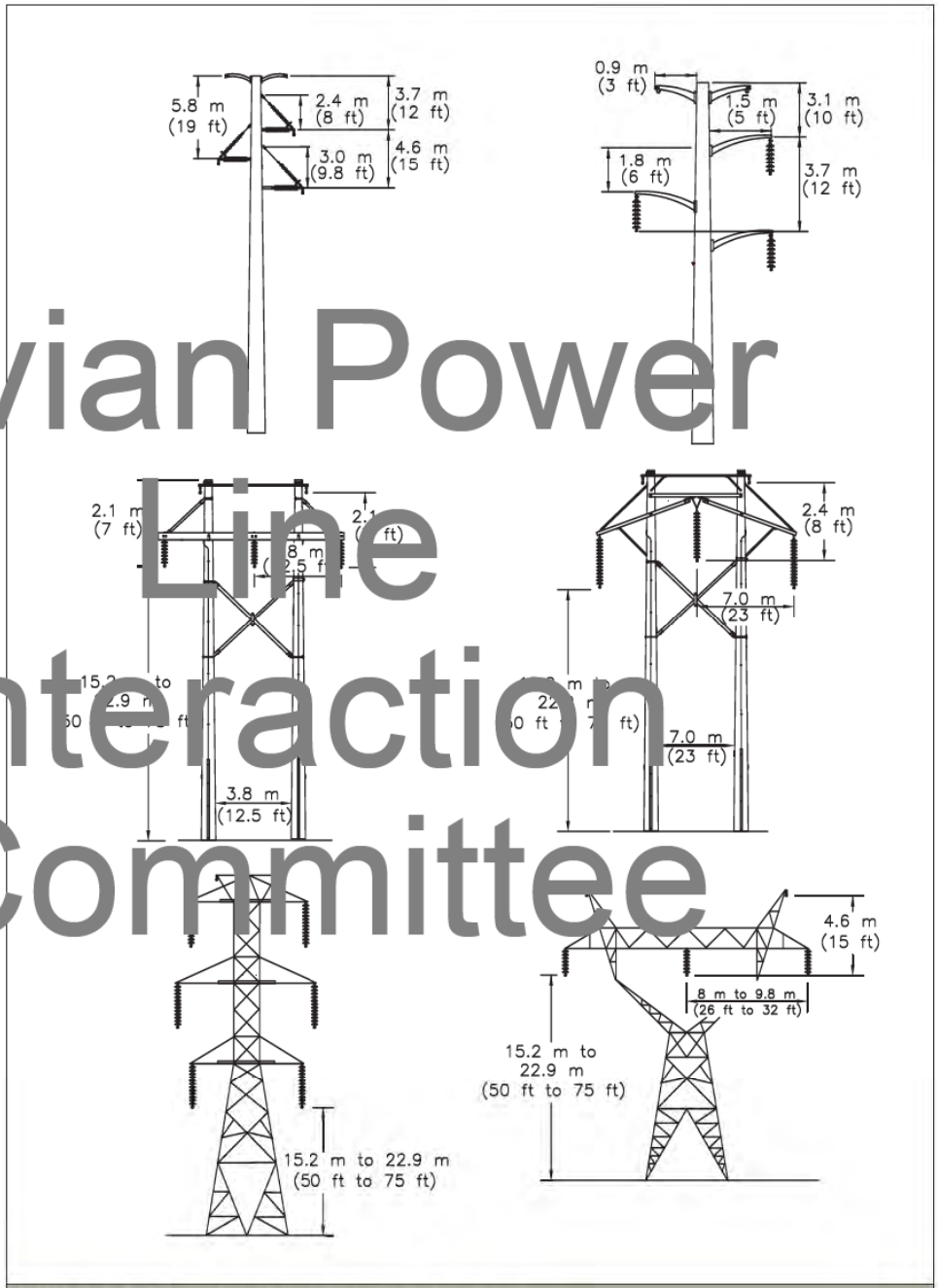

FIGURE 5.4: Examples of transmission structures.

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Distribution line conductors are generally spaced 0.6 to 1.8 m (2 to 6 ft) apart, and are supported on wood, steel, composite or concrete poles that range from 9.1 to 19.8 m (30 to 65 ft) in height (Figure 5.5). As with transmission poles and towers, distribution poles can accommodate more than one circuit (Figure 5.5). The addition of jumper wires, transformers, switches, and electrical protective devices (fuses, reclosers, and other circuit sectionalizing equipment), as well as grou[illegible] hardware included on pole-top assemblies, increase the potential for avian electrocutions due to close separation of energized and grounded parts.

BONDING AND GROUNDING

Bonding electrically interconnects all metal or metal-reinforced supporting structures—including lamp posts, metal conduits and raceways, cable sheaths, messengers, metal frames, cases, equipment hangers or brackets,

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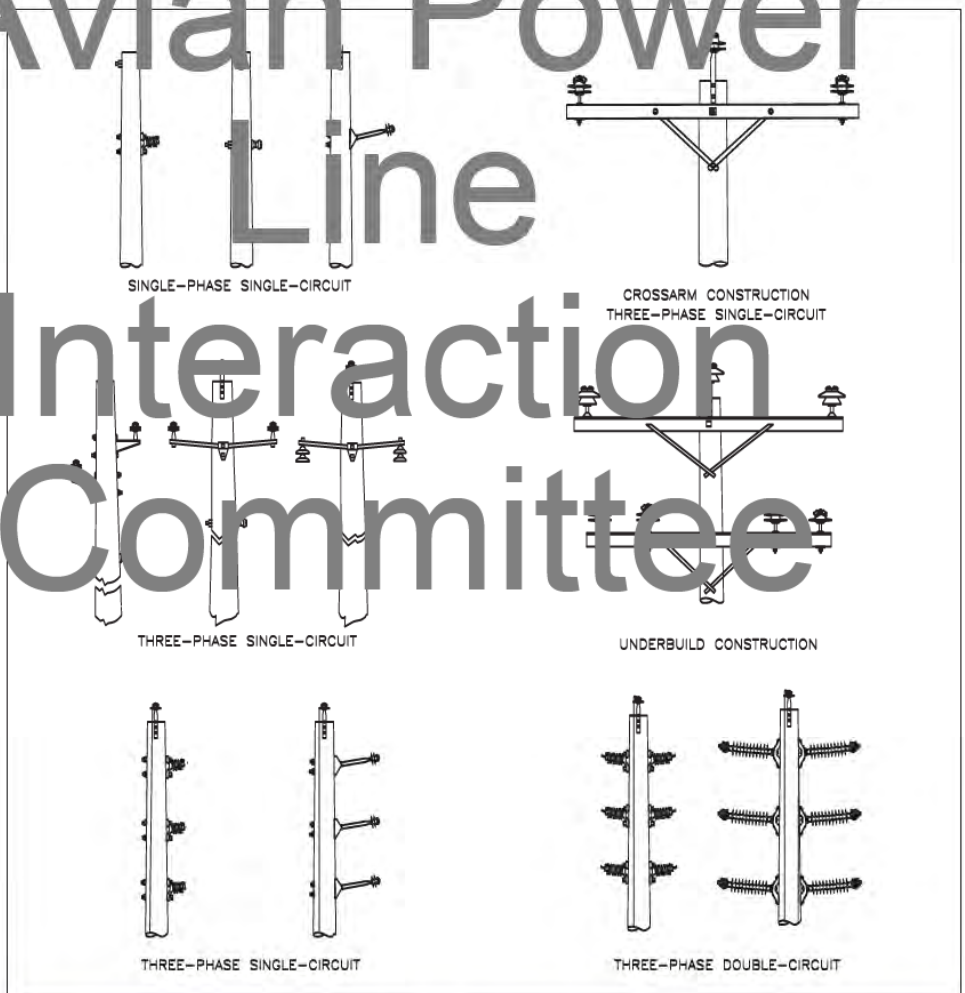

FIGURE 5.5: Examples of typical distribution configurations.

and metal switch handles and operating rods. In most cases these bonded hardware items are grounded in accordance with NESC Rule 215 C1.[23] The NESC requires the grounding of these metallic items to help keep the metal at the same voltage as the earth to which it is grounded. Bonding is particularly necessary in areas (industrial, agricultural, or coastal locations with salt, particulates, or other matter in the air) where excessive leakage currents may cause burning around metal items in the presence of moisture. On multi-grounded neutral power systems, the neutral is grounded by connecting it to a grounding electrode (ground rod) installed in the earth at the base of a pole at least four times in each mile of line. For birds, bonding and grounding provide pathways for contacts from energized conductors or energized hardware to metal items that are grounded.

The position of the neutral depends on the area's isokeraunic level and/or the practices of the utility. For some utilities, the neutral serves as an overhead ground wire (static wire) for lightning protection. If this type of construction is used, the designer should provide avian-safe separation and insure that appropriate coverings are used on the grounding conductors and bonded hardware.

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SUGGESTED PRACTICES

The remainder of this chapter presents configurations that can pose avian electrocution risks and suggested practices for modifying those problem configurations (Table 5.2). Recommendations are based on providing 150 cm (60 in) separation for eagle protection. Other avian species may require more or less separation, depending on the size and behavior of the bird (see Chapter 4, Size). Recommendations are provided for avian-safe modifications of existing facilities, and avian-safe designs for new facilities. These practices either provide birds with a safer place to land or attempt to discourage birds from perching on parts of the structure where optimal separation cannot be provided.

Two basic principles should be considered when attempting to make a structure avian-safe: *isolation* and *insulation*. The term *isolation* refers to providing a minimum separation of 150 cm (60 in) between phase conductors or a phase conductor and grounded hardware/

TABLE 5.2: Summary of figures and pages for problem configurations and suggested solutions.

Configuration	Problem Figure	Solution Figure	Pages
Single-phase	Figures 5.6, 5.8	Figures 5.7, 5.9, 5.10	61–66
Three-phase	Figures 5.11, 5.15, 5.17, 5.20	Figures 5.12, 5.13, 5.14, 5.16, 5.18, 5.19, 5.21	66–76
Corner poles	Figure 5.22	Figures 5.23, 5.24, 5.25	76–80
Steel/concrete distribution poles	Figures 5.27, 5.29	Figures 5.28, 5.30, 5.31, 5.32, 5.33	81–88
Problem transmission designs	Figures 5.34, 5.36, 5.40, 5.42	Figures 5.35, 5.37, 5.38, 5.39, 5.41, 5.43	88–99
Transformers and other equipment	Figures 5.44, 5.45	Figures 5.46, 5.47	99–102

[23] In some jurisdictions, bond wires are not grounded if the facilities comply with the exceptions of NESC Rule 215 C1.

conductor.[24] Using the principle of isolation may be most applicable for new or rebuilt structures in areas where avian electrocution risk is a concern. The term *insulation* refers to covering phases or grounds where adequate separation is not feasible. Although equipment that is covered with specifically designed avian protection materials can prevent bird mortality, it should not be considered insulation for human protection. Examples of such coverings are phase covers, bushing covers, arrester covers, cutout covers, jumper wire hoses, and covered conductor. In addition, perch discouragers may be used to deter birds from landing on hazardous (to birds) pole locations where isolation, covers, or other insulating techniques cannot be used. Many equipment poles necessitate using a combination of techniques to achieve avian safety.

Both avian-safe modifications of existing structures and avian-safe new construction should be employed if circumstances indicate they are necessary. In areas with known populations of raptors or other birds of concern, new lines should be designed with adequate separations for birds. Given the diversity of line designs and voltages used by power companies, across-the-board standards and guidelines are not possible. It is not realistic to expect to eliminate all hazards to birds. However, it is feasible to reduce known and potential hazards.

MODIFICATION OF EXISTING FACILITIES

In recommending remedial actions for a particular problem, the following generalizations can be made:

- In areas with vulnerable avian populations, power lines built to past construction standards may present serious threats to birds. Such lines are characterized by closely separated, energized components including bare conductors, equipment bushings, primary transition terminations, arresters, and cutout tops. In addition, all of these energized sources may be close to grounded steel brackets, metal crossarm braces, conductors, or guy wires.
- The phase-to-phase and phase-to-ground separation of most transmission lines is typically greater than 150 cm (60 in) and, therefore, the likelihood of electrocutions occurring at voltages greater than 60 kV is low.
- Priority should be given to poles preferred by raptors or other birds that have a high electrocution risk.
- Raptors may use any pole located in homogenous areas of suitable habitat. In these areas, poles of like configuration may pose similar electrocution risks. These areas can be assessed to prioritize structures for corrective actions.
- Electrocutions that have occurred on distribution lines with crossarm construction should be evaluated closely. Although remedial actions should be made at structures with avian mortalities, modifications of entire line sections are generally not recommended in response to an electrocution, which is a localized event. Risk assessments should be conducted to determine the likelihood of multiple electrocutions on a given section of line and to identify the poles that pose that risk. Criteria could include electrocuted birds found near a pole, prey availability, proximity to active nests, terrain advantage, and/or consistent use of preferred poles for perching or still-hunting.
- Poles supporting additional electrical equipment (e.g., transformers and switches)

[24] The drawings and text in this chapter refer to providing 150-cm (60-in) separation for eagle protection. Dimensions can be modified for other species (see Table 4.1 for measurements of other avian species). A utility's APP may include approved construction standards for avian protection; this may be particularly necessary for designs that do not provide 150-cm (60-in) separation.

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in avian use areas are more likely to cause electrocution (Olendorff et al. 1981; APLIC 1996; Harness and Wilson 2001; Liguori and Burruss 2003; Idaho Power Co., unpubl. data). Retrofitting these structures can reduce avian electrocution risk and improve power reliability.

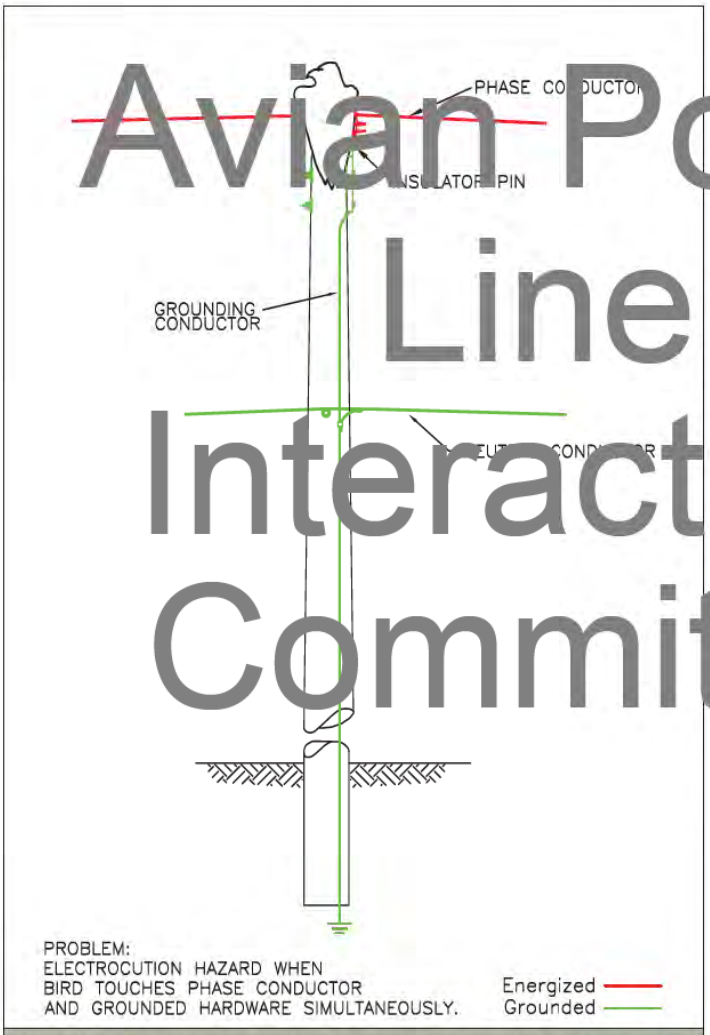

FIGURE 5.6: Problem single-phase with grounded pole-top pin.

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AVIAN-SAFE DESIGN OF NEW FACILITIES

Concepts used to modify existing power lines also apply to new construction. Again, two basic considerations are conductor separation and grounding procedures. As with retrofitting, the objective is to provide a 150-cm (60-in) separation between energized conductors or energized hardware and grounded conductors/hardware. If enough separation is not possible, appropriate covers can be used to prevent simultaneous contact between energized and/or grounded facilities. When planning the construction of new power lines, it is important to consider the safety of the public and utility personnel, biological aspects, ROW permit requirements, service reliability, and other economic and political factors. Although biological significance cannot be overlooked, it may not be possible to site lines outside high-quality bird habitat. In many instances, ROW permits will require avian-safe construction on federal lands. Biologists and engineers should cooperatively consider all factors when developing recommendations for preventing avian mortality problems.

SPECIFIC DESIGN PROBLEMS AND SOLUTIONS

Distribution

WOODEN POLES

Single-Phase Lines

Figure 5.6 shows a typical single-phase line with the phase conductor mounted on the top and the neutral mounted on the side of the pole.[25] In this example, the pole bond (grounding conductor) extends up to the top of the pole to ground the metal bracket. With this configuration, the feet of a large bird perched on the pole top could touch the grounding conductor or grounded insulator pin, while its breast or other body parts contact the phase conductor. In 1971, 17 dead

[25] Note that in this and subsequent figures, grounded conductors and hardware are shown in green and energized conductors and hardware in red. The designs presented in this section apply to poles of a non-conducting nature (i.e. wood or fiberglass). See Steel/Concrete Poles for avian-safe designs of steel/concrete poles.

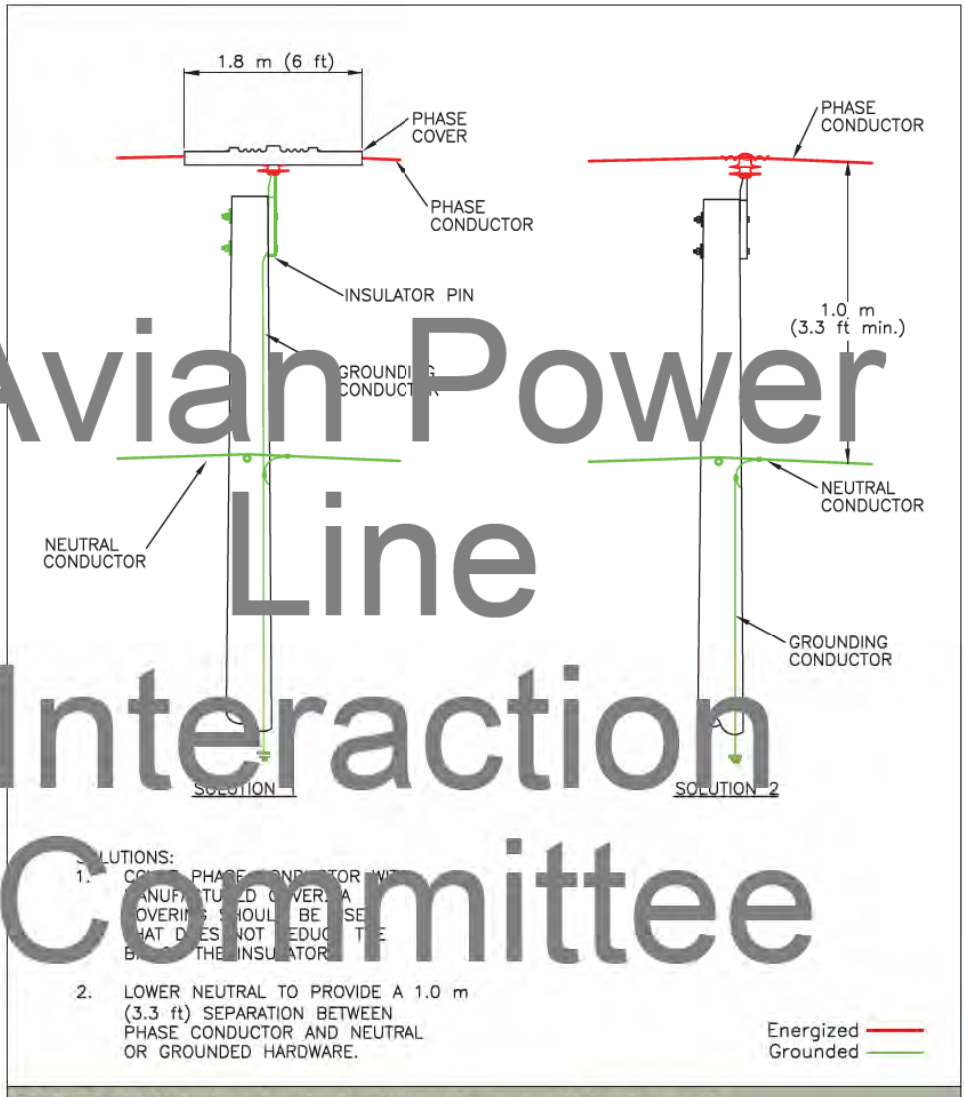

FIGURE 5.7: Solutions for single-phase with grounded pole-top pin.

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eagles were found below poles of this configuration in the Pawnee National Grasslands and adjacent areas in Colorado, where habitat and prey attracted wintering eagles (Olendorff 1972a). One retrofitting option for this configuration is to place a cover manufactured for this purpose over the phase conductor to help prevent simultaneous phase-to-ground contact (Figure 5.7, Solution 1). For further information on the use of cover-up products see Precautions (page 102).

If the pole bond or grounding conductor does not extend above the neutral conductor and there is at least 100 cm (40 in) of vertical

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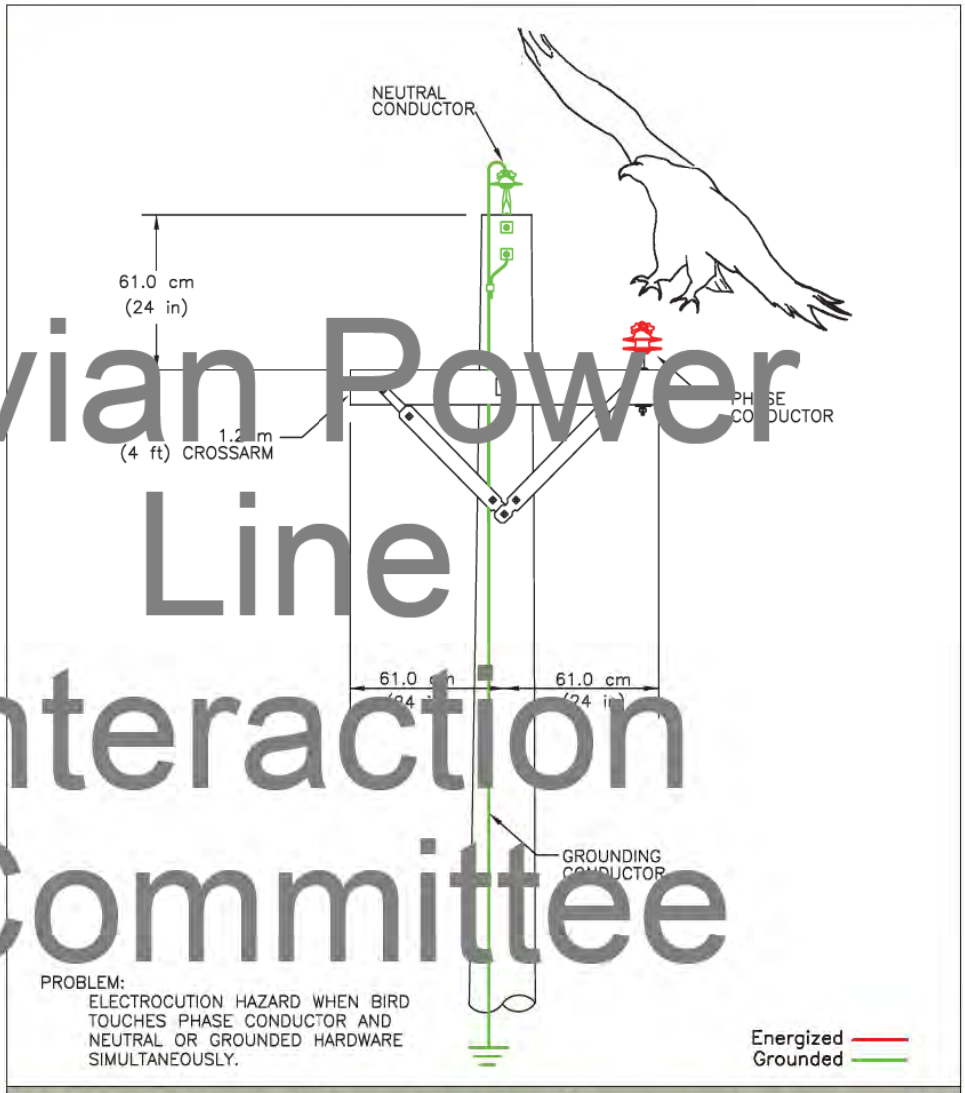

FIGURE 5.8: Problem single-phase configuration with crossarm and overhead neutral.

separation between the phase and neutral conductors, then no further avian protection action should be needed (Figure 5.7, Solution 2).

Figure 5.8 shows another problem single-phase power line, where a pole-top neutral conductor was mounted 61 cm (24 in) above an energized conductor that was supported on a 1.2-m (4-ft) crossarm. In 1992, 17 dead eagles were found below poles with such a configuration along a 24-kilometer (km) (15-mile [mi]) stretch of distribution line in central Wyoming (PacifiCorp, unpubl. data). When the eagles tried to perch on the

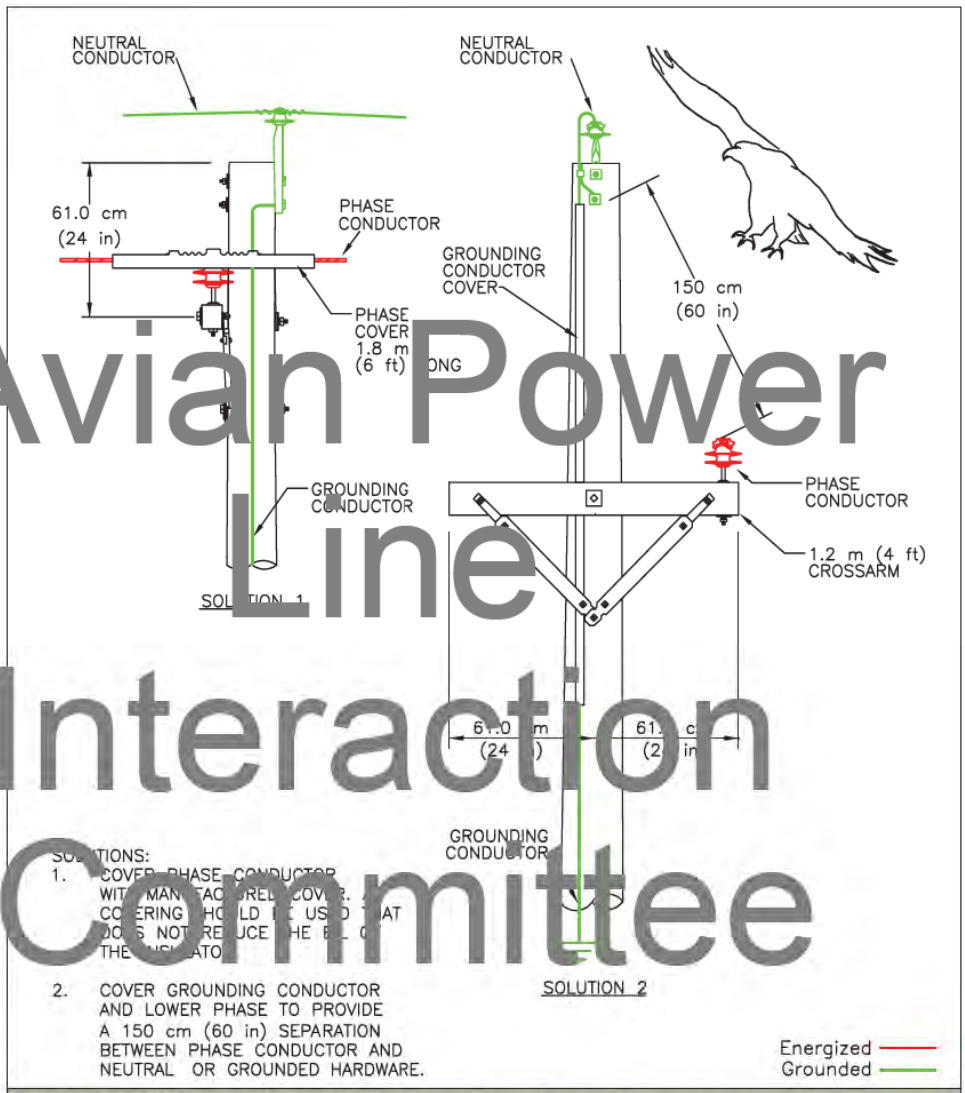

FIGURE 5.9: Solutions for single-phase configuration with crossarm and overhead neutral.

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conductor end of the crossarm where there was less than the wrist-to-wrist separation between the phase and neutral conductors, the birds were electrocuted. Surveys conducted in 2002 found that, although this configuration is now uncommon (only 3.9% of 10,946 poles surveyed), it accounted for a disproportionate number (6.4%) of raptor mortalities (n=94) (PacifiCorp, unpubl. data). For this single-phase crossarm configuration (Figure 5.8), the phase conductor can be covered to prevent avian electrocutions (Figure 5.9, Solution 1). Another option is to lower the crossarm and cover the grounding conductor

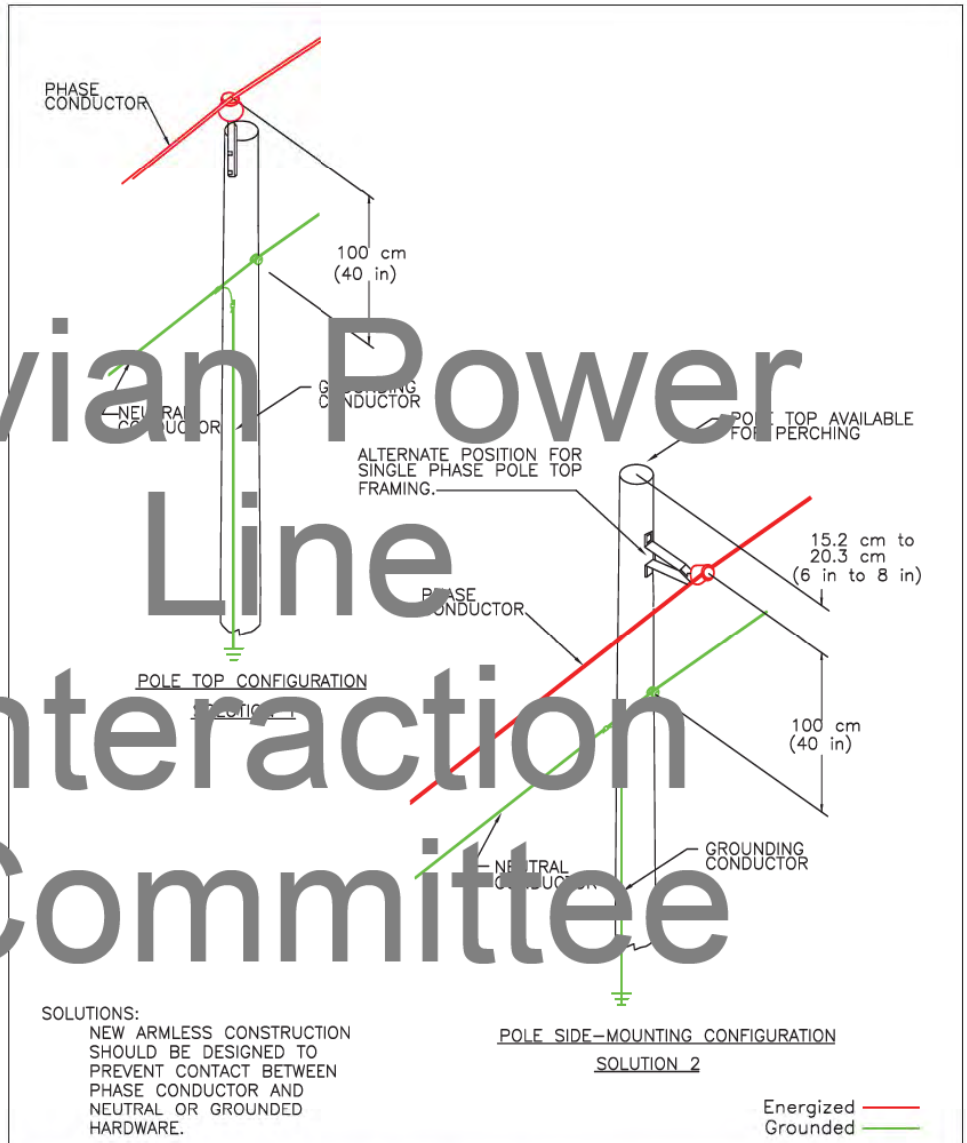

FIGURE 5.10: Single-phase avian-safe new construction.

for avian-safe phase-to-ground separation (Figure 5.9, Solution 2).

When constructing new armless single-phase lines in bird concentration areas, structures should be designed to prevent contact between energized phase conductors/hardware and grounded conductors/hardware (Figure 5.10). If the pole bond and grounding conductor do not extend above the neutral conductor and there is a 100-cm (40-in)

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spacing between the phase conductor and the neutral conductor, then no further avian protection should be needed (Figure 5.10, Solution 1). Figure 5.10 (Solution 2) shows a single-phase configuration with the phase conductor mounted on the side of the pole. This provides the pole top as a perch.

Three-Phase Lines

Crossarms of 1.8 or 2.4 m (6 or 8 ft) are typically used for most single-pole, three-phase configurations (Figure 5.11). For raptors, the crossarm can provide excellent perching opportunities between phases, but the phase conductor separation is often insufficient to safely accommodate wrist-to-wrist distances of large birds. Utility use of grounded steel crossarm braces[26] may further reduce ground-to-phase separation, increasing the risk of avian electrocution. Although the Rural Electrification Administration (REA)[27] specifications were changed in 1972 to increase conductor separation and include the use of wooden crossarm braces (U.S. REA 1972; see Appendix B) many pre-1972 poles are still in use today. The center phase is supported either on a pin insulator on the crossarm (Figure 5.11, Problem 1) or with a pin and insulator attached to the pole top (Figure 5.11, Problem 2).

Several remedial measures are available to achieve avian-safe separation between phases

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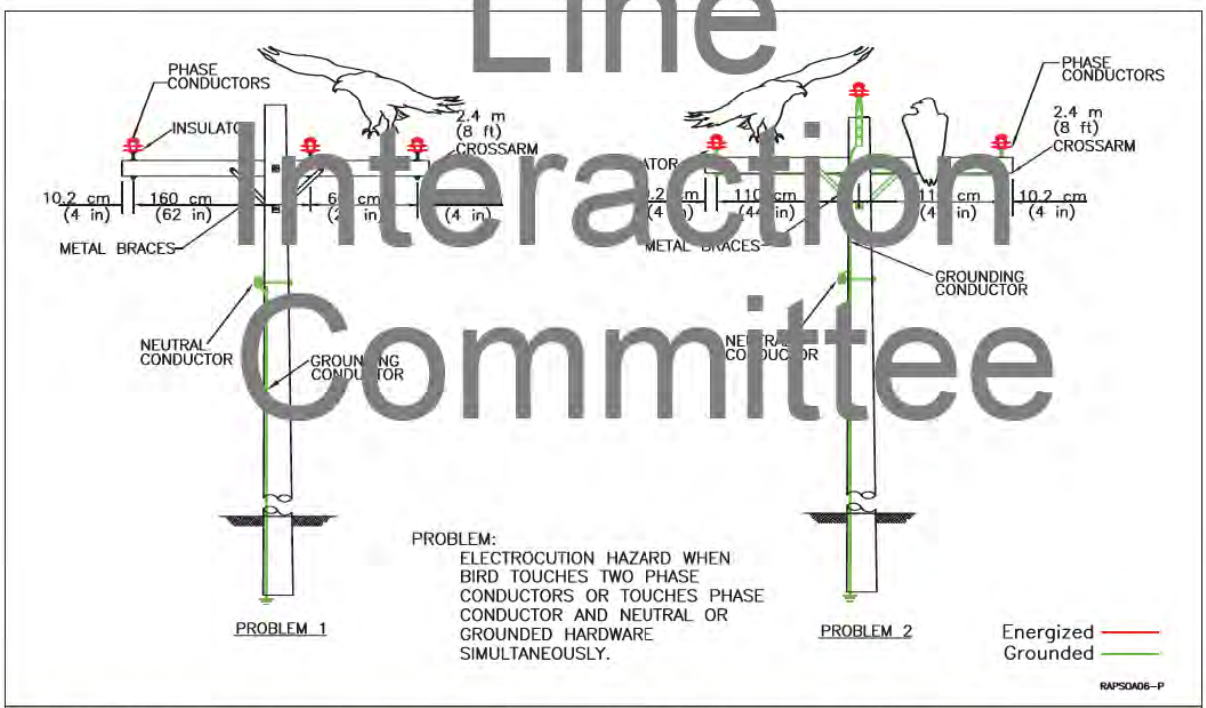

FIGURE 5.11: Problem three-phase crossarm designs with and without grounded hardware.

[26] Grounded to prevent pole fires resulting from insulator leakage currents.

[27] REA, the predecessor to the Rural Utilities Service (RUS), provides financing assistance to rural electric utilities that agree to install facilities in accordance with the standards and specifications established by REA/RUS.

or between phase and ground where all hardware is bonded (as shown in Figure 5.11):

- Install covers over the insulator and conductor on the center phase and remove bonding down to the neutral (Figure 5.12, Solution 1). For further information on the use of cover-up products, see Precautions (page 102).
- If bonds are not removed, install phase covers over all three insulators and conductors (Figure 5.12, Solution 2).
- For pole-top pin construction, the crossarm can be lowered and/or replaced with a longer crossarm (Figure 5.13).[28] A 2.4-m (8-ft) crossarm should be lowered 104 cm (41 in) to achieve 150-cm (60-in) conductor separation. A 3-m (10-ft)

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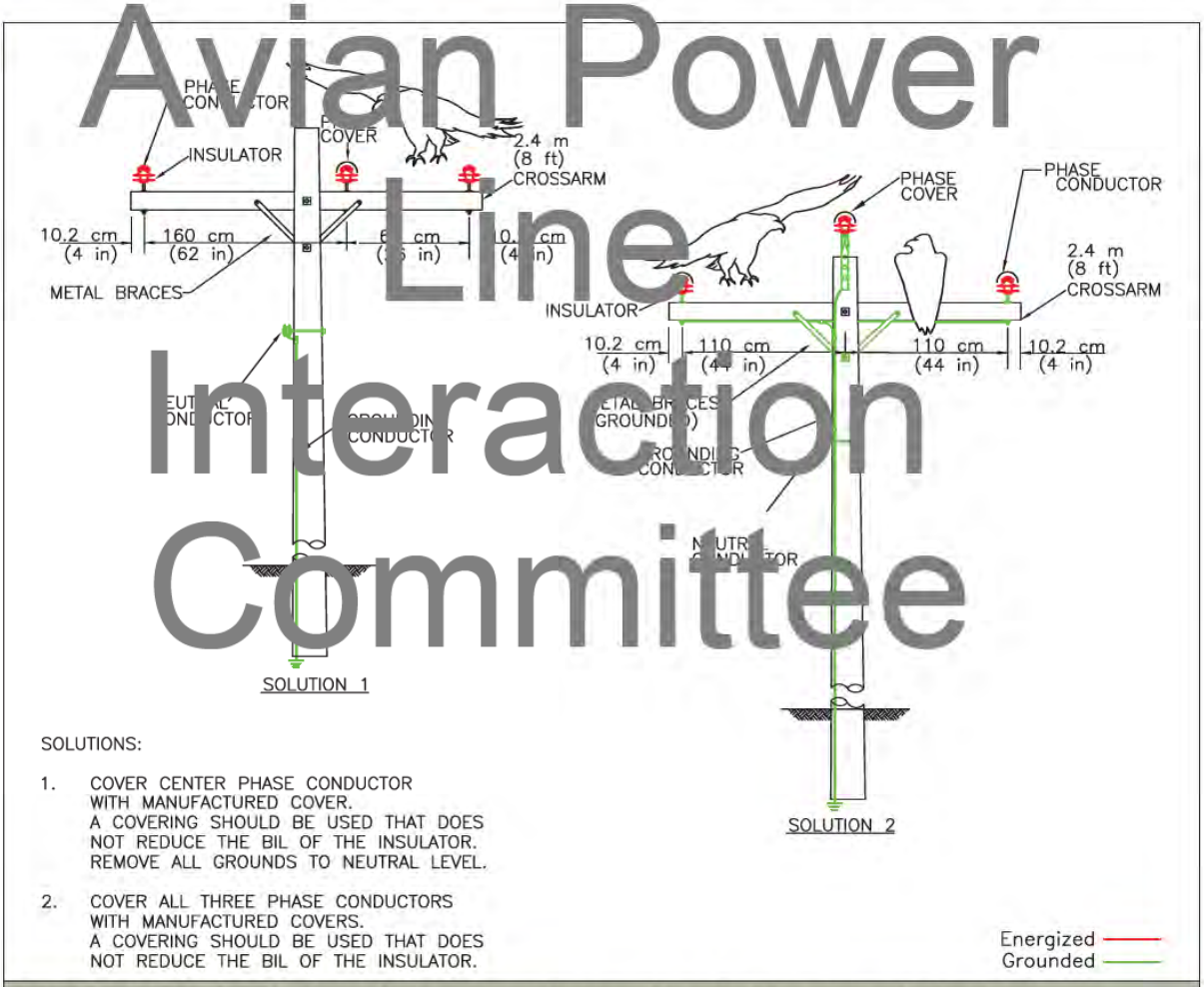

FIGURE 5.12: Solutions for three-phase crossarm designs with and without grounded hardware.

[28] Provided that NESC requirements can be met.

crossarm could be mounted 55 cm (21.5 in) below the top of the pole to provide 150 cm (60 in) of conductor separation between the center and outer phase conductors. In addition, the bond wire must be lowered to the neutral position. This lowered arm configuration can also be used for avian-safe new construction.

On three-phase crossarm construction where there is no grounding conductor along the neutral and the center phase is on the crossarm a perch discourager may be installed to deter perching between closely separated phase conductors (Figure 5.14). If there is less than a 150-cm (60-in) spacing between the center and outer phases (opposite the perch discourager), a phase cover should be installed on the center phase instead of using a perch discourager. Design consideration must be given to meet minimum NESC clearances on the supporting structure (pole, crossarm, insulator and perch discourager).[29] Proper distance between the perch discourager and the phase conductor is required and increases as the system voltage increases. In addition, to prevent birds from perching between the discourager and phase conductor, no more than 12.7-cm (5-in) space should be allowed between a perch discourager and the insulator skirt. When these two parameters conflict, the perch discourager

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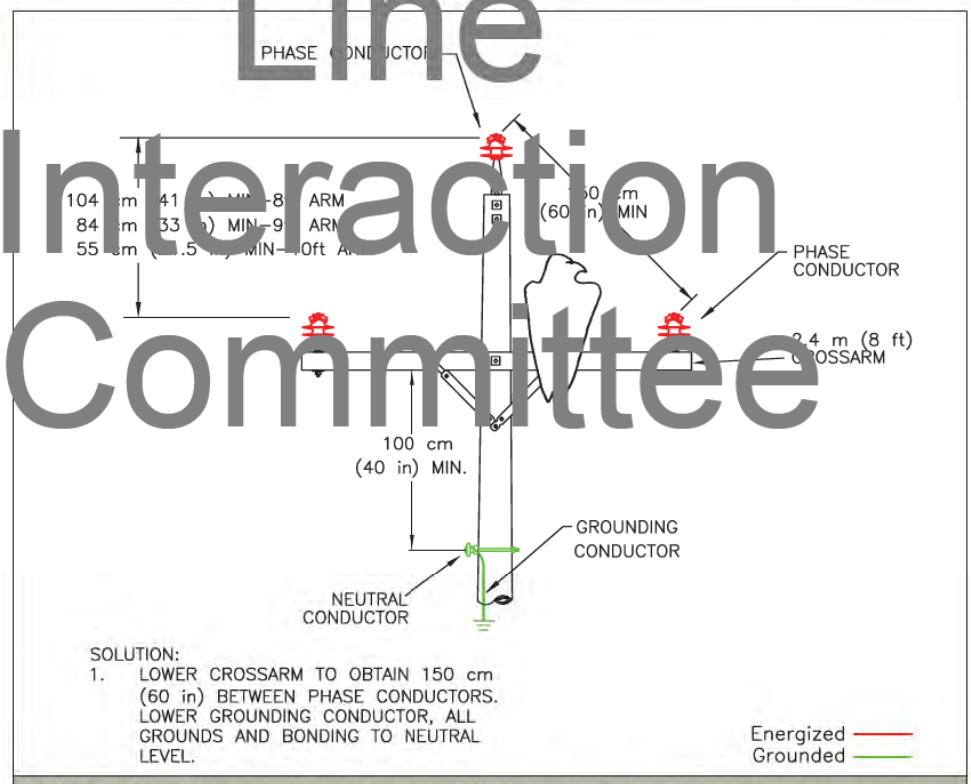

FIGURE 5.13: Avian-safe three-phase construction for different length crossarms.

[29] NESC Rule 235E, Table 235-6.

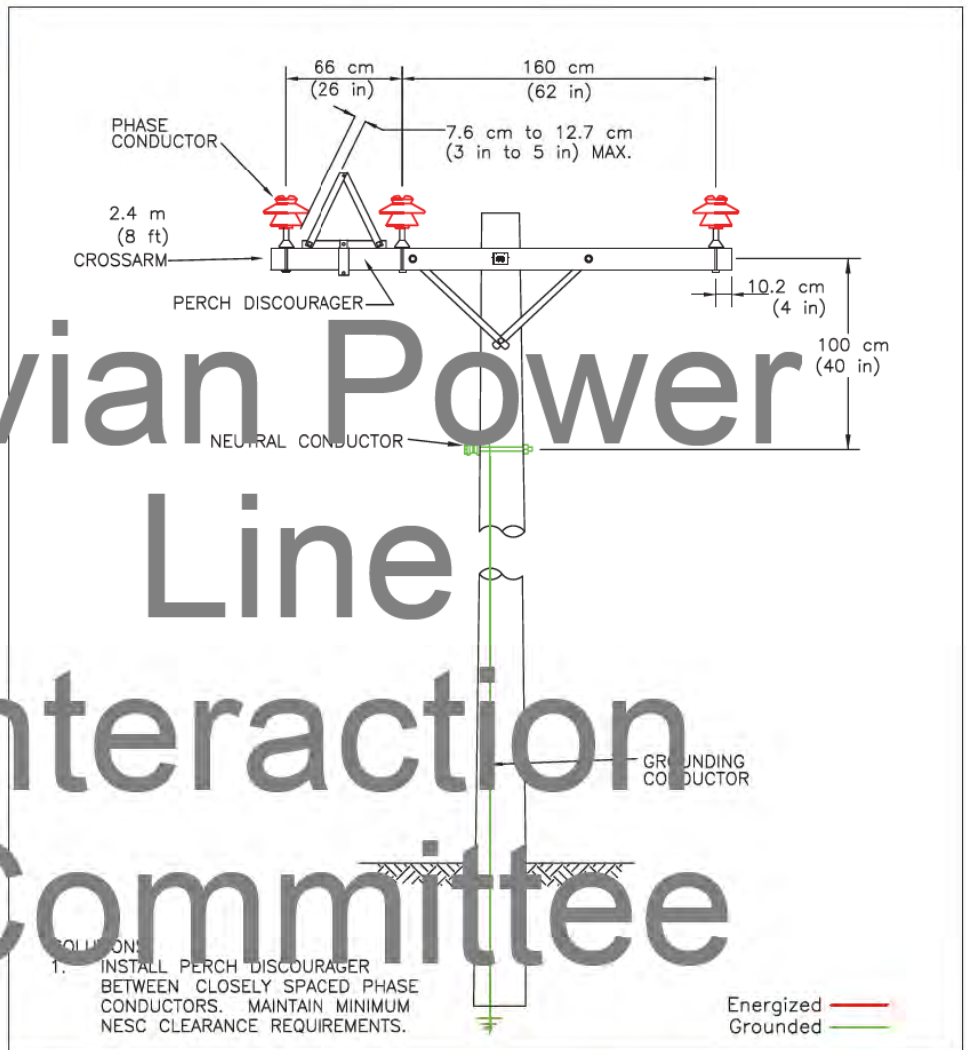

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FIGURE 5.14: Solution for three-phase crossarm using perch discourager.

is not an acceptable mitigation tool. For example, on system voltages exceeding 18.7 kV phase to phase, electrical clearance will require greater than 12.7 cm (5 in), which exceeds the maximum avian-safe physical spacing and would not be effective. If spacing and system voltage are not compatible with a perch discourager, a phase cover should be used instead. See page 17 for a discussion of appropriate uses of perch discouragers for deterring birds.

Dead-end distribution structures accommodate directional changes, line terminations, and lateral taps. These structures handle greater loads, usually use anchor and guy wire assemblies, and have energized jumper wires.

These characteristics can pose electrocution risks to birds. Figure 5.15 depicts a three-phase, double dead-end pole in which jumper wires extend over the crossarm. On such a configuration, a bird can be electrocuted by simultaneously touching two of the phase jumpers. To reduce this risk, use dead-end covers on both sides of the center conductor

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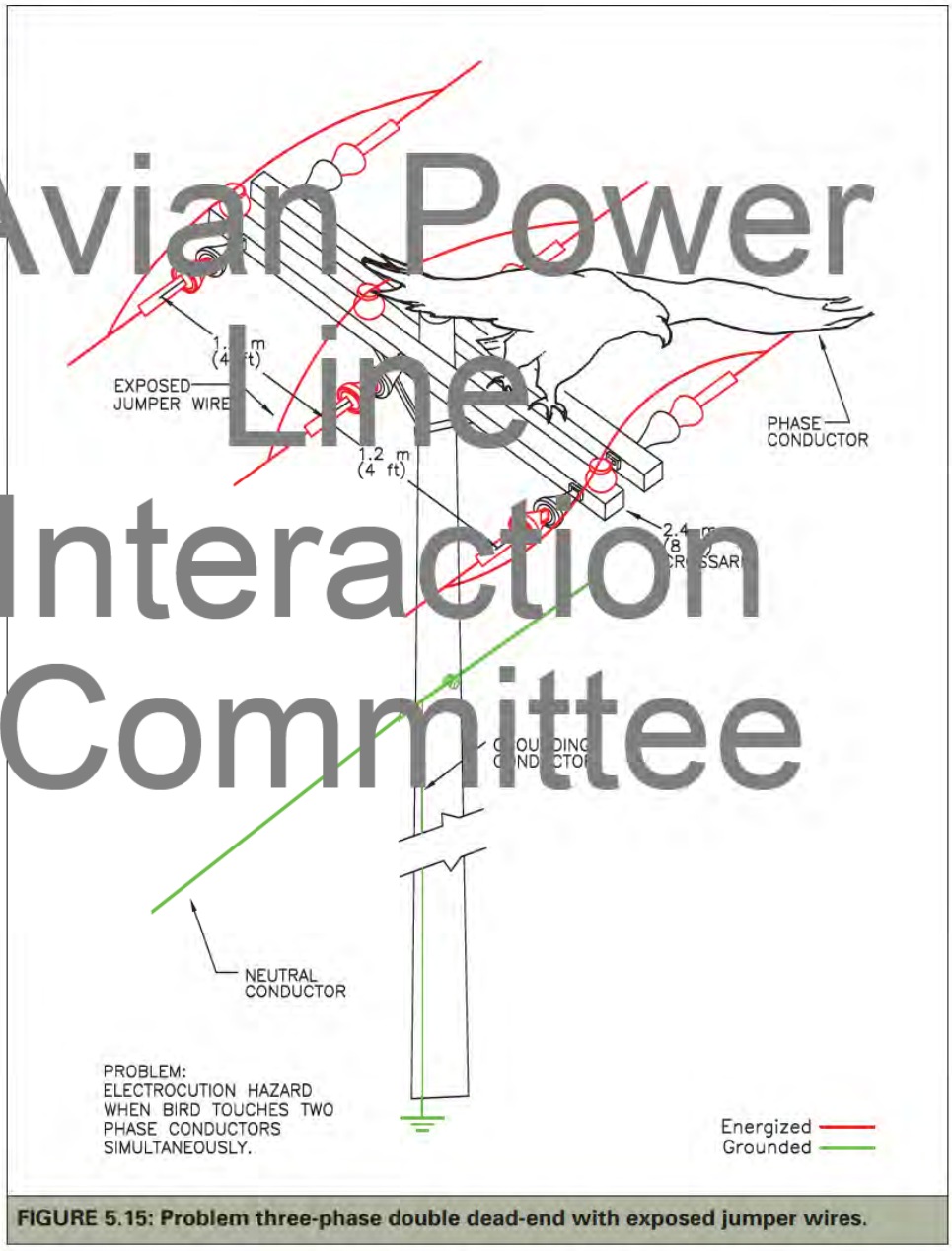

FIGURE 5.15: Problem three-phase double dead-end with exposed jumper wires.

and cover the center phase jumper wire with a material designed for the purpose. A covered conductor can also be used (Figure 5.16), as can insulated links or insulators that move the energized conductor 91 cm (36 in) from the center of the pole.

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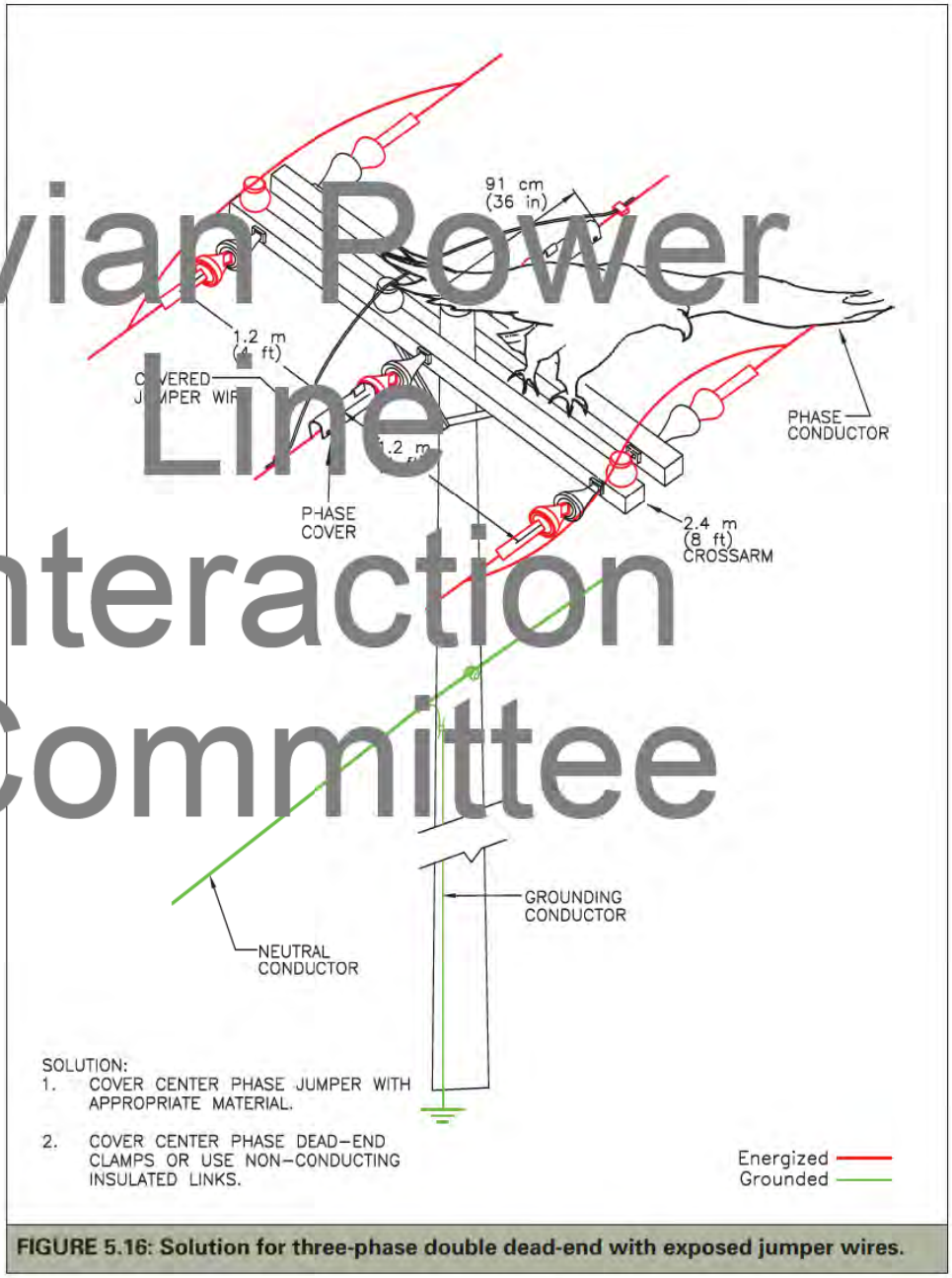

FIGURE 5.16: Solution for three-phase double dead-end with exposed jumper wires.

Compact Designs

The three-phase compact design shown in Figure 5.17 was not originally considered a high-risk configuration (Olendorff et al. 1981; APLIC 1996). However, raptors and other large birds may be electrocuted when flying in to perch on the short fiberglass arms that support the phase conductors. Interestingly, this configuration presented a significant eagle electrocution problem on a line in southern Utah, while a nearby line of the same construction did not electrocute any eagles (PacifiCorp, unpubl. data). Overall, streamline poles comprised 10% of poles surveyed in Utah and Wyoming from 2001 to 2002 (n=74,020) and accounted for 13%

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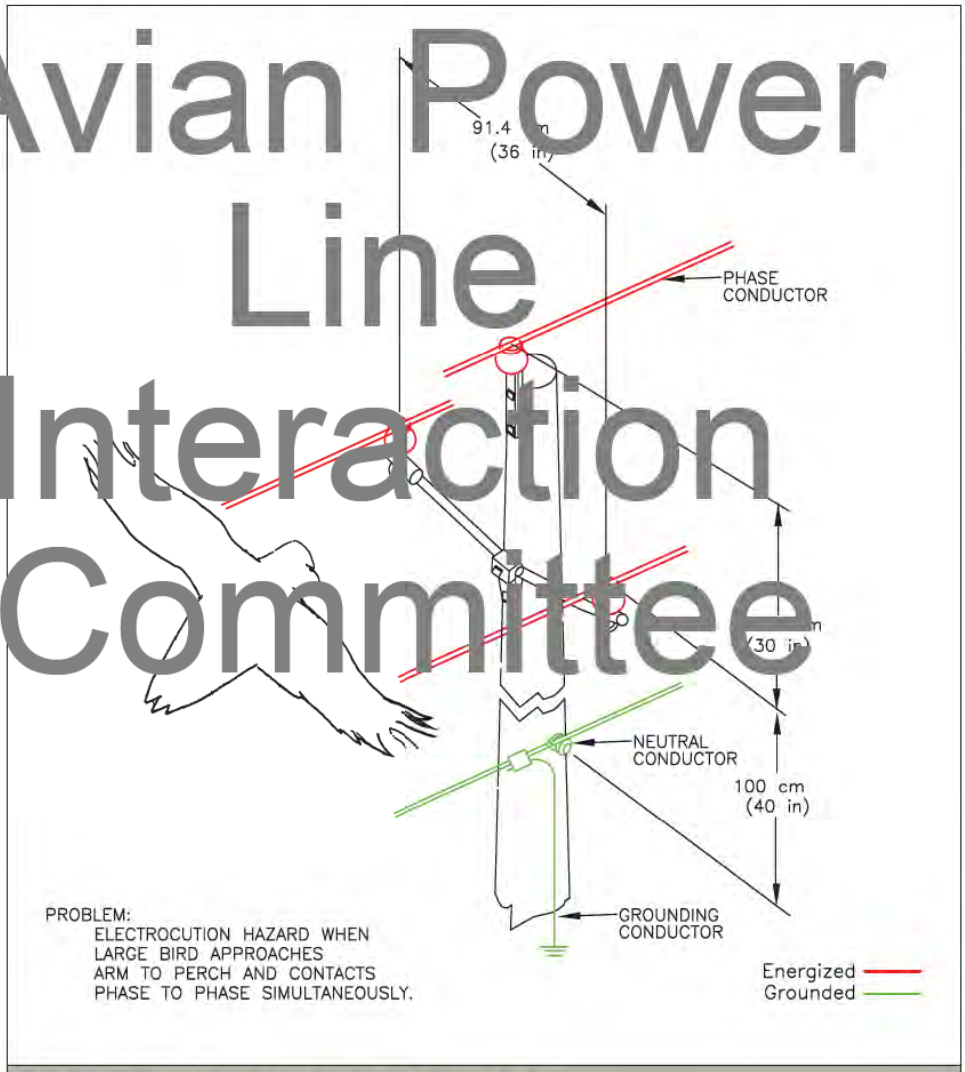

FIGURE 5.17: Problem compact three-phase design.

of avian mortality (n=547) (Liguori and Burruss 2003).

Solutions for the problem compact design shown in Figure 5.17 include the following:

- Install phase covers over the lower, outer phase conductors (Figure 5.18). Note that phase covers may not fit on compact designs with side-tied conductors or angled insulators.
- Replace the existing epoxy bracket with a longer bracket and lower it to achieve a 150-cm (60-in) phase separation (see Figure 5.19, Solution 3).

In addition, there are several avian-safe design options for new construction that may

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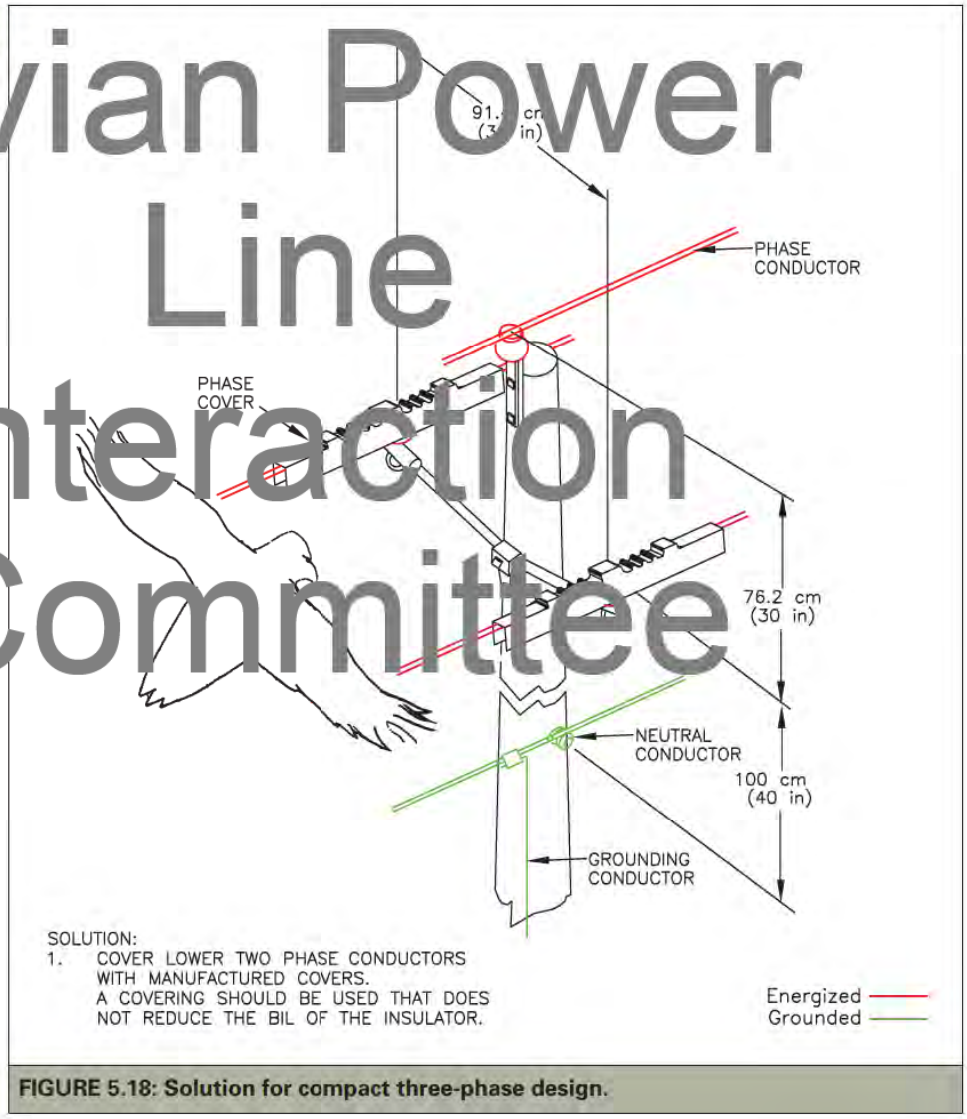

FIGURE 5.18: Solution for compact three-phase design.

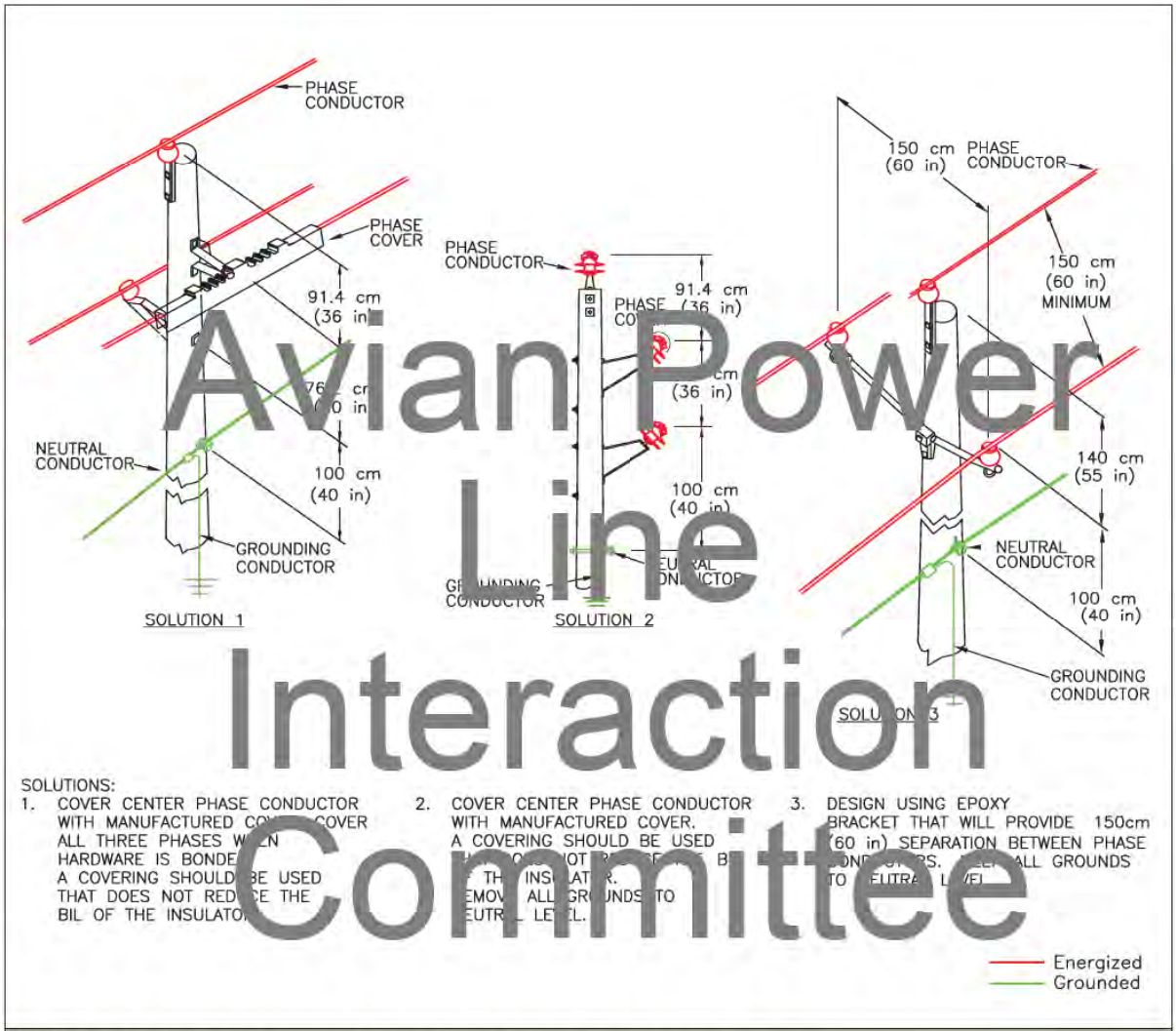

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FIGURE 5.19: Avian-safe compact three-phase designs for new construction.

be used where ROW restrictions require compact configurations in areas that attract large birds (Figure 5.19). Inventories of avian populations, food sources, locations preferred by birds, alternative configurations, electrical reliability requirements, and other data should be obtained before determining the final design.

The armless configuration, in which conductors are mounted on horizontal post insulators, can be used for distribution lines (Figure 5.20). In utility service areas subject to high lightning levels, lightning protection on such lines may include an overhead conductor that must be grounded. On some installations with wood poles, utilities, particularly in salt

spray or other contaminated areas, may bond the bases of the post insulators to the pole-grounding conductor to prevent pole fires. A bird perched on the insulator can be electrocuted if it comes in contact with the energized conductor and either the grounded insulator base or the bonding conductor. Solutions for avian-safe horizontal post designs are provided in Figure 5.21. Solution options include:

- Covering the vertical grounding conductor from the overhead grounding conductor clamp to 30 cm (12 in) below the lowest phase and disconnecting insulator bracket bonds (Figure 5.21, Solution 1);

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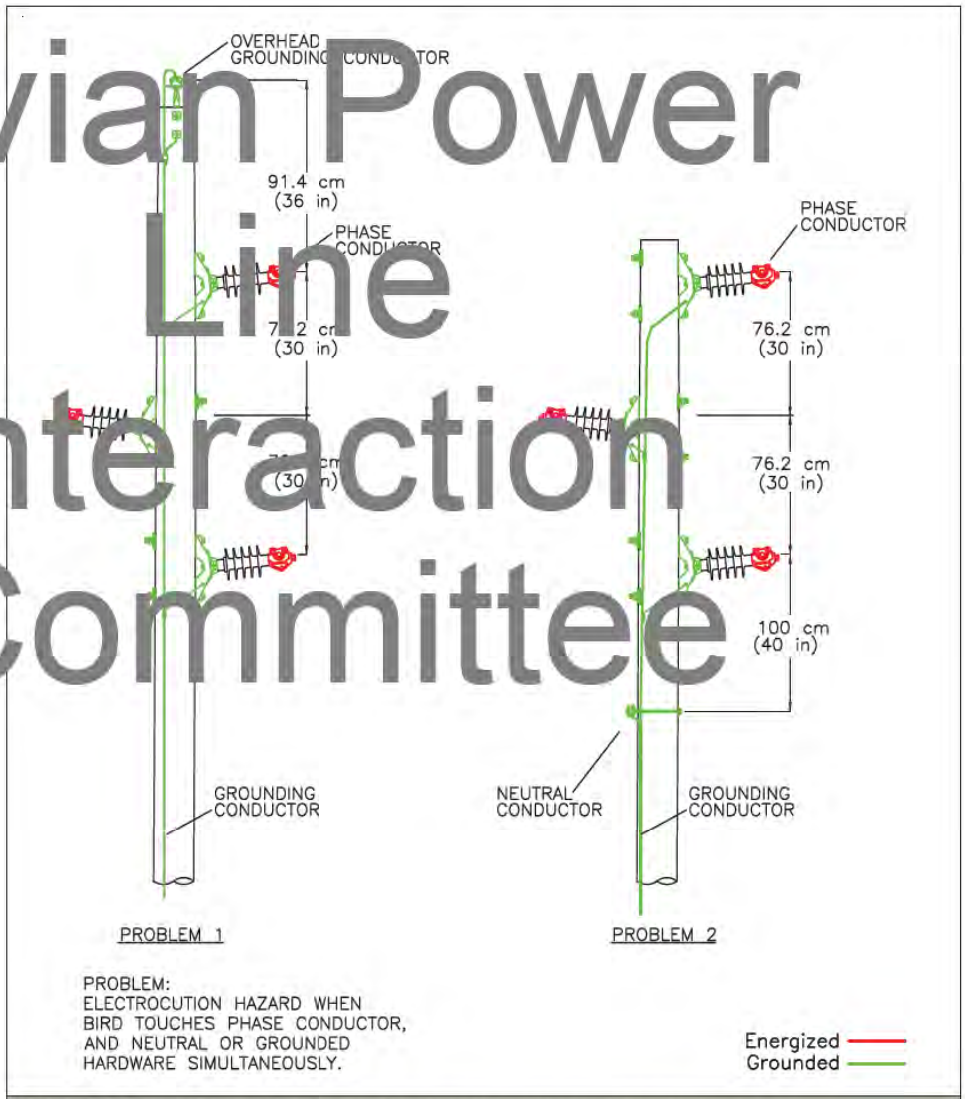

FIGURE 5.20: Problem distribution horizontal post insulator designs.

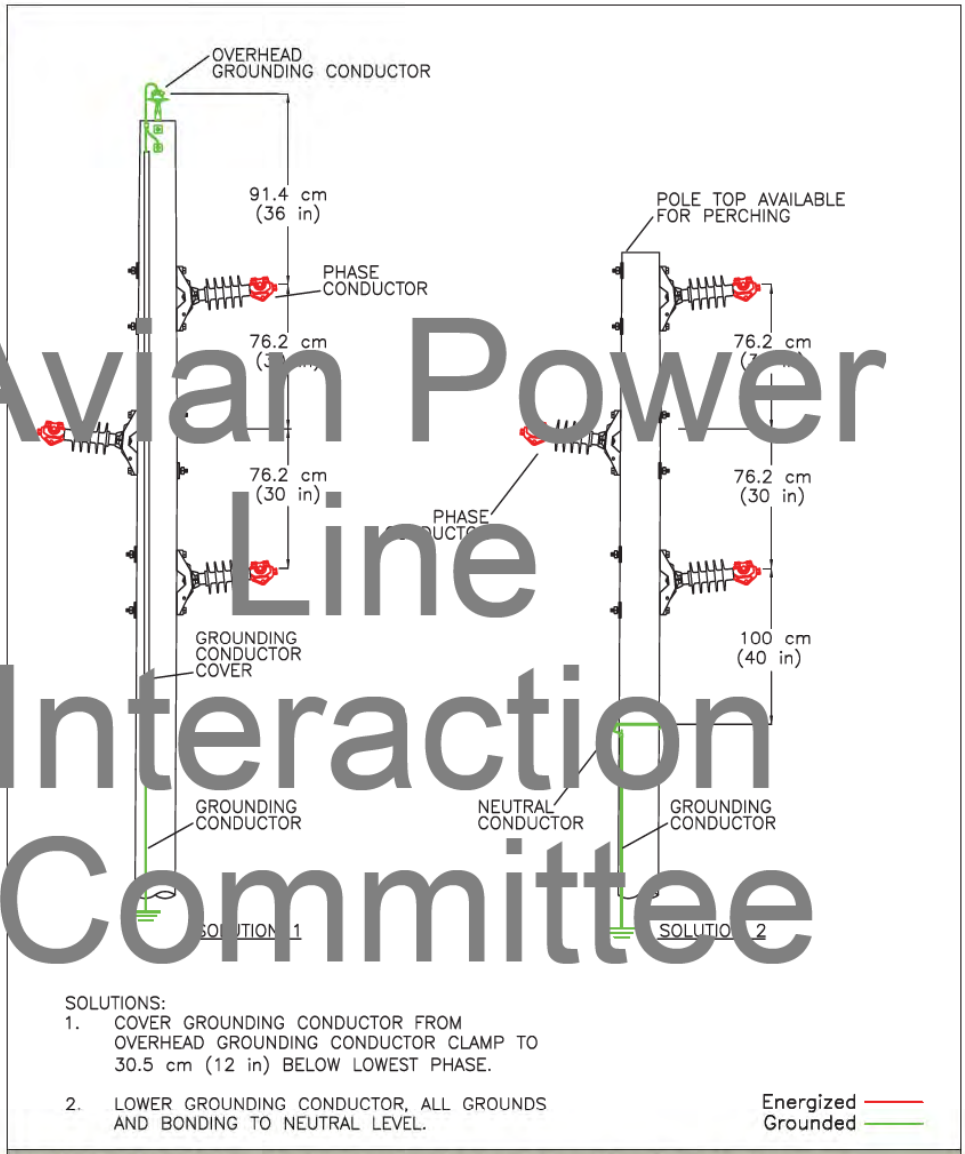

FIGURE 5.21: Solutions for distribution horizontal post insulator designs.

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- Removing all bonds and the grounding conductor to the neutral (Figure 5.21, Solution 2); or
- Installing phase covers on all three phases if hardware is bonded and grounding conductor is uncovered.

Corner Poles

Poles designed to accommodate directional changes in power lines (Figure 5.22) can create hazards for birds. On these poles, uncovered jumper wires are normally used to complete electrical connections and connect the phase

conductors. In this case, the typical 110-cm (42-in) or less horizontal separation between conductors is insufficient to protect large birds. If grounded metal crossarm braces, grounded guying attachments, and uncovered grounding conductors are present, the avian electrocution risk may be further increased.

On corner poles, the center phase conductor can be attached to the top set of crossarms with additional insulators or

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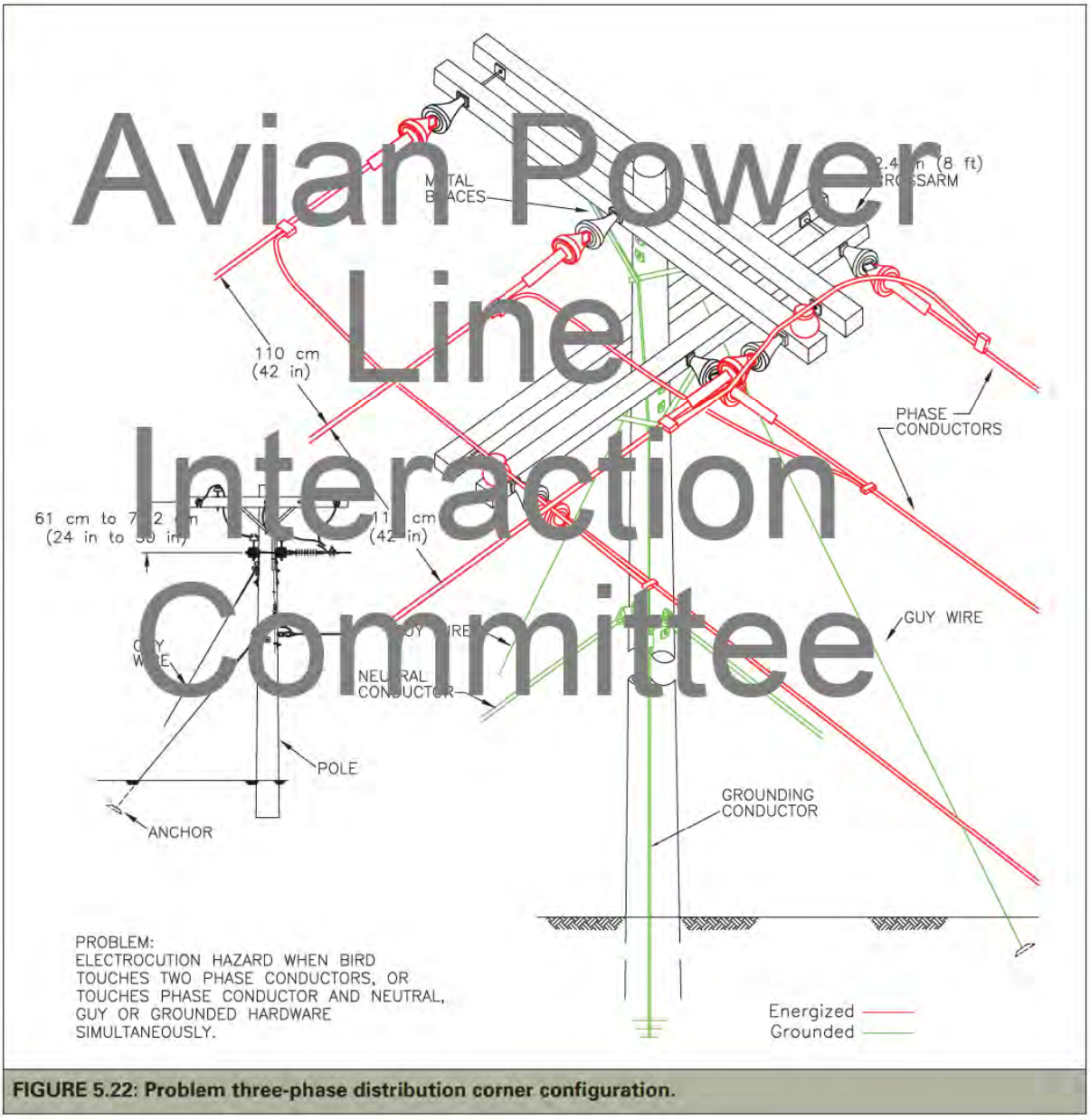

FIGURE 5.22: Problem three-phase distribution corner configuration.

with a non-conducting extension link to prevent contact by birds. An alternative to using an extension link may be to install a phase cover on the center phase (Figure 5.23). The extension link or phase cover should extend 91 cm (36 in) from the pole to the conductor. Bare jumper wires should be covered with a material designed for the purpose or replaced with covered conductors. In addition, all down guy-wires should have guy strain

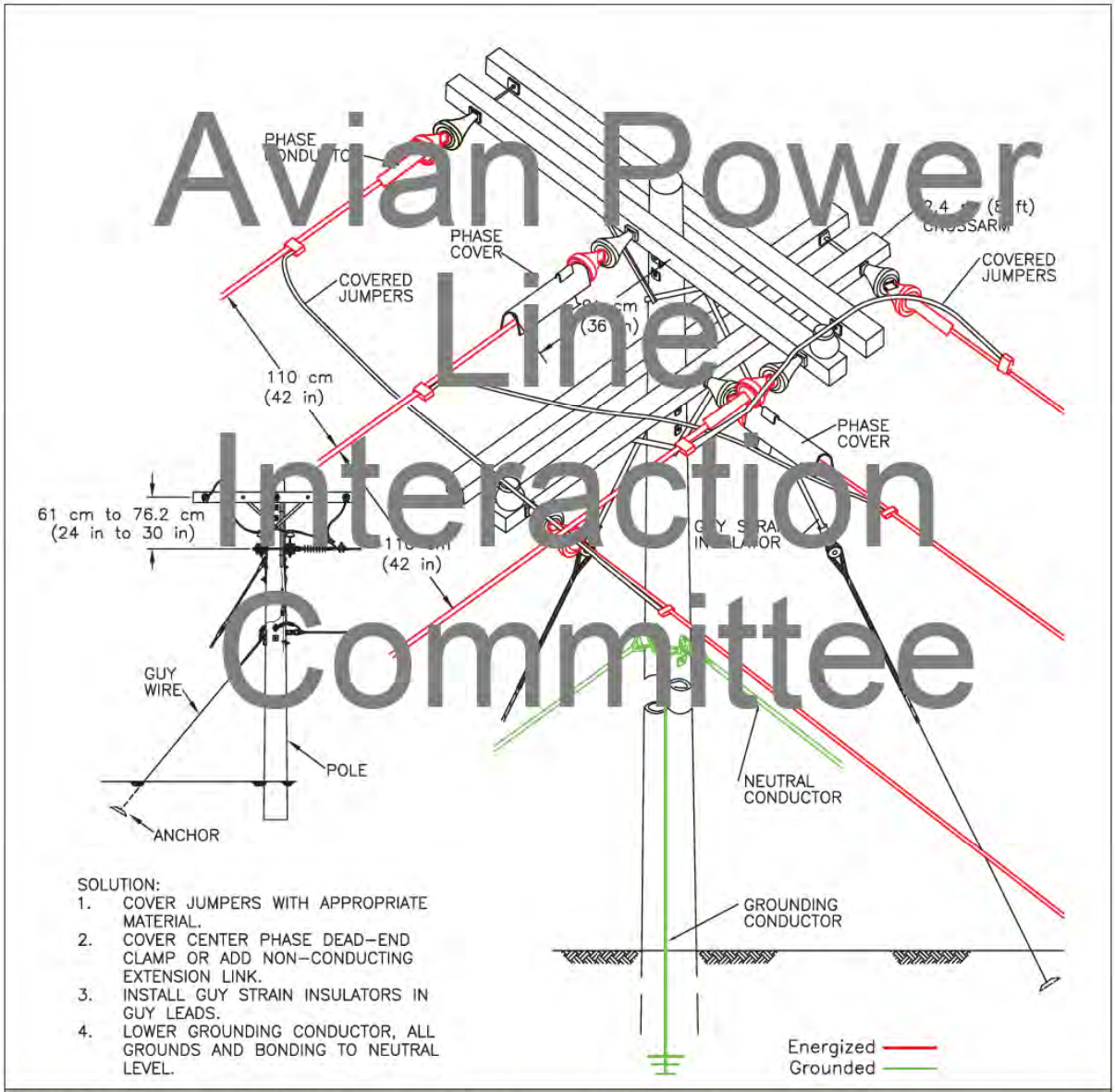

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FIGURE 5.23: Solution for three-phase distribution corner configuration.

insulators to prevent them from acting as grounds.

For new structures, corner poles can be constructed with lowered crossarms (i.e. 104 cm [41 in] from the pole top if using 2.4-m [8-ft] arms) that provide 150 cm (60 in) of phase-to-phase separation. Conventional corner poles can be constructed in the manner depicted in Figure 5.23. Other alternatives are the vertical designs shown in Figures 5.24

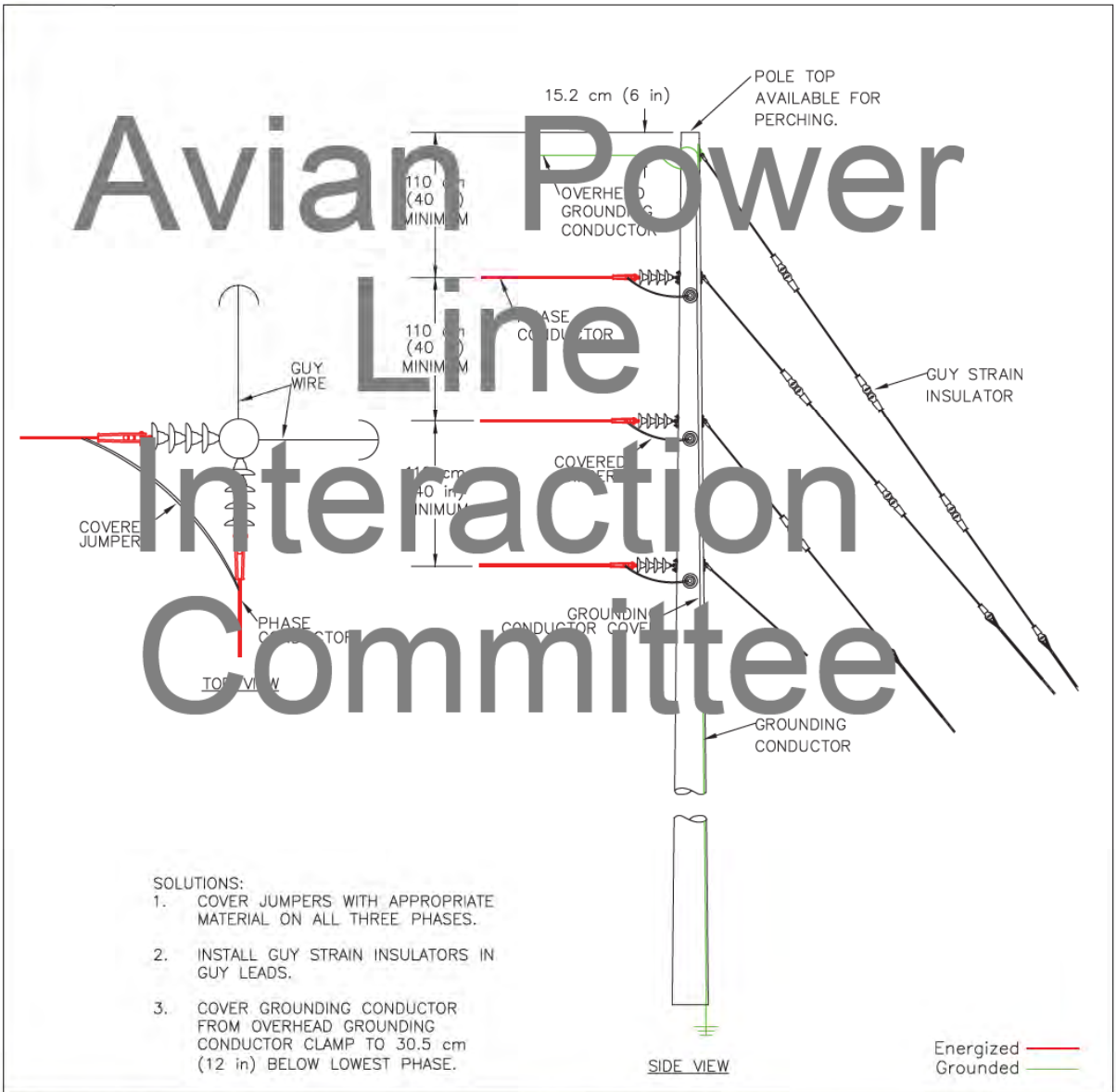

FIGURE 5.24: Three-phase vertical corner configuration—overhead grounding conductor on pole top.

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and 5.25, which prevent simultaneous contact by birds. In Figure 24, the grounding conductor should be covered with a material appropriate for avian protection. Taller poles are usually required, but vertical avian-safe corner designs eliminate crossarms and unwieldy jumper wire arrangements. They can also accommodate overhead grounding conductors.

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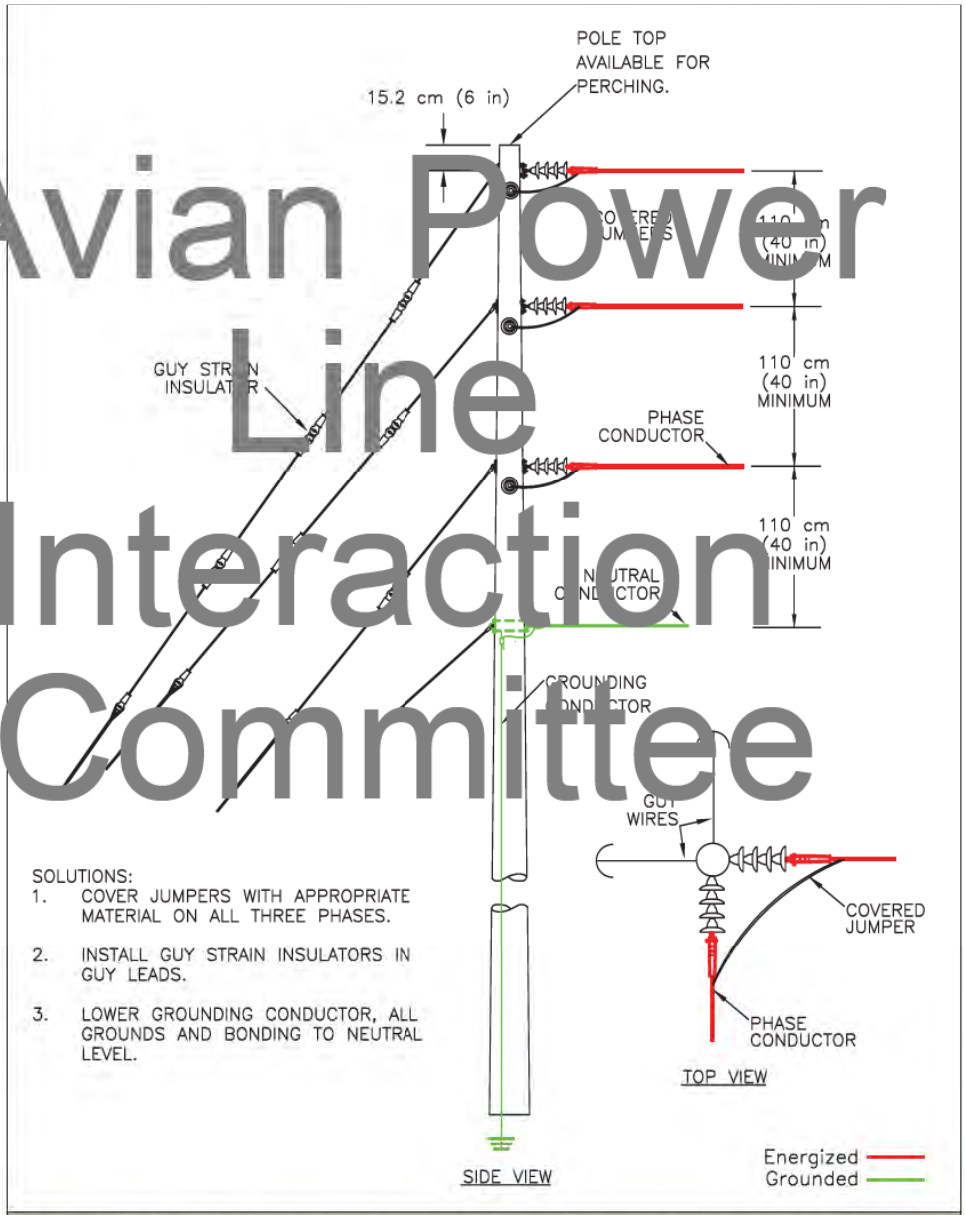

FIGURE 5.25: Three-phase vertical corner configuration—neutral below phases.

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STEEL/CONCRETE POLES

Steel/Concrete Pole Construction Worldwide

Most distribution power poles in the United States are made of wood, a nonconductive material.[30] In contrast, steel and concrete poles are commonly used in distribution line construction in Europe and other parts of the world. In Western Europe, it is estimated over 90% of the distribution poles are metal with grounded metal crossarms (Janss and Ferrer 1999). On these configurations, electrocutions can occur from phase conductor to pole or phase conductor to metal crossarm, placing both large and small birds at risk (Bayle 1999; Negro 1999; Janss and Ferrer 1999). Accordingly, European electrocution mitigation methods differ from those of the United States because measures effective on wooden power poles have not solved electrocution problems on conductive poles (Janss and Ferrer 1999). However, covering conductors with a dielectric material appropriate for avian protection is typically more effective at preventing electrocution than is perch management, regardless of whether the pole is wooden, steel, or concrete (Negro 1999). Covering conductors is the preferred method on new, retrofitted, steel and concrete poles in Europe (Janss and Ferrer 1999).

Concrete poles, with their internal metal rebar support structure, pose similar electrocution risks to metal poles. Concrete poles also provide a pathway to ground, further increasing their electrocution risk, especially when wet or when fitted with conductive crossarms. The largest remaining black-tailed prairie dog *(Cynomys ludovicianus)* colony complex in North America is in northwestern Chihuahua, Mexico (Ceballos et al. 1993). This complex supports a high density of raptors and nearby power lines are constructed with reinforced concrete poles with steel crossarms. In 2000, 1,826 power poles were surveyed and 49 electrocuted birds were found, including Chihuahuan ravens *(Corvus cryptoleucus)*, ferruginous hawks *(Buteo regalis)*, red-tailed hawks *(B. jamaicensis)*, prairie falcons *(Falco mexicanus)*, American kestrels *(F. sparverius)*, and golden eagles. The number of electrocutions led researchers to conclude that these poles represent a serious risk for wintering raptors (Cartron et al. 2000). The subsequent replacement of steel crossarms with wooden arms on over 200 poles in this area significantly reduced the electrocution risk of these structures (Cartron et al. 2005).

Steel/Concrete Pole Construction in the United States

Historically, utilities in the United States have primarily used wood for distribution poles and crossarms. Accordingly, many avian retrofitting techniques today are designed for use on wood structures. Fiberglass, concrete, and steel poles are now being used more in distribution line construction for a variety of reasons. Sometimes non-wood poles are used because they are not susceptible to damage by woodpeckers. In some regions of the United States, woodpecker damage is the most significant cause of pole deterioration (Abbey et al. 1997). Steel poles and concrete poles are hard for animals to climb, such as squirrels, raccoons, and other rodents. By keeping these animals off structures, utilities can help reduce outages. Non-wood poles may also be used because they are not susceptible to fungal, bacterial, or insect damage.

Distribution power lines constructed with steel or concrete poles using standard utility configurations can significantly reduce phase-to-ground separations. Fiberglass poles have a higher insulation resistance than steel, concrete, and wood poles.

Single-phase lines are usually constructed without crossarms and support a single energized phase conductor on a pole-top insulator.

[30] The insulation value of wood poles and crossarms is variable based on age, condition, contamination, and wetness.

Wood or fiberglass distribution structures, without pole-top grounds or pole-mounted equipment, generally provide adequate separation for birds (Figure 5.26).

When steel or concrete poles are used (Figure 5.27), a bird perched on the pole top can touch its body to the conductor while simultaneously contacting the grounded pole

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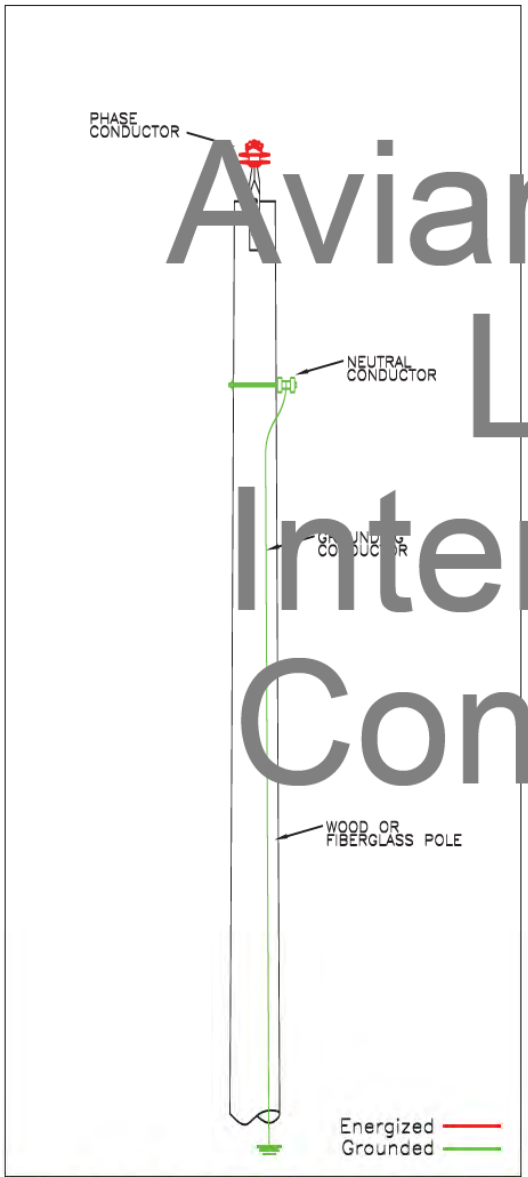

FIGURE 5.26. Typical single-phase distribution configuration on a wood or fiberglass pole.

FIGURE 5.27: Problem single-phase configuration on a steel or reinforced concrete pole.

top or hardware with its feet, resulting in electrocution. One solution to this problem is to install a phase cover (Figure 5.28, Solution 1). Another solution is a two-step process: (1) place the phase conductor on an insulator installed on an extended fiberglass-reinforced pole-top pin to increase the separation between the phase conductor and the pole top, (2) install a pole cap to deter birds from perching on top of the pole (Figure 5.28, Solution 2). In tests with captive raptors at the Rocky Mountain Raptor Program, a pole cap's slick surface discouraged birds from perching (Harness 1998).

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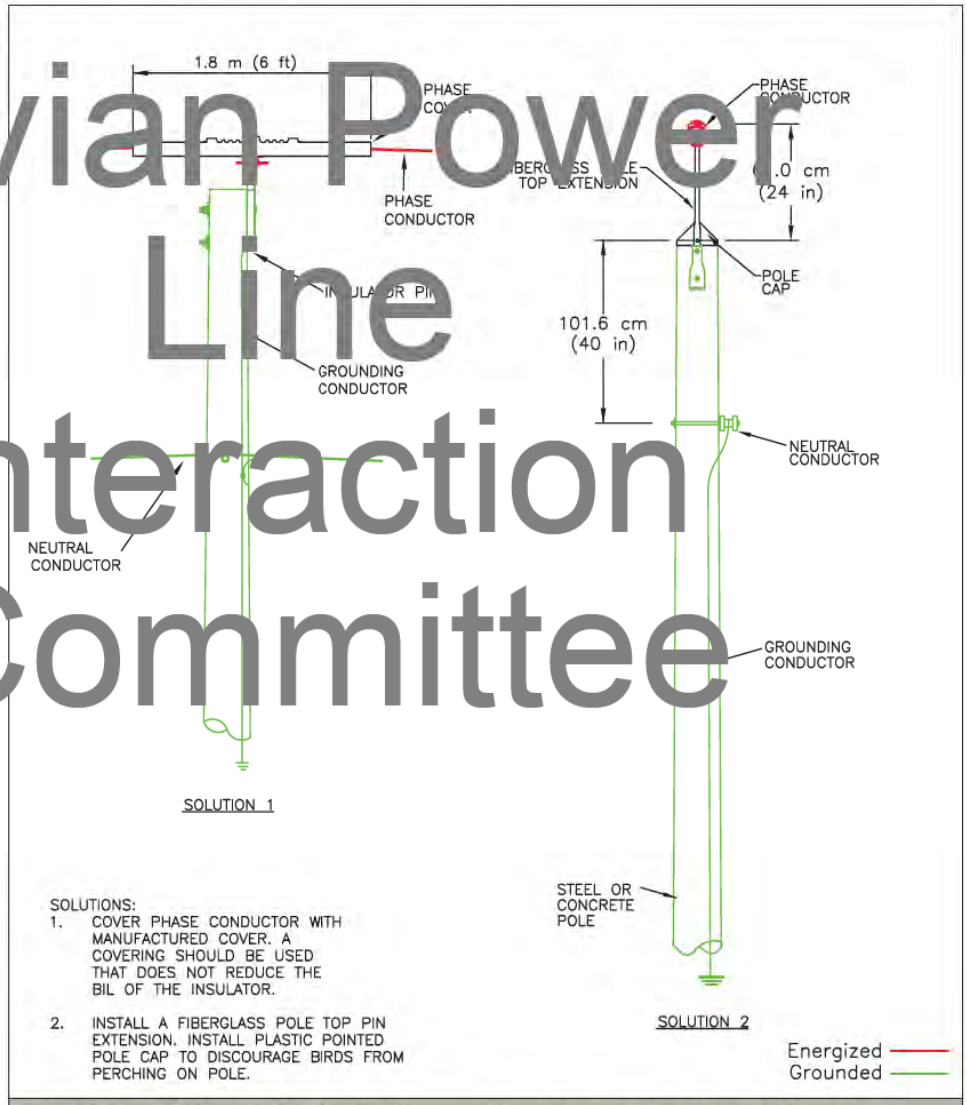

FIGURE 5.28: Solutions for single-phase configuration on a steel or reinforced concrete pole.

When steel or concrete poles are used for multi-phase structures, the critical separations for birds are both the phase-to-phase and the phase-to-pole (i.e., phase-to-ground) separation (Figure 5.29). Although the phase-to-phase issues are the same as encountered on wood poles, the phase-to-pole issue is not.

As on the single-phase structure (Figure 5.28, Solution 2), additional separation should be provided for the center pole-top phase conductor by placing it on an extension fiberglass reinforced pole-top pin and adding a pole cap to discourage perching. Additionally, wood or fiberglass crossarms should be used. Steel crossarms mounted on steel poles should be avoided because their minimal phase-to-ground separations make them extremely hazardous. Birds landing on grounded steel arms become grounded and need only touch one energized conductor or piece of hardware to be electrocuted.

The reduced phase-to-ground separations found on existing steel or concrete poles can be mitigated in several ways. One method is

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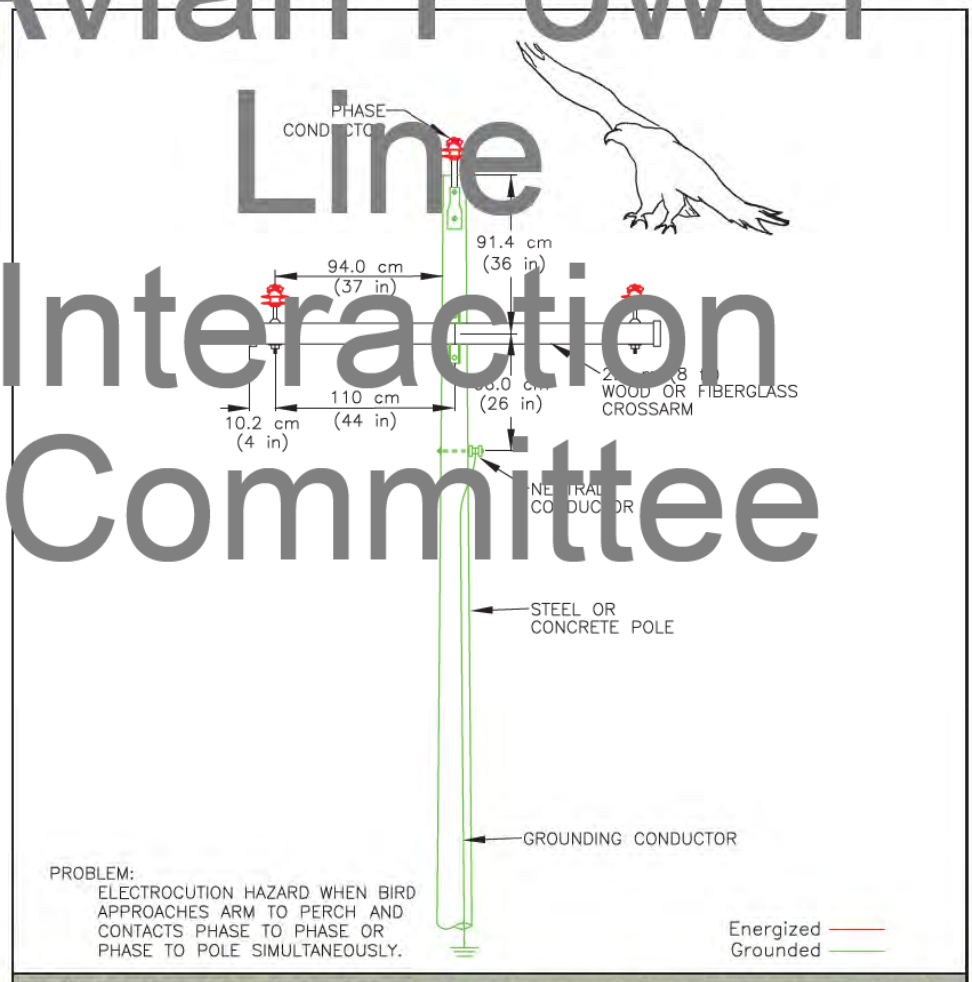

FIGURE 5.29: Problem three-phase configuration on a steel or reinforced concrete pole.

to cover the pole from the crossarm to the pole top with a material designed for this purpose (Figure 5.30). This can be achieved by wrapping a band of 40-mil thermoplastic polymer membrane backed with a pressure-sensitive adhesive around the pole from the crossarm up to and including the top of the pole, or by spraying the same area with a protective coating that has sufficient dielectric strength. A utility performed a dielectric test of a thermoplastic wrap, and determined that a 46 x 167-cm (18 x 66-in) piece allows no appreciable current leakage at 35 kV for a three-minute duration. The thermoplastic wrap also can effectively increase phase-to-ground separations on narrow profile configurations.

As an alternative to wrapping the pole top, perch discouragers can be mounted on the crossarm to deter birds from perching on the crossarm (Figure 5.31). Crossarms fitted with perch discouragers are effective in reducing

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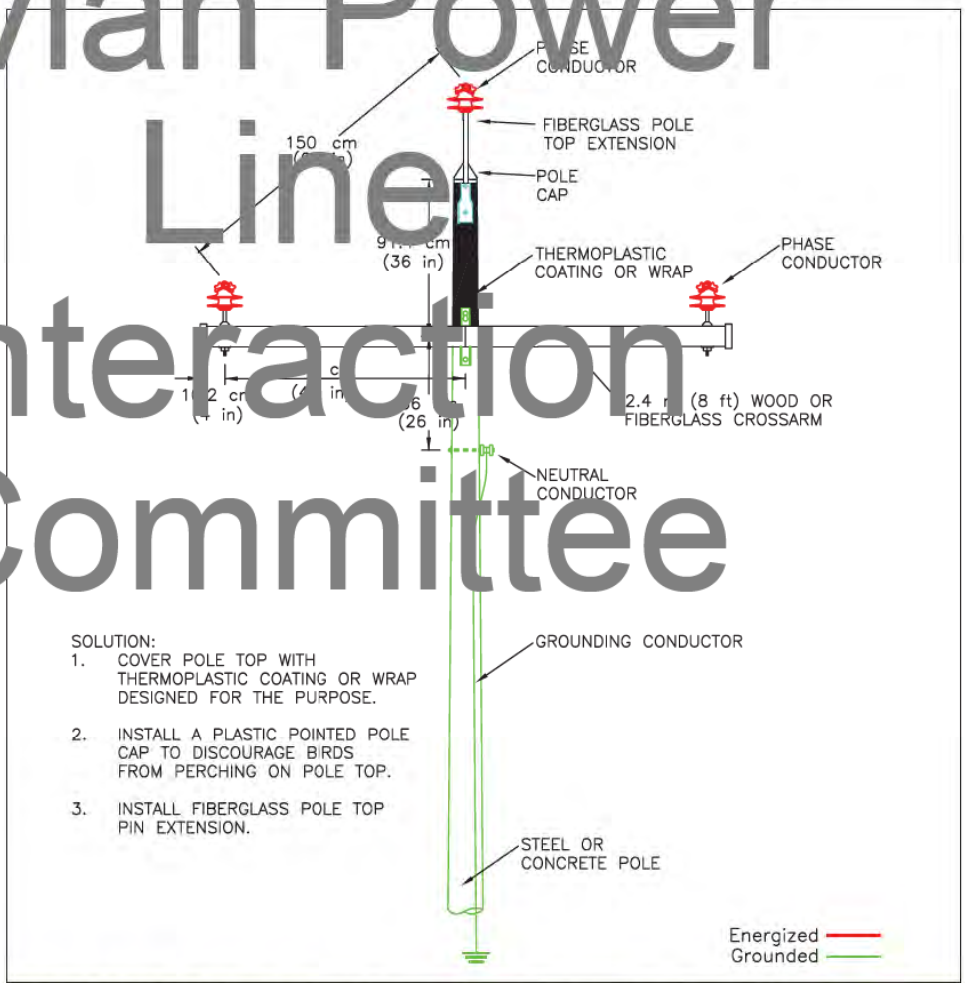

FIGURE 5.30: Solution for three-phase configuration on a steel or reinforced concrete pole using thermoplastic wrap.

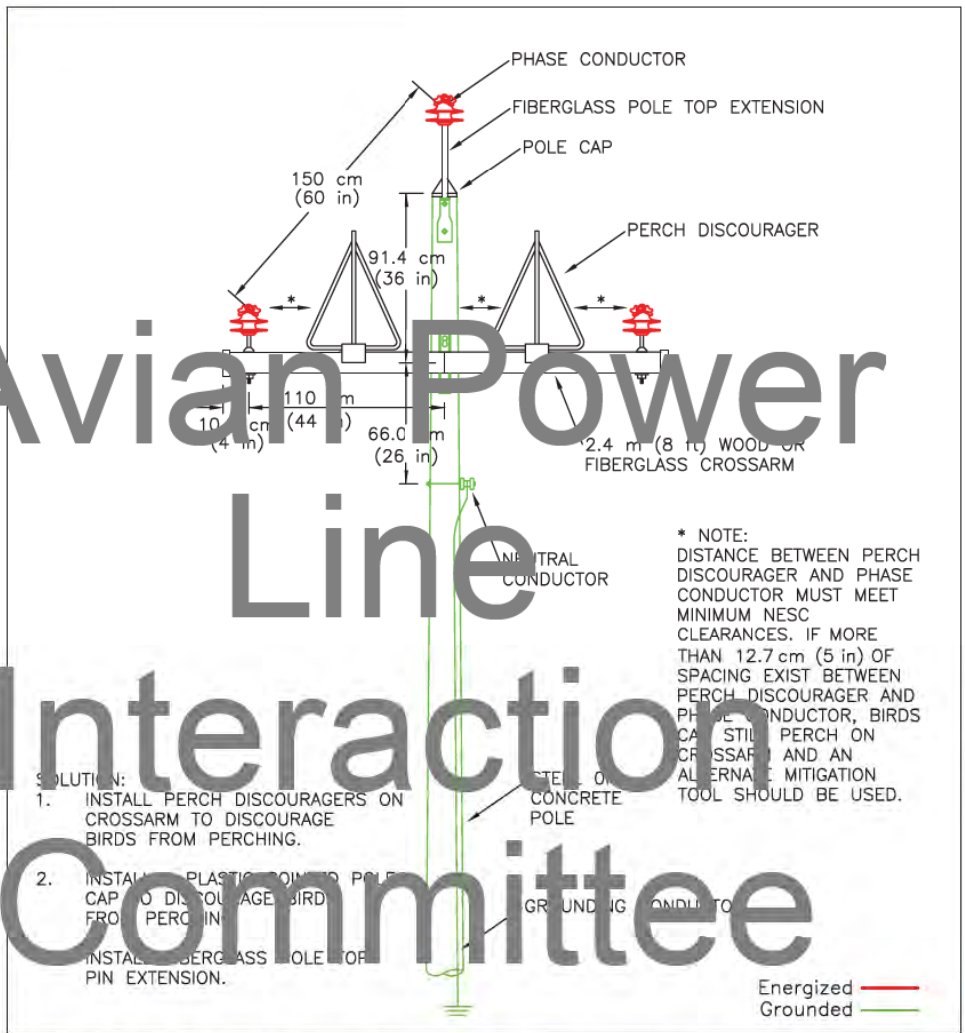

FIGURE 5.31: Solution for three-phase configuration on a steel or reinforced concrete pole using perch discouragers.

some but may not eliminate all avian mortality (Harness and Garrett 1999). Perch discouragers also may shift birds to other nearby poles that might not be any safer. For guidance on the use of perch discouragers from both biological and engineering perspectives, see page 17 and page 68.

Another suitable method for reducing avian electrocution risk is covering the outer two phase conductors to prevent phase-to-pole (i.e., phase-to-ground) contacts (Figure 5.32). On the center phase, a phase cover or a pole cap with extension pin should also be installed.

Another option is to suspend two of the energized conductors from the crossarm, instead of supporting them on the arm (Figure 5.33). Suspending the conductors allows birds to perch on the crossarm without con-

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tacting energized conductors. A pole cap and extended fiberglass reinforced insulator pin should still be used to discourage perching on the pole top to prevent contact with the center phase. Suspending the insulators and conductors will also allow utilities to achieve 150-cm (60-in) separation with 1.8 or 2.4-m (6 or 8-ft) crossarms (as shown in Figure 5.33). If vertical construction is used with steel or reinforced concrete poles, phase covers should be installed on all three conductors.

Avian-safe separation can be achieved on steel and reinforced concrete dead-end or corner poles by installing fiberglass extension links or adding additional insulators between the primary dead-end suspension insulators and the pole. This solution is similar to those recommended for three-phase distribution dead-end and corner configurations using wooden poles and crossarms (Figures 5.16 and 5.23). Bare jumper wires are commonly used to connect incoming conductors to the

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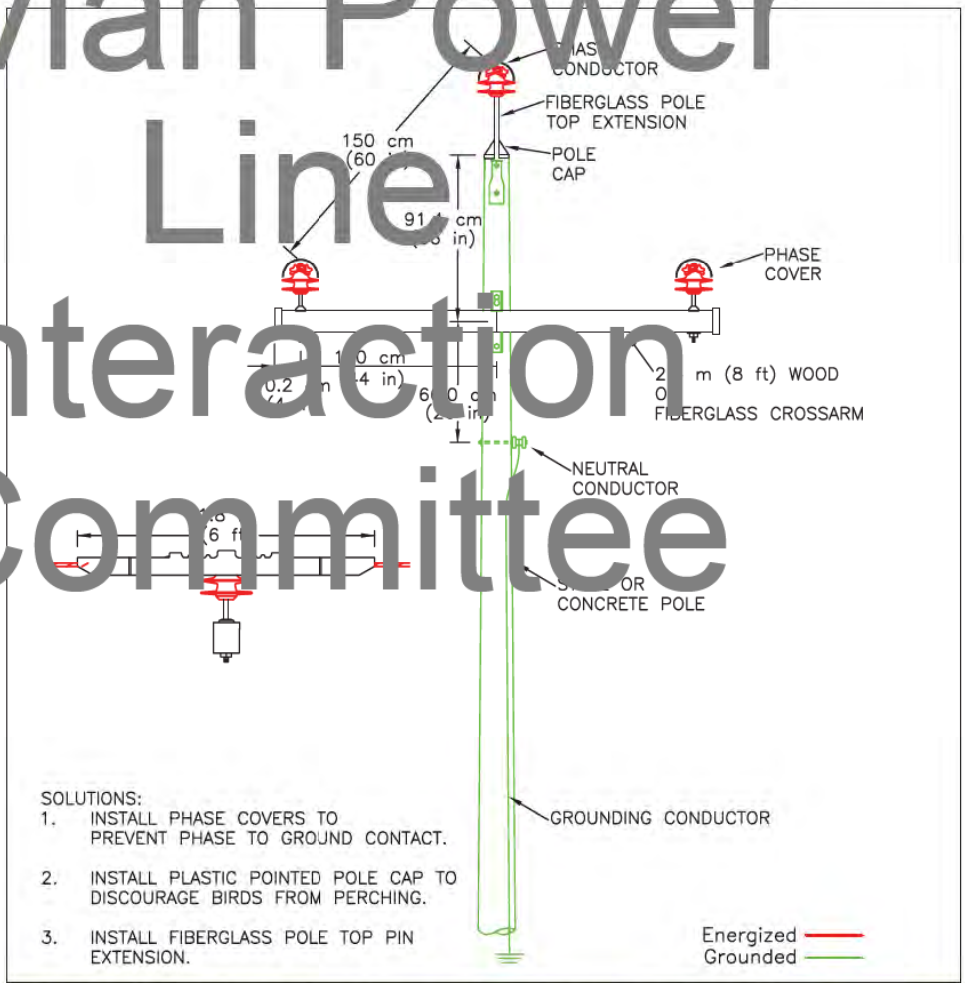

FIGURE 5.32: Solution for three-phase configuration on a steel or reinforced concrete pole using phase covers.

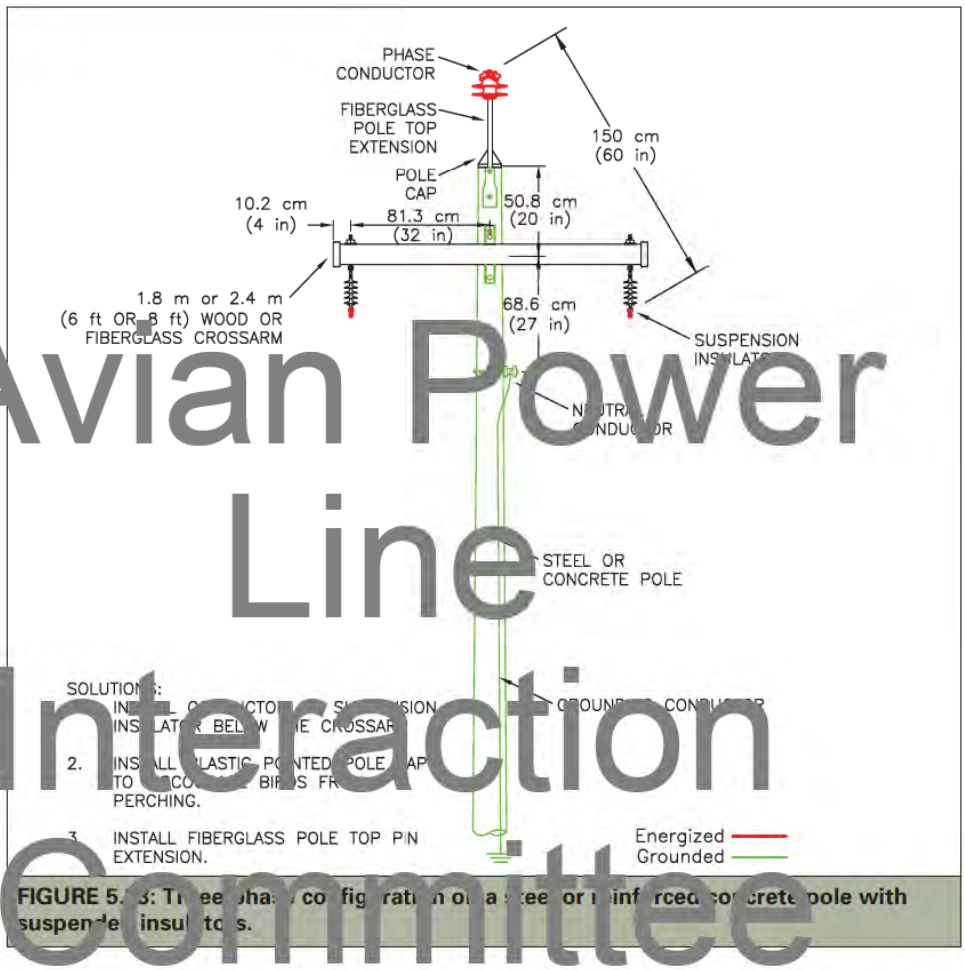

FIGURE 5.13: Three-phase configuration on a steel or reinforced concrete pole with suspended insulators.

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outgoing conductors, making the line turn or tapping off the main circuit. Covering the jumper wires with a material suitable for avian protection or replacing them with covered conductor will reduce electrocution risk.

Problem Transmission Designs

Although transmission lines rarely electrocute birds, there are a few exceptions, particularly on lower voltage transmission lines (i.e., 60 kV or 69 kV).[31] The armless configuration, in which conductors are mounted on horizontal post insulators, commonly used for distribution lines (see Figures 5.20 and 5.21), may also be used for some transmission lines below 115 kV (Figure 5.34). In areas subject to high lightning levels, lightning protection may include an overhead static wire that must be grounded. On installations with wood poles, utilities, particularly in salt spray or other contaminated areas, may bond the bases of the post insulators to the grounding conductor to prevent pole fires. A bird perched on the insulator can be electrocuted if it comes in

[31] If distribution underbuild is present on a transmission structure, the recommendations shown previously for distribution configurations should be used to make the underbuild avian-safe.

contact with the energized conductor and either the grounded insulator base or the bonding conductor. From 1991 through 1993, more than 30 golden eagles were electrocuted along approximately 32 km (20 mi) of a 69-kV line with this configuration in central Wyoming (PacifiCorp, unpubl. data).

This configuration was once thought to be avian-safe because it was anticipated that birds would perch on the pole top rather than on the insulators. The 1996 edition of *Suggested Practices* recommended installing perch discouragers on the insulators to prevent electrocutions. However, because birds were still able to fit between the perch discourager and the conductor, the use of perch discouragers alone has been determined ineffective (PacifiCorp, unpubl. data).

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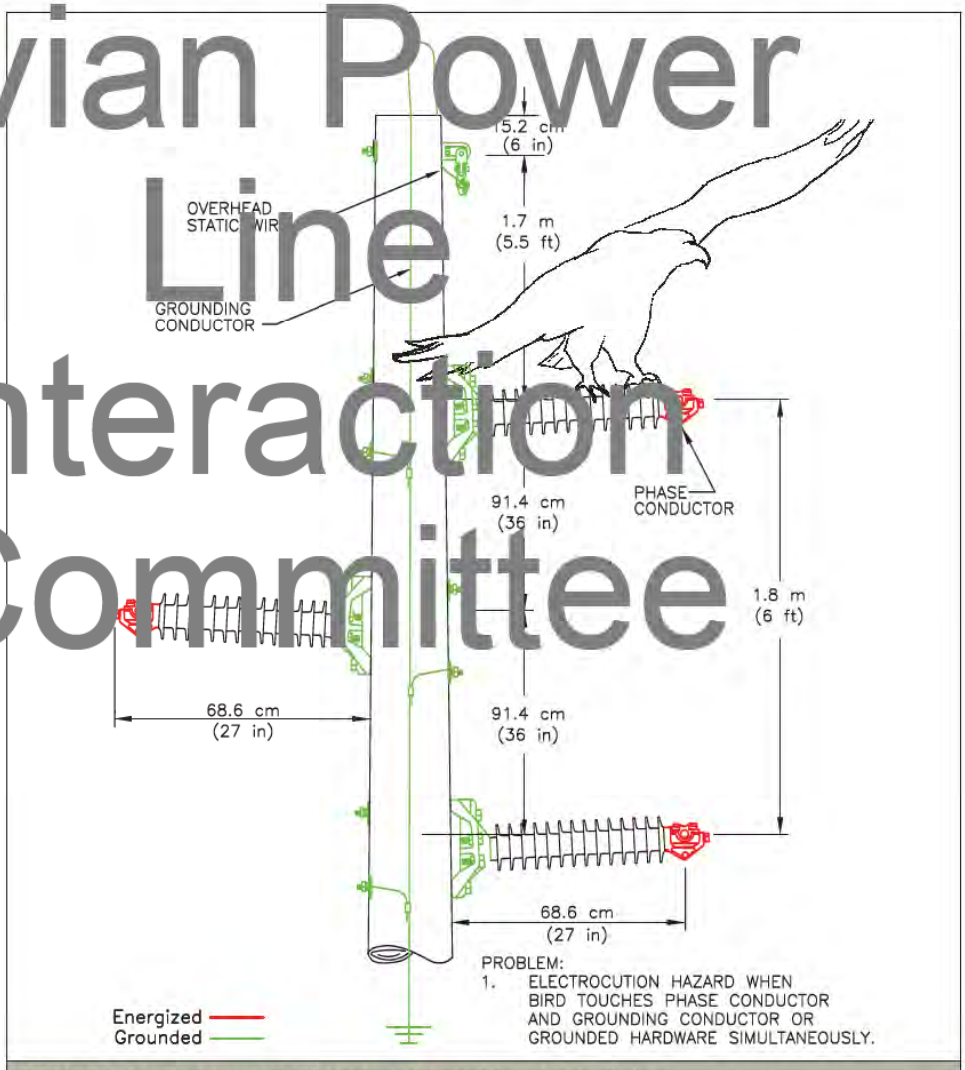

FIGURE 5.34: Problem 69-kV horizontal post insulator design.

Utilities are testing different options (Figure 5.35) for reducing electrocution risk on horizontal post construction. These options include:

- Covering the insulator bases and bolts with cover-up material designed for this purpose.

Installing an insulated pole grounding conductor or covering the pole grounding conductor with appropriate cover-up material, or wood or plastic moldings. The grounding conductor should be covered at least 30.5 cm (12 in) below the lowest energized conductor.

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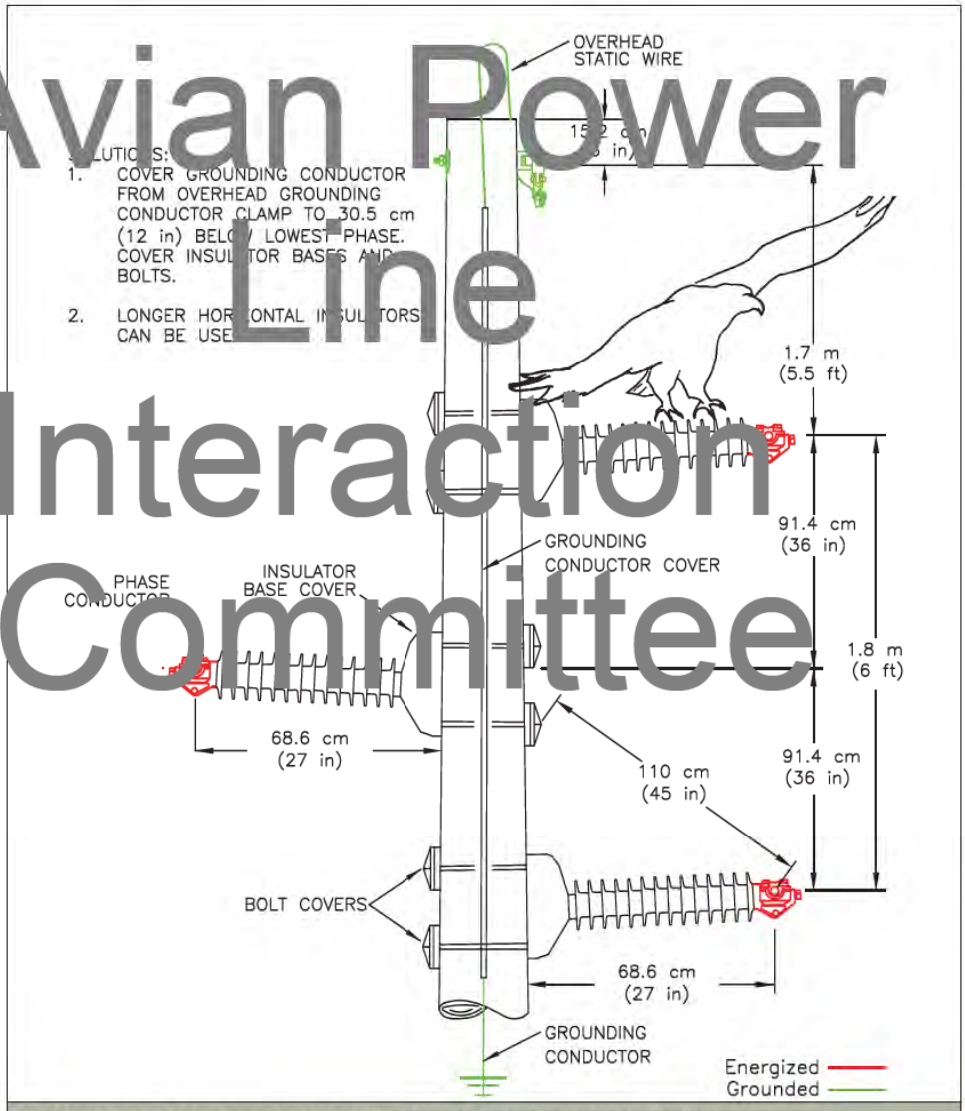

FIGURE 5.35. Solutions for 69-kV horizontal post insulator design.

- Replacing 60-kV or 69-kV post insulators with longer insulators (i.e., 115 or 138 kV) to provide the necessary 150-cm (60-in) separation. Although this may be a costly retrofit option, it can be used for new construction.

The wishbone configuration (Figure 5.36) is commonly used for 34-kV to 69-kV lines. The distance from the top phase to the lower arm can be less than 1 m (3.3 ft), which presents an electrocution hazard when large birds such as eagles or waders touch their heads to the energized conductor while

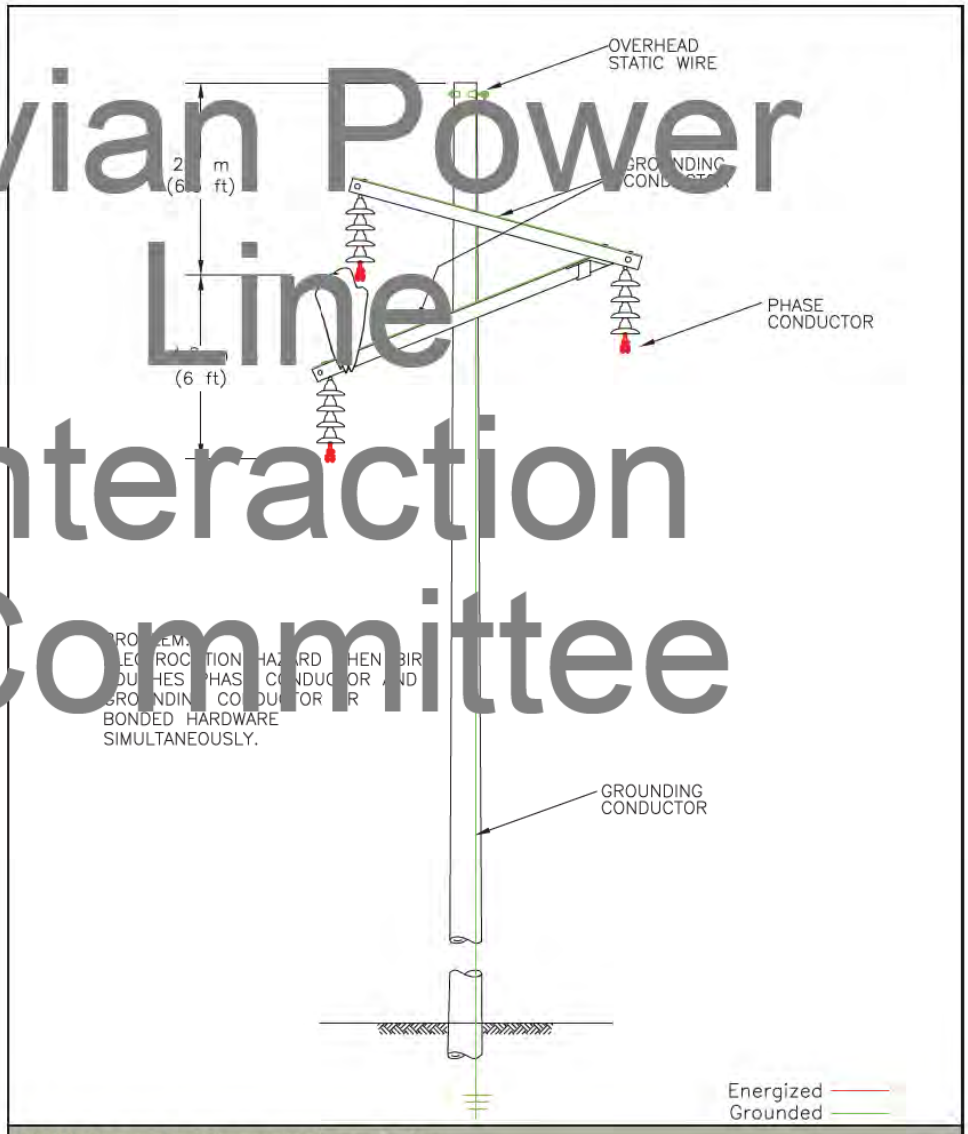

FIGURE 5.36: Problem wishbone design.

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perched on the grounding conductor or bonded hardware on the crossarm.

To prevent phase-to-ground contact on the wishbone design, the grounding conductor and bonded hardware should be covered. This can be accomplished by:

- installing a dielectric cover on the lower crossarm (Figure 5.37), and
- covering the grounding conductor with plastic or wood molding or plastic tubing. A covered ground wire may also be used. The grounding conductor should be

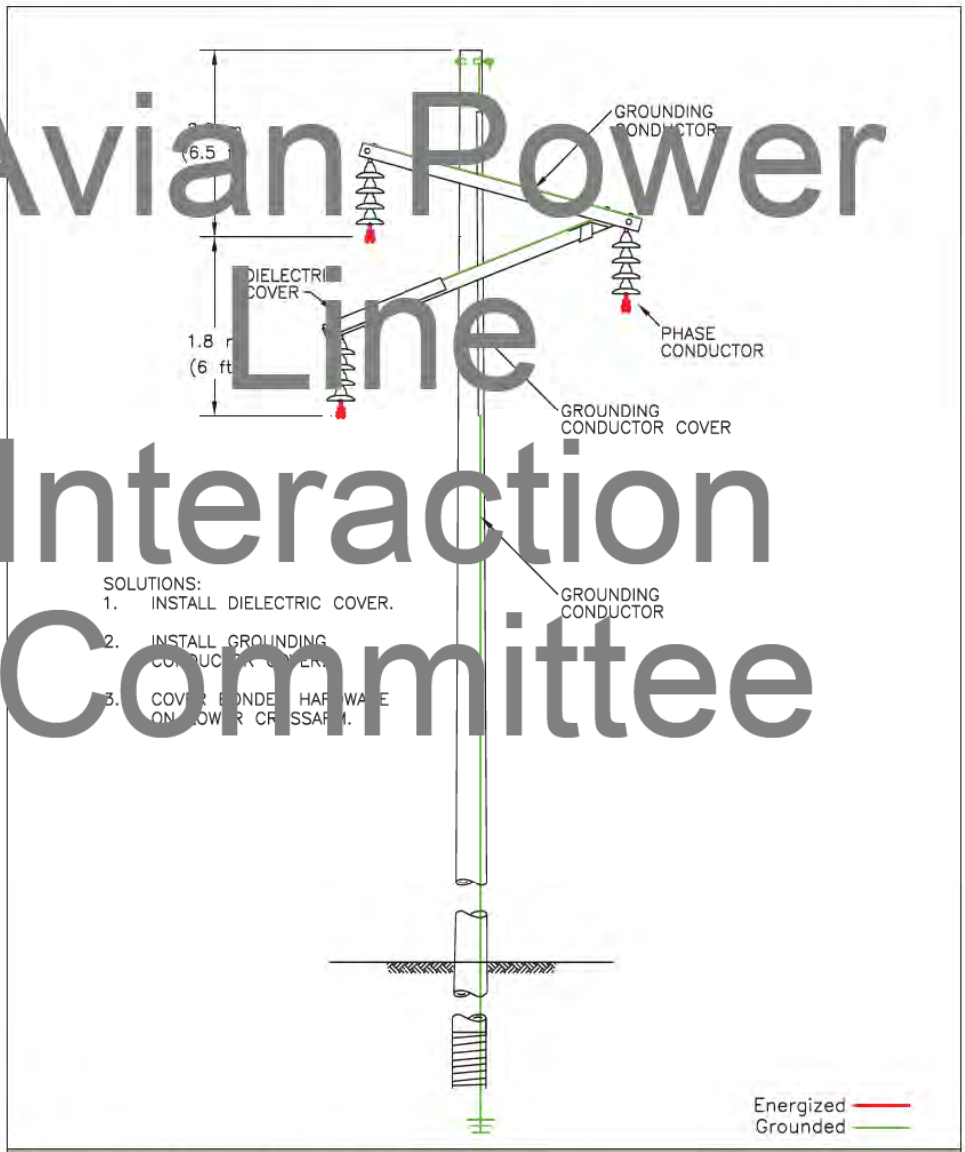

FIGURE 5.37: Solution for the wishbone design.

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covered at least 30.5 cm (12 in) below the lowest energized conductor. Bonded hardware on the lower crossarm should also be covered with a material appropriate for avian protection.

For new construction, a wishbone design that provides adequate separation for large birds can be used (Figure 5.38). An avian-safe suspension configuration (Figure 5.39) can also be used for new construction as an

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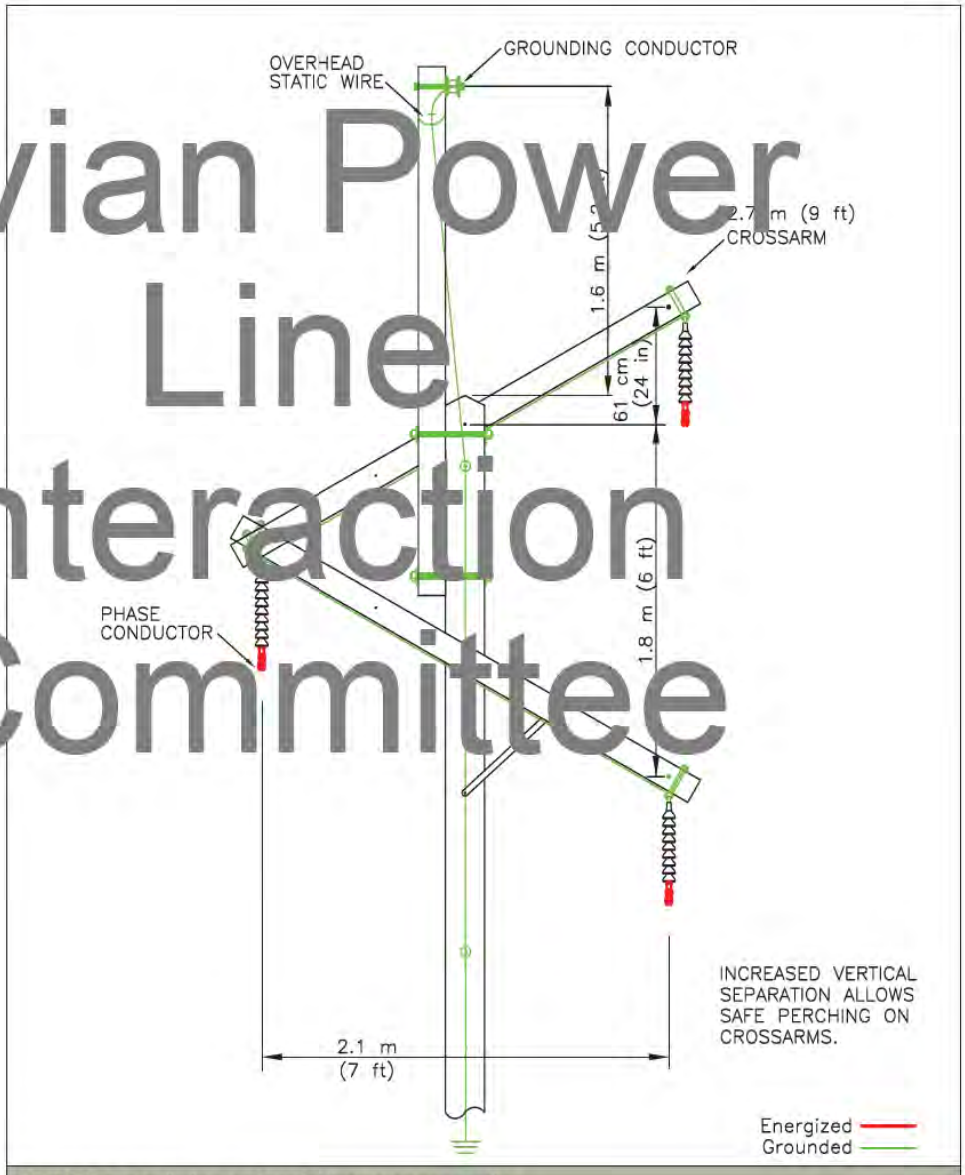

FIGURE 5.38: Avian-safe wishbone construction.

alternative to the wishbone or horizontal post designs. This suspension configuration provides adequate separation between phases and accommodates perching on the davit arms. The ridge pin overhead-grounding conductor attachment may also be replaced with a side-mounted suspension arrangement so the pole top is also available for perching. Although this construction can reduce electrocutions, it may contribute to streamer problems from

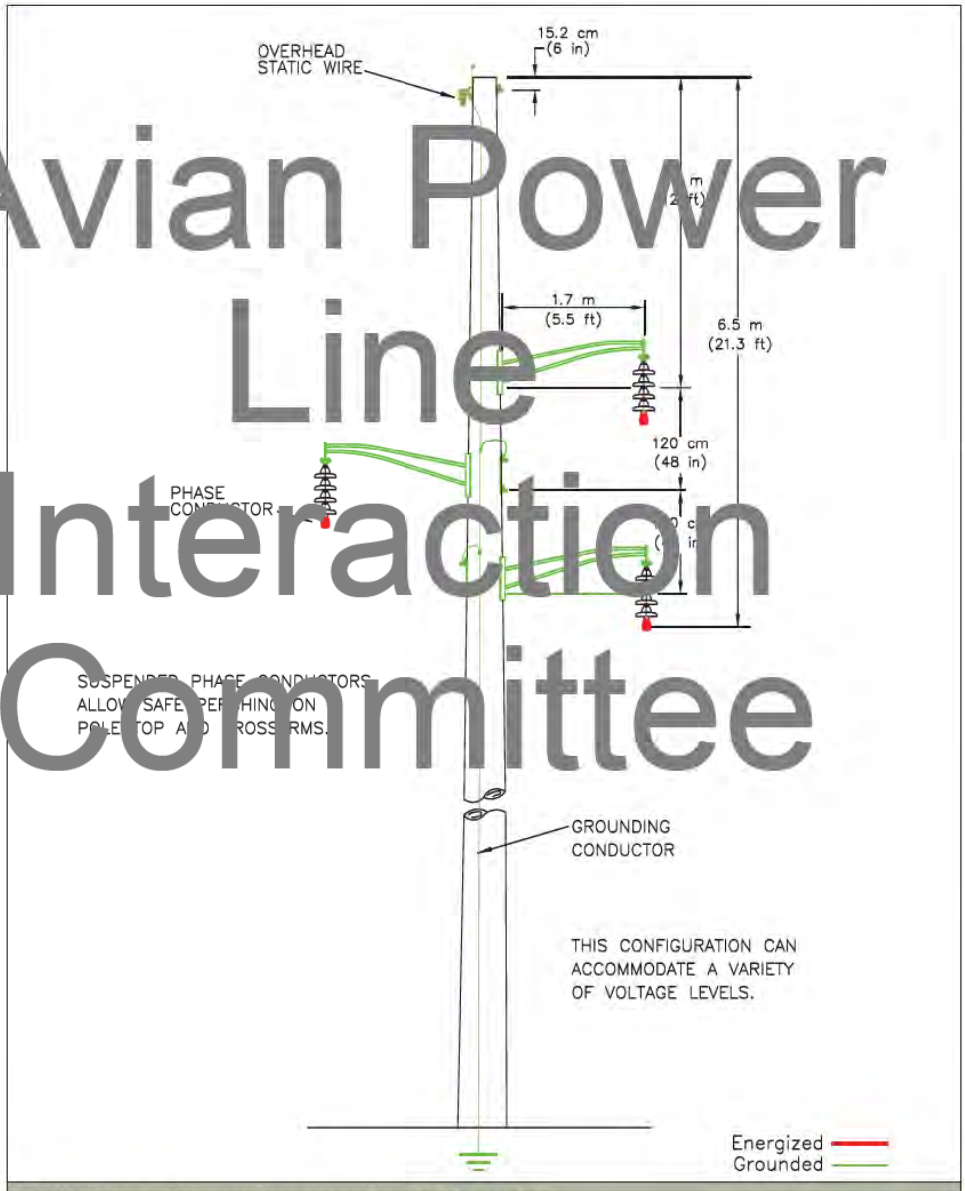

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FIGURE 5.39: Avian-safe suspension configuration.

birds perching on a davit arm and defecating on the conductor or insulator below.

Figure 5.40 depicts a 69-kV design with a steel bayonet added as a lightning rod. This rod is grounded and significantly reduces separation between energized hardware and itself. This configuration can pose a phase-to-ground electrocution risk for birds that attempt to land or perch on the crossarms. In one year, 69 raptor carcasses were recovered from under a line of this configuration in southern Idaho (Idaho Power Co., unpubl. data). If

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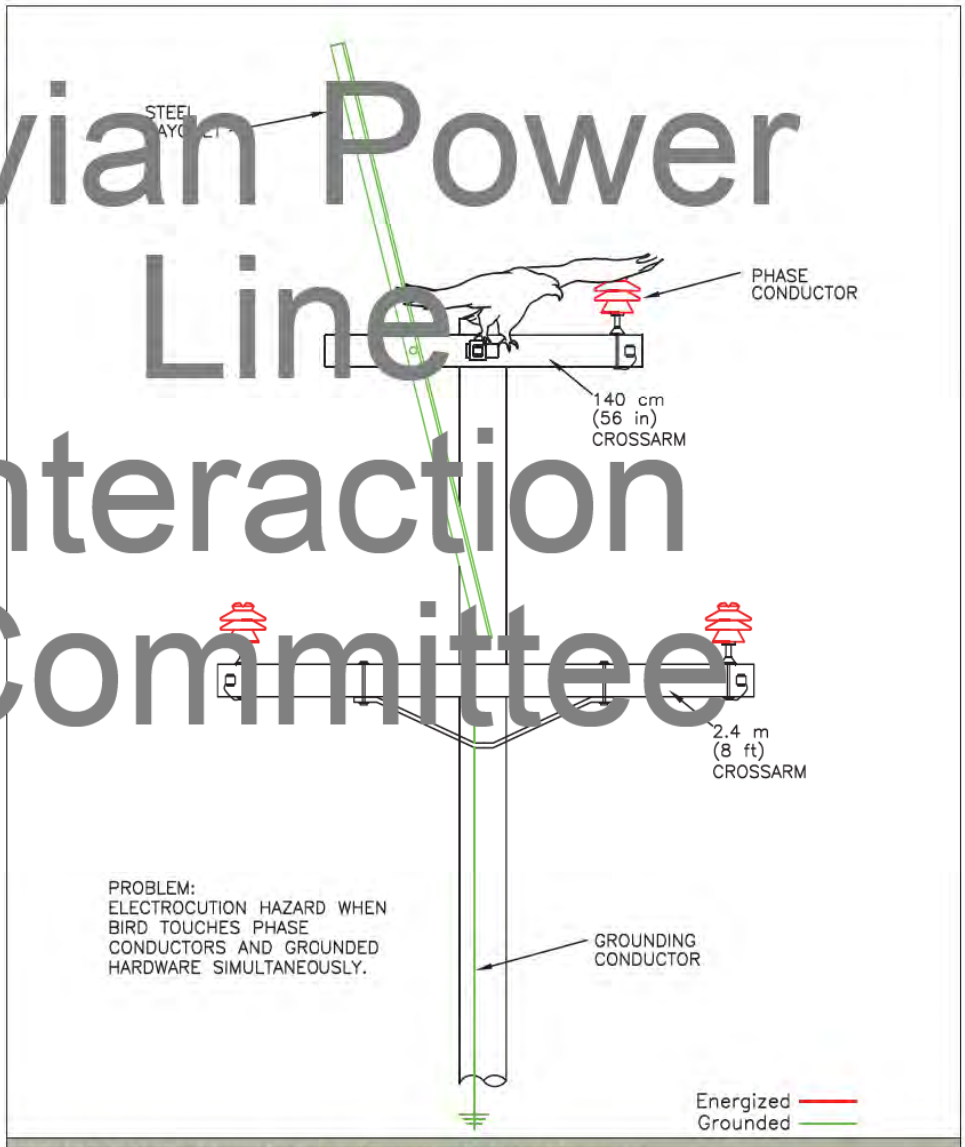

FIGURE 5.40: Problem design with grounded steel bayonet.

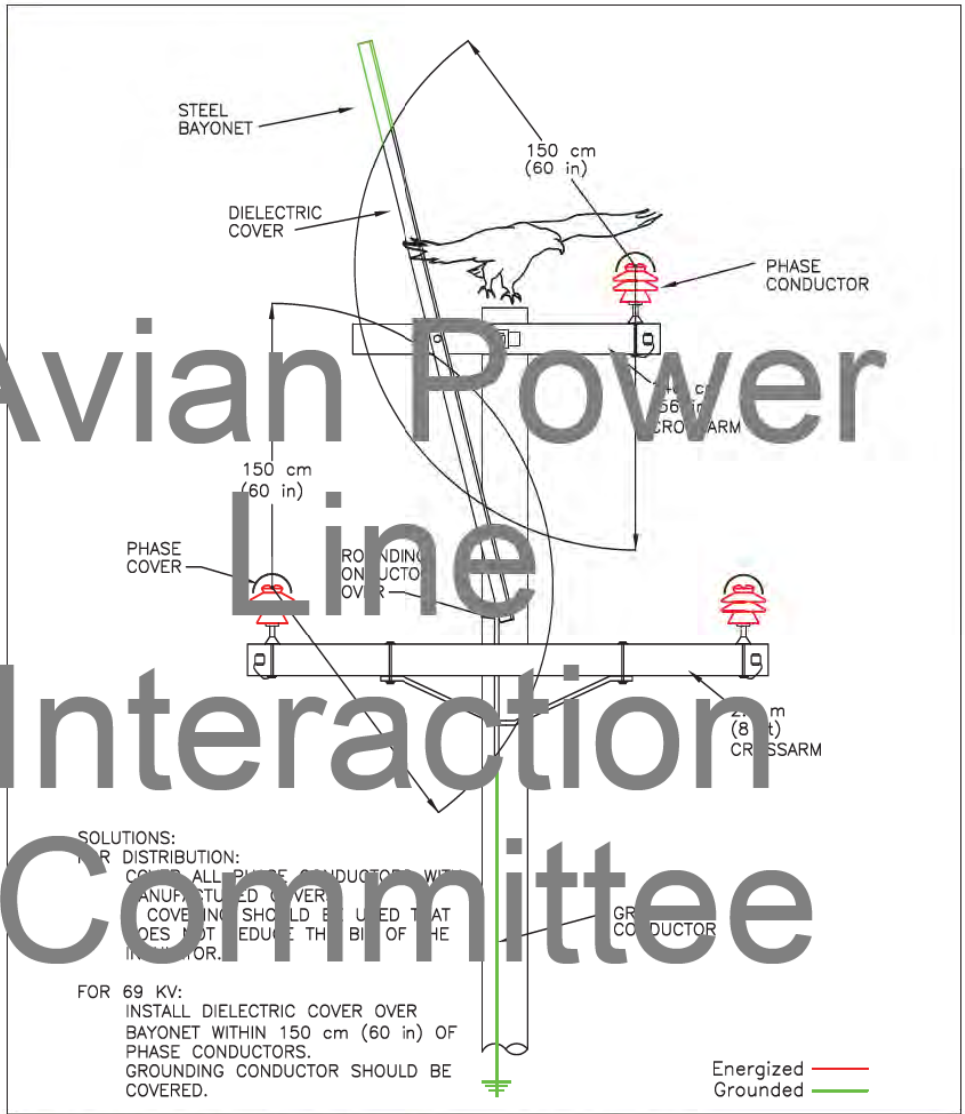

FIGURE 5.41: Solutions for design with grounded steel bayonet.

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this configuration is used for a distribution line, phase covers can be installed on all three phases to prevent electrocutions (Figure 5.41). If mitigating a transmission line of this configuration, the bayonet should be covered with a dielectric cover within 150 cm (60 in) of the phase conductors. The grounding conductor should also be covered.

On the corner structure shown in Figure 5.42 (Problem 1), large birds may be electrocuted by making simultaneous contact with uncovered phase jumpers and the grounded

structure. A solution to this problem is to install horizontal post insulators to move the phase jumpers further from ground (Figure 5.43, Solution 1).

Raptor mortalities have occurred on double-circuit transmission tower designs with insufficient clearance for perching raptors from the grounded center crossarm brace (also called grounded tension member or wind brace) to the top phase (E. Colson, Colson and Associates, pers. comm. in APLIC 1996) (Figure 5.42, Problem 2). Electrocutions on this configuration may be remedied by covering grounded tension members with dielectric material (Figure 5.43, Solution 2). It may also be possible to replace the tension

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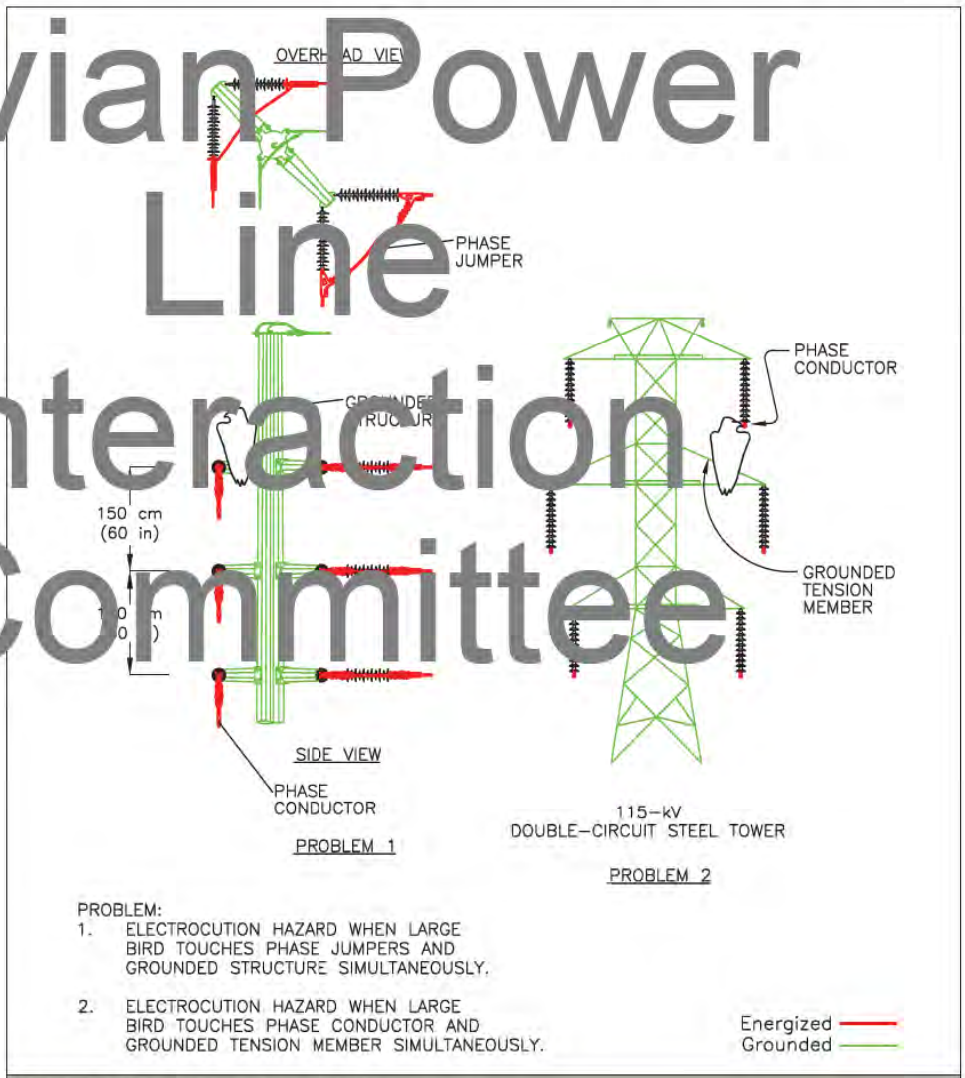

FIGURE 5.42: Problem transmission designs.

member with a non-conducting material (e.g., fiberglass) that meets structural requirements.

Transmission lines may produce arcing, where current jumps, or arcs, from a conductor to a bird on the structure. Though the conductor separation on higher voltage lines is sufficient to avoid this, it can occur on the more closely spaced lower voltage transmission lines. To prevent bird-induced arcing on more closely spaced transmission lines, conductor separation should be increased from 152 cm (60 in) by 0.5 cm (0.2 in) for each kV over 60 kV (see Table 5.3).

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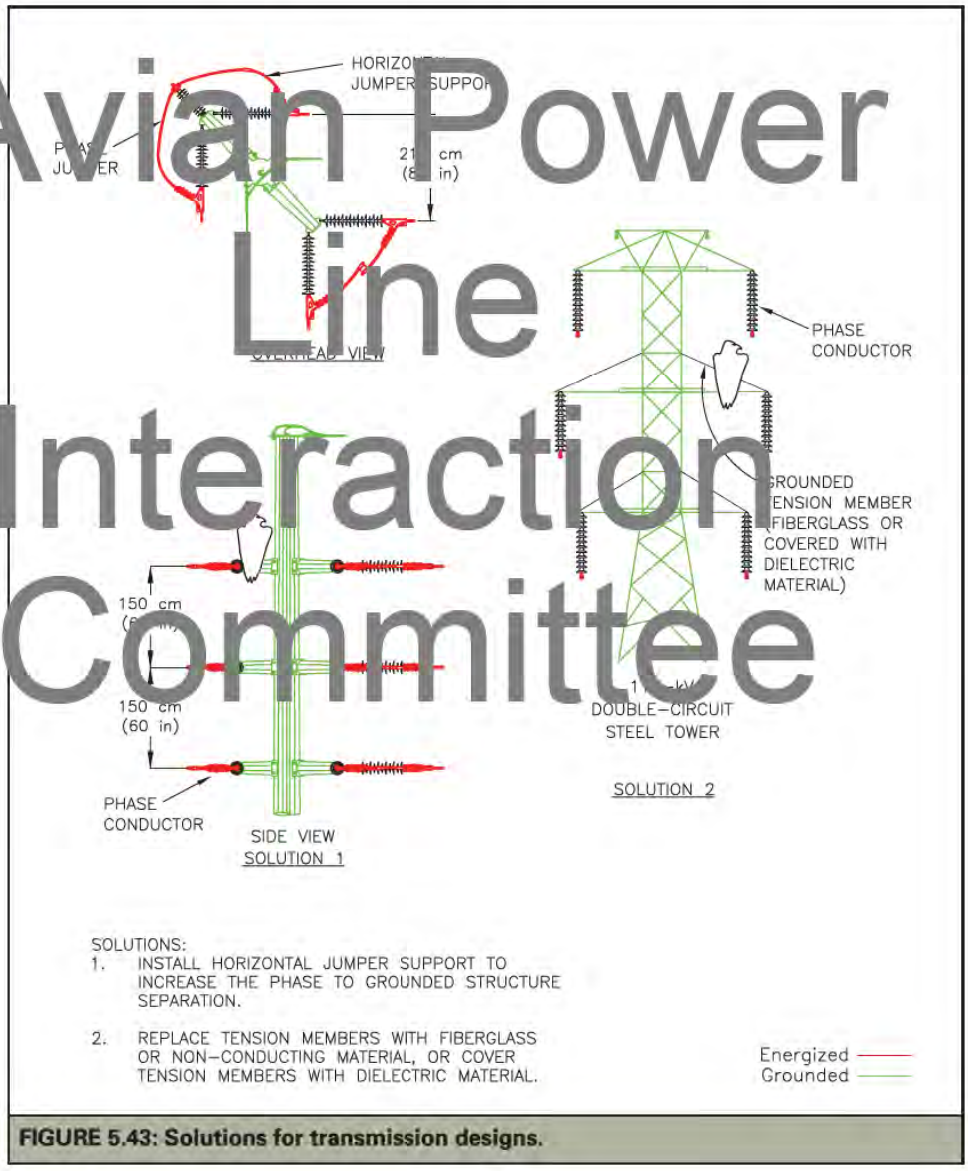

FIGURE 5.43: Solutions for transmission designs.

TABLE 5.3: Recommended conductor separation for transmission lines >60 kV.

kV	Horizontal Spacing	Vertical Spacing
69 kV	157 cm (62 in)	106 cm (42 in)
115 kV	180 cm (71 in)	130 cm (51 in)
138 kV	192 cm (76 in)	141 cm

Equipment Poles

TRANSFORMERS AND OTHER EQUIPMENT

Equipment poles are poles that have transformers, capacitor banks, reclosers, regulators, disconnect switches, cutouts, arresters, or overhead-to-underground transitions (often referred to as *riser poles*). Equipment poles pose increased electrocution risks to birds of all sizes because of close separations between both phase-to-phase and phase-to-ground (Figure 5.44–5.45).

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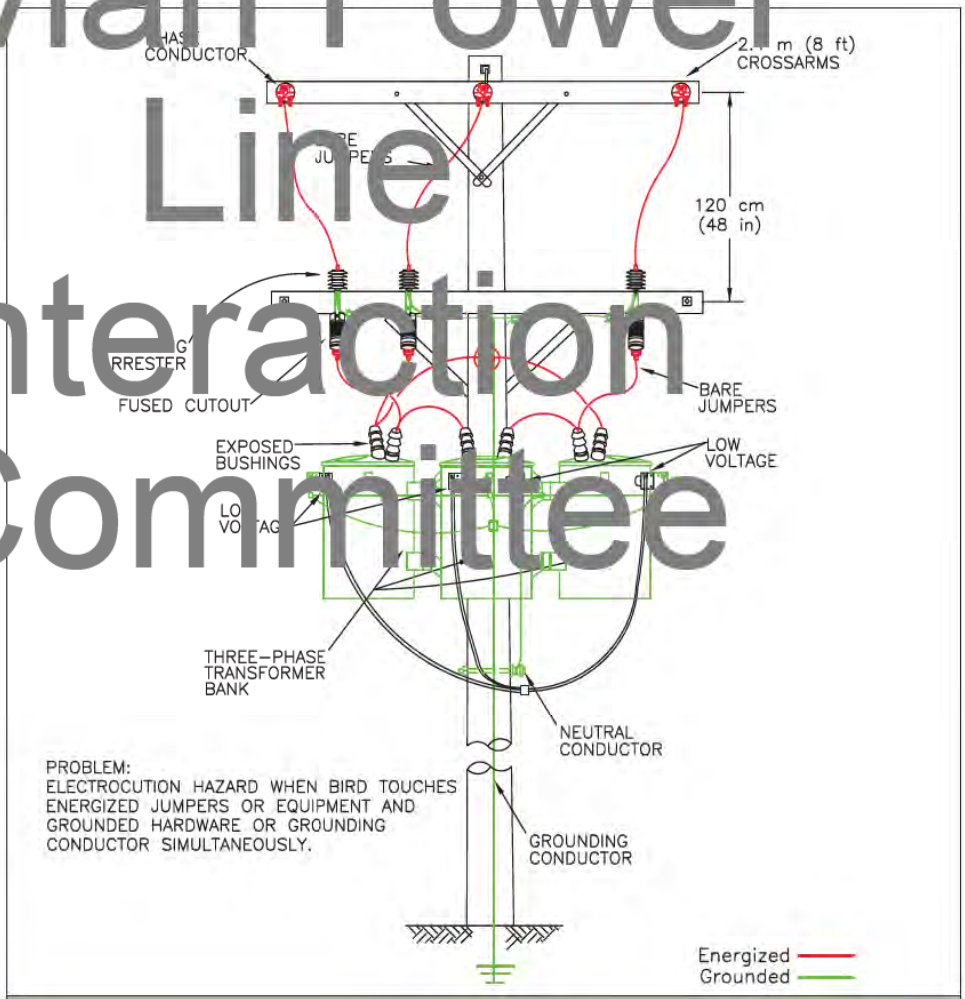

FIGURE 5.44: Problem three-phase transformer bank.

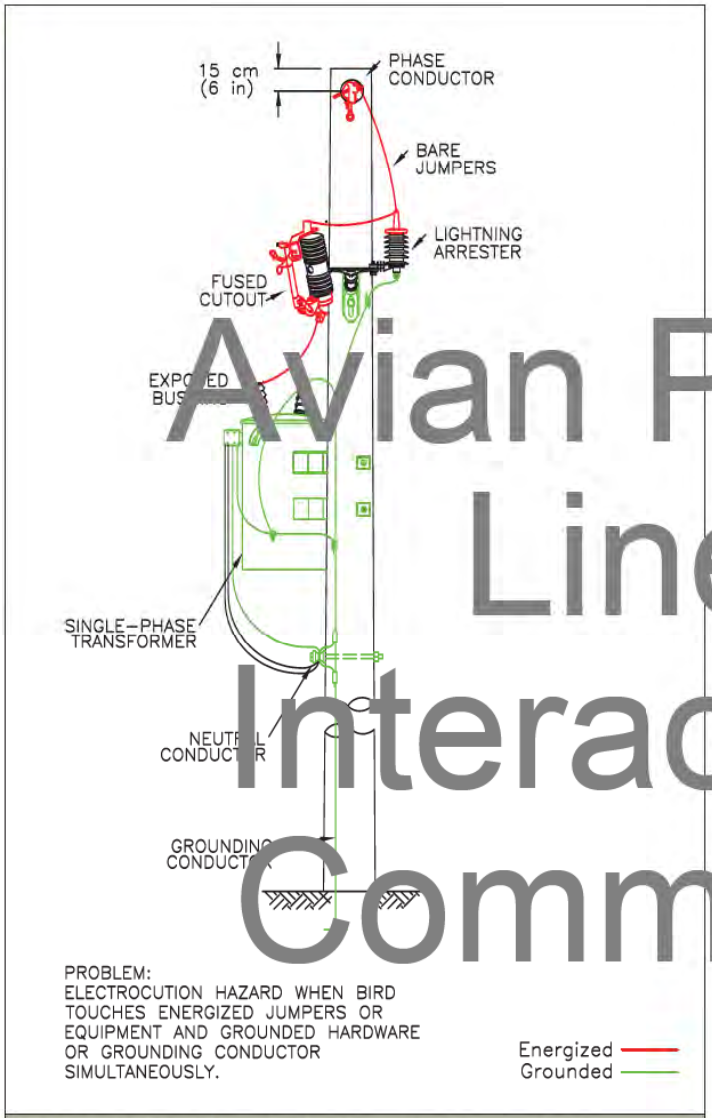

FIGURE 5.45: Problem single-phase transformer bank.

If a line is located in an area of high lightning activity, some utilities may install an overhead (grounded) static wire, requiring the installation of a grounding conductor all the way to the top of some or all structures. To assure the safety of line personnel and the general public, the NESC requires that all electrical equipment such as transformers, switches, lightning arresters, etc., must also be grounded. This grounding usually reduces the separation between energized and grounded parts of the system.

In a review of raptor electrocutions from 58 utilities in the western United States between 1986 and 1996, more than half were associated with transformers (Harness and Wilson 2001). Fifty-three percent of confirmed electrocutions (n=421) were associated with transformers, yet only one-quarter of the poles in these areas were equipped poles. Single or three-phase transformer banks were associated with 41% of eagle mortalities (n=748), 59% of hawk mortalities (n=278), and 52% of owl mortalities (n=344). In Utah and Wyoming, poles with exposed equipment accounted for only 32% of all structures surveyed (n=74,020), yet 53% of poles with mortalities (n=457) had exposed equipment (Liguori and Burruss 2003). In particular, transformers were present on 16% of structures surveyed, yet were found on 36% of poles with mortalities. Small birds (including starlings, magpies, and songbirds), ravens, and owls were more frequently electrocuted at poles with transformers or other equipment than at poles without equipment.

Utilities should address electrocution risk on the entire pole when retrofitting or designing equipment poles. Electrocution risk on new or retrofitted equipment poles can be reduced by using a variety of cover-up materials including covered conductors, moldings, covered jumper wires, arrester covers, bushing covers, cutout covers, phase covers, and other covers to prevent birds from making simultaneous contact between grounded and energized conductors or hardware (Figures 5.46, 5.47). See the *Precautions* section (below) for a discussion of cover-up materials. When lightning arresters are installed on a wooden crossarm in combination with fused cutouts, the arrester ground wire is normally attached beneath the arm connecting the base

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of the arresters to ground without bonding or contacting the arrester brackets.

The use of perch discouragers alone on or near equipment poles is not recommended, as perch discouragers may deter birds from landing on the crossarm, leaving equipment arms or transformers as perching alternatives. However, perch discouragers may be used if an alternative perch is provided and exposed equipment is covered with appropriate avian protection devices.

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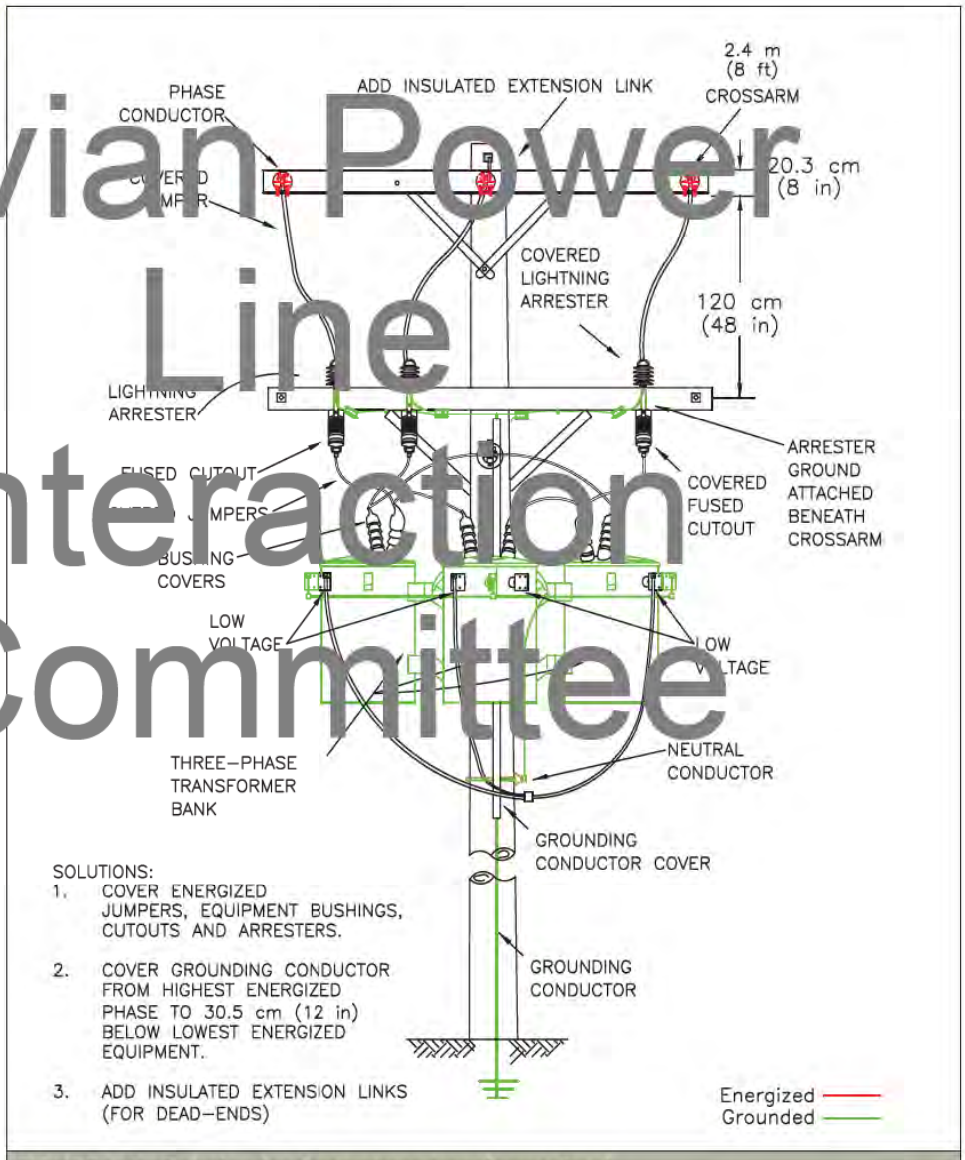

FIGURE 5.46: Solution for three-phase transformer bank.

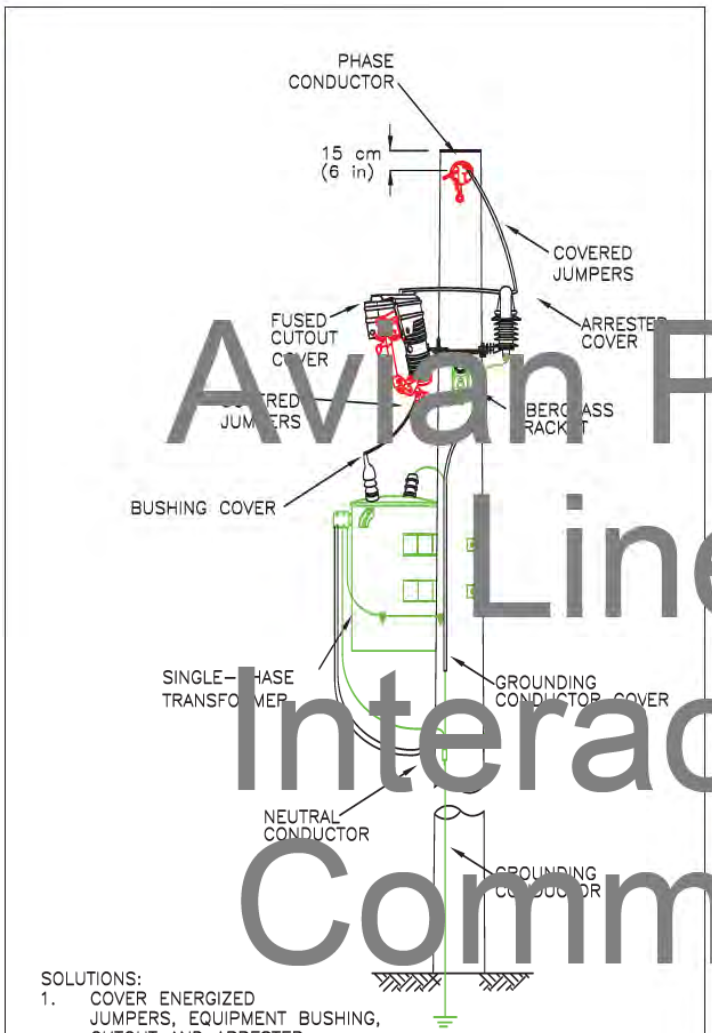

FIGURE 5.47: Solution for single-phase transformer bank.

PRECAUTIONS

When using cover-up products on equipment, a utility should be aware of several important points. First, these products are intended only for wildlife protection; **they are not intended for human protection.** Second, there are currently no standard protocols for testing such products (see page 51 for further information on testing). Utilities are advised to evaluate the products that they select for durability, effectiveness, ease of installation, etc. Finally, wildlife protection products may not be effective or can cause problems if installed improperly. Bushing covers and arrester covers should fit between the first and second skirts of the bushing or arrester. Likewise, phase covers should sit on the top skirt of the insulator and not extend to the crossarm. If covers are pushed down too far, they can cause tracking, outages, or fires. Cutout covers should also be evaluated to ensure that they will not interfere with the operation of the cutouts or the use of a load-break tool. Coverings on jumper wire should cover the entire jumper, because exposed gaps can pose an electrocution risk. See the APLIC website (www.aplic.org) for a current list of avian protection product manufacturers.

SWITCHES

Many types of switches are used to isolate circuits or redirect current for the operation and maintenance of a distribution system. Several examples are shown in Figures 5.48, 5.49, and 5.50. Because of the close separation, it may be difficult to mitigate electrocutions on switch poles. Efforts can be made to either provide birds with safe perch sites on adjacent poles or to make switch poles less hazardous to birds. The installation of unprotected switch poles is discouraged in raptor use areas due to the electrocution risk and difficulty of making these poles avian-safe. Where switches are installed, offset or staggered vertical switch configurations with an

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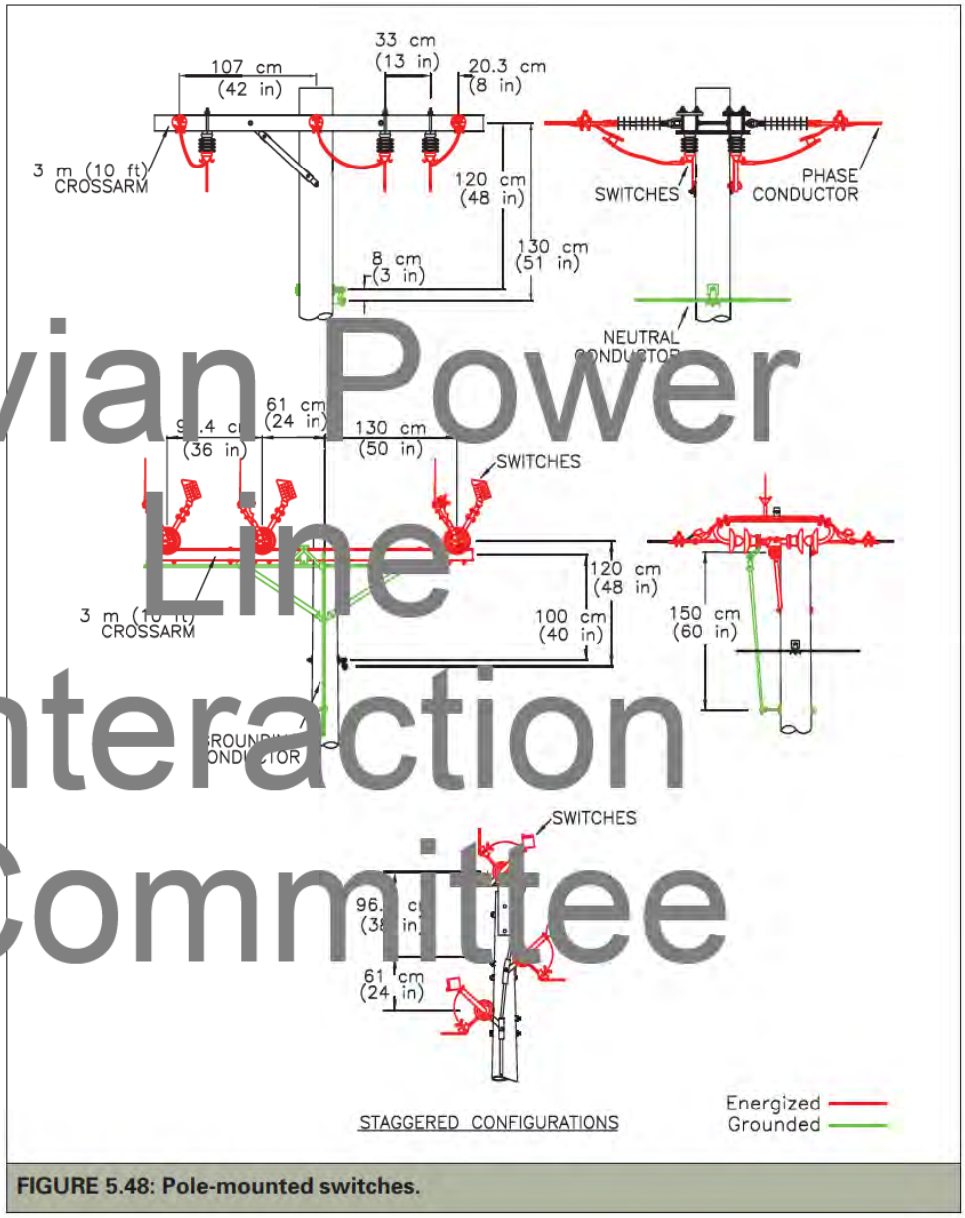

FIGURE 5.48: Pole-mounted switches.

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alternate perch above the top switch may provide a safer perching site (see Figure 5.49). Separation is key to making these structures safer for birds. Coverings designed for the purpose should be used on as many of the energized components as possible. Using fiberglass arms for switches may also help reduce electrocutions.

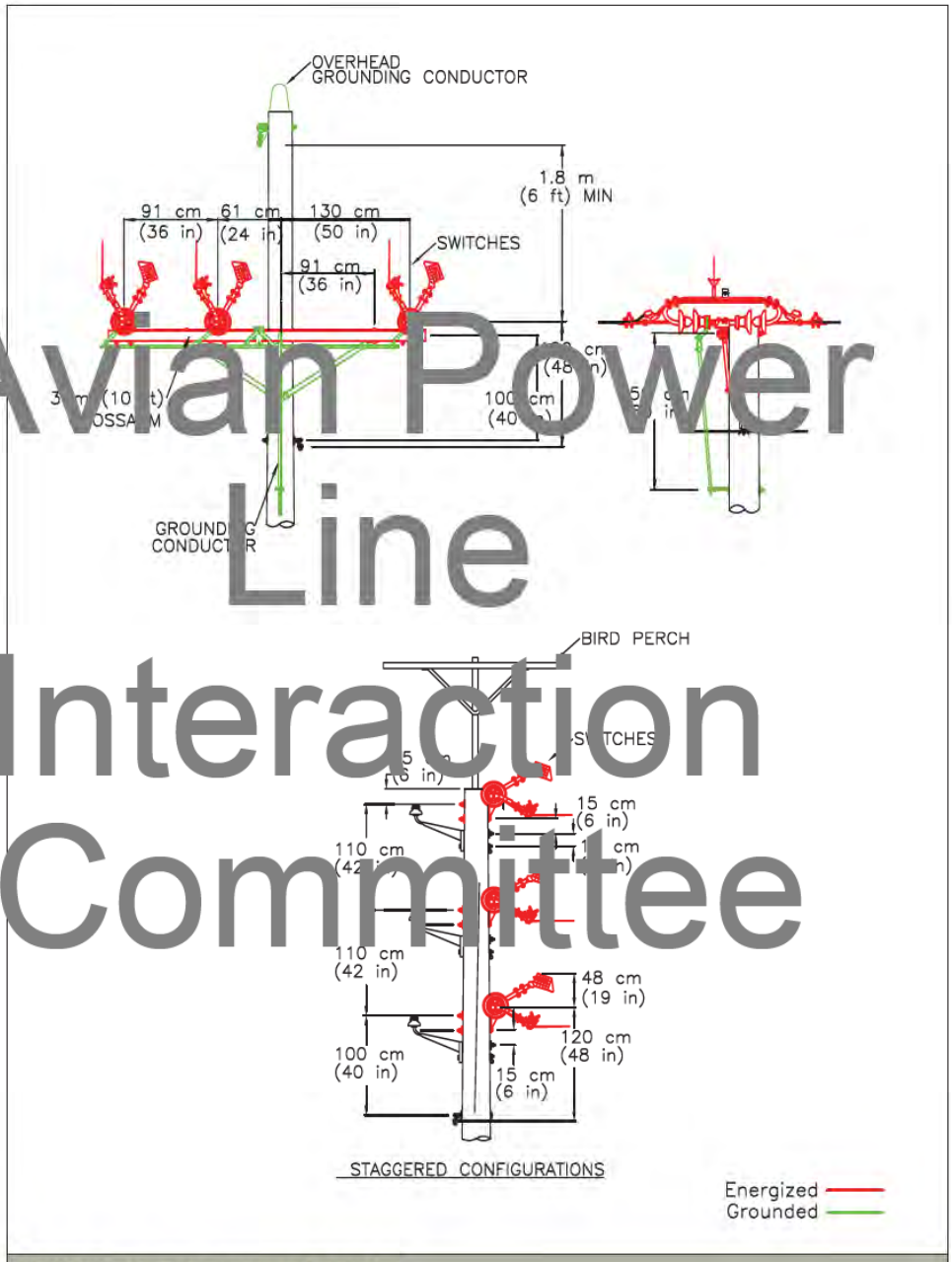

FIGURE 5.49: Pole-mounted switches.

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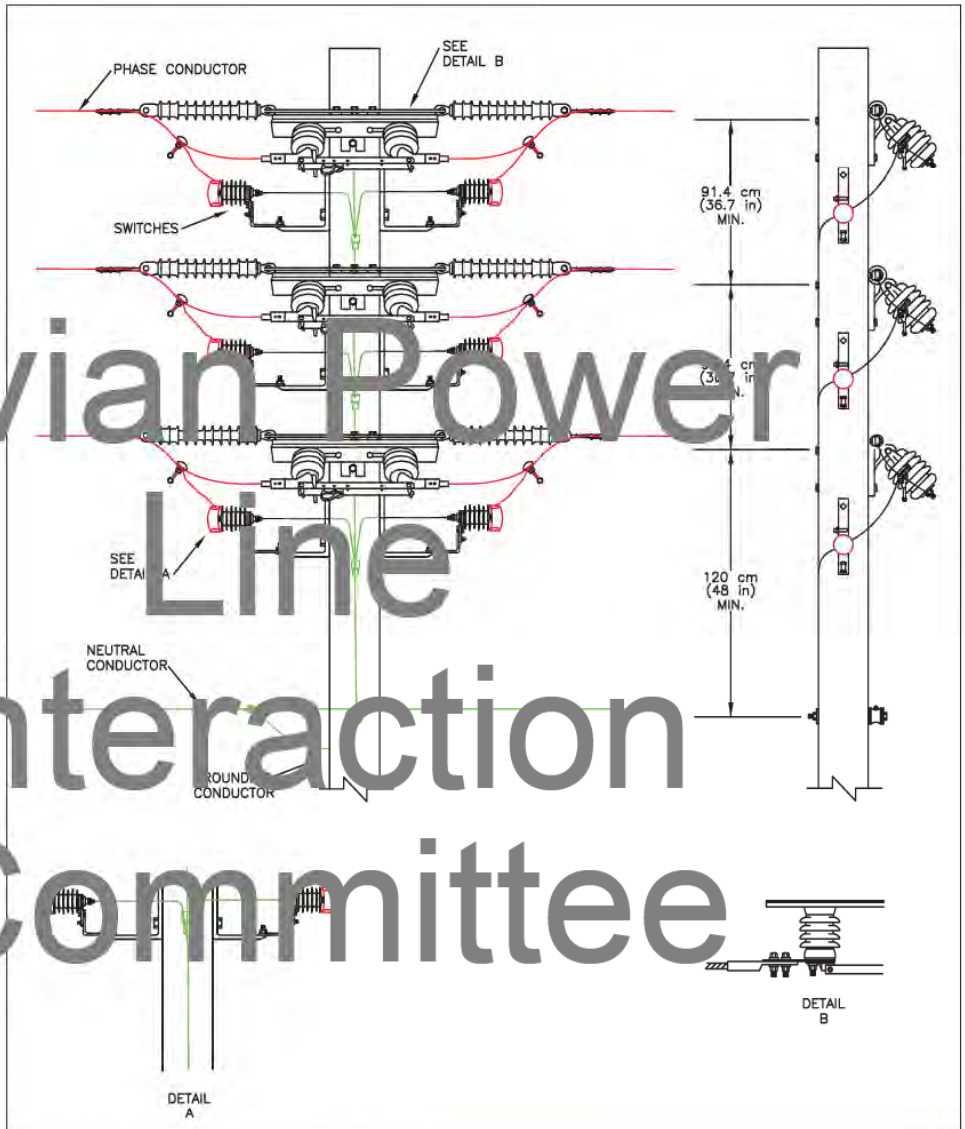

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FIGURE 5.50: Pole-mounted switches.

SUBSTATION MODIFICATION AND DESIGN

Substations are transitional points in the transmission and distribution system. While raptor electrocutions at substations are uncommon, smaller birds such as songbirds and corvids may perch, roost, or nest in substations, causing electrocution and outage risks. Numerous bird species have caused substation outages, including great horned owl *(Bubo virginianus)*, American kestrel, black-billed magpie *(Pica hudsonia)*, European starling

(Sturnus vulgaris), golden eagle, and monk parakeet *(Myiopsitta monachus)* (PacifiCorp, unpubl. data; Florida Power and Light, unpubl. data). Over an 18-month period, 18 bird-caused outages were documented in substations in six western states, which affected over 50,000 customers (PacifiCorp, unpubl. data).

Over the years, numerous techniques have been used to prevent bird and animal contacts in substations. Such techniques include habitat modification, physical barriers, auditory, visual, olfactory, and pyrotechnic discouragers, and physically removing animals. Many of these practices have had limited success, or are cost-prohibitive or impractical. The most effective method for preventing bird contacts in substations employs the practices used for distribution and transmission structures, "insulate" or isolate (see page 59). For new substations, a combination of framing and covering can prevent contacts by birds and other animals. For existing substations, cover-up materials designed for the purpose can be installed to make substations avian safe.

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SUMMARY

Power line structures can present electrocution hazards to birds when less than adequate separation exists between energized conductors or between energized conductors/hardware and grounded conductors/hardware. This document recommends 152 cm (60 in) separation for eagles. Other separations may be used based upon the species impacted. Avian-safe facilities can be provided by one or more of the following:

- increasing separations to achieve adequate separation for the species involved
- covering energized parts and/or covering grounded parts with materials appropriate for providing incidental contact protection to birds
- applying perch management techniques.

A utility's Avian Protection Plan (see Chapter 7) should identify new construction designs, retrofitting options, approved avian protection devices, proper installation techniques, and other procedures related to avian protection.

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CHAPTER 6

Perching, Roosting, and Nesting of Birds on Power Line Structures

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IN THIS CHAPTER Avian Use of Power Lines | Nest Management | Reliability Concerns

This chapter examines how birds use power line structures. It considers the advantages and disadvantages that utility structures present to birds as well as the effects birds have on power reliability.

Power line structures provide perching, roosting, and nesting substrates for [illegible] avian species in [illegible] habitats in areas where natural substrates are limited. Nest management, including platforms installed on or near power structures, can provide nesting sites for several protected species while minimizing the risks of electrocution, equipment damage, or outages. Nest management might also include the control of the monk parakeet *(Myiopsitta monachus)*, a species introduced from South America, which constructs large, communal nests, often on power line structures, causing significant reliability problems.

AVIAN USE OF POWER LINES

RAPTORS

Perching

Power line structures in relatively treeless areas have made millions of kilometers of suitable habitat available to perch-hunting raptors (Olendoff et al. 1980). Power poles offer raptors an expansive view of the surrounding terrain while they inconspicuously watch for prey below (see Figure 4.9). Perch-hunting also allows raptors to conserve energy by minimizing flight activity (Figure 6.1). Ospreys *(Pandion haliaetus)* readily perch-hunt from power poles that have been placed near treeless wetlands or other water bodies.

FIGURE 6.1: Peregrine falcon with prey on distribution pole.

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There is a strong association between raptor activity and utility rights-of-way (Williams and Colson 1989). Following the 1974 construction of a 230-kV transmission line in Colorado, raptor density near the line increased from 4 to 13 raptors per square kilometer (km^2) (10 to 34 per square mile [mi^2]) to 21 to 32 raptors/km^2 (54 to 83/mi^2) after construction (Stahlecker 1978).

Although transmission towers comprised only 1.5% of available perches in this area, 81% of raptors sighted during surveys used them as perches. Rough-legged hawks (*Buteo lagopus*), golden eagles (*Aquila chrysaetos*), and prairie falcons (*Falco mexicanus*) used towers more than any of the other available perches (e.g., distribution poles, fence posts, trees, windmills, etc.). Craig (1978) noted that almost 70% of all raptors perched along a 487-km (303-mi) survey route in Idaho were perched on power poles or wires. During a three-year study in southern New Mexico, Kimsey and Conley (1988) found that open terrain traversed by transmission towers received more use by raptors than similar areas without towers. In Wyoming, golden eagles and other raptors perched on distribution poles during winter to exploit a locally abundant food source (Harness and Garrett 1999).

Roosting

Raptors also use power line structures for roosting. Roosts may be selected for protection from predators and inclement weather, or for their proximity to food sources. Raptors that nest on utility structures often use those nests as nocturnal roosts as well. They can roost singly (e.g., osprey or buteos), or communally (e.g., Harris' hawks *[Parabuteo unicinctus]* or wintering bald eagles *[Haliaeetus leucocephalus]*). When perched side-by-side, birds can span the distance between phases or phase and ground, which increases the risk of an electrocution as well as an outage. Excrement from multiple birds can also create outage risks by contaminating equipment.

Craig and Craig (1984) found that golden eagles wintering in Idaho often roosted communally on several types of power line structures. These structures allowed eagles to exploit local populations of jackrabbits, and provided shelter from inclement weather. Eagles and hawks may use the lower portions of transmission towers, which provide some degree of cover for night roosting in barren areas (Smith 1985). In Spain, transmission substations serve as summer roost sites for congregations of lesser kestrels (*Falco naumanni*). These sites may play an important role in the conservation of this declining species (Arevalo et al. 2004).

Nesting

Casual observation attests, and many studies have documented, that raptors nest on distribution and transmission structures (see Table 6.1). Although most species that nest on power line structures inhabit open, arid areas, one notable exception is the osprey (Figure 6.1). Ospreys use utility structures for nesting more than any other North American raptor. They typically select poles that are located near or over waters where fish are abundant. To protect ospreys and the power systems, platforms have been installed on or near transmission towers and distribution poles so nest material and excrement will not contaminate lines. In addition, power poles that are left standing when lines are decommissioned can provide both nest and perch sites. During an 11-year period in Michigan, an average of 55% of the osprey platforms available were occupied (Postupalsky 1978). On Lake Huron in Canada, 82% of artificial platforms were occupied within one year of installation (Ewins 1996). In 1995, nearly 46% of osprey nests studied in Finland (n=951) were located on artificial structures and, in southern Finland, up to 90% of occupied nests (n=79) were on artificial platforms (Saurola 1997).

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TABLE 6.1: Accounts of raptor species nesting on transmission structures (T), distribution poles (D), and substations (S).*

Species	Reference
African hawk-eagle *(Hieraaetus faciatus)*	Tarboton and Allan 1984 (T); Allan 1988 (T)
American kestrel *(Falco sparverius)*	Illinois Power Company 1972 (T); Blue 1996 (P); Georgia Power Company, unpubl. data (T)
Aplomado falcon *(Falco femoralis)*	The Peregrine Fund 1995 (T); D. Bouchard, pers. comm. (T)
Bald eagle *(Haliaeetus leucocephalus)*	Keran 1986 (T); Bohm 1988 (T); Hanson 1988 (T); Marion et al. 1992 (T); J. Swan, pers. comm. (T)
Black-breasted snake eagle *(Circaetus*	Brown and Lawson 1989 (T)
Black eagle *(Aquila verreauxi)*	Boshoff and Fabricius 1986 (T); Hobbs and Ledger 1986 (T); Boshoff et al. 1987 (T); Jenkins et al. 2005 (T)
Brown snake eagle *(Circaetus cinereus)*	Brown and Lawson 1989 (T)
Crested caracara *(Caracara cheriway)*	J. Lindsay, pers. comm. (S)
Eurasian kestrel *(Falco tinnunculus)*	Boshoff et al. 1983 (T)
Ferruginous hawk *(Buteo regalis)*	Nelson and Nelson 1976 (T); Gilbertson 1982 (T); Gilmer and Stewart 1983 (T); Gaines 1985 (T); Bridges and McConnon 1997 (T); Electric Power Research Institute 1988 (T); Fitzner and Newell 1989 (T); Steenhof et al. 1993 (T); Olendorff 1993a (T); Beck and Schmutz 1995 (P); Blue 1996 (T); Erickson 2004 (T)
Golden eagle *(Aquila chrysaetos)*	Anderson 1975 (T); Nelson and Nelson 1976 (T); Herron et al. 1980 (T); Electric Power Research Institute 1988 (T); Steenhof et al. 1993 (T); Lee 1996 (T); Lockert et al. 2002 (T); PacifiCorp, unpubl. data (T)
Great horned owl *(Bubo virginianus)*	Olendorff and Wilson 1977 (T); Steenhof et al. 1993 (T); Blue 1996 (P); PacifiCorp, unpubl. data (D, S)
Greater kestrel *(Falco rupicoloides)*	Kemp 1984 (T); Hartley et al. 1996 (P)
Harris' hawk *(Parabuteo unicinctus)*	Ellis et al. 1978 (D); Whaley 1986 (T); Bednarz 1995 (T); Blue 1996 (P)
Lanner falcon *(Falco biarmicus)*	Tarboton and Allan 1984 (T); Hartley et al. 1996 (P)
Martial eagle *(Polemaetus bellicosus)*	Dean 1975 (T); Boshoff and Fabricius 1986 (T); Hobbs and Ledger 1986 (T); Boshoff 1993 (T); Jenkins et al. 2005 (T)
Mountain caracara *(Phalcoboenus megalopterus)*	White and Boyce 1987 (P)

** Note that some studies refer only to nesting on power line structures (P).*

Continued

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TABLE 6.1: Accounts of raptor species nesting on transmission structures (T), distribution poles (D), and substations (S).* (cont.)

Species	Reference
Osprey *(Pandion haliaetus)*	Melquist 1974 (D); Detrich 1978 (T); Henny et al. 1978 (T, D); Prevost et al. 1978 (T); Henny and Anderson 1979 (D); van Daele et al. 1980 (D); Jamieson et al. 1982 (D); Austin-Smith and Rhodenizer 1983 (T); Fulton 1984 (T); Keran 1986 (T); Hanson 1988 (T); Vanderburgh 1993 (D); Blue 1996 (P); Ewins 1996 (T, D); Henny and Kaiser 1996 (T, D); Meyburg et al. 1996 (P); Poole et al. 2002 (P); Henny et al. 2003 (T, D); Henny and Anderson 2004 (D)
Pallid-charging goshawk *(Melierax canorus)*	Brown and Lawson 1989
Peregrine falcon *(Falco peregrinus)*	Bunnell et al. 1997 (T); White et al. 2002 (T); PacifiCorp, unpubl. data (T)
Prairie falcon *(Falco mexicanus)*	Roppe et al. 1989 (T); Blue 1996 (P); Bunnell et al. 1997 (T)
Red-tailed hawk *(Buteo jamaicensis)*	Nelson and Nelson 1976 (T); Ellis et al. 1978 (T); Fitzner [illegible]; Gilbertson 1982 (T); Brett 1987 (T); Electric Power Research Institute 1988 (T); Fitzner and Newell 1989 (T); Steenhof et al. 1993 (T); Knight and Kawashima 1993 (P); Blue 1996 (T); Stout et al. 1996 (D); Brubaker et al. 2003 (P)
Rough-legged hawk *(Buteo lagopus)*	Bechard and Swen 2002 (P)
Swainson's hawk *(Buteo swainsoni)*	Olendorff and Stoddart 1974 (P); Fitzner 1978 (D); Fitzner and Newell 1989 (T); Blue 1996 (P); England et al. 1997 (P, T)
Tawny eagle *(Aquila rapax)*	Dean 1975 (T); Tarboton and Allan 1984 (T); Jenkins et al. 2005 (T)
White-backed vulture *(Gyps africanus)*	Hodge and Hobbs 1985 (T)
Zone-tailed hawk *(Buteo albonotatus)*	Blue 1996 (P)

** Note that some studies refer only to nesting on power line structures (P).*

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Nest location on a power structure can vary by species and structure type. On natural substrates, ospreys typically nest on the flat tops of dead trees and broken tops of live trees. Likewise, on power structures, ospreys prefer the upper portions of transmission towers or the tops of distribution poles. Red-tailed, Swainson's *(Buteo swainsoni)*, and ferruginous hawks *(B. regalis)* generally prefer nest heights that are relatively high, moderate, and low, respectively. Tower sections where steel lattice-work is relatively dense are generally preferred, as this provides more support for nests (Figure 6.3). The configuration of two poles supporting four paired sets of crossarms was most often used by raptors in New Mexico (Brubaker et al. 2003). Double dead-end and dead-end distribution poles (see Figures 5.15, 5.16, 6.2, 6.23, 6.24, 6.25, and 6.26 for examples) are the distribution configurations most commonly used by osprey and some other raptors throughout North America.

Steenhof et al. (1993) reported an 89% success rate for ferruginous hawk nests on

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FIGURE 6.2: Osprey nest on double crossarm of non-energized pole.

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FIGURE 6.3: Red-tailed hawk nest on steel lattice transmission tower.

platforms (n=19), which was higher than nesting success on cliffs (58%, n=38) or other natural substrates (20%, n=5). Likewise, ferruginous hawk nesting success was higher on artificial platforms in Wyoming than on natural substrates (Tigner et al. 1996). Schmutz (1995) stated that nesting platforms would be beneficial for ferruginous hawks, especially in previously occupied habitats where the number of natural nest sites is in decline. They recommend spacing nest platforms out-of-sight of other buteo nests.

Nest platforms for bald eagles provide support for weak or collapsed nests, attract birds searching for a breeding site, encourage the reuse of historic sites, and support nests moved from areas of pending human activity or development (Postupalsky 1978; Hunter et al. 1997). In Florida an increased number of bald eagle nests on man-made structures has been reported. In 2003, there were 24 bald eagle nests on man-made structures with

46% on transmission towers (J. Swan, pers. comm.). In 2004 and 2005, the number of nests on towers increased due to the loss of nesting trees to hurricanes in 2004 (S. Nesbitt, pers. comm.).

ADVANTAGES TO RAPTORS NESTING ON UTILITY STRUCTURES

Utility structures can provide nesting substrates in habitats where natural sites are scarce, facilitate the range expansion of some species, increase the local density of some species, and offer some protection from the elements. In addition, some raptors have increased their nest success and productivity on power line structures.

In New Mexico, decommissioned telephone poles and energized electrical poles were used by nesting raptors (Brucker et al. 2003). Thirty-two of 338 poles used by nesting raptors, including 27 pairs of Swainson's hawks, 3 pairs of red-tailed hawks, and 2 pairs of great horned owls *(Bubo virginianus)*. In Wisconsin red-tailed hawks nested on artificial structures including transmission towers, as the availability of natural nest sites declined in human-altered landscapes (Stout et al. 1996). New 230-kV and 500-kV lines on the Hanford Reservation in Washington were monitored between 1979 and 1988 (Fitzner and Newell 1989). After construction of the lines in 1979, only one red-tailed hawk nest appeared on these structures. By 1988, 19 Swainson's, ferruginous, and red-tailed hawks' nests were found on the structures. Red-tailed hawks and common ravens *(Corvus corax)* in southern California nested on utility structures in greater numbers than expected based on the availability of potential nest substrates (Knight and Kawashima 1993). In 1980 and 1981, the PacifiCorp Malin-to-Midpoint 500-kV transmission line was constructed across eastern Oregon and southern Idaho (Steenhof et al. 1993). In cooperation with the BLM, PacifiCorp installed 37 nesting platforms designed by Morley Nelson (Figure 6.4) (Nelson and Nelson 1976; Olendorff et al. 1981; Nelson 1982). Within one year, raptors and ravens began nesting on these platforms. Although only 2% of the towers had platforms, 72% (n=29) of the golden eagle and 48% (n=52) of the ferruginous hawk nesting attempts were made on the artificial platforms. Nineteen (51%) of the platforms were used at least once. Steenhof et al. (1993) suggested that the needs of nesting raptors should be considered and assistance integrated during the construction of transmission lines, especially when the line traverses treeless habitat and the disturbance of a sensitive prey species is not an issue.

The construction of artificial nesting platforms, including those on power poles, has contributed to the ospreys' population growth and range expansion in North America (Houston and Scott 2001; Henny and Anderson 2004). Although the number of ospreys nesting on natural substrates remained constant in the Willamette Valley, Oregon, from the 1970s to 1990s, the number of active nests on power line structures increased from 1 in 1977 to 66 in 1993 (Henny and Kaiser 1996). In 2001, 34 osprey pairs were nesting in this area, 74% of the nests located on power poles or platforms erected by electric utilities (Henny et al. 2003).

Power line structures may also help local raptor populations increase (Olendorff et al. 1981). Within ten years after construction of a 500-kV transmission line across eastern Oregon and southern Idaho, 53 pairs of raptors and ravens nested on line structures while their nesting densities on nearby natural substrates remained at pre-construction levels (Steenhof et al. 1993). In South Africa as well, raptor nests are not removed unless they pose a threat to the power supply. Consequently, many raptor species regularly nest on transmission towers (Ledger et al. 1993).

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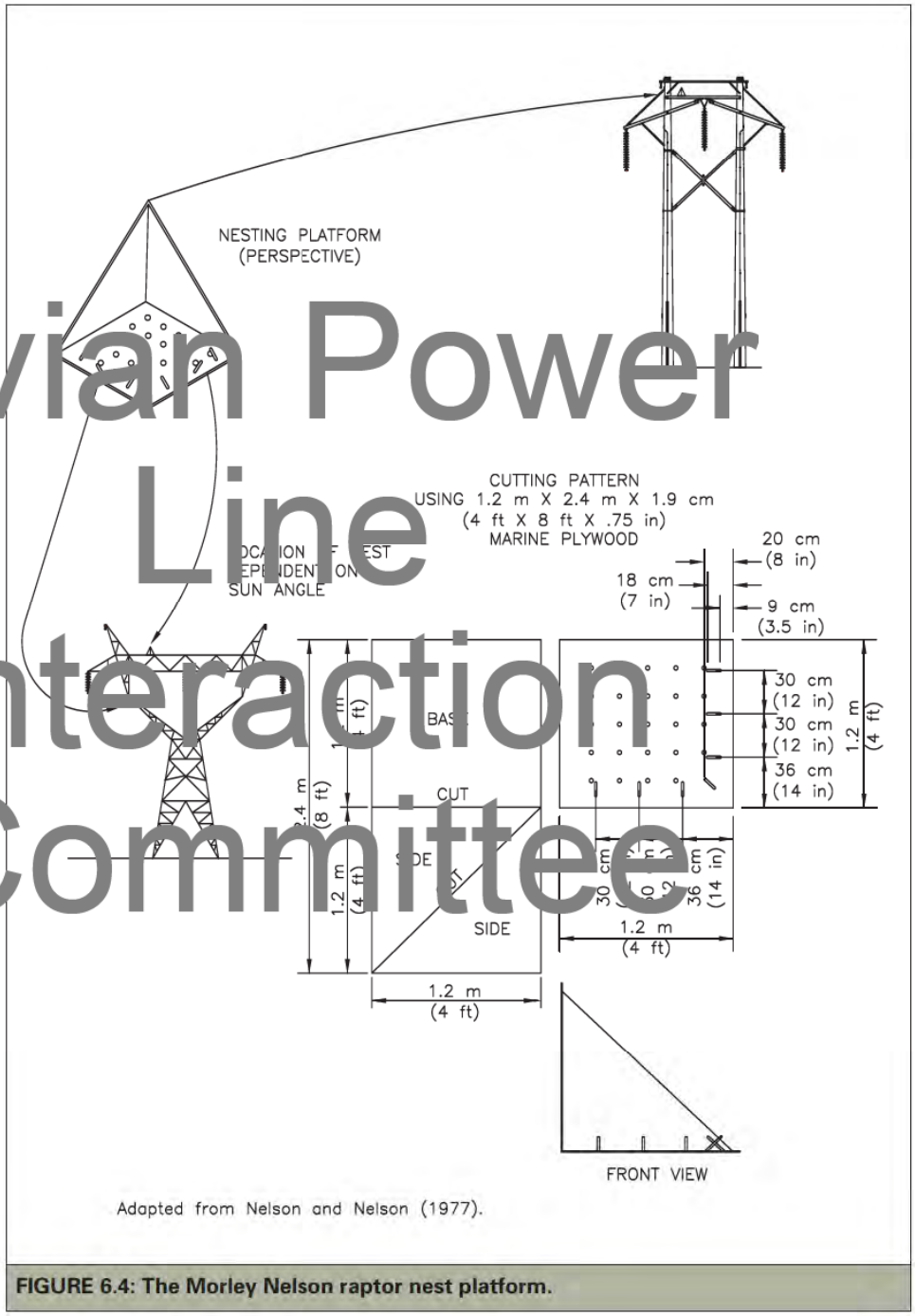

FIGURE 6.4: The Morley Nelson raptor nest platform.

Transmission towers may afford nesting raptors some protection from the elements. Beams and cross-braces provide shade and windbreaks for nesting birds (Anderson 1975). Compared to cliffs, towers allow more air circulation and lower heat absorption. Raptors nesting on transmission towers are also more protected from range fires (Steenhof et al. 1993).

Some studies have documented greater nest productivity on artificial nesting substrates than on natural substrates (van Daele et al. 1982; Haines 1935; Olendorff 1993a). Martial eagle (*Polemaetus bellicosus*) in southern Africa had higher breeding success on electrical transmission towers than elsewhere (Boshoff 1993). Ospreys using artificial sites in Germany produced more young than those nesting in trees (Meyburg et al. 1996). Similar rates of raptor occupancy have been found between natural and man-made substrates in the Canadian Great Basin and in southern Wisconsin (Ewins 1996; Stout et al. 1995). Improved reproductivity on poles, towers and other artificial structures can usually be attributed to nest stability and protection from mammalian predators.

DISADVANTAGES TO RAPTORS NESTING ON UTILITY STRUCTURES

Raptors that nest on power poles face disadvantages that include: increased risk of electrocution and collision, susceptibility to nest damage from wind and weather, disturbance from line maintenance or construction, and vulnerability to shooting. Raptors nesting on power line structures may also impact some prey species and can reduce power reliability by contaminating equipment with excrement or nesting material (see Reliability Concerns). Another possible disadvantage is that raptors, specifically ospreys, reared from power pole nests may only select power poles as nest substrates when they nest as adults (Henny and Kaiser 1996).

Raptors nesting on utility structures have an increased electrocution risk if nearby poles are not avian-safe (see Chapter 5). Entanglement in wires and other utility hardware can also occur (Olendorff et al. 1981). In the United States, raptor collisions with power lines do occur, but not as frequently as electrocutions (Oldendorff and Lehman 1986; Kochert and Olendorff 1999). Although raptors may become familiar with power lines in their breeding territory, repeated flights across power lines increases the risk of collision, especially in bad weather or in the pursuit of prey (Manosa and Real 2001). In Europe, transmission lines near nests were associated with high turnover rates of breeding Bonelli's eagles (*Hieraaetus fasciatus*). Collisions with power lines were the suspected cause (Manosa and Real 2001).

The dense latticework of transmission towers offer some protection from the elements, but relatively open distribution poles do not. Consequently, nests on distribution poles are more often damaged or destroyed by strong winds (Grimmer and Viehl 1977; Postovit and Postovit 1987). Raised edges on nesting platforms can help stabilize and protect nests during high winds. Destruction of nests by fire was common and caused nest failures (49%) on transmission towers in Idaho. Poles with artificial platforms afforded more protection from wind than poles without platforms (Steenhof et al. 1993). A bald eagle nest on an H-frame structure in Florida repeatedly fell during windstorms until an artificial platform was erected to support it (Marion et al. 1992).

Although short-lived, the activity and alteration of surrounding habitat that occurs during power-line construction can disturb raptors. Maintenance operations may also temporarily disrupt normal bird nesting, hunting and roosting behavior (Williams and Colson 1989).

Indiscriminate shooting of raptors may

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be higher along power lines than at natural nest sites because poles are often highly visible and close to access roads (Williams and Colson 1989).

The addition of artificial raptor nests can have negative impacts on others animals (Fitzner 1980a). For example, burrowing owls *(Athene cunicularia)*, which are preyed upon by larger raptors, can be more susceptible to predation if nest platforms are erected in their territories. The introductio[illegible] of great horned owls to [illegible] via nest platforms can threaten nestlings of diurnal raptors.

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FIGURE 6.5: Loggerhead shrike *(Lanius ludovicianus)* perched on conductor.

OTHER BIRDS

Perching

Many other bird species use distribution poles, transmission towers, and conductors for perching, particularly where suitable foraging or nesting habitat is nearby (see Yahner et al. 2002). As they do for raptors, power line structures provide a view of the surroundings and facilitate hunting. From these perches, kingfishers pursue fish in lakes or streams, and shrikes seek their prey along power line corridors (Figure 6.5). Utility structures, especially conductors, are commonly used as perches by flocking birds, such as blackbirds, swallows, European starlings *(Sturnus vulgaris)*.

Roosting

Species such as cormorants, vultures, ravens, and crows use power line structures for roosting. Poorly adapted to cold environments, vultures often seek roosts that are protected from harsh weather. Cape Griffons, or Cape vultures *(Gyps coprotheres)* and, to a lesser extent, white-backed vultures *(Gyps africanus)*, roost in large numbers on transmission towers in southern Africa (Ledger and Hobbs 1999). Likewise, turkey vultures *(Cathartes aura)* and black vultures *(Coragyps atratus)* use transmission towers for roosting in North America.

Some [illegible] species roost communally or congregate on power line structures. Engel et al. (1992b) documented the largest known communal roost of common ravens in the world. There were as many as 2,103 ravens on adjoining 500-kV transmission towers in southwestern Idaho. The towers appeared to present an attractive alternative to natural roost sites by offering increased safety from predators and close proximity to food sources.

Nesting

A number of non-raptor species also nest on utility structures. Transmission tower lattice-work can provide suitable nesting substrate for ravens, herons, cormorants and other large birds [illegible] poles are used by smaller birds that build their nests on support brackets, transformers, or capacitors. Table 6.2 presents a list of non-raptor species that have nested on power line structures. This list is not comprehensive, but it illustrates the variety of species attracted to utility structures.

Birds that build stick nests may find areas on transmission and distribution structures suitable for nesting sites. In Europe, the white stork *(Ciconia ciconia)* commonly nests on distribution and transmission towers (Janss 1998). Double-crested cormorants *(Phalacrocorax auritus)* and great blue herons *(Ardea herodias)* nest on steel-lattice transmission towers along the Great Salt Lake in Utah (PacifiCorp,

TABLE 6.2: Examples of non-raptor species nesting on power line structures.*

Species	Source
Double-crested cormorant *(Phalacrocorax auritus)*	PacifiCorp (unpubl. data)
Great blue heron *(Ardea herodias)*	PacifiCorp (unpubl. data)
Hadeda ibis *(Bostrychia hagedash)*	C.S. van Rooyen (pers. comm.)
White stork *(Ciconia ciconia)*	Janss 1998
Egyptian goose *(Alopochen aegyptiaca)*	C.S. van Rooyen (pers. comm.)
Canada goose *(Branta canadensis)*	J. Burruss (pers. comm.)
Monk parakeet *(Myiopsitta monachus)*	J. Lindsay (pers. comm.)
Eastern kingbird *(Tyrannus tyrannus)*	The Maryland Ornithological Society (http://www.mdbirds.org/atlas/spnotes.html)
Western kingbird *(T. verticalis)*	M. Fiedler (pers. comm.); PacifiCorp (unpubl. data)
Scissor-tailed flycatcher *(T. forficatus)*	Georgia Ornithological Society (http://www.gos.org/rbas/ga2000-2000-05.html)
Pied crow *(Corvus albus)*	C.S. van Rooyen (pers. comm.)
Cape crow *(C. capensis)*	C.S. van Rooyen (pers. comm.)
Common raven *(C. corax)*	Knight and Kawashima 1993; Steenhof et al. 1993
Chihuahuan raven *(C. cryptoleucus)*	Bednarz and Haitt 2002; Brubaker et al. 2003
Sociable weaver *(Philetairus socius)*	C.S. van Rooyen (pers. comm.)

** This table includes species that have constructed nests or used existing nests on poles, not those which may nest in cavities within poles, e.g. woodpeckers, chickadees, etc.*

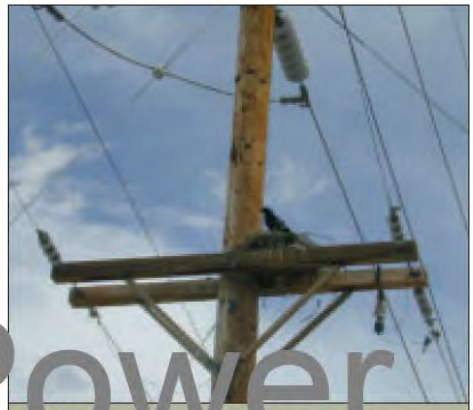

FIGURE 6.6: Common raven nest on distribution underbuild of transmission structure.

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FIGURE 6.7: Western kingbird nest (see highlighted area) on transformer.

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unpubl. data). In the western United States, Canada geese *(Branta canadensis)* have nested on platforms erected for raptors (J. Burruss, pers. comm.).

Common ravens often nest on utility structures (Figure 6.6). Within ten years of the construction of a 500-kV transmission line across Oregon and Idaho, 81 pairs of common ravens nested on the transmission structures (Steenhof et al. 1993). Their success was similar to or greater than nest success in natural substrates. In New Mexico, ravens preferred to nest on the configuration with two poles supporting four paired sets of crossarms (Brubaker et al. 2003).

Throughout a 45,000-km^2 (17,375-mi^2) area of the Mojave Desert in southern California, 26 pairs of common ravens used power line structures for nesting. There were more nests than expected based on the availability of natural nest substrates

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(Knight and Kawashima 1993).

Some species exhibit preferences for nest location on a structure. For example, 98% of raven nests (*n*=408) were found on the uppermost portion of towers (Steenhof et al. 1993). Western kingbirds often nest on transformer brackets, riser poles, switches, and transmission structures (Figure 6.7) (M. Fiedler, pers. comm.; PacifiCorp, unpubl. data).

The use of non-raptor nests by raptors on power line structures has been reported. For example, prairie falcons have been documented using common raven nests (DeLong and Steenhof 2004), and a pair of peregrine falcons *(Falco peregrinus)* occupied a common raven nest on a transmission tower along the Great Salt Lake, Utah (J. Burruss, pers. comm.). In Texas, a pair of aplomado falcons *(Falco femoralis)* used a common raven nest on an H-frame, 138-kV tower (D. Bouchard, pers. obs.). Although the nest was destroyed by wind, a platform was installed in the same place and was also successful.

FIGURE 6.8: Monk parakeet nests on transmission tower.

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FIGURE 6.9: Monk parakeet nest on distribution pole.

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MONK PARAKEETS

The native range of the Argentine monk parakeet was brought to the United States in the late 1960s as pets. Escaped birds have adapted well and established populations from Florida to New York, Texas to Oregon, and in parts of southern Canada. Populations in some states have grown exponentially in the last 10 to 15 years (Pruett-Jones et al. 2005). Monk parakeets build bulky stick nests on trees, power poles, and substations (Spreyer and Bucher 1998; Newman et al. 2004). The number of nests can range from several on distribution or transmission poles to more than 50 in a single substation (Figures 6.8, 6.9). Since monk parakeets are colonial breeders, the size

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of their nests can increase each year and may reach several meters in diameter. Examination of the monk parakeet's annual nesting patterns in south Florida suggests an increasing preference for both power line structures and substations (Newman et al., in press).

Monk parakeet nest site selection on power line structures in Florida is quite predictable, and they show similar behavior in other states as well (Newman et al. 2004). In south Florida, 82% of nests occurred on distribution poles with transformers and capacitor banks. Most of these nests were built on the bracelets that attach the equipment to poles. On the transmission towers surveyed, most nests were located on the secondary arms, followed by the primary arms (Newman et al., in press). A commonality between nests on substations and transmission lines is the parakeets' apparent preference for nesting on 45°-angled braces. On transmission towers, 93% of nests occurred on 45° angle braces. In substations, 44% of nesting occurred on 45° angle crossbeams, followed by switches (18%) and vertical supports (18%) (Newman et al., in press). The remaining 20% were on 90° primary supports, insulator/switches, and substation support structures.

Monk parakeet nests have caused power reliability, fire and safety problems, especially when they contact energized portions of a utility structure. This problem is compounded when one structure supports multiple nests. Safety concerns related to monk parakeet nests include loss of power to critical care facilities, risk of injury to maintenance crews, and risk of electrocution to trespassers attempting to capture wild birds. In service areas such as New York City, some distribution poles have signs indicating that continuous power is necessary for a resident on life-support. Nests on these poles or nearby distribution feeders pose a serious risk to these residents.

Psitticosis is a rare disease that can be transmitted from psittacine birds (parrots) to humans. Thus, nest removal activities associated with colonial psitticines can present a risk to utility workers. Utility crews should also protect themselves from nest materials that may contain mites and insects that can cause discomfort.

MONK PARAKEET NEST MANAGEMENT

The significant increase in monk parakeet population and associated power reliability problems, management concerns and safety concerns warrant short- and long-term nest management strategies. Short-term objectives include removing high-risk nests from utility structures and preventing birds from re-nesting on them. Long-term objectives include reducing population size and growth, and enacting legislation to aid in the control of this species. Because of structural and operational differences between transmission lines, distribution lines, and substations, specific nest management and control strategies need to be developed for each (Newman et al. 2004). Much of what is known about monk parakeet management has been developed through field-testing in Florida where the species has been a challenge for utilities for over a decade (Pittaway personal communication; Newman et al. 2004). Monk parakeets are protected by the Migratory Bird Treaty Act, however removal of nests and birds can be received negatively by the public.

Short-term control of monk parakeets by nest removal alone is ineffective and can actually increase the number of new nests. Often, multiple pairs of monk parakeets occupy a single nest. When a nest is destroyed, the pair that started the nest will not rejoin its neighbors. Instead, it will build a separate nest on the same or nearby structure. Simultaneously removing the parakeets **and** the nest has proven successful in reducing the number of high-risk nests and in preventing re-nesting in the short-term. Birds are removed from the nests at night and the nests are removed later.

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Nets have been designed for trapping monk parakeets on distribution poles, but because monk parakeets are vigilant and astute, the trapping efficiency per nest is approximately 50% (Tillman et al. 2004). Trapping and nest removal are labor intensive and also have public acceptance issues. Trapping may be effective as a long-term strategy for reducing populations if these efforts are continued until all nesting ceases at a particular location (Neltman et al. 2004). Passive trapping with a trap is somewhat effective for substations.

Trapping techniques for transmission towers have not been developed.

Florida Power & Light has investigated a wide range of other strategies including physical, behavioral, chemical and biological controls. Presently, only one potential long-term control has been identified. In the laboratory, Diazacon, a chemical sterilant, has been effective in reducing the number of eggs laid. However, additional research is needed to determine if its use is practical and effective in the field.

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NEST MANAGEMENT

ENCOURAGING BIRDS TO NEST IN DESIRED AREAS

Distribution Poles

Installing nest platforms in [illegible] near utility structures is effective for [illegible] management and line maintenance. Of 88 utilities that responded to a survey regarding raptors nesting on their utility structures, 66% had raptor nest enhancement projects (Blue 1990). Artificial nest platforms were most commonly used (n=40) and 95% of these companies erected platforms for ospreys. Generally, there is a greater need for nest platforms on distribution poles than on transmission structures because the closer separation between distribution conductors increases the risk of electrocutions and outages.

An osprey nest structure erected above a power pole should have a well-supported platform with some nest material added to entice the birds to the new site (Figure 6.10). A perch, situated above the nest (Figure 6.11) or extending from the platform (Figures 6.12

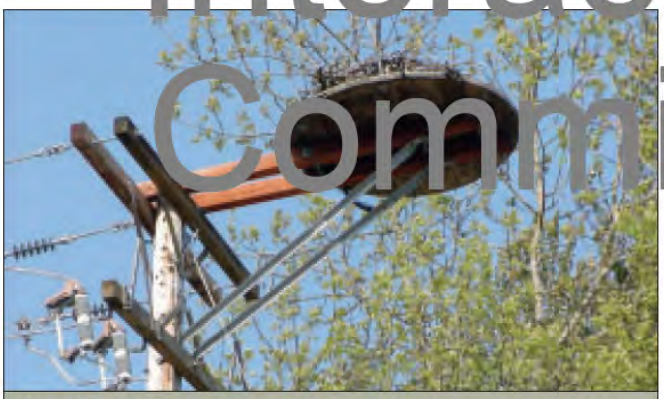

FIGURE 6.10: Osprey nest platform design developed by Portland General Electric. The platform is constructed from the end of a 1.5-meter (m) (5-foot [ft]) diameter wooden cable spool with coated cable along the edge to contain nest material. Utilities should ensure energized parts and equipment below the nest are covered to prevent electrocution of birds or outages from nest material. Consumer's Power, Inc. retrofitted this pole to their avian-safe standards.

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FIGURE 6.11: A nest platform built atop a pole using crossarms to extend the platform above the conductors. This design also includes an optional elevated perch to attract ospreys. The perch should be perpendicular to the prevailing wind.

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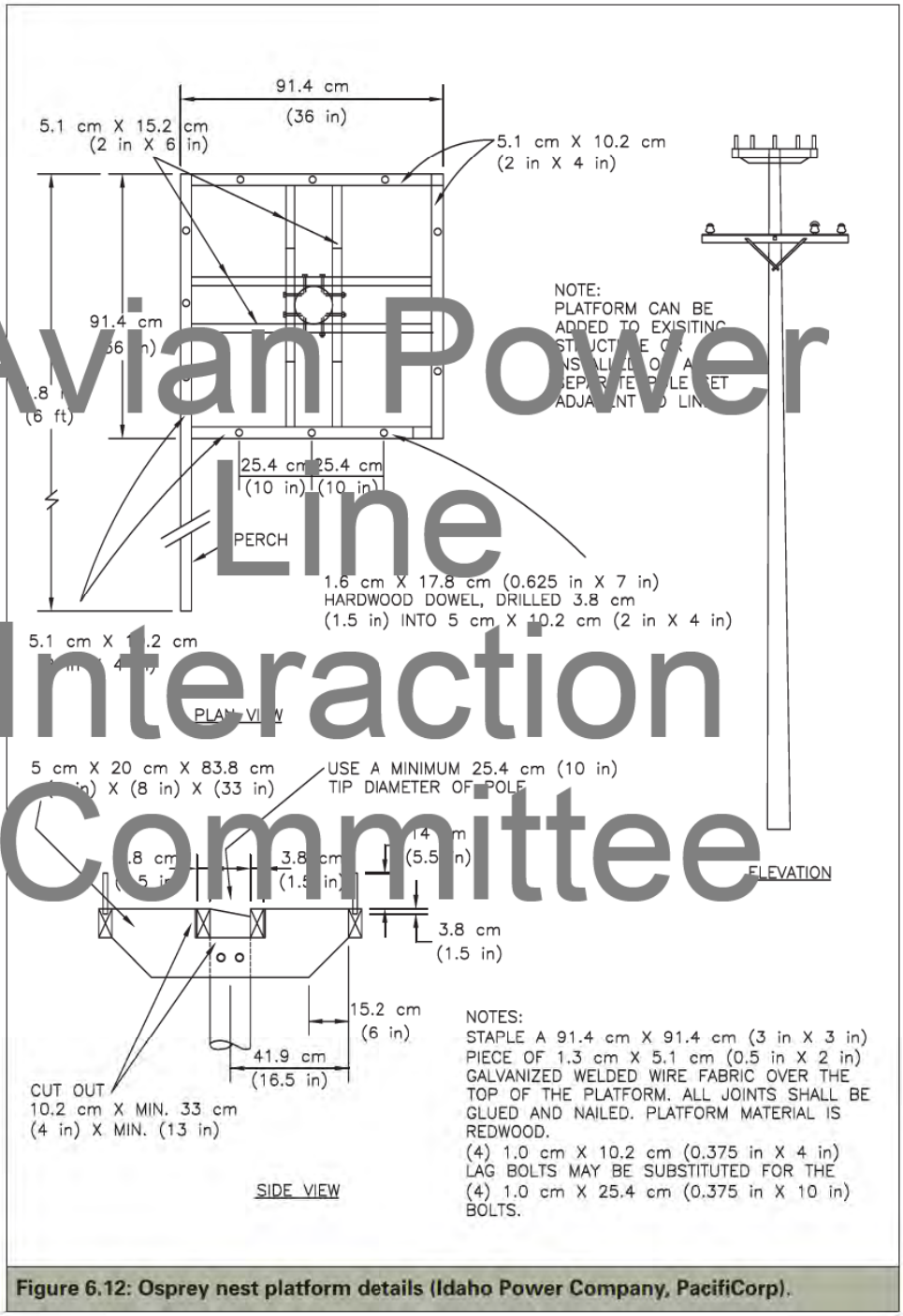

Figure 6.12: Osprey nest platform details (Idaho Power Company, PacifiCorp).

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FIGURE 6.13: Photo of nest platform depicted in Figure 6.12.

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FIGURE 6.14: A simple and cost-effective osprey nesting platform built for ospreys in Washington. Pallets can be used as platforms, providing ospreys with a flat nesting area.

and 6.13) may increase its desirability. Perches should be perpendicular to the prevailing wind. Care should be taken to arrange sticks and other nest materials so they mimic the size and form of a natural nest. Various nest platform designs are used by utility companies throughout the United States, Canada, and Europe (van Daele et al. 1980; Ewins 1994).

Platforms made from discarded wooden cable spools have been used by nesting ospreys (Austin-Smith and Rhodenizer 1983) (see Figure 6.10). The offset-pallet-platform design developed in Ontario (Ewins 1994:13) is simple and cost-effective (Figure 6.14). Figure 6.15 depicts another nest platform design that may be used for some buteos and ospreys. Grubb (1995) provides a guide for eagle nest designs.

Osprey nest management may include building alternate nest platforms above power lines, installing a nearby taller non-energized pole with a nest platform, or leaving the nest intact but retrofitting the pole (Henny et al. 2003).[32] However, utilities should be aware that installing a nest platform above lines or leaving a nest on a crossarm may result in outages from nesting material, excrement, or

[32] See Chapter 5 for retrofitting recommendations.

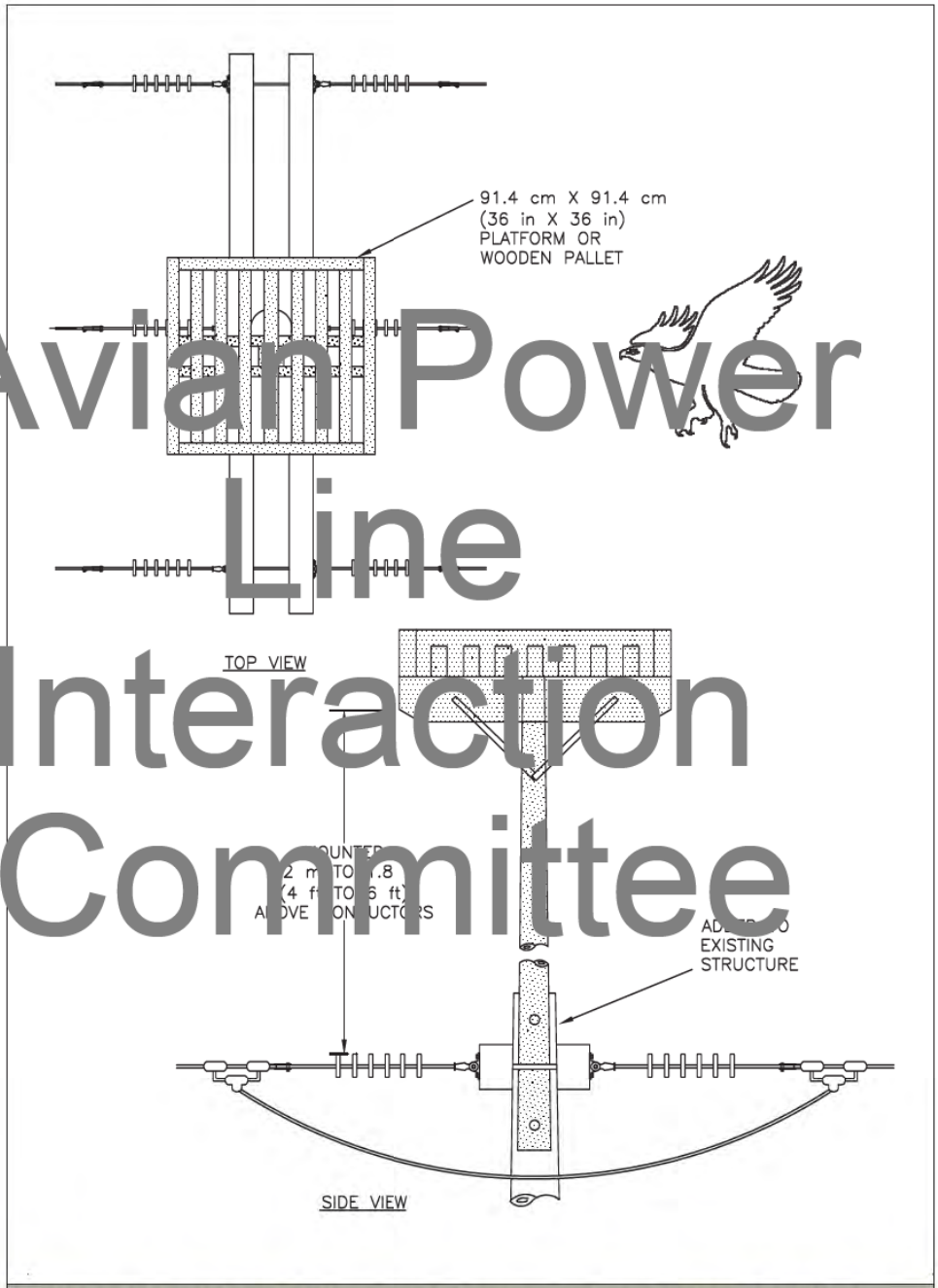

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FIGURE 6.15: Raptor nest platform used by ospreys and some buteos (PacifiCorp). This design is recommended when a new nest pole cannot be erected.

prey remains dropping onto conductors or energized equipment (Figure 6.16). Installing a platform on a nearby non-energized pole reduces these risks.

Transmission Structures

The greater separation between conductors on transmission towers generally allows raptors and other birds room to nest without causing problems for electric operations (e.g., Hobbs and Hedger 1986). The latticework of some steel transmission towers provides adequate support for nests without the aid of platforms (Figure 6.17). However, a nest situated above insulator strings may cause equipment failures due to contamination with excrement, prey remains, or nesting materials.

In Spain, nesting platforms were placed on transmission towers, where they would not interfere with normal operations, to keep white storks away from sites elsewhere on the towers (Janss 1998). The storks accepted the platforms, but the original nests remained in use as well.

The location of a nesting platform can also influence roosting behavior, and either increase or decrease the risk of streamer-caused faults (C.S. van Rooyen, pers. comm.). In South Africa, roosting cattle egrets, hamerkops from roosting martial eagles (*Polemaetus bellicosus*), lanneryy eagles (*Aquila rapax*), and Verreaux's eagles (*A. verreauxii*) were concentrated within a ten-transmission tower radius of active nests. These outages occurred on configurations that were both preferred for nesting and susceptible to streamer contamination (Jenkins et al. 2005). Conversely, eagles with nests located below phase conductors also roosted below conductors, reducing the outage incidence and risk.

Progress Energy reduced its osprey nest problem on double-crossarm structures by installing fiberglass nest platforms above the conductors (D. Voights, pers. comm.) (Figure 6.18).

FIGURE 6.16: Osprey nest in Wyoming atop double dead-end pole. Nesting material that may drop onto the conductors or equipment poses fire, outage, and equipment damage risks.

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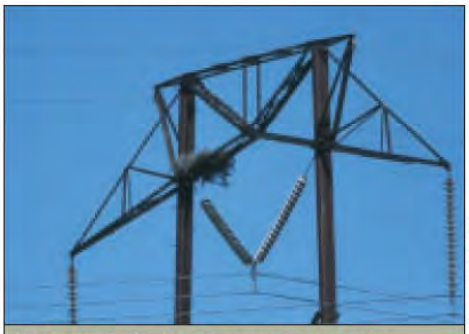

FIGURE 6.17: Golden eagle nest on transmission tower.

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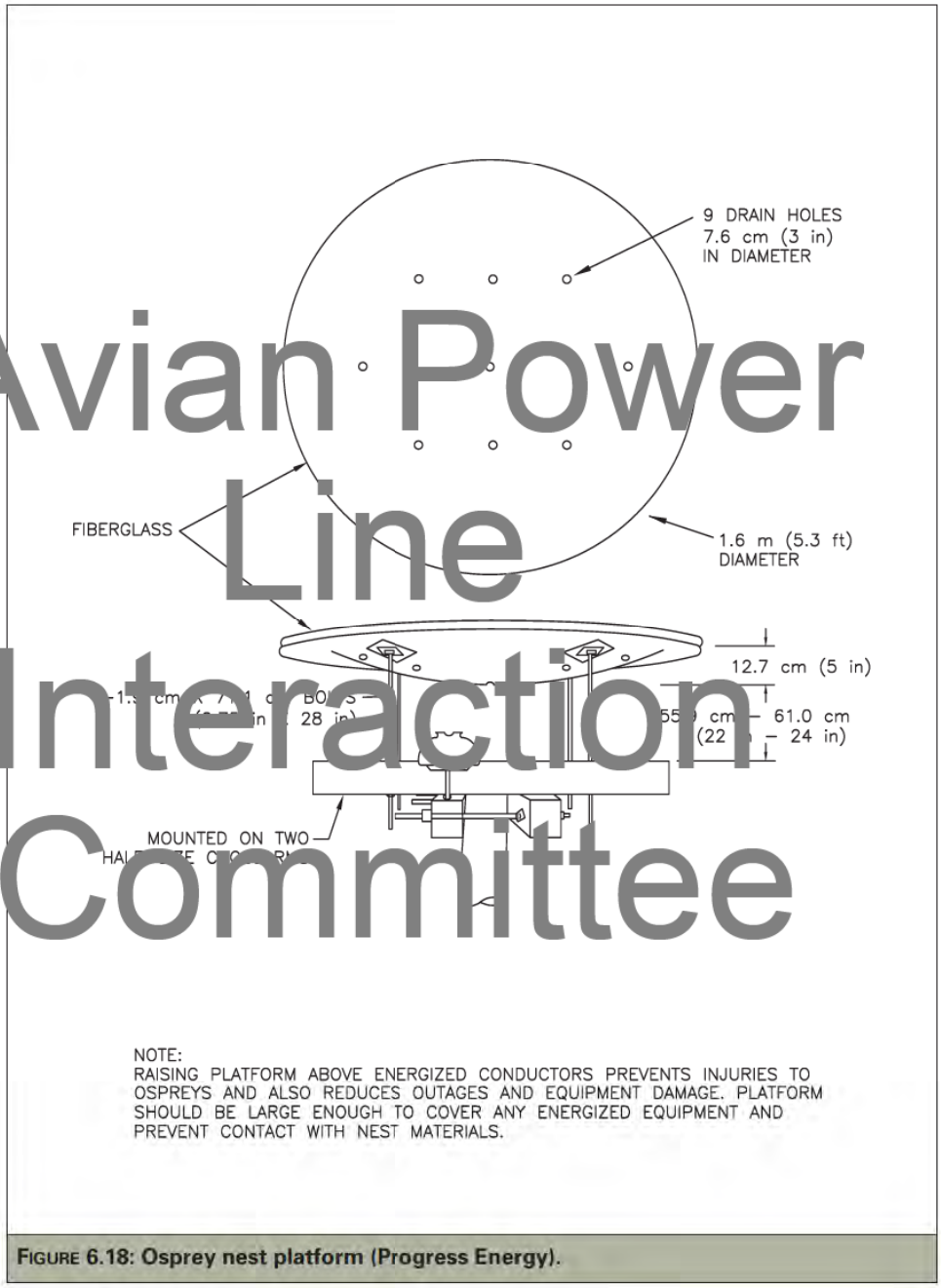

FIGURE 6.18: Osprey nest platform (Progress Energy).

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Georgia Southern University and Georgia Power Company have erected nest boxes and tubes on transmission structures in Georgia for American kestrels (J. Parrish, pers. comm.). The nesting tubes were constructed of 30.5-cm (12-in) diameter, UV-resistant PVC pipe cut at lengths of either 46 or 91 cm (18 or 36 in). All tubes were drilled with drainage holes in the bottom and slits on the sides, and lined with several inches of pine straw. The entrance of each nest tube was positioned to face east or south. The 91-cm (36-in) long tube included 30.5-cm (12-in) end caps with a 7.6-cm (3-in) hole cut in the middle of one of them (Figure 6.19). In 2003 and 2004, two of these tubes were mounted horizontally on transmission towers at a height of 30.5 m (100 ft). The tube mounted in 2003 was used in 2004, and both were used by nesting kestrels in 2005. The 46-cm (18-in) tube, which could be mounted either horizontally or vertically, included a 7.6-cm (3-in) hole in either the end or the top of the tube (Figure 6.20). These tubes were installed both vertically and horizontally at a height of 4.5 m (15 ft). Kestrels used one of the four vertically mounted tubes in 2005, but did not use either of the horizontally mounted tubes that year.

FIGURE 6.19 Kestrel nesting tube (91-cm [36-in] length) installed on transmission tower in Georgia.

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FIGURE 6.20 Kestrel nesting tube (46-cm [18-in] length) installed on transmission tower in Georgia.

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30.5 cm TO 45.5 cm (12 in TO 18 in) PVC PIPE OR CORRUGATED DRAIN PIPE CUT IN HALF LENGTHWISE. WIDTH OF PIPE SHOULD BE AT LEAST AS WIDE AS BOTH CROSSARMS. PIPE CAN BE BOLTED OR STRAPPED TO CROSSARMS. IF STRAPPED, STAINLESS STEEL BANDING MATERIALS SHOULD BE USED.

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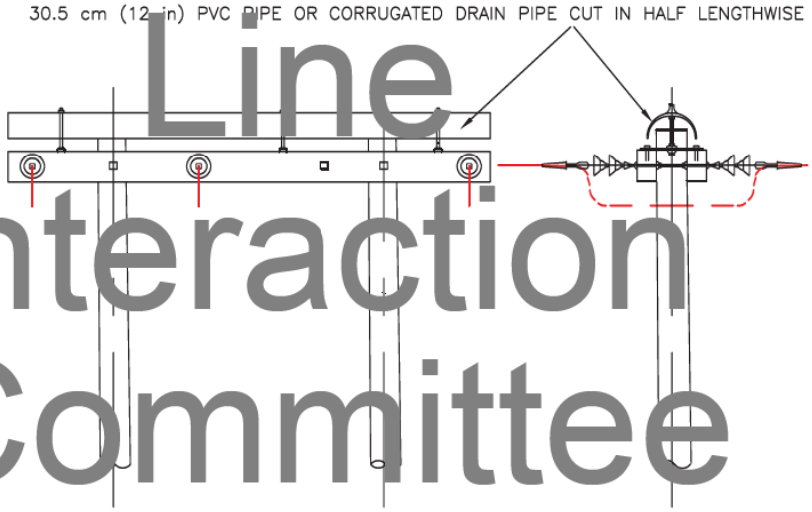

FIGURE 6.21: Nesting discourager (PacifiCorp).

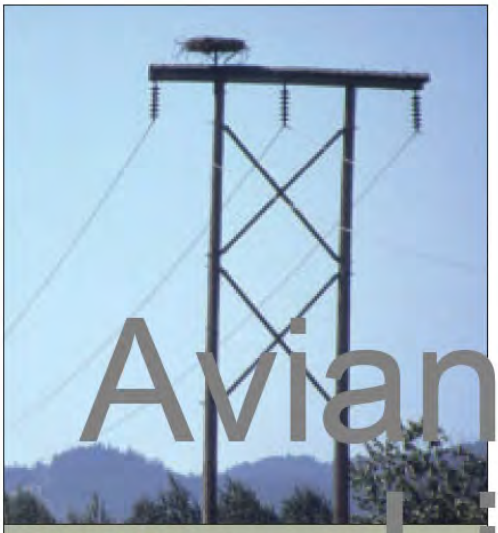

FIGURE 6.22: This osprey nest was originally located on the crossarms above the center conductor where contamination from fallen nest material and excrement accumulated. It was relocated to the platform shown. A halved, corrugated pipe was installed to prevent nesting on the crossarms. Relocating problem nests to a nest platform on an adjacent non-energized pole is preferred. However, if pole cost, rights-of-way restrictions, or limited access prevent installation of a new structure, it is best to install a safe nest platform on the existing structure.

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FIGURE 6.23: A segment of plastic pipe was installed on a dead-end pole in Oregon to discourage osprey nesting. However, the osprey pair continued nest construction after the pipe was installed.

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DISCOURAGING NEST CONSTRUCTION

Nesting should sometimes be discouraged due to the risks to people, nesting birds, or the power system. PVC pipe or corrugated drain pipe banded to the crossarms can prevent birds from nesting on "H" frame transmission structures (Figure 6.21). A nest platform can then be placed above the arm and away from the insulators (Figure 6.22) or on a nearby non-energized pole. To discourage nest rebuilding on distribution poles where nests have been removed, a large plastic pipe can be installed above the crossarm (van Daele et al. 1980). In Montana, this has been effective in deterring nesting ospreys (S. Milodragovich, pers. comm.). However, in other areas, this nest discourager has been ineffective (Figure 6.23). Poles with conductors and insulators above the crossarms require a more complicated design. A PVC tube positioned above and extending the length of the crossarm with diagonal tubes extending toward the crossarms can deter nesting (Figure 6.24) (Henny et al. 2003). Such nest

FIGURE 6.24: A pipe mounted above the conductors can be used as a nest discourager on distribution poles with insulators mounted on the crossarm. The use of triangles is cautioned against, as they may aid in the accumulation of nesting material. This design may pose an electrocution risk if exposed equipment and conductors are not covered or adequately spaced.

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discouragers should be installed close enough to the crossarm to prevent birds from nesting under them. They should be mounted securely on the arm, and should be installed so they do not reduce the BIL of the design.

Triangles, plastic owls, and small spikes have also been used to discourage nesting on power poles. However, these devices are often unsuccessful. For example, birds may nest in open spaces adjacent to triangles (Figure 6.25), birds may initially react to plastic owls, b[illegible] over time they can become habituated to them (Figure 6.26), and plastic spikes may aid [illegible]

the accumulation of nest material (Figure 6.27). As discussed in Chapter 5, materials placed on poles to discourage birds from perching or nesting degrade over time, particularly in areas with extreme weather conditions. Utilities should consult with their standards and engineering personnel to identify company-approved devices prior to installation.

RECOMMENDATIONS FOR DESIGNING AND INSTALLING NEST PLATFORMS

Wh[illegible] designing and installing nest platforms, biologists, engineers, and line workers should consider the following:

- Platforms should be placed where conductors and energized equipment will not be fouled by dropped nest material, prey remains, or excrement.
- To prevent electrocutions, avian-safe designs and retrofitting materials and methods (see Chapter 5) should be applied to poles with or near nest platforms. However, the use of perch discouragers should be avoided near nests. If a nest fails, the pair may attempt to nest on a nearby

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FIGURE 6.25: Red-tailed hawk nest on pole with triangle perch discouragers.

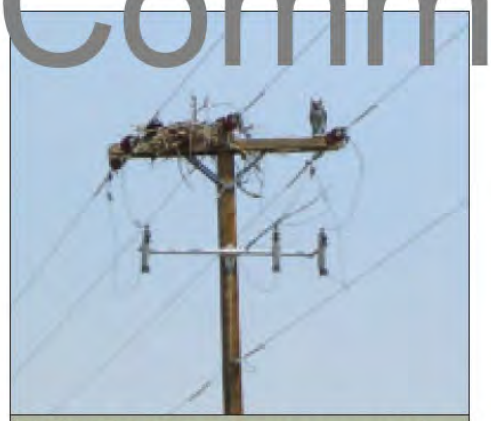

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FIGURE 6.26: Osprey nest constructed on pole with plastic owl intended to haze birds.

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FIGURE 6.27: Osprey nest on pole with plastic spikes.

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pole, possibly selecting a pole with perch discouragers because it more easily accumulates sticks (S. Milodragovich, pers. comm.).

- Platforms should be located in areas with adequate habitat and prey for the target species.
- Discretion should be used when placing nest platforms near sites with sensitive wildlife such as sage grouse, prairie chickens, or prairie dogs that may fall prey to nesting raptors.
- Nest platforms may not be needed on all types of transmission towers. For example, the metal latticework of certain steel towers and the double crossarms of H-frame construction typically provide adequate nest substrates (Lee 1980; Steenhof et al. 1993).
- If possible and appropriate, nesting platforms can be installed on decommissioned poles to draw nesting activity away from energized structures.
- For ospreys, a 1.2-m (4-ft) square or 1.5-m (5-ft) diameter platform (see Figure 6.18) can be more effective than a 0.9-m (3-ft) square platform (see Figures 6.12 and 6.15) in preventing nest material from sloughing off (J. Kaiser, pers. comm.). A lip or pegs on the edge of the nest platform also helps prevent nest sticks from falling off the platform. Carriage bolts, which may already be carried on line-trucks, can be used as alternative to a lip or pegs. The addition of sticks to a newly-constructed platform may help entice nesting birds. Birds may also be more likely to use a new nest platform if it is higher than adjacent substrates or a reasonable distance away from other alternative(s).
- The weight of a nest platform under wet or snowy conditions should be considered. If it is too heavy for an existing pole, the platform should be installed on a nearby, suitable pole.
- Federal and/or state permits are required for managing active nests of protected species (see Chapter 3). No active nests (nests with eggs or young) may be altered, moved, or destroyed without proper authorization from appropriate agencies. Nests of eagles and endangered species cannot be altered, moved, or destroyed at any time without proper authorization from appropriate agencies. Because of the biological/behavioral characteristics of some birds (e.g., colonial- and ground-nesting birds), construction of an inactive nest could also result in a take (USFWS 2003).
- If platforms are used to relocate problem nests, relocation distances should not be excessive; success is directly related to proximity. Distances between 20 and 100 m (66 and 328 ft) are most common for ospreys (J. Kaiser, pers. comm.). Golden eagle nests have been successfully moved as far as 2.6 km (1.6 mi), but in incremental steps (Phillips and Beske 1982). The new location should be in line-of-sight to the old location. A biologist should be consulted to provide guidance, and appropriate permits must be obtained.
- On poles with platform nests, predator guards can be used to prevent raccoons and other mammals from climbing to the nests. A commonly used device is a 1.5-m (5-ft) length of sheet metal wrapped completely and tightly around the pole at about 1 to 1.5 m (3 to 5 ft) above the ground. However, predator guards should not be used on poles that utility personnel are required to climb.
- Maintenance of platforms and platform supports will extend the life of the structures and will minimize future conflicts with utility operations. Maintenance activities should take place before the breeding season to avoid disturbing nest building efforts, eggs, or nestlings.

RELIABILITY CONCERNS

Unfortunately, despite the benefits utility structures provide nesting birds, there are some negative effects as well. For example, nesting material, electrocuted birds, streamers, or prey debris can cause interruptions and outages. During the nest building process, birds may drop sticks onto conductors causing flashovers (Ledger and Hobbs 1999). Likewise, nests located over exposed, energized equipment can cause flashovers or nest fires during wet conditions. Osprey nests in agricultural areas often contain baling wire or twine that could cause power outages or dangle nesting (Bloom et al. 2002; PacifiCorp, unpubl. data). Dangling or falling prey can also contact energized wires (EDM International 2004).

Utility companies have dealt with bird-caused power reliability problems in a number of ways. One management concept is to maintain nests when they are in desirable locations (Henny et al. 2003; J. Kaiser, pers. comm.). Nest material can be trimmed away from conductors (Hobbs and Ledger 1986; Torres and Bancroft 1986). Occupied nests are well maintained by raptors, but abandoned nests may partially or completely collapse, thereby threatening electrical equipment (Ledger and Hobbs 1992). The use of perch or nest discouragers alone may not be effective in preventing nesting. In Florida, monk parakeets began using raptor perch discouragers as nest substrates in areas where they had not previously nested (J. Lindsay, pers. comm.). In the western United States, red-tailed hawks, ospreys, and common ravens have built nests around perch discouragers that were installed to discourage nesting on equipment or double dead-end poles (J. Burruss, pers. comm.) (see Figures 6.23, and 6.25 through 6.27).

Suspending a vulture carcass or decoy by its feet in a tower was an effective means of ridding the structure of communally roosting black and turkey vultures for many months (Avery et al. 2002). However, before using a carcass for this, a utility must consult with federal and state wildlife resource agencies regarding permits, and should closely evaluate the public response. Shields attached below the latticework on transmission towers with roosting ravens have been used to prevent the accumulation of excrement on insulators (Engel et al. 1992a). In South Africa, high-density polyethylene (HDPE) welded rod bird guards have been effective in reducing line faults (Vosloo and van Rooyen 2001; van Rooyen et al. 2003).

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BIRD-RELATED OUTAGES

Bird-related outages are a concern for many utilities. Although outages may occur as the result of an electrocution or collision, there are several other causes that do not result in human mortality, for example:

- Nest material contact,
- Conductor-to-conductor contact caused by the line gallop started by a large flock of birds flushing,
- Prey falling on energized conductors or equipment,
- Bird streamers or contamination of equipment with accumulated feed and feces, and
- Bird collisions with conductors that cause outages but do not kill the birds.

Bird electrocutions do not necessarily result in outages. Of eagle electrocutions in the western United States with known mortality dates (n=612), only 16% were associated with an outage (Harness and Wilson 2001). Likewise, only 16% of known bald eagle mortalities in western Washington from 2000 to 2005 (n=62) caused outages (M. Walters, pers. comm.). Less than 10% of raptor electrocutions documented in Arizona were associated with outages (Dwyer 2004). However, higher proportions of mortalities have been

associated with outages in other areas of the western United States. For example, 55% of bird electrocutions (n=327) resulted in outages in Utah, Wyoming, Idaho, California, Oregon, and Washington (PacifiCorp, unpubl. data).

Momentary short circuits, which do not cause outages, can cause disruptions for customers with high power quality requirements, and can also result in electrocutions. During these disturbances, the cause of the fault is cleared from the circuit before circuit protection devices trip the line, making it difficult to identify the cause. Some utilities have begun tracking this class of disruption, which might yield important bird mortality information.

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Collection of Outage Data

Two key aspects of quantifying bird-caused outages are tracking and verification. Utilities should collect data to quantify outage numbers and causes. These data may include outage location, duration, cause, associated equipment, and pole type. Outage data can help identify outage locations, quantify the impact of birds on system reliability, identify the species associated with outages, and guide retrofitting and new construction efforts for prevention. To accurately address an outage, its cause(s) must be verified. Local regulations require some utilities to list the causes of all outages. In some cases, birds are just speculatively recorded as the cause. In others, their carcasses are not discovered for various reasons: scavengers or people removed them, the victim fell into dense vegetation, or a systematic search was not conducted. Identifying the causes of outages is critical to developing corrective plans. Utilities should recognize that the number of bird-caused outages reported may increase after a tracking or verification program is implemented simply because the causes of more outages are properly identified. On the other hand, the total number of bird-related outages on record may decrease when erroneous reports are corrected.

Although the causes of bird-related outages are well documented, few studies quantify bird-related outage rates. The National Rural Electric Cooperative Association (NRECA) listed animals as the third leading cause of power outages nationwide (Southern Engineering Company 1996). Of Avian Power Line Interaction Committee (APLIC) utility members surveyed in 2005 (n=12), 58% tracked bird-caused outages (APLIC 2005). Of utilities that provided data, bird-caused outages ranged from 1% to <10% of their total outages. Half of these utility respondents reported major outages due to birds. In California, wildlife-related incidents accounted for 10 to 25% of all outages (Energy and Environmental Economics, Inc. 2005). Wildlife was considered a contributing cause in up to 20% of outages in Wisconsin during 2003 (Kysely 2004). Birds accounted for 23.5% of substation outages for a Canadian utility in 2002–2003 (BC Hydro 2004). In an assessment of 2,174 bird-related outages documented in the western United States, 60% were caused by federally unprotected species (i.e. starlings or pigeons), 21% were associated with protected bird deaths, 12% were [illegible]-caused although no carcasses were found (e.g., flocks flushing from lines), and 7% were due to bird nests not associated with a mortality (PacifiCorp, unpubl. data). Within this study, seasonal outage trends were also documented, and revealed that outages peaked during summer and fall (likely due to nesting activity and fall migration).

Costs of Outages

Costs associated with bird-related outages include those related to:

- Lost revenue,
- Power restoration,

- Equipment repair,
- Nest removal and other animal damage-control measures,
- Administrative and managerial time,
- Lost service to customers and negative public perception, and
- Reduced electrical system reliability.

Stocek (1981) estimated that the annual cost of bird-related damage to Canadian utilities was $374,600. Recent data from Canadian utility estimated wildlife outages (=2,500 to 3,500) cost $2 million annually (BC Hydro 1999). Wildlife-related outages are estimated to cost up to $3 billion each year in California (Hunting 2002; Singer 2002; Energy and Environmental Economics, Inc. 2005). One utility documented that bird-related outages cost them $2 million annually (ALIC 2005). During a five-month period in 2001 in south Florida, 198 outages affecting over 10,000 customers were related to monk parakeets. Lost revenue from electric power sales due to these outages was $24,000 (Florida Power & Light, unpubl. data). Outage repair was a much more significant cost, estimated at $221,000 annually. The total estimated cost associated with the 198 outages in this small part of the U.S. area was $245,000.

FIGURE 6.28: Red-tailed hawk expelling streamer.

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BIRD STREAMERS

Large raptors, vultures, and herons can expel long streams of excrement (Figure 6.28). These "streamers" can cause flashovers and short-outs when they span energized conductors and other line structures. Flashovers are faults that originate on live hardware and travel through the streamer to the structure. Although bird streamers were first thought to be a cause of unexplained transmission line faults in the 1920s (Michener 1924), this hypothesis has been difficult to verify because flashovers are rarely witnessed, and the resulting evidence is difficult to find. Yet, Burnham (1995) estimated that bird streamers might cause as many transmission outages in Florida as lightning, dust, coal, or industrial contamination. Recent studies in South Africa have emphasized the role of bird streamers as a cause of line faults (van Rooyen et al. 2003).

Evaluating streamer-related faults has often relied upon indirect evidence. Studies conducted by Burnham (1995), van Rooyen and Taylor (2001), Vosloo and van Rooyen (2001), Vosloo et al. (2002), and Acklen et al. (2003) documented patterns that are indicative of streamer-related transmission faults and described methods for preventing outages of this kind. There are several indicators of streamer-caused faults; e.g., the presence of large birds along transmission lines that are subject to faulting (Burnham 1995; van Rooyen et al. 2003; van Rooyen and Smallie 2004). Streamer-related faults are not normally lethal to birds, as streamers are often released as a bird departs from a structure. However, in some cases flashover mortalities do occur. Streamer-related faults occur most frequently

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FIGURE 6.29: Burn marks on transmission structure associated with streamer-caused flashover.

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on horizontally configured, steel transmission structures that provide perching space above the conductors. Structures with small windows and shorter air-gaps are especially fault-prone (van Rooyen et al. 2003), although faults can also occur on wooden or concrete structures (Burnham 1995). Faults are most prevalent on the highest phase of the tower, or the phase closest to a preferred perching space on the tower. Structures that are horizontally configured or vertically configured structures that generally provide little perching space above the conductors. Streamer-related flashovers have been simulated in the laboratory and flash marks on structures and insulators were recognizable (West et al. 1971; Burger and Sardurksi 1995).

Flashovers are generally indicated by burn marks on the insulator string, or the corona ring and tower top. Burn marks may occur as pitting. They are shiny on aluminum structures and black on steel structures (Figure 6.29). Streamer-caused faults typically occur during the late evening and early morning. A late night peak, usually around 11 p.m., occurs as birds finish digesting their last meal. Likewise, an early morning peak occurs when birds leave their roosts (Burnham 1995; van Rooyen et al. 2003). Faults often occur in clusters, indicating that concentrations of large birds have been attracted by a favorable prey base or suitable habitat, or that there is a seasonal population increase.

Devices designed to prevent excrement build-up on insulator strings have had limited success because they fail to prevent the air-gap breakdown caused by streamers. The most successful devices create a barrier that keeps birds from roosting over the conductors. Examples of such devices include welded-rod bird guards and cones. The most comprehensive application of bird-guarding devices for preventing streamer-related faults is practiced in South Africa by Eskom Transmission Group through its National Bird Guard Project. Eskom has installed thousands of HDPE welded-rod bird guards and dramatically reduced faults (Kosztya and van Rooyen 2001; van Rooyen et al. 2003). In addition, perch discouragers installed over insulators on lines in Florida have been effective in reducing streamer-related faults (Burnham 1995).

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CHAPTER 7

Developing an Avian Protection Plan

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IN THIS CHAPTER

- Choosing the Right Tools—MOUs and APPs
- Components of an APP
- Implementing an Avian Protection Plan

In 2005, the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (USFWS) announced the jointly developed Avian Protection Plan Guidelines (Guidelines) that are intended to help utilities manage their avian/power line issues. The Guidelines offer resources for developing avian protection plans (APPs). An APP should provide the framework necessary for implementing a program to reduce bird mortalities, document utility actions, and improve service reliability. The components that a utility may wish to include in its APP are summarized in this chapter.

The 1996 edition of *Suggested Practices* included a chapter, "Cooperative Management of the Electrocution Issue," that focused on relationships among utilities and agencies and offered recommendations for mortality reporting, training, and prioritizing remedial actions. Since 1996, utilities and agencies have continued to advance the understanding of avian electrocutions. Efforts between the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (USFWS) have culminated in the Avian Protection Plan Guidelines (Guidelines) (see Appendix C). The Guidelines are a "toolbox" from which utilities may select and tailor components to fit their needs. In this chapter, an overview of the Guidelines is presented, along with recommendations for developing and implementing an Avian Protection Plan (APP). There is an abbreviated version of the Guidelines in Appendix C. The complete version can be obtained from either the APLIC (www.aplic.org) or USFWS (www.fws.gov) website.

CHOOSING THE RIGHT TOOL—MOUs AND APPs

When developing a bird protection program, two tools, the Memorandum of Understanding (MOU) and the APP, have been used effectively. Historically, MOUs have been initiated by the USFWS when it finds a utility has violated bird protection laws and has not implemented or abided by the law or an APP. MOUs are signed by both the utility

and the USFWS and establish the program's requirements. They generally include a statement of purpose, the contract's duration, definitions, a requirement to develop an APP, and requirements for permitting, possessing, retrieving, salvaging, reporting, and record keeping.

Although APPs are typically a component of MOUs, they may be initiated voluntarily and signed only by the utility. This can allow for greater flexibility in developing timetables and enables a utility to tailor components to match its specific needs.

Because an APP represents a utility's commitment to reducing its avian impacts and is shared with the USFWS, it is understood to be binding. Since they emanate from the utility, APPs are more easily modified for addressing newly developing problems and unforeseen needs. Despite the fact that APPs are generally initiated by utilities, a cooperative dialog between the utility and the USFWS during development is strongly encouraged. This sets the tenor for those conversations that will inevitably follow, as the APP is implemented and refined over time.

A utility that implements the principles contained in the Guidelines will greatly reduce avian electrocution risk. Developing and implementing an APP makes good business sense because animal- and bird-caused outages can be costly. A utility that creates an APP to address its specific avian issues can benefit through reduced regulatory risk, reliability improvements, cost savings, and positive recognition from regulators, employees, and customers.

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COMPONENTS OF AN APP

An APP is a utility-specific program to reduce the operational and avian risks that result from avian interactions with electric utility facilities. Although each utility's APP will be different, the overall goal of reducing avian mortality is the same. The Guidelines provide a framework along with principles and examples to help a utility craft its APP to best fit its needs while furthering avian conservation and improving reliability and customer service. Because of utility-specific circumstances, some of the elements of the Guidelines may not be applicable. The Guidelines present a comprehensive overview of the elements that should be considered when a utility develops its own APP. An APP should also be a "living document" that is modified over time to improve its effectiveness. The following are the principles of an APP:

- Corporate policy
- Training
- Permit compliance
- Construction design standards
- Nest management
- Avian reporting system
- Risk assessment methodology
- Mortality reduction measures
- Avian enhancement options
- Quality control
- Public awareness
- Key resources

CORPORATE POLICY

An APP typically includes a statement that balances the company's commitment to minimizing its impact on migratory birds and complying with bird-protection regulations with its goal of providing reliable, cost-effective electrical service. To do this, it will comply with all necessary permits, monitor avian mortality incidents, and make reasonable efforts to construct and alter infrastructure to reduce the incidence of avian mortality.

TRAINING

Training is an important element of an APP. All appropriate utility personnel, including managers, supervisors, line crews, engineering, dispatch, and design personnel, should be

properly trained in avian issues. This training should encompass the reasons, needs, and methods for reporting avian mortalities, following nest management protocols, disposing of carcasses, and complying with applicable regulations, and understanding the potential consequences of non-compliance. Supplemental training also may be appropriate when there are changes in regulations, permit conditions, or internal policies. APLIC-sponsored short-courses on avian electrocution, collision, and other issues are conducted annually at locations throughout the United States. In addition, a two-hour overview presentation of avian issues that can be used for internal company training is available from APLIC (see www.aplic.org).

PERMIT COMPLIANCE

An APP can describe the process through which a company will obtain and comply with all necessary avian-related permits. The activities that may require permits include, but are not limited to, nest relocation, temporary possession, depredation, salvage/disposal, and scientific collection.

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FIGURE 7.1: Utility crew installing raptor nest platform.

CONSTRUCTION DESIGN STANDARDS

Avian interactions with electrical facilities can cause outages and reduce system reliability. To improve system reliability, avian interactions should be considered when designing and siting new facilities as well as when operating and maintaining existing facilities. For those reasons, inclusion of accepted standards for both new construction and retrofitting techniques should be included in an APP. Companies can either rely upon construction standards recommended in this document or may develop their own standards that meet or exceed these guidelines. These standards may be used in areas where new construction should be avian-safe, and where existing infrastructure should be retrofitted for avian safety.

NEST MANAGEMENT

An APP may include procedures for managing nests on utility structures (Figure 7.1). This could include procedures for problem nests (ones that need to be relocated or removed) as well as for safe nest sites. These procedures should be explained to company employees during training to ensure consistent treatment of avian nest issues and compliance with regulations or permits related to nest management.

AVIAN REPORTING SYSTEM

Although avian mortality reports may be required as a condition of federal or state permits, a utility may also voluntarily monitor relevant avian interactions, including mortalities, by developing an internal reporting system. A well-implemented system can help pinpoint the locations of mortalities and the extent to which they are occurring. These data can be limited to avian mortalities or injuries,

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or could be expanded to track avian nest problems, problem poles or line configurations, and the remedial actions taken. All data should be regularly entered into a searchable database compatible for use in additional analyses (see Risk Assessment Methodology below). Some companies have developed their own bird interaction reporting systems, and the USFWS has created an online bird electrocution reporting system for utilities (see Appendix C, Avian Reporting Systems).

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RISK ASSESSMENT METHODOLOGY

A utility can cost-effectively reduce avian mortalities by focusing its efforts on the areas of greatest risk to migratory birds. Therefore, an APP should include a method for evaluating the specific risks a company poses to migratory birds. A risk assessment will often begin with a review of available data that address areas of high avian use, avian mortality, problem nests, established flyways, preferred habitats, prey populations, perch availability, effectiveness of existing procedures, remedial actions, and other factors that can increase avian interactions with utility facilities. The avian reporting system discussed in the previous section is an integral component of this risk assessment, as is the use of avian experts, birders, and biologists who can provide additional information on avian distribution. A risk assessment can be used to develop models that will enable a company to use biological and electrical design information to prioritize poles most in need of modification. A risk assessment may also provide data about the various causes of avian mortality as well as the benefits that birds receive from utility structures.

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FIGURE 7.2: Reframing a crossarm to prevent avian electrocutions.

MORTALITY REDUCTION MEASURES

After completing a risk assessment, a company can focus its efforts on areas of concern, ensure that its responses are not out of proportion to the risks presented to migratory birds, and determine whether avian mortality reduction plans need to be implemented (Figure 7.3). Risk reduction measures may be implemented through the design by using risk assessment results to direct monitoring and retrofitting activity in the existing system, and to direct attention to avian issues encountered during new construction projects. If a utility finds that avian protection measures are appropriate, it also may choose to develop an implementation schedule for these measures.

AVIAN ENHANCEMENT OPTIONS

In addition to reducing avian mortality risk, an APP also may include opportunities for a utility to enhance avian populations and/or habitat. This may include installing nest platforms, managing habitats to benefit migratory birds, or working with agencies or organizations in these efforts (Figure 7.3).

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FIGURE 7.3: Volunteers and utility personnel work together to create nesting platforms.

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Where feasible, new ideas and methods for protecting migratory birds should be encouraged and explored.

QUALITY CONTROL

An APP also may include a mechanism for reviewing existing practices and ensuring their efficiency and effectiveness. For instance, a utility may examine its reporting systems, performance, or evaluate the techniques and technologies it uses for preventing collisions, electrocutions and problem nests.

PUBLIC AWARENESS

An APP may include a method for educating the public about the avian electrocution issue, the company's avian protection program, and its successes in avian protection.

KEY RESOURCES

An APP should identify key resources that address avian protection issues including a list of experts who may be called upon when resolving avian-related problems. Experts could include company specialists, consultants, state and federal resource agents, university faculty, or other conservationists. Engineers may find that company personnel such as environmental specialists can help find creative solutions to avian interaction problems, and that members of external organizations like APLIC can also serve as helpful resources through workshops, materials, and contacts. An understanding of avian behavior can influence how and when avian protection should be provided. An APP that connects biologists with utility decision-makers may reduce bird mortality and improve system reliability.

IMPLEMENTING AN AVIAN PROTECTION PLAN

Integrating an APP into an electric utility operation will help the utility meet demands for reliable, cost-efficient, and environmentally compatible power delivery. A utility that creates and manages an APP will quickly become familiar with avian-related science, engineering, law, and politics. It will also need to establish a program that satisfies the law, utility employees, utility customers, investors, and other interests.

The ease of implementing an APP will depend on the size of a utility's transmission and distribution system, the range of avian species in the service area, and the frequency of bird/power line interactions. The extent of bird/power line interactions may not be realized until several years into a fully implemented program. Thus, APP implementation and operation is a long-term commitment and a process of continual evaluation and improvement.

An APP may be the first species-oriented environmental compliance initiative to which utility employees are exposed. Depending on the company's culture, the rate of adoption may vary. High-profile endorsements by corporate officers and managers can facilitate a program's adoption. Some larger utilities have effectively linked APP compliance with financial incentives, similar to more common budget, schedule, and safety goal incentives. Compliance with an APP will reduce utility costs in the long term through improved reliability and reduced regulatory risk.

Management support is critical for a successful program. However, even with management support, successful implementation is unlikely unless all the affected organizations within the utility also support it. An effective way to build a broad consensus during APP preparation is to form a team within the utility that includes representatives from standards, engineering, environmental services, vegetation management, construction and maintenance, public relations, customer service, and other departments that will be impacted by the APP. Considerable input and assistance from team members are needed to understand how APP implementation will best fit the operations of each department. Solutions to reducing avian mortality can be developed that are responsive to the work requirements of each functional unit. In this manner, individuals from each department will feel invested in the mortality reduction solutions they helped develop and will have an interest in assuring APP effectiveness.

Beyond developing and communicating corporate APP policy, the most important component of an APP is a consistent and mandatory reporting process. An electronic or paper form of documenting bird-power line conflicts (e.g., time, place, equipment) becomes the foundation for appropriate corrective actions both to correct unsafe situations and to build a dataset to guide future engineering/construction needs. Managing data for these purposes, as well as for meeting any state and federal agency reporting requirements is an important function of APP administration. Using Geographic Information System (GIS) technology to track and report bird mortalities, remedial actions, outages, and avian risks enables a utility to identify problems and to track the effectiveness of its APP.

Use of existing processes and systems (e.g., outage reporting, environmental review, asset management, and accounting) will help control costs of developing and implementing an APP. Whether an APP is driven by an environmental, engineering, or operations department, cooperation will be necessary across all departmental lines to reduce actual and potential avian-power line conflicts. As with any project, better planning yields better results. The ultimate goals of an APP are a measurable decrease in avian-power line fatalities, and an increase in electric service reliability.

A utility's APP will represent the continuation of a long-term proactive conservation partnership between the utility industry, the conservation community, and the USFWS. These voluntary plans will provide utilities with a framework for addressing electrocution hazards, managing risk their power lines pose to birds, and working with the USFWS to conserve federally protected migratory birds.

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APPENDIX A

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APPENDIX B

Early History of Agency Action

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Chapter 2 provides a brief history of the initial agency and industry responses to the raptor electrocution problems identified after a systematic campaign to kill eagles was uncovered in the early 1970s. This Appendix provides additional detail for those interested in the process and people involved in this first cooperative response.

In May 1971, the carcasses of 11 bald eagles *(Haliaeetus leucocephalus)* and four golden eagles *(Aquila chrysaetos)* were discovered in Jackson Canyon, near Casper, Wyoming, a traditional roosting place for both species. The full extent of the kill was 24 birds. External examinations revealed no gunshot wounds, and there were no power lines in the area on which the birds could have been electrocuted. It was determined that several antelope carcasses had been baited with thallium sulfate (then a widely used predator control poison), and left as bait.

Surveys in Wyoming and Colorado uncovered a major shooting campaign. During August 1971, a Wyoming helicopter pilot told the Senate Environmental Appropriations Subcommittee that he had piloted several eagle hunts in the preceding seven months where roughly 560 eagles were killed. The shooting was commissioned by the father-in-law of the sheep rancher who had poisoned the eagles in Jackson Canyon. Revised testimony by the helicopter pilot set the estimate of eagle kills at nearly 800, and implicated at least 12 other Wyoming ranching companies. During the surveys in Wyoming and Colorado, more than 300 eagles were found dead near power lines (Turner 1971; Laycock 1973).

When the Jackson Canyon, Wyoming, incident and subsequent investigation revealed a close connection between raptor deaths and power lines, individuals, agencies, and concerned groups collaborated to study the problem and begin corrective action. On 19 January 1972, agency representatives met in Washington, D.C. to discuss the electrocution problem (U.S. Fish and Wildlife Service 1972). Agencies included the Rural Electrification Administration (REA; now the Rural Utilities Service), U.S. Forest Service (USFS), Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), and Bureau of Indian Affairs (BIA). The USFWS coordinated the search for lethal lines, while the REA began developing line modifications to minimize eagle electrocutions.

In January 1972, Robert K. Turner, Rocky Mountain Regional Representative of the National Audubon Society, wrote to Thomas Riley of the Pacific Gas and Electric Company drawing attention to the raptor electrocutions in Colorado and Wyoming (R. Turner,

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National Audubon Society, pers. comm. in APLIC 1996). The letter, forwarded to Richards S. Thorsell of the Edison Electric Institute (EEI)[33] in New York City, became the impetus for utility company participation, fund-raising, and publications aimed at decreasing power line hazards to eagles. Thorsell coordinated representatives from a group of western utilities[34] to assess the problem. They determined that grounding practices of 4 kV- to 69 kV-distribution lines (along with certain configurations of transformer bank fused cutouts, lightning arresters, and conductor phase spacings) could be a substantial cause of raptor deaths. Engineering solutions were then to be developed in a cooperative public/private effort to help solve the problem of raptor electrocution.

On 6 April 1972, EEI hosted a meeting in Denver, Colorado, the first of several workshops on eagle electrocutions and their relationship to power outages and other related issues (Olendorff 1972c). It was attended by representatives of western power companies, the REA, state and federal wildlife agencies, and conservation organizations.[35] Three concrete actions resulted:

1. The participants agreed to seek and implement power line modifications and restrictions that would be biologically and economically feasible and that would reduce raptor electrocutions.
2. A raptor mortality reporting system was established, to be administered by the USFWS.
3. Participants would document modifications with drawings and suggestions that could be used by private and public entities.

The REA, an agency of the U.S. Department of Agriculture, lends money to cooperatives that supply electricity primarily to customers in rural areas. As part of loan conditions, the REA sets minimum standards for power line design. Even before the Denver meeting, it had been determined that older three-phase and single-phase power lines presented the most serious electrocution problems for eagles. REA Bulletin 61-10, *Powerline Contacts by Eagles and Other Large Birds*, describes causes of power electrocutions resulting from certain grounding practices and conductor spacing (U.S. REA 1972). The bulletin included suggestions on how member companies could correct existing problem lines or design new lines that would be safe for eagles.

The USFWS raptor electrocution reporting system was instituted in 1973.[36] About 300 eagle carcasses and skeletons were found between 1969 and 1972. Subsequently, the number of reported eagle mortalities along power lines dropped to 123 in 1973, 88 in 1974, and 65 in 1975. No conclusions can be drawn from these figures, however, because other variables were involved that affect the reliability of the data. For example, during the same period, mid-winter golden eagle populations declined in response to a steep jackrabbit population decline one to two years earlier. The number of golden eagles electrocuted in Idaho declined during those years (Kochert 1980) when fewer golden eagles fledged. Additionally, reporting system figures are contradicted by findings of substantial numbers of eagle mortalities along power lines in some western states (Benson 1981; PacifiCorp, unpubl. data; Idaho Power, unpubl. data).

[33] Now located in Washington, D.C., EEI is an association of investor-owned electric utility companies in the United States and provides a committee structure and coordination for the industry.

[34] Including Idaho Power Company, Pacific Gas and Electric Company, Public Service Company of Colorado, Tucson Gas & Electric, Pacific Power and Light Company and Utah Power & Light Company (both currently PacifiCorp).

[35] Including Colorado Division of Wildlife, National Audubon Society, National Wildlife Federation, and USFWS.

[36] The USFWS reporting system of the 1970s is no longer in effect, although an internet-based reporting system has been recently developed by USFWS (see APP Guidelines, Appendix C).

APPENDIX C

Avian Protection Plan Guidelines

Avian Power Line Interaction Committee

Avian Protection Plan Guidelines Guidelines were developed by the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (USFWS) in 2005. This appendix contains excerpts from the Guidelines. To download the Guidelines in its entirety, see www.aplic.org or www.fws.gov.

The following appendix provides guidance for implementation of each of the Avian Protection Plan (APP) principles listed below:

1. Corporate Policy
2. Training
3. Permit Compliance
4. Construction Design Standards
5. Nest Management
6. Avian Reporting System
7. Risk Assessment Methodology
8. Mortality Reduction Measures
9. Avian Enhancement Options
10. Quality Control
11. Public Awareness
12. Key Resources

1. CORPORATE POLICY

The following is an example of a utility Bird Management Policy.

EXAMPLE 1: Bird Management Policy.

[Company] Bird Management Policy

Bird interactions with power lines may cause bird injuries and mortalities, which, in turn, may result in outages, violations of bird protection laws, grass and forest fires, or raise concerns by employees, resource agencies and the public.

This policy is intended to ensure compliance with legal requirements while improving distribution system reliability. [Company] management and employees are responsible for managing bird interactions with power lines and are committed to reducing the detrimental effects of these interactions.

To fulfill this commitment, [Company] will:

- Implement and comply with its comprehensive Avian Protection Plan (APP).
- Ensure its actions comply with applicable laws, regulations, permits, and APP procedures.
- Document bird mortalities, problem poles and lines, and problem nests. Provide information, training, and training to improve its employees' knowledge and awareness of the APP.
- Construct all new or rebuilt facilities in rural areas (outside city limits or beyond residential/commercial developments) and in areas of known raptor use, where appropriate, to [Company] avian-safe standards. Retrofit or modify power poles where a protected bird has died. Modifications will be made in accordance with APP procedures.
- Participate with public and private organizations in programs and research to reduce the detrimental effects of bird interactions with power lines.

[Company] customer service and regulatory compliance will be enhanced and risk to migratory birds will be reduced through the proactive and innovative resolutions of bird power line interactions guided by this policy.

Signature _____ Date _____

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2. TRAINING

Training is an integral component of an APP. Workshops and short courses on avian/power line interactions are provided by APLIC (www.aplic.org) and the Edison Electric Institute (EEI, www.eei.org). A two-hour overview of avian electrocutions and collisions intended for training use is also available through the APLIC website as part of the APP "tool box."

The following are examples of PacifiCorp and Southern California Edison employee training materials, including:

- Flow diagrams of company procedures for bird and nest management that can be distributed to field personnel as part of employee training.
- A brochure describing electrocution and nest issues and company raptor protection procedures.
- A brochure describing nest management procedures and protection.

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EXAMPLE 2. Bird mortality flow diagram based on PacifiCorp training materials.*

* Individual utility permits may contain different conditions regarding transport or salvage of protected species.

EXAMPLE 3: Nest management flow diagram based on PacifiCorp training materials.*

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* Individual utility permits may contain different conditions regarding nest management of protected species.

EXAMPLE 4: "Raptor Protection Program" brochure, Southern California Edison.

SOUTHERN CALIFORNIA EDISON®
An EDISON INTERNATIONAL® Company

RAPTOR PROTECTION PROGRAM

Raptor Protection Program Goals

Raptors, or birds of prey, are meat-eating birds that include the hawks, eagles, and owls. Most species of raptors are protected under one or more laws and/or regulations.

Edison's Raptor Protection Program is designed to:

1. Reduce impacts to raptors.
2. Ensure compliance with state and federal laws and rules and regulations protecting these species.
3. Gather and provide information from operating divisions within Edison to Environmental Affairs on facility-caused electrocutions. This information will assist Environmental Affairs in responding to regulatory agency inquiries and provide informed responses to concerns expressed by the public.
4. Assist Company biologists in identifying problem areas where raptor protection may be required. Selectively identify and install cost-effective raptor protection devices to ensure Company compliance with existing laws and regulations.
5. Help identify and isolate where bird-caused outages occur so that these can be minimized, providing higher levels of service to our customers.

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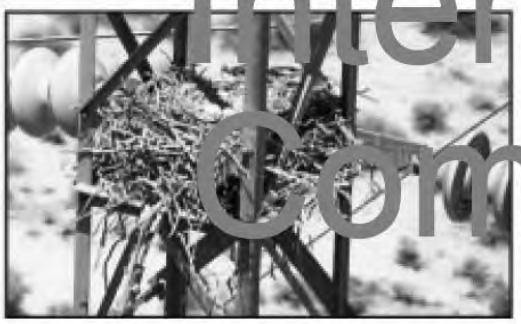
EXAMPLE 4: "Raptor Protection Program" brochure, Southern California Edison. (cont.)

Raptor Protection

Electrocutions

Raptors often perch or nest on transmission or distribution towers or poles. Occasionally, the birds will make accidental contact between phases or phase and ground, causing harm to or electrocuting the bird. These electrocutions are most common on distribution or subtransmission facilities where energized conductors are close together.

The number of electrocutions can be decreased by either designing the line to minimize contact between phases, or by retrofitting existing lines where necessary with a protective device that prevents this contact. Studies have demonstrated that raptors prefer certain poles for nesting and perching. By identifying these preferred poles, we can modify them, and thus greatly diminish the potential for raptor electrocutions in a cost-effective manner.



Nest Protection

In the absence of other suitable nest sites, raptors often use transmission towers and distribution poles for nesting. State and federal laws and regulations protect these nests from removal at certain times of the year without necessary permits. It is important that nests not be disturbed when eggs or young birds are in them.

Raptor Protection Program Procedures

1. All incidents of facility-related raptor mortality should be reported to your supervisor. You should then fill out the raptor mortality report form available in all district offices or from your supervisor. The completed form should be sent to Environmental Affairs in the General Office.
2. From February through June, nests should not be removed or disturbed. Under no circumstances should known eagle nests be disturbed at any time of the year.
3. If a nest is discovered during this February–June period that presents a hazardous situation for the continued safe operation of the line, try to trim the nest rather than remove it. If a nest must be removed, call Environmental Affairs. Environmental Affairs personnel will obtain the necessary permits for removing nests.

If you have questions regarding these procedures, please discuss them with your supervisor or call Environmental Affairs, Dan Pearson at PAX 29562, or Janet Baas at PAX 29541.

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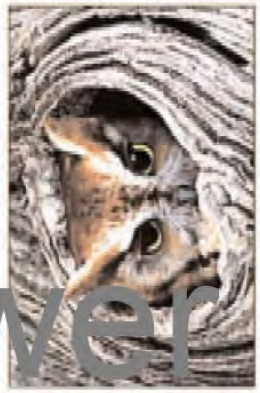
EXAMPLE 5: "Protection of Breeding Bird Nest Sites" brochure, Southern California Edison.

SOUTHERN CALIFORNIA EDISON

PROTECTION OF BREEDING BIRD NEST SITES

Why SCE is Concerned About Bird Nests



Screech-owl (Cavity Nest)

What to Do if You Have Questions

If you have any questions such as whether or not you [illegible] working in a specific area, if there is the potential for protected species to be nesting [illegible] you will be working, or have found an active bird nest while you are working, contact your [illegible] (first) or [illegible] following EA personnel:

Tim Abelonek PAX 27547 or (626) [illegible]-7547
Jan Haas PAX 28241 or (626) [illegible]-8541
[illegible] PAX 28245 or (626) [illegible]
Dan Pearson PAX [illegible] or (626) 302-6582

What to Do if You Are Working in Sensitive Areas or Find an Active Nest

- Avoid tree or shrub trimming to the extent feasible during the nesting season, especially in sensitive areas (riparian or sage scrub habitats).
- Limit noise during the nesting season to the extent feasible by turning off equipment when not in use and/or using equipment with mufflers.
- If a nest is found, **carefully** determine if the nest is active, that is, if it contains eggs or young. Do not touch the nest or its contents.
- If young are inadvertently knocked out of a nest or are found on the ground after trimming **call Environmental Affairs (EA) immediately.** If the young are small and the nest can be found and is intact, the young may be carefully replaced in the nest (using gloves). If the young are large and active or the nest can not be found or is not intact, the young should be protected and kept warm, if possible. EA will contact a rehabilitation expert for pick up.
- CONTACT EA IF YOU MUST WORK IN A SENSITIVE AREA DURING THE NESTING SEASON OR ENCOUNTER AN ACTIVE NEST THAT MUST BE REMOVED, TRIMMED, OR MAY BE DISTURBED BY VEGETATION CLEARING ACTIVITIES OR TO PROTECT PUBLIC HEALTH AND SAFETY. Note: eagle nests may never be removed or relocated at any time of year without clearance from the US Fish and Wildlife Service and the California Department of Fish and Game. Contact EA if it is necessary to handle an eagle nest in any way.

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EXAMPLE 5: "Protection of Breeding Bird Nest Sites" brochure, Southern California Edison. (cont.)

Virtually all birds in North America are protected by one or more state or federal laws. SCE must be in compliance with all laws and regulations protecting birds, their habitat, and nest sites. It is illegal to, among other things, pursue, hunt, harass, kill, or collect any migratory or listed bird species, including their eggs or nest. Fines and penalties, including jail, can be substantial for non-compliance.

When and Where Birds Nest

Most birds nest during the period from mid-February through August. The specific timing depends on several factors such as species of bird, its nest location (altitude and latitude), abundance of food, and weather. Birds nest in a wide variety of habitats, such as riparian areas along streams, creeks, ponds, forests, beaches, deserts, and foothills. That is, anywhere adequate shelter and food for young can be found. Nesting sites within these habitats include trees, shrubs, forbs and cavities in trees or dirt embankments, on cliff ledges, on the ground, and utility poles and towers.

How to Locate and Avoid Disturbing Nesting Birds

- Be aware of when birds nest (generally [illegible] through August).
- Be [illegible] working in especially [illegible]nts, such as riparian and [illegible] scrub for least partly natural areas [illegible] greenest woody shrubs, below about [illegible].
- [illegible] bird activity within shrubs or trees, [illegible] bird appears agitated or [illegible]ant to leave an area, it may indicate a [illegible] nest.
- [illegible] small dark, generally cup-shaped [illegible] among the branches of shrubs or [illegible] and larger masses in trees.
- Prior to [illegible] trimming or cutting down trees, [illegible] poles or cavities that may contain nests.

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3. PERMIT COMPLIANCE[37]

A company should work with resource agencies to determine if permits are required for operational activities that may impact protected avian species. Particular attention should be given to activities that may require Special Purpose or related permits, including, but not limited to, nest relocation, temporary possession, depredation, salvage/disposal, and scientific collection.

While it is recommended that each utility developing an APP familiarize itself with the different permit types and their provisions located in 50 CFR part 21 (Migratory Bird Permits; http://www.fws.gov/permits/mbpermits/regulations/regulations.htm), it is highly recommended that the utility make initial contact with the Migratory Bird Permit Examiner located in the USFWS Region where the utility is planning to implement its APP.

To acquire a permit application, contact the Migratory Bird Permit Office in the region where your business is headquartered or in the region (if it is different) where you propose to implement your APP. Information about regional boundaries can be accessed at http://permits.fws.gov/mbpermits/birdbasics.html then click on Regional Bird Permit Offices for locations and addresses. State permits may also be required to manage protected bird species for temporary possession of avian species. Specific information on required permits should be obtained from your state resource agency. Both state and federal agencies should be consulted as you develop your APP.

4. CONSTRUCTION DESIGN STANDARDS

In habitats that have electrical facilities and the potential for avian interactions, the design and installation of new facilities, as well as the operation and maintenance of existing facilities, should be avian-safe. Accepted construction standards for both new and retrofit techniques are highly recommended for inclusion in an APP. Companies can either rely upon construction design standards referenced in this document and in APLIC's Mitigating Bird Collisions with Power Lines: The State of the Art in 1994 (or current edition), or may develop their own internal construction standards that meet or exceed these guidelines. These standards should be used in areas where new construction should be avian-safe, as well as where existing infrastructure needs to be retrofitted. An APP may require that all new or rebuilt lines in identified avian use or potential problem areas be built to current avian-safe standards. Implementing avian-safe construction standards in such areas will reduce future legal and public relations problems and will enhance service reliability.

NEW CONSTRUCTION

Distribution, transmission and substation construction standards must meet National Electric Safety Code (NESC) requirements and should provide general information on specialized construction designs for avian use areas. Transmission construction, designed to prevent electrocutions, should provide conductor separation of 150 cm (60 in) (or a distance appropriate to the species expected in the area of the line) between energized conductors and grounded hardware, or utilities should cover energized parts and hardware if such spacing is not possible.[38]

MODIFICATION OF EXISTING FACILITIES

Modification of existing facilities is necessary when dead and/or injured birds are found,

[37] See Chapter 3 for additional information on regulations and permits.

[38] See Chapter 5 for additional information on construction design standards.

high-risk lines are identified, or legal compliance is an issue. A "problem pole" is one where there has been a documented avian collision, electrocution, or problem nest; or where there is a high risk of an avian mortality. The need for remedial action may result when "problem poles" are identified through bird mortality records, field surveys, or when the company is notified by agency representatives or concerned customers. System reliability concerns due to bird interactions may also result in requests from field operations staff.

SITE-SPECIFIC PLAN

The factors that create hazards for birds near power lines are complex and often site-specific. When a problem is identified, a site meeting with engineering and operations personnel along with company biologists or consultants brings the relevant expertise together for the most effective analysis. The timeframe for action will be based on agency requests, reliability concerns, public relations, budget, logistical and manpower constraints, and the biology of the affected species. Remediation of a few problem poles or spans often reduces problems over a wide area. Therefore, the most efficient solution for correcting a problem line is a site-specific plan that considers the local conditions (i.e., topography, avian populations or vocal use areas, land use practices, line configuration, habitat types, historical bird use areas). The plan should include recommendations for the most appropriate remedial action, and a timetable for job completion.

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5. NEST MANAGEMENT

Raptors, and some other avian species, benefit from the presence of power line structures by using them for nesting.[39] Although electrocution of birds that nest on transmission towers is infrequent, nests themselves can cause operational problems. Nest removal generally does not solve the problem because most species are site-tenacious and rebuild shortly after the nest is removed. There are also regulatory and public relations components to nest removal (see Chapter 3). Furthermore, companies may experience public relations and reliability benefits by providing safe nesting locations. All active nests (those with eggs or young present) of designated migratory birds are protected by the Migratory Bird Treaty Act. A permit issued by USFWS may be required before managing an active nest. If a problem with a nest is anticipated, permit requirements may be avoided by moving or removing the nest while it is inactive (excluding eagles and endangered/threatened species). The breeding season and nest activity varies by location and species, but for most North American raptors it falls between February 1 and August 31. However, a nest is considered active only when eggs or young are present. In those rare situations about whether a problem nest is active or inactive, company environmental staff, USFWS, or state wildlife agencies should be consulted. A memorandum from USFWS on nest management and nest destruction is provided on the following page. This document can also be accessed online at http://permits.fws.gov/mbpermits/PoliciesHandbooks/MBPM-2.nest.PDF.

[39] See Chapter 6 for additional information on nest management.

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United States Department of the Interior
FISH AND WILDLIFE SERVICE
Washington, D C 20240
MBPM-2
Date: APR 15, 2003

MIGRATORY BIRD PERMIT MEMORANDUM

SUBJECT: Nest Destruction

PURPOSE: The purpose of the memorandum is to clarify the application of the Migratory Bird Treaty Act (MBTA) to migratory bird nest destruction and to provide guidance for advising the public regarding this issue.

POLICY: The MBTA does not contain any prohibition that applies to the destruction of a migratory bird nest alone (without birds or eggs), provided that no possession occurs during the destruction. To minimize MBTA violations, Service employees should make every effort to inform the public of how to minimize the risk of taking migratory bird species whose nesting behaviors make it difficult to determine occupancy status or continuing nest dependency.

The MBTA specifically protects migratory bird nests from *possession, sale, purchase, barter, transport, import,* and *export,* and *take*. The other prohibitions of the MBTA - *capture, pursue, hunt,* and *kill* are inapplicable to nests. The regulatory definition of *take*, as defined by 50 CFR 10.12, *means to pursue, hunt, shoot, wound, kill, trap, capture, or collect*; it does not include *attempt to hunt, shoot, wound, kill, trap, capture, or collect.* Only *collect* applies to nests.

While it is illegal to collect, possess, and by any means transfer possession of any migratory bird nest, the MBTA does not contain any prohibition that applies to the destruction of a bird nest alone (without birds or eggs), provided that no possession occurs during the destruction. The MBTA does not authorize the Service to issue permits in situations in which the prohibitions of the Act do not apply, such as the destruction of unoccupied nests. (Some unoccupied nests are legally protected by statutes other than the MBTA, including nests of threatened and endangered migratory bird species and bald and golden eagles, within certain parameters.)

However, the public should be made aware that, while destruction of a nest by itself is not prohibited under the MBTA, nest destruction that results in the unpermitted take of migratory birds or their eggs is illegal and fully prosecutable under the MBTA.

Due to the biological and behavioral characteristics of some migratory bird species, destruction of their nests entails an elevated degree of risk of violating the MBTA. For example, colonial nesting birds are highly vulnerable to disturbance; the destruction of unoccupied nests during or even the nesting season could result in a significant loss of eggs. As another example, ground nesting species such as burrowing owls and bank swallows, which nest in cavities in the ground, making it difficult to detect whether or not their nests are occupied by eggs or nestlings or are otherwise still essential to the survival of the juvenile birds. The Service should make every effort to raise public awareness regarding the possible presence of birds and the risk of violating the MBTA, the Endangered Species Act (ESA), and the Bald and Golden Eagle Protection Act (BGEPA), and should inform the public of factors that will help minimize the likelihood that take would occur should nests be destroyed (i.e., when active nesting season normally occurs).

The Service should also take care to discern that persons who request MBTA permits for nest destruction are not targeting nests of endangered or threatened species or bald or golden eagles, so that the public can be made aware of the prohibitions of the ESA and the BGEPA against nest destruction.

In situations where it is necessary (i.e., for public safety) to remove (destroy) a nest that is occupied by eggs or nestlings or is otherwise still essential to the survival of a juvenile bird, and a permit is available pursuant to 50 CFR parts 13 and 21, the Service may issue a permit to take individual birds.

Steve Williams
Director

6. AVIAN REPORTING SYSTEM

An important part of an APP is a utility's system for documenting bird mortalities and nest management activities. This system should be designed to meet the needs of the utility and be compatible with other data management and analysis programs. The system could be based on paper forms like the following examples or may be an internal web-based program. The information collected should be used to help a utility conduct risk assessments to identify avian problem areas and potential known high risk structures. To protect birds and minimize outages, these data can be prioritized for corrective actions. Avian information collected by a utility should be maintained internally. Data may be required as a condition of an annual federal permit for direct take of birds or their nests. The USFWS does not issue "accidental, incidental or unintentional" take permits under authority of the MBTA.

In 2002, USFWS created an online bird electrocution reporting system for utilities (J. Birchell, pers. comm.). Initiated in Alaska, the system was developed to provide a central data repository and to encourage utilities to voluntarily report bird electrocutions. Information is collected on how, where, when, and why a bird electrocution or collision occurred and is used to help prevent future incidents. Utilities that use this reporting system hold an account to which only they can report and access their data. The online system also offers a forum for open discussion among utilities of retrofitting measures and their effectiveness. Throughout the lower 48 states most of this system's current users are Alaska utilities. Since the inception of the USFWS reporting system, cooperation and communication between electric utilities in Alaska and USFWS have increased. By working together to address electrocution problems, USFWS is able to better protect wildlife resources while utilities are able to mitigate avian electrocution risks.

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EXAMPLE 6: Dead bird/nest reporting form.

Dead Bird/Nest Form

Operations Area:

Dead Bird (circle one)	or	**Nest (circle one)**
Crow/magpie/raven		Active
Hawk/falcon/osprey		Inactive
Small bird (protected)		
Eagle		
Owl		
Waterfowl		
Unknown species		

Bird Count _____

Date Found _____ **Time Found** _____

Sign of Death (circle one)
Collision Electrocution Unknown Other _____

County _____

Finder's Name _____

Finder's Phone _____

Line Name/Circuit No. _____

Pole Identification No. _____

Recommended Action (circle)

Dead Bird Actions	*Nest Actions*
Cover transformer equipment	Install nest platform
Install insulator cover(s)	Relocate nest
Install triangle(s)	Trim nest
Reframe structure	Install nest discouragers
Replace structure	Remove nest
Remove pole	Evaluate to determine appropriate action
De-energize	No action
Install bird flight diverters/fireflies	
Continue to monitor line (Justification required)	
No action (Justification required)	

Comments _____

_____

_____

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EXAMPLE 7: Dead Bird Reporting Form.

Animal/Bird Mortality Report

Date _____

Name _____

Work location _____ Phone _____

Describe the species of the animal or bird that was mortally injured (electrocution/collision)

_____

_____

If any bands or tags please return to Environmental Department or write number and agency here

_____

_____

Describe how the animal or bird was mortally injured (bird contacted transformer bushings, etc.)

_____

_____

_____

_____

Weather conditions at time of death if known (e.g. rain and cold, sunny and warm, etc.)

_____

_____

_____

Circuit name & voltage _____

Specific problem location (e.g. pole #/address/cross streets, etc.)

_____

_____

_____

Description of terrain and vegetation in area (e.g. near agricultural area, urban area, residential, etc.)

_____

_____

_____

Recommended corrective action

_____

_____

Please attach picture of the bird or animal if possible.

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EXAMPLE 8: Bird Nest Reporting Form.

Raptor/Bird Nesting Record

Date _____

Name _____

Work location _____ Phone _____

Species of raptor/bird (if known) _____

Circuit name and number _____

Specific location (pole no.) _____

Condition of nest

_____

_____

Are eggs or young birds apparent? If so, please describe.

_____

_____

_____

Description of terrain and vegetation in area (e.g. near agricultural area, urban area, residential, etc.)

_____

_____

_____

History of previous nesting on this circuit

_____

_____

_____

History of electrocutions/mortality on this circuit

_____

_____

_____

Recommendations

_____

_____

_____

Please attach picture of the bird and/or nest, if possible.

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7. RISK ASSESSMENT METHODOLOGY

Thousands of utility poles are located in areas of suitable habitat for migratory birds. Because remedial actions on all poles in such areas are not economically or biologically necessary, a method is needed to identify configurations or locations of greatest risk. While utilities vary based on geographic scale, available data, and funding resources, risk assessment studies and models can be used by any utility to more effectively protect migratory birds.

Risk assessment may use existing data sources or new information collected specifically for the purpose. Electrocution risk assessment data may include habitat, topography, prey populations, avian nesting territories or concentration areas, avian use of poles, pole configuration, avian electrocutions, and bird-caused or unknown-cause outages. Although individual data layers alone may be inadequate for risk assessment, when all risk assessment data are overlaid, high-risk locations, configurations, or other factors may become apparent. Following a risk assessment, remedial actions can be prioritized throughout a utility's transmission and distribution system.

8. MORTALITY REDUCTION MEASURES

A utility can have its most cost-effective impact on reducing avian mortality by focusing efforts on the areas that pose the greatest risk to migratory birds. A risk assessment will often begin with an evaluation of available data that address areas of high avian use, avian mortality, nesting problems, established flyways, adjacent wetlands, prey populations, perch availability, and other factors that can increase avian interactions with utility facilities. The assessment may also include outage and circuit reliability information. Mortality reduction plans should use biological and electrical design information to prioritize poles in most need of repair. The causes of avian mortality and benefits to utility customers should be identified. A successful APP and mortality reduction plan require management support as well as the following:

- Assessment of facilities to identify risks
- Allocation of resources
- Standards for new or retrofit avian-safe construction
- Budget for operation and maintenance (O&M) and capital investment
- System for tracking remedial actions and associated costs
- Timely implementation of remedial measures
- Positive working relationship with agencies.

Mortality reduction plans may use strategies that include preventative, reactive, and proactive measures that focus on issues, risks, and reliability commitments facing a utility. The following are examples of how this multi-faceted approach may be used.

- **Preventative**: Construct all new or rebuilt lines in high avian use areas to Company avian-safe standards. Ensure that APP is in compliance with applicable laws, regulations and permits.
- **Reactive**: Document bird mortalities and problem areas, conduct assessment of problems and apply remedial measures where appropriate. Notify resource agencies in accordance with the company's permits and policy.
- **Proactive**: Provide resources and training to improve employee's knowledge and awareness. Partner with organizations that conduct research on effects of bird interactions with power lines. Evaluate electrocution and collision risks of existing lines in high avian use areas and modify structures where appropriate.

The USFWS and state agencies should be consulted on electrocutions and the remedial actions undertaken. Utilities should annually

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review their APPs in the context of risk assessment and electrocution and collision incidents and modify as appropriate, ideally with agency input.

9. AVIAN ENHANCEMENT OPTIONS

While an APP will include measures to reduce avian mortality associated with electrical operations, it can also include opportunities to enhance avian populations by installing nest platforms, improving habitats, and collaborating with agencies or conservation organizations. USFWS and state wildlife resource agencies, as well as other experts, can be consulted for recommendations for habitat enhancement projects. Nest platforms can be erected on poles for birds such as osprey, eagles, hawks, owls, herons, and cormorants (see Chapter 6). In addition, nest boxes can be erected for cavity-nesting species such as kestrels, owls, bluebirds, swallows, chickadees, wrens, and others. Such boxes may also benefit bats and flying squirrels.

Nest box construction, maintenance, and monitoring can be done in conjunction with volunteers, such as Boy Scouts and Girl Scouts or avian conservation organizations. These efforts are excellent opportunities to educate the public about the company's APP and its partnerships.

10. QUALITY CONTROL

A quality control mechanism can and should be incorporated into an APP to evaluate the effectiveness of a company's avian protection procedures. Some examples of quality control include assessing:

- the effectiveness of remediation techniques in reducing avian mortality
- avian protection devices to identify products preferred for avian protection as well as ease of application and durability
- mortality reporting procedures to ensure that discoveries of avian mortalities are properly documented
- response to avian mortalities to ensure that appropriate actions are taken in a timely manner
- compliance with company procedures to ensure that personnel are consistently following company methods for avian-safe construction, mortality reporting, vegetation management, etc.
- public and agency opinions on system reliability and avian protection.

The quality control component of an APP is a continuous process. Information gathered during assessments of existing practices should be used to improve the effectiveness and timeliness of avian protection efforts, which, in turn, can help to reduce costs associated with such efforts.

11. PUBLIC AWARENESS

A public awareness program can be an integral part of an APP. It can be used to enhance public awareness and support for a company's APP. It allows stakeholders such as government agencies, tribes, non-profit organizations, wildlife rehabilitators, and other interested parties an opportunity to provide input to the decision-making process, enabling all parties to work openly and collaboratively towards recommendations that can be effectively implemented. This collaboration often leads to improved relationships within the community and to more efficient and positive projects. The relationships developed through this process may also encourage the public to report bird

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mortalities and encourage them to seek assistance for birds that have been injured in power line-related accidents.

Effectively communicating an APP can be done through a variety of public outreach tools, including fact sheets, newsletters, brochures, videos, websites, and speaker bureau presentations. These tools can also be used to record the successes of an APP, thereby documenting the utility and electric industry's efforts to reduce avian mortalities. The goal of these outreach efforts is to convey to the public that electric utilities are responsible stewards of the environment, working cooperatively with wildlife agencies towards reducing avian mortalities while continuing to provide safe, reliable, affordable electricity to their customers.

Many utilities have examples of their environmental stewardship and of the innovative ways they have reduced environmental impacts through their business decisions. A company's efforts to minimize avian mortalities should be shared with the public and resource agencies.

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12. KEY RESOURCES

Key resources may include utility personnel or external contacts. Internal personnel may include representatives from environmental engineering, operations and maintenance, standards, procurement, vegetation management, and other departments. External resources may include biologists and law enforcement agents from state and federal agencies as well as avian specialists from NGOs or universities, and wildlife rehabilitators. External utility industry resources include APLIC, Edison Electric Institute (EEI), Electric Power Research Institute (EPRI), Institute of Electrical and Electronics Engineers (IEEE), National Rural Electric Cooperative Association (NRECA), and Rural Utilities Service (RUS). Contact information and websites for a number of resources are available in the complete APP Guidelines (see www.aplic.org or www.fws.gov).

APPENDIX D

Glossary

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adult
a bird that has acquired its final plumage.

air-gap
the empty space or window around a conductor on a steel transmission structure. The empty space provides insulation for the conductors. A fault can occur when something bridges all or a sufficient portion of the air gap between the steel tower and an energized conductor.

ampere
unit measure of current.

avian-safe
a power pole configuration designed to minimize avian electrocution risk by providing sufficient separation between phases and between phases and grounds to accommodate the wrist-to-wrist or head-to-foot distance of a bird. If such separation cannot be provided, exposed parts are covered to reduce electrocution risk, or perch management is employed. This term has replaced the term "raptor-safe" used in the 1996 edition of *Suggested Practices*.

Basic Insulation Level (BIL)
the measure of a line's ability to withstand rapidly rising surge voltages such as those resulting from lightning strikes. It is provided by porcelain, wood, fiberglass, air, or combinations of these. Using the same insulators, a line built on wood poles will have a higher BIL than one built on concrete or steel poles unless the insulator bases are grounded on the wood poles. BIL is also affected by pole framing. For example, if the phase conductors and neutral conductors are both framed on wood crossarms, the BIL is reduced.

bushing (transformer)
an insulator inserted in the top of a transformer tank to isolate the electrical leads of the transformer winding from the tank. Bushings are usually made of porcelain, and are also used on circuit breakers and capacitor banks.

bushing cover
a covering installed over a bushing to prevent incidental contact by birds or other animals.

capacitance
the capacity of the condenser to hold an electrical charge; the property of an electrical nonconductor for storing energy.

capacitor
a device consisting of conductors isolated in a dielectric medium; each capacitor is attached to one side of a circuit only. It is used to increase the capacitance of a circuit. Capacitors are constructed in metal cans and above ground bushings.

capacitor bank
a series of capacitors connected together and inserted into an electrical circuit to change the efficiency of the energy use.

circuit (single)
a conductor or system of conductors through which an electric current is intended to flow. The circuit is energized at a specified voltage.

circuit (multiple)
a configuration that supports more than one circuit.

conductivity
the capacity to transmit electrical energy.

conductor
the material (usually copper or aluminum)—usually in the form of a wire, cable or bus bar—suitable for carrying an electric current.

configuration
the arrangement of parts or equipment. A distribution configuration would include the necessary arrangement of crossarms, braces, insulators, etc. to support one or more electrical circuits.

corona ring
a device used on transmission suspension insulators to reduce the electrical field stress at the end fittings.

corvid
birds belonging to the family Corvidae; includes crows, ravens, magpies, and jays.

crossarm
a horizontal supporting member used to support electrical conductors and equipment for the purpose of distributing electrical energy. Can be made of wood, fiberglass, concrete, or steel, and manufactured in various lengths.

current
a movement or flow of electricity passing through a conductor. Current is measured in amperes.

davit arm
a formed, laminated wood or steel crossarm attached to wood or steel poles and used to support electrical conductors or overhead ground wires.

de-energized
any electrical conducting device disconnected from all sources of electricity.

dielectric strength
the ability of an insulating material to withstand the electrical voltage stress of the energized conductor.

distribution line
a circuit of low-voltage wires, energized at voltages from 2.4 kV to 60 kV, and used to distribute electricity to residential, industrial and commercial customers.

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electrode
a conductor used to establish electrical contact with a nonmetallic part of a circuit. In the case of testing the conductivity of an eagle feather, electrodes were attached to both ends of the feather, and electrical current was passed through the feather.

energized
[illegible] electrical conducting de[illegible]nect-ed to [illegible] electricity.

fault
a power disturbance that interrupts the quality of electrical supply. A fault can have a variety of causes including fires, ice storms, lightning, animal electrocutions, or equipment failures.

fledgling
a bird that has recently left the nest and may still be dependent on its parents for food.

fused cutouts
electrical switches fitted with a fuse, so that the switch will open when the current rating of the fuse is exceeded. Fused cutouts are used to protect electrical equipment and circuits from lightning and short-circuiting caused by wires, wind, animals, or conductive equipment of all kinds.

generation plant
a facility that generates electricity.

ground
an object that makes an electrical connection with the earth.

ground rod
normally a copper-clad steel rod or galvanized steel rod, driven into the ground so that ground wires can be physically connected to the ground potential.

grounding conductor
a conductor used to bond all of the bolts and other pieces of hardware to the ground. Grounding conductors may be copper-clad, solid copper or stranded galvanized wires and are attached to poles with staples. Sometimes also called *downwire*.

guy
secures the upright position of a pole and offsets physical loads imposed by conductors, wind, ice, etc. Guys are normally attached to anchors that are securely placed in the ground to withstand loads within various limits.

hacking
the process of transitioning birds reared in captivity to independence in the wild. Hacking has been used to bolster populations of endangered species such as peregrine falcons, California condors, and bald eagles.

insulator
nonconductive material in a form designed to support a conductor physically and to separate it electrically from another conductor or object. Insulators are normally made of porcelain or polymer.

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isokeraunic level
refers to the average number of thunderstorm (lightning) days per year that are present in a region. Electric lines in areas of high levels may have overhead grounding conductors (static wires) installed so that lightning strikes to the line can be diverted directly to earth away from the phase conductors.

jumper wire
conductive wire normally copper, used to connect various types of electrical equipment. Jumper wires are also used to make electrical conductors on lines continuous when it becomes necessary to change direction of the line (e.g., angle poles, dead-end poles).

juvenile
(plumage)—first plumage of a bird.
(bird)—a young bird in its first year of life.

kilovolt
1000 volts, abbreviated kV.

lattice work
the combination of steel members connected together to make complete structures such as transmission towers or substation structures.

lightning arrester
an electrical protection device used to divert the energy of lightning strikes to the earth.

lightning days
lightning or thunderstorm days. One or several lightning storms in the same day would be classed as a lightning day.

nest substrate
the base upon which a nest is built, e.g. cliffs, trees, ground, power poles, boxes, platforms, etc.

nestling
a young bird that has not yet reached sufficient size and maturity to leave the nest.

neutral conductor
a conductor or wire that is at ground potential, i.e. grounded.

outage
event that occurs when the energy source is cut off from the load.

phase
an energized electrical conductor.

phase-to-ground
the contact of an energized phase conductor to ground potential. A bird can cause a phase-to-ground fault when fleshy parts of its body touch an energized phase and ground simultaneously.

phase-to-phase
the contact of two energized phase conductors. Birds can cause a phase-to-phase fault when the fleshy part of their wings or other body parts contact two energized phase conductors at the same time.

pole
a vertical structure used to support electrical conductors and equipment for the purpose of distributing electrical energy. It can be made of wood, fiberglass, concrete, or steel, and manufactured in various heights.

power line
a combination of conductors used to transmit or distribute electrical energy, normally supported by poles.

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primary feathers
also called **primaries**. The ten outermost flight feathers of the wing that meet at the wrist to form the "hand" of the wing.

problem pole
a pole used by birds (usually for perching, nesting, or roosting) that has electrocuted birds or has a high electrocution risk.

raptor
bird of prey. Raptors are members of the orders Falconiformes (diurnal raptors) and Strigiformes (owls). Raptors have a sharp hooked bill and sharp talons used for killing and eating prey.

raptor-safe
see **avian-safe**

retrofitting
the modification of an existing electrical power line structure to make it avian-safe

ridge pin
the support bracket for an insulator that is attached to the top of a pole with two or more bolts and supports energized or grounded conductors, depending on the power line design.

rights-of-way (ROW)
the strip of land that has been acquired by an agreement between two or more parties for the purpose of constructing and maintaining a utility easement.

sectionalize
refers to the practice of isolating an energy source from a load. It is sometimes necessary to isolate electric systems (using switches) for operations and maintenance.

separation
the physical distance between conductors and/or grounds from one another.

site-tenacity
strongly attached or drawn to a chosen location.

still-hunting
the practice of hunting from a perch, as opposed to hunting in flight.

structure
pole or lattice assembly that supports electrical equipment for the transmission or distribution of electricity.

subadult
age(s) of a bird between juvenile and adult.

substation
a transitional point (where voltage is increased or decreased) in the transmission and distribution system.

switch
an electrical device used to sectionalize electrical energy sources.

transmission
the tower member on steel lattice towers that supports the crossarm from the topside.

transformer
a device used to increase or decrease voltage.

transmission line
power lines designed and constructed to support voltages >60 kV.

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trust resource
wildlife, such as migratory birds, that are held in the public trust and managed and protected by federal and state agencies. These trust agencies are designated by statute and regulations as responsible for upholding the protection, conservation, and management of these resources.

underbuild
refers to a circuit that is placed on the same pole but below another circuit of a higher voltage. The lower circuit is often referred to as the underbuilt circuit.

volt
the measure of electrical potential.

voltage
electromotive force expressed in volts.

wrist
joint toward the middle of the leading edge of the wing. The skin covering the wrist is the outermost fleshy part on a bird's wing.

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APPENDIX E

List of Acronyms

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APLIC	Avian Power Line Interaction Committee
APP	Avian Protection Plan
BGEPA	Bald and Golden Eagle Protection Act
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BSPB	Bulgarian Society for the Protection of Birds
CFE	Comisión Federal de Electricidad
CFR	Code of Federal Regulations
EEI	Edison Electric Institute
EPRI	Electric Power Research Institute
ESA	Endangered Species Act
EWT	Endangered Wildlife Trust
FERC	Federal Energy Regulatory Commission
GIS	Geographical Information System
HCP	Habitat Conservation Plan
IBA	Important Bird Area
IEEE	Institute of Electrical and Electronics Engineers
ITP	Incidental Take Permit
MBTA	Migratory Bird Treaty Act
MLEA	Moon Lake Electric Association
MOU	Memorandum of Understanding
NESC	National Electric Safety Code
NGO	Non-governmental organization
NMFS	National Marine Fisheries Service
NPS	National Park Service
NRECA	National Rural Electric Cooperative Association
NWCC	National Wind Coordinating Committee
REA	Rural Electrification Association
ROW	Rights-of-Way
RUS	Rural Utilities Service
USC	United States Code
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

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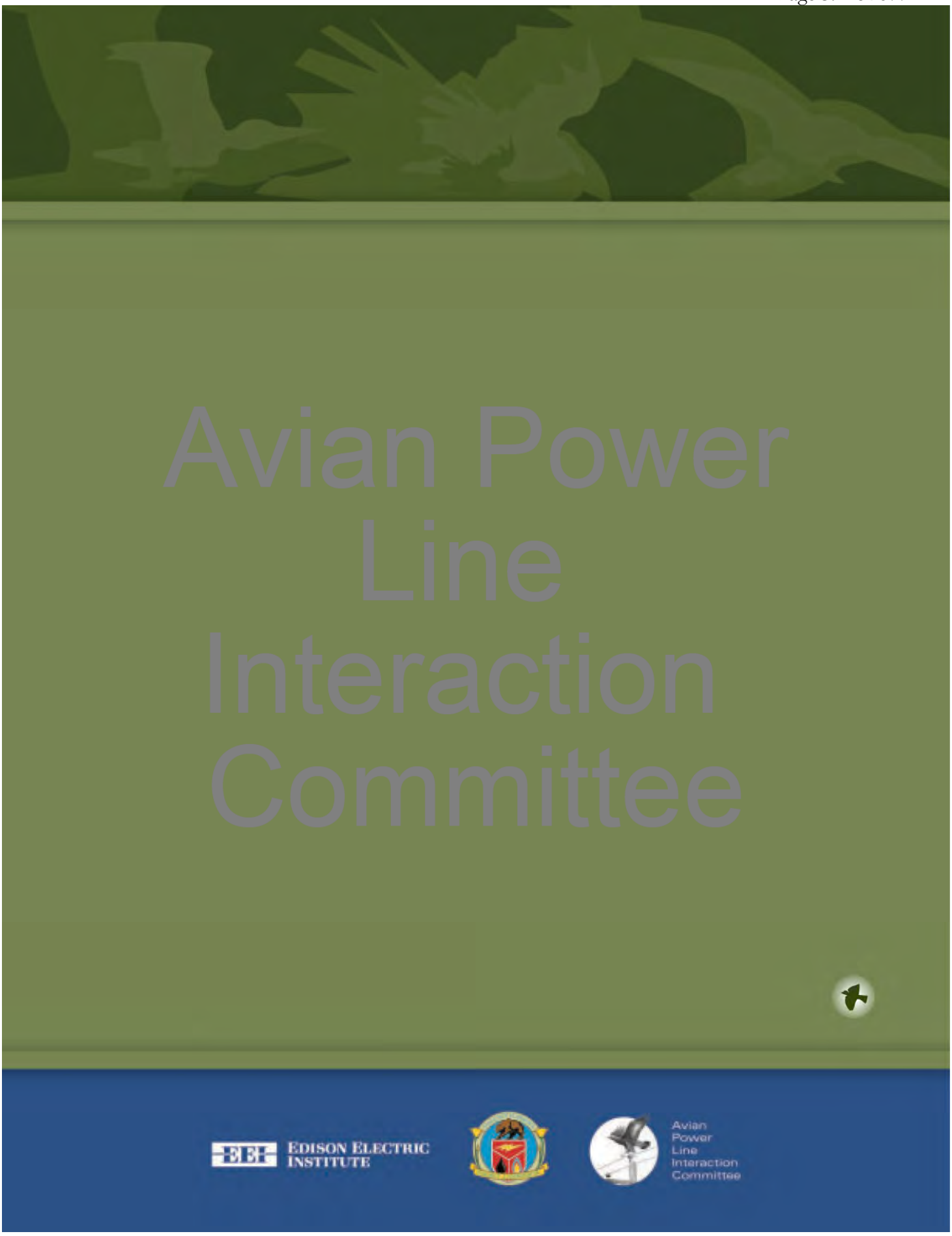
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Prepared by:

Avian Power Line Interaction Committee

October 2012

Edison Electric Institute
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PREVIOUS VIEW

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PURPOSE AND SCOPE OF THIS MANUAL

Reducing Avian Collisions with Power Lines (Collision Manual) was first published by the Avian Power Line Interaction Committee (APLIC) and Edison Electric Institute (EEI) in 1994 under the title *Mitigating Bird Collisions with Power Lines*. The 2012 edition of this manual provides electric utilities, wildlife agencies, and other stakeholders with guidance for reducing bird collisions with power lines based on the most current information. This is especially important given the need to reduce bird injury and mortality from collisions, comply with bird protection laws, and enhance the reliability of electrical energy delivery.

PROGRESS IN DEALING WITH COLLISION ISSUES

In the United States, most studies of bird collisions have occurred since the late 1970s. These studies described the problem and led to a growing awareness among stakeholders. In 1989, APLIC was founded to address whooping crane (*Grus americana*) collisions with power lines. APLIC published its first *Collision Manual* in 1994 to summarize the knowledge of bird collisions with power lines at that time. National and international collaboration on bird/power line interactions has since grown. Research today includes studies on collision reduction, monitoring systems, and standardization of collision mortality data collection. Future priorities include improving the comparability of studies, testing and documenting line marker efficacy, and refining remote collision detection devices.

As power line infrastructure expands to meet the growing demand for electricity, the collision risk to avian species also seems likely to increase. Yet, this risk may be reduced by assessing potential avian impacts during line siting and routing, improving line marking devices, standardizing study methods, and increasing awareness.

AVIAN REGULATIONS AND COMPLIANCE

In the United States, three federal laws protect almost all native avian species and prohibit *taking* (killing or injuring) them even if the act was unintended and occurred as a result of otherwise legal activities. The Migratory Bird Treaty Act (16 U.S.C. 703-712) protects 1,007 (2012) North American migratory bird species (50 CFR 10.13). The Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c) provides additional protection for these two species. The Endangered Species Act (16 U.S.C. 1531-1555) provides protection to federally listed species (designated as threatened or endangered) and to their critical habitat. Utilities in the United States should work with both the U.S. Fish and Wildlife Service (USFWS) and state wildlife agencies to identify permits and procedures that may be required.

In Canada, two laws protect avian species by prohibiting *take*. The Migratory Birds Convention Act protects most species of migratory birds in Canada. The Canadian Species at Risk Act provides for the protection and recovery of threatened and endangered species. Additional protection for species at risk has been developed by the provincial governments, such as the Alberta Wildlife Act. Utilities in Canada should work with the Canadian Wildlife Service and provincial wildlife agencies to identify permits and procedures that may be required.

UNDERSTANDING BIRD COLLISIONS

Understanding the nature of bird collisions is essential for minimizing them. Bird collisions with power lines result from a complex mixture of biological, environmental, and engineering factors. Biological characteristics include body size, weight, maneuverability, flight behavior, vision, age, sex, health, time of day, season, habitat, and habitat use. Environmental conditions include land uses, weather, visibility, lighting, and sudden disturbances.

ABSTRACT

Engineering aspects include size of lines, line placement, line orientation, line configuration, structure type, and sometimes obstruction lighting under Federal Aviation Administration rules.

It is difficult to extrapolate collision risk from one power line study and apply or compare it with other studies because of site-specific conditions and the lack of standard study methods, which result in variability of reported mortality rates. Species of birds reported to be susceptible to collisions generally have a large body size, long wing span, heavy body, and poor maneuverability. Examples include species of loons, storks, grebes, waterfowl, and some species of hawks and eagles. Flight behavior and other biological attributes contribute to species risk. Individual losses from collision mortality are unlikely to affect large and robust populations. However, for species that are rare or endangered, the loss of a few or even one individual may impact a local population or the overall population's viability.

MINIMIZING COLLISION RISKS

Engineers and biologists can work together to identify and address collision issues when modifying existing lines or planning new lines. Early consideration of risk factors may reduce the need for costly modifications later. In addition, while a utility is taking steps to minimize collision risk, a proactive public participation program can address social issues by building positive relationships, increasing public knowledge, identifying and responding to public concerns early, and promoting responsible behavior (e.g., discouraging vandalism of line marking devices).

When modifying existing lines, study options include collision monitoring, line modification studies, and avian risk assessment. Line modifications must be carefully evaluated to identify, quantify, and balance the existing risks with the potential effectiveness and risks posed by the alternatives. Risk reduction options include line marking, managing surrounding lands, removing the shield wire, changing the size or configuration of wires, rerouting the line, and burying lines. Typically, the first options are line marking and managing surrounding lands because the remaining options are seldom feasible.

When planning new lines, three study options can be used to identify the optimal route: spatial analysis using GIS, field assessment, and avian risk assessment. Risk reduction options could include line placement, orientation, and configuration relative to biological and environmental factors.

LINE MARKING DEVICES

Studies suggest that most bird collisions occur with the shield wire, which is the smallest diameter and highest wire on a transmission line. Many studies of lines with high collision rates indicate that collision risk can be lowered by 50% to 80% when these lines are marked, though the most recent study published at this writing demonstrated only a 9.6% reduction (Barrientos 2012). However, recommendations for which device is the most effective and standard spacing are not possible due to differences in study designs and site-specific conditions. As a result of these differences, reduction rates may not be replicable from one line or study to another.

Since 1994, line marking devices have been further developed in North America, Europe, and South Africa. Advances in aerial marker spheres, spirals, and suspended devices include changes to design, colors, attachments, and materials in an effort to improve effectiveness and durability and to reduce possible damage to lines.

AVIAN PROTECTION PLANS

In 2005, APLIC and the USFWS announced their jointly developed *Avian Protection Plan Guidelines (Guidelines)*. An Avian Protection

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ABSTRACT

Plan (APP) is a voluntary, utility-specific plan for reducing the risks to birds and system reliability that result from avian interactions with electric utility facilities. An APP provides the framework necessary for implementing a program to reduce bird mortalities, document utility actions, improve service reliability, and comply with bird protection laws. The *Guidelines* are intended to help utilities craft their own APPs for managing avian/power line issues that are particular to their location and operations.

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FOREWORD

Avian interactions with power lines, including collisions, electrocutions, and nesting have been documented since the early 1900s. Collisions with telegraph lines were first reported in 1876. However, it was not until the 1970s that biologists, engineers, resource agencies, and conservationists began to realize the extent of these interactions. It was then that they began investigating and addressing collision issues. We commend this early professional leadership in tackling a complex issue and building a foundation of credibility and cooperation that characterizes the relationship between the U.S. Fish and Wildlife Service (USFWS) and the Avian Power Line Interaction Committee (APLIC) today.

In December 1983, an ad hoc group began to address whooping crane (*Grus americana*) collisions with power lines in the San Luis Valley, Colorado. This work led to the 1989 founding of APLIC and the publication of *Mitigating Bird Collisions with Power Lines: State of the Art in 1994* (*Collision Manual*), which became the companion of *Suggested Practices for Raptor Protection on Power Lines: State of the Art in 1981* (*Electrocution Manual*). The 1994 *Collision Manual* brought together what was known about collision mitigation and presented research protocols for studying problem lines. It focused on standardizing these protocols so that data from various studies might be comparable and applicable to the issues experienced by electric utilities nationwide. This theme is carried forth and expanded upon in this 2012 revision.

Today electric utilities across North America recognize that bird/power line interactions may create operational risks, health and safety concerns, and avian injuries or mortalities, all of which reduce electrical reliability and increase a utility's liability. The USFWS is responsible for conserving and protecting United States trust resources covered by the Migratory Bird Treaty Act, Bald and Golden Eagle Protection Act, and Endangered Species Act. It is within this potentially adversarial framework that the longstanding collaborative partnership between industry and agency has emerged.

With this edition of the *Collision Manual* (now titled *Reducing Avian Collisions with Power Lines*) along with the 2006 *Electrocution Manual*, the 2005 *Avian Protection Plan Guidelines*, and Edison Electric Institute's 2001 *Introduction to Public Participation*, utilities have a toolbox of the latest technology, science, expertise, and field experience. APLIC and the USFWS hope you will use this edition of the *Collision Manual*, along with its companion documents, to help implement avian protection plans, conserve protected birds, and improve electrical system reliability.

Jerome Ford
USFWS, Assistant Director Migratory Bird Program

Dave Bouchard
APLIC, Immediate Past Chair

Peggy Jelen
APLIC, Chair

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APLIC also wishes to thank the following individuals for their service during the production of this edition of the manual: Brad Loveless, Dave Bouchard, and Peggy Jelen for serving as Chair of APLIC and Rick Loughery for serving as the Edison Electric Institute Liaison to APLIC.

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A diverse collection of literature was used in the research to prepare this manual. APLIC acknowledges the great contribution that this body of literature made. This literature is included in Appendix A. Literature Cited and Bibliography.

This manual was funded by the Edison Electric Institute and the Avian Power Line Interaction Committee.

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THIS PUBLICATION IS DEDICATED TO THE MEMORY OF

Richard "Dick" S. Thorsell

(April 11, 1927 – April 15, 2012)

Dick Thorsell had a lifetime devotion to birds and was one of the founders of APLIC. He brought electric utilities, government agencies, and environmental groups together to work in cooperation to study and mitigate bird deaths from power line collisions and electrocutions. Dick came to the Edison Electric Institute (EEI) in 1970 after serving as the Executive Director of the Stony Brook–Millstone Watershed Association in New Jersey. Dick was the producer of films on utility/natural resource issues, including *Silver Wires, Golden Wings.* The film featured Morley Nelson's work on understanding and reducing raptor electrocutions. It brought awareness of electrocution issues to electric utilities and credibility to the industry for its efforts to address the problem.

Dick was a WWII Navy veteran, and in 1953 he graduated from Lehigh University with a B.A. in Conservation. During the summer of 1950, he took a job as a Ranger Naturalist for the U.S. National Park Service. In 1954, as a graduate student, he travelled to Bermuda to help determine what was destroying nests of the Bermuda petrel, or cahow *(Petrodroma cahow),* a bird that until 1951 was thought to have been extinct for more than 300 years. During 47 days of field observations he conceived a way to reduce nest predation of the cahow by the more aggressive white-tailed tropic bird *(Phaethon lepturus),* known in the islands as the longtail. His solution was credited as one of the most critical developments in the cahow's recovery and conservation.

In 1988, Dick was honored by the Raptor Research Foundation for his pioneering efforts in raptor protection: *"All who appreciate the flight, spirit, and symbolism of the golden eagle are in your debt; and those who know you well enough understand that having hundreds, if not thousands of living eagles to your credit, is sufficient personal award for your accomplishments."*

Dick received APLIC's Morley Nelson Award in 2009 to acknowledge his efforts in pioneering avian/power line conservation and his dedication to developing and maintaining positive partnerships among the key interests in avian/power line issues.

Dick retired from EEI in1991 and pursued his personal interests while remaining ever ready to advise the industry on developing issues and to keep us on track.

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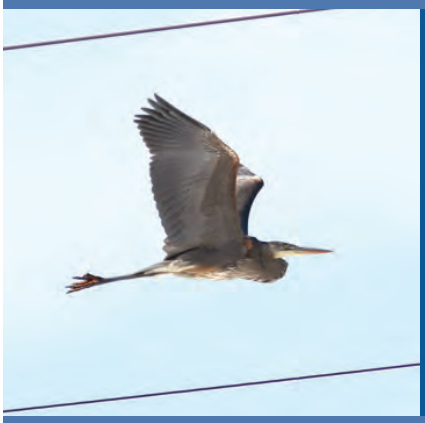

CHAPTER 1

Introduction

IN THIS CHAPTER

- Purpose and Scope of the Manual
- Reader Guide to the Manual
- Overview of Power Lines
- Perspectives for Dealing with Bird Collisions

Some birds flying in the vicinity of power lines may be susceptible to collision. While power lines are only one of numerous causes of bird injury and mortality, collisions with power lines can be reduced. This chapter introduces the problem of bird collisions, defines the categories and configurations of power lines, and presents the biological, engineering, economic, and social and cultural perspectives on bird/power line collisions.

PURPOSE AND SCOPE OF THE MANUAL

Reducing Avian Collisions with Power Lines (Collision Manual) was first published by the Avian Power Line Interaction Committee (APLIC) and the Edison Electric Institute (EEI) in 1994, under the title *Mitigating Bird Collisions with Power Lines*, as a comprehensive review of avian collisions with power lines (collisions) and recommendations for minimizing them. Since 1994, the understanding of bird collisions and the methods for reducing them has grown (e.g., Bevanger 1994, 1998; Janss 2000; Rubolini et al. 2005; and Jenkins et al. 2010). Collisions with power lines cannot be eliminated, but they can be reduced. This edition of the manual builds upon the foundation of the 1994 *Collision Manual* using the research and experience gained through the years since its original publication.

Power lines are an integral part of the modern landscape. Estimates of the number of miles of transmission lines in the United States range from 862,000 kilometers (km) (535,622 miles [mi]) (J. Goodrich-Mahoney, EPRI, pers. comm.) to 1,024,534 km (636,616 mi) (EEI 2010) based on 2009 and 2010 data from the Federal Energy Regulatory Commission, North American Electric Reliability Corporation, and other sources. For distribution lines, the number of miles is less certain, but it is about five to six times that of transmission lines based on two large company systems (D. Bouchard, pers. comm.).

Some bird species that are active in the vicinity of power lines are more susceptible to collision and electrocution risk than others. The risks and reduction measures for bird electrocutions are addressed in the publication *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006* (APLIC 2006).

Power lines are only one of numerous anthropogenic causes of bird collision mor-

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tality. Others include tall buildings, windows, vehicles, communication towers, airplanes, and wind turbines (Avery et al. 1980; Erickson et al. 2005). Estimates of bird collision mortality vary widely because of differences in mortality monitoring and extrapolations of those data. Based on reviews, Erickson et al. (2005) estimated that buildings and windows account for most bird collision mortality in the United States, followed by power lines, automobiles, communication towers, and wind turbines. This manual only addresses bird collisions with power lines.

Interactions between birds and power lines are a complex mixture of biological, environmental, and engineering factors. Electric utility stakeholders need to understand the nature of bird interactions with power lines when siting, routing, and designing power lines and determining mortality reduction measures. This is especially true given the need to reduce bird collisions, comply with bird protection laws, and enhance reliable electrical energy delivery.

This manual was developed for electric utilities, wildlife agencies, and other stakeholders and is based on what is known to date about collisions. It is intended to provide this audience with:

- An overview of power lines and perspectives on dealing with avian/power line collisions (Chapter 1)
- A summary of current knowledge, literature, and field experience related to avian collisions with power lines and the factors that influence them (Chapters 2 and 4)
- A discussion of the laws, regulations, and the operational implications of avian collisions (Chapter 3)
- A review and discussion of current practices for planning, management options, study design, and devices used to minimize avian collisions with power lines (Chapter 5, Chapter 6 and Appendix B)
- An overview for developing an Avian Protection Plan (Chapter 7)
- A compilation of collision literature spanning several decades (Appendix A)
- A glossary of collision terms and resources for further information (Appendices C and E)

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FIGURE 1.1: The highest wire on a transmission line is the shield wire, which can be difficult for birds, especially flocking birds such as waterfowl, to see.

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READER GUIDE TO THE MANUAL

Table 1.1 provides a quick guide to common collision topics in this manual. Readers can also search the electronic version (a CD is included) for specific keywords. This manual consists of the following chapters and appendices.

TABLE 1.1: Quick guide to the Collision Manual.

Subject	Chapter(s)
Power lines, voltage, and the electric power system	1
Perspective of power line engineers	1, 4, 5, 6
Perspective of biologists	1, 4, 5, Appendix B
Perspective of the public and other stakeholders	1, 5, 6, 7
Advantages and disadvantages of underground power lines	1, 5
History of bird collisions and mitigation	2, 6, Appendix A
Current state of knowledge related to bird collisions	2, 4, 5, Appendix A
Funding organizations for collision research	2, Appendix E
Study methods and options	2, 4, 5, Appendix B
Strategies and approaches to address bird collisions	2, 4, 5, 6, 7
Laws and policies governing birds and bird mortality	3
Permits related to bird laws and policies	3
Factors that contribute to collisions	4
Variability in reported collision mortality rates	4
Significance of mortality for bird populations	4
Scientific methods to assess risk and impacts	4, 5, Appendix B
Methods for reducing bird collisions on an existing power line	5, 6
Methods for routing and designing a new power line while minimizing bird collisions	5, 6
Benefits of public participation	5, 7
Legal issues and other considerations for line marking	6
Effectiveness of line marking devices	6
How to develop a voluntary, utility-specific Avian Protection Plan	7

- Chapter 1. Introduction
- Chapter 2. Progress in Dealing with Collision Issues
- Chapter 3. Avian Regulations and Compliance
- Chapter 4. Understanding Bird Collisions
- Chapter 5. Minimizing Collision Risks
- Chapter 6. Line Marking to Reduce Collisions
- Chapter 7. Avian Protection Plans
- Appendix A. Literature Cited and Bibliography
- Appendix B. Designing Site-Specific Studies for Collision Monitoring
- Appendix C. Glossary
- Appendix D. Acronyms
- Appendix E. Resources

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OVERVIEW OF POWER LINES

TRANSMISSION VERSUS DISTRIBUTION LINES

Power lines are rated and categorized, in part, by the level of electrical voltage they carry. Because the amount of electricity is large, voltage is usually specified as kilovolts (kV) where 1 kV is equal to 1,000 volts (V). In a power system, from the power generation facility to the customer (Figure 1.2), four voltage classifications are used: power source, transmission, distribution, and utilization (Table 1.2). Although there are exceptions to these voltage classifications, they hold in general and will be used this way in this manual.

Voltage classification also depends on the purpose a power line serves. Transmission lines (≥60 to 765 kV) are used to transmit large blocks of electricity from the power generation facility to the load centers (communities). Within load centers, the high voltage of transmission lines is reduced at substations and then delivered via distribution lines (2.4 to 60 kV) for residential, commercial, and industrial uses. The distribution voltages are again stepped down to the lower voltages for the end user (120 to 600 V) usually by pole- and pad-mounted transformers. Both transmission and distribution lines are power lines, a term used throughout this manual (Figure 1.3).

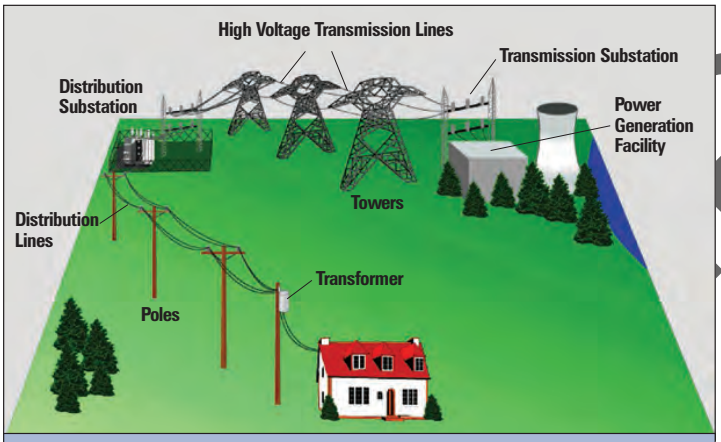

FIGURE 1.2: Schematic of the electric power system from the generation facility to the customer (modified from Rural Utilities Service).

TABLE 1.2: Voltage classifications in North America.

Classification	Voltage
Power Generation Facility	12 V to 22 kV
Transmission	60 to 765 kV*
Distribution	2.4 to 60 kV
Utilization	120 to 600 V

* This is the typical range for transmission; however, there are exceptions.

FIGURE 1.3: Transmission lines (left) and distribution lines (right).

© JERRY LIGUORI (LEFT) AND DAVE BOUCHARD, AEP (RIGHT)

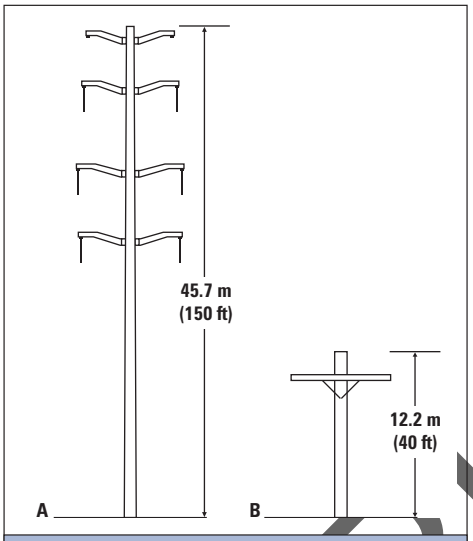

FIGURE 1.4: Height comparison of transmission (typically 18.3 to 58 m [60 to 190 ft] tall) (A) and distribution structures (typically 6.4 to 14.6 m [21 to 48 ft] tall) (B).

POWER LINE CONFIGURATION

Power lines may be energized (carrying electricity) or non-energized (grounded). Energized lines are called phase conductors. Distribution lines may have one, two, or three phase conductors per circuit. Alternating current (AC) transmission lines always have three phases per circuit, and structures may carry multiple circuits. For example, a three-phase, double-circuit line would have six phase conductors. Phase conductors may be configured horizontally or vertically on the tower or pole (Figure 1.5). High voltage transmission lines may be bundled, which means two to six lines per phase are placed in close proximity to each other instead of using only one line per phase (Figure 1.6). Distribution lines may also be installed on transmission structures below the transmission lines; this is referred to as a distribution underbuild (Figure 1.7).

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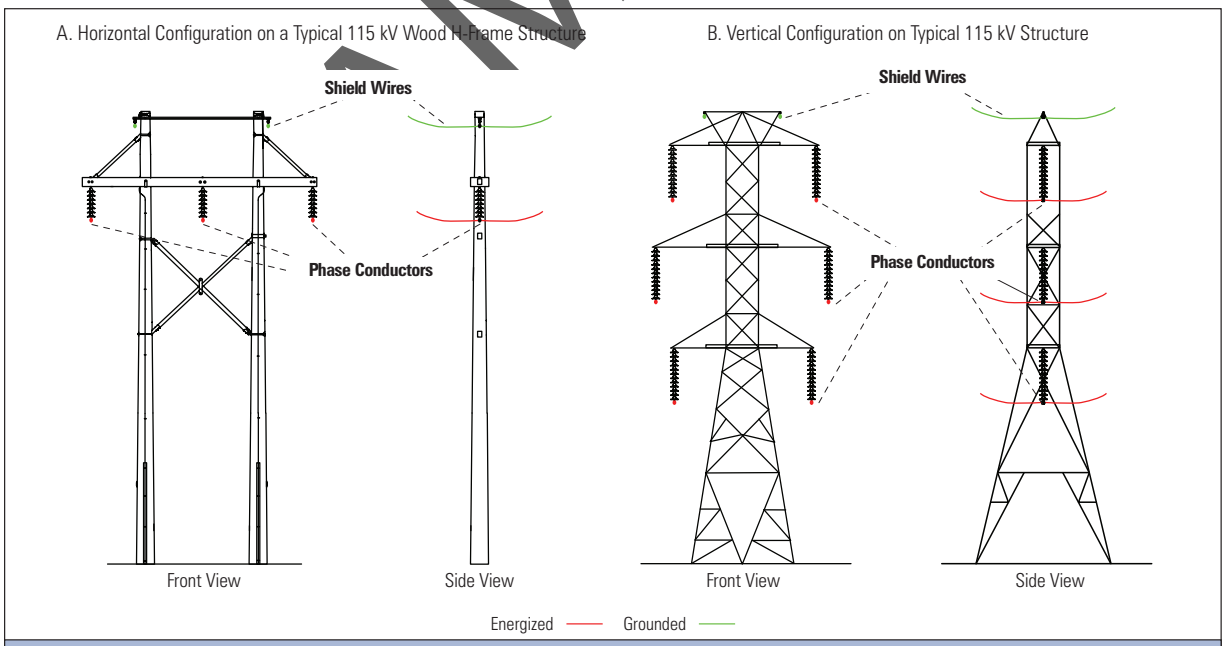

FIGURE 1.5: Horizontal (A) and vertical (B) transmission line configurations.

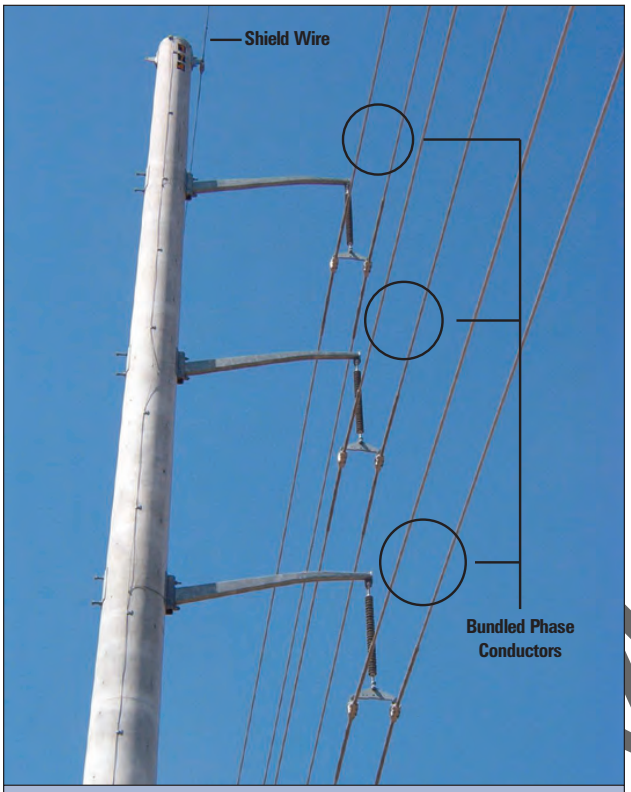

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FIGURE 1.6: Bundled phase conductors on a three-phase, single-circuit, 138-kV transmission line.

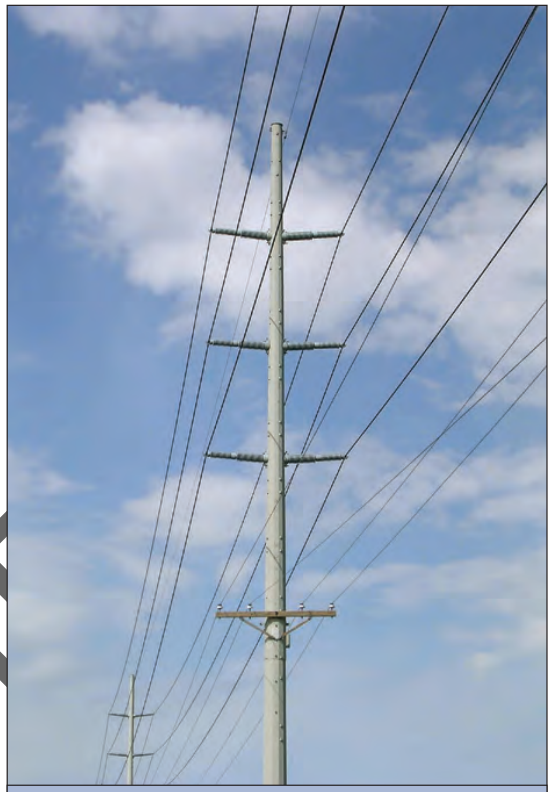

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FIGURE 1.7: Distribution underbuild on a double-circuit transmission line.

Non-energized conductors are at ground potential or zero voltage potential. There are two kinds of non-energized conductors: shield wire (also called static wire or overhead ground wire) and neutral wire.

Shield wires are installed above the phase conductors on transmission lines to protect them from lightning (Figure 1.8). Static electricity from the shield wire is taken to earth (ground) by grounding conductors. In a low lightning area, some transmission lines with lower voltages (e.g., 69 kV) may not have a shield wire. Shield wires are the lines most associated with bird collisions on transmission lines because they are the highest wire and are smaller in diameter (1 to 1.3 centimeters [cm]; 0.4 to 0.5 inches [in])[1] than phase conductors (2.5 to 5 cm [1 to 2 in]; bundled lines are multiples of these), making them more difficult to see (e.g., Savereno et al. 1996). When birds are flying at the elevation of shield wires or gaining altitude to avoid the more visible phase conductors, the potential for collision with the shield wire increases. For more information on how power line configuration affects collision risk, see Chapters 4 and 5.

[1] Measurements are provided first in metric, then in English form.

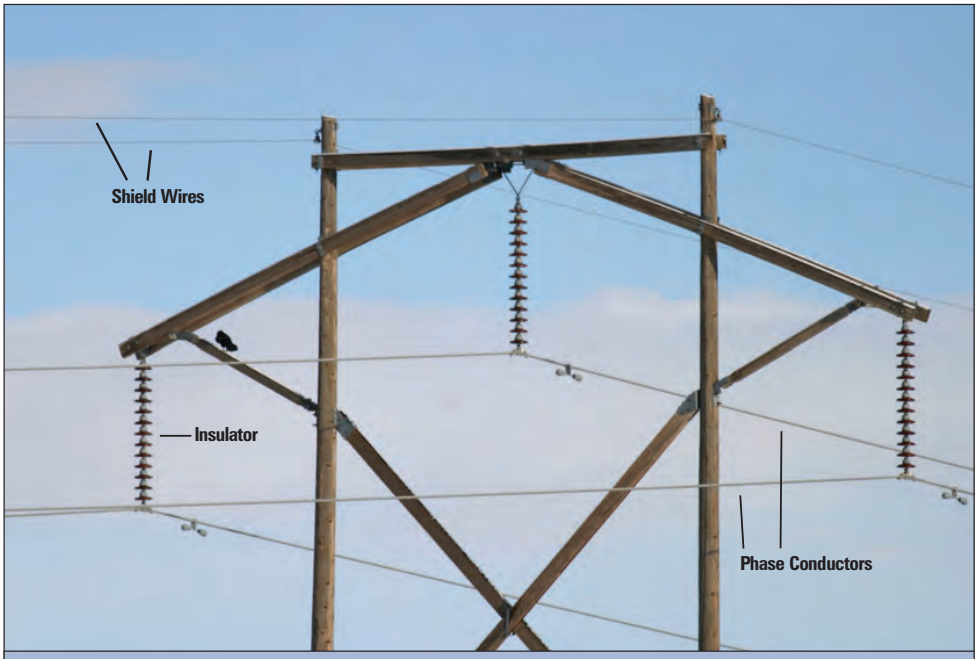

FIGURE 1.8: Shield wires are the highest wires on a transmission line.

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The neutral wire, with regional exceptions, is installed below or parallel to the phase conductors on a distribution line (Figure 1.9) and carries return current, which is taken safely to ground via grounding conductors. In high lightning areas there are exceptions where the neutral is also used as a shield wire on a distribution line.

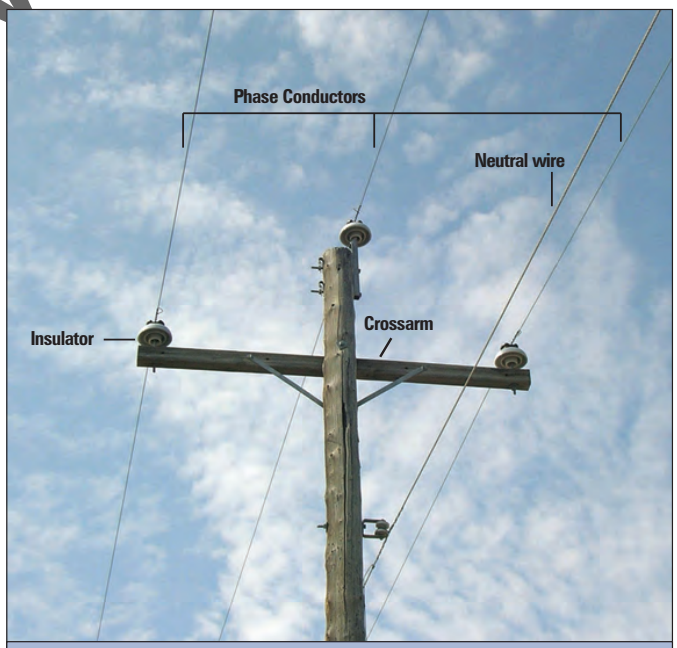

FIGURE 1.9: The neutral wire is usually positioned below the phase conductors on a distribution line.

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High Voltage: Alternating Current versus Direct Current

Alternating current (AC) transmission and distribution systems are the world's most prevalent type of line. AC transmission systems consist of three phases, each phase consists of 1 to 6 wires (two or more is a bundle). Three phases make a circuit, and a line may have more than one circuit. AC phases may be arranged either horizontally or vertically. As voltage increases, loss over distance decreases, but at some distance high voltage direct current (HVDC) becomes more efficient than high voltage alternating current (HVAC). HVDC transmission systems have a growing presence in the United States and the world. They are most effective in transmitting electricity long distances at high voltages (400 to 600 kV in North America and up to 800 kV in other countries). HVDC structure design is similar to HVAC designs, but with two poles instead of three phases (Figure 1.10). HVDC is transmitted on two bundled conductors known as positive and negative poles. The poles are spaced at least 9.1 meters (m) (30 feet [ft]) apart and are always arranged horizontally. Both systems require shield wires for lightning protection. Most importantly, both systems have the same cautions for attaching collision-preventive devices, i.e., these devices may be applied to shield wires, but are not always compatible with energized lines ≥150 kV or as manufacturers have otherwise demonstrated.

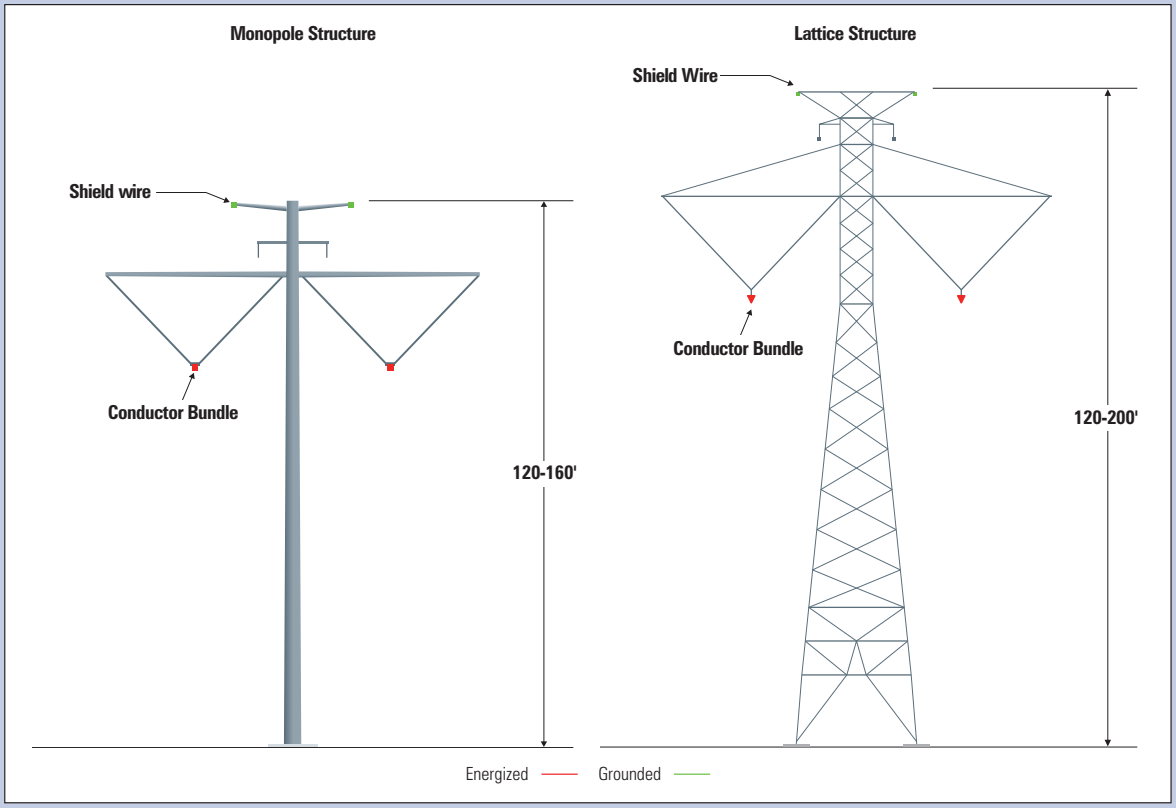

FIGURE 1.10: Typical high voltage direct current transmission line structures.

MEETING ELECTRICAL POWER DEMANDS (LOAD REQUIREMENTS)

A power line's voltage, configuration, conductor spacing, location, and structure type are determined by the present and anticipated power demands or load requirements the line will serve. Because electric utilities are required by law to provide reliable electrical service, they plan, fund, and build new power lines. If enough power is available in an area, then building new distribution lines can sometimes meet the increasing demand. Alternatively or additionally, transmission lines can be built to bring power to the load center from distant power generation facilities.

Transmission line corridors are determined by the location of power generation facilities and substations in relation to load centers. Within the corridor, the preferred and alternative routes are determined, among other things, by rights-of-way (ROWs) availability, land use patterns, potential environmental impacts, terrain, archeological sites, proximity to habitable dwellings, and crossings over water, highways, and other power lines (see *Planning New Power Lines* in Chapter 5 for a discussion and illustration of the planning process).

Different ROW widths are required for different transmission line voltage ratings; these are generally determined by state statutes and the National Electrical Safety Code. ROW widths are also a function of structure height, span length, the conductor height above ground, and the low point of the conductor. ROW widths for transmission lines will vary from 15.2 m (50 ft) to more than 60.9 m (200 ft). Because ROWs are becoming increasingly difficult to obtain,

Transmission Lines and Renewable Energy

Current renewable energy mandates are leading to the development of wind, solar, and other renewable sources. Because these renewable energy sources are typically remote, new transmission lines are often needed to connect them to the grid and carry electricity to load centers.

Overhead versus Underground Power Lines

Electric utilities install power lines either overhead or underground depending upon numerous considerations. Some key factors include customer needs, costs, code requirements, terrain, voltage, and technological and environmental restrictions. Cost is a major concern as electric utilities have mandates to serve customers with high quality, reliable electric service at the lowest cost possible.

Power lines, particularly residential distribution lines, are installed underground in many areas throughout the country where it has been found technically and financially feasible to do so. However, at transmission voltages, there are many more areas where installing lines underground is not feasible (see *Burying Power Lines* on page 62). It becomes more practical to build them overhead as the voltage of the line increases. Therefore, the focus of this manual is to provide guidance for addressing issues associated with reducing collision risks on overhead power lines.

SAMPLE

it is a common practice to increase the voltage levels of lines in existing ROWs when statutes and safety allow. As voltages increase, the amount of power that can be transmitted increases by a greater multiple.[2] Transmission voltages for carrying electricity long distances are generally in the range of 115 to 765 kV in the United States.

PERSPECTIVES FOR DEALING WITH BIRD COLLISIONS

A single approach is rarely successful in solving a complicated, multi-faceted issue such as bird collisions with power lines. An integrated approach that considers the biological, environmental, engineering, economic, and social and cultural perspectives of collisions is needed.

BIOLOGICAL AND ENVIRONMENTAL PERSPECTIVES

Biologists generally focus on gathering data to better understand the problem and creating solutions to minimize collision risk. Utility biologists and/or their consultants may be responsible for site evaluation studies and collision studies (see Chapters 5 and 6 and Appendix B). Site evaluation studies determine baseline avian and habitat conditions and assess the possible collision risks to birds following power line construction. Collision studies can help determine reliable mortality rates and quantify the effectiveness of measures taken to minimize collisions.

Collecting high quality data is critical for collision studies. Utilities should plan their studies carefully, using methods and metrics that can be replicated to gather and analyze data. The data should be sufficient for use in estimating the likelihood of collisions and for measuring the effectiveness of collision reduction efforts. In addition, methods must be sufficiently flexible to accommodate the species and site-specific conditions being studied and applied consistently throughout a study and between studies (Bevanger 1999; Barrientos et al. 2011).

In most cases, the approach to these studies is based on type of information needed to make management decisions, determine if line modifications are effective, and/or identify areas of bird activity and high collision risk. In some cases, wildlife agencies may recommend specific studies or protocols, and it is advisable to obtain their comments on a study design. Utilities and their consultants should also consider peer review by independent scientists for the study findings, since the results may undergo rigorous legal cross-examination if the issue is litigated. Publication in a refereed scientific journal is encouraged because it makes the data more widely available and contributes to a greater resource pool for the development of study design methods.

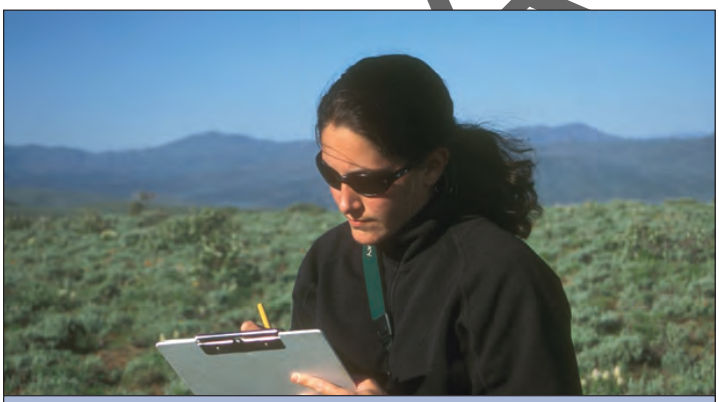

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FIGURE 1.11: Biologists gather data to assess the risk of bird collisions.

[2] The carrying capacity of a line increases at a greater rate than the increase in voltage, i.e., one 765-kV circuit = three 500-kV circuits = six 345-kV circuits. Another advantage of higher voltage is that the voltage drop or loss over distance decreases as the voltage increases.

SAMPLE

FIGURE 1.12: Engineers work with biologists to reduce risk through appropriate design and routing of power facilities.

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ENGINEERING PERSPECTIVE

Engineering research, development, and design are essential in the integrated approach to preventing or minimizing bird/power line collisions. Utility engineers should work with biologists early in the design and routing process to identify the key collision issues (see Chapter 4) and to develop feasible collision reduction strategies when modifying existing lines and planning new lines (see Chapters 5 and 6). Early science-based site evaluations and avian risk assessments can be part of improving route selection and line configurations to minimize collision problems. This can reduce or eliminate the need for costly modifications after construction. Design decisions also include other factors such as cost, routing through public or private land, crew availability, and material availability; as a result, a less favorable design for avian interactions may need to be used.

ECONOMIC PERSPECTIVE

No integrated approach would be complete without considering the economics of construction, operation, and maintenance of a power line. The cost for bird friendly power lines and configurations needs to be included during the design phase and route selection. A cost benefit analysis of appropriate collision minimization designs and mitigation can be performed. The later in the process that a biological or engineering solution is initiated, the more difficult, time-consuming, and costly it can become. Since electrical reliability is mandated by utility commissions, avoiding power outages, including those caused by birds, is a priority for electric utilities. Early planning can help meet requirements for reliability, regulatory compliance, efficiency, public acceptance, and cost-effectiveness.

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FIGURE 1.13: Engaging the public may help a utility meet requirements for electrical reliability and reduce collision risk to birds.

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SOCIAL AND CULTURAL PERSPECTIVES

In addition to cost and power reliability, the public may have concerns about power line design and placement, including esthetics, environmental effects, wildlife, and safety. Vandalism is also a persistent problem. Electrical components and line marking devices on power lines can become targets. Engaging the public may make it easier for a utility to meet the requirements of providing reliable electricity while reducing risks to birds. It can also reduce delays and costs associated with controversy and litigation (EEI 2001).

Utilities and their consultants can use a variety of public participation tools to engage the public (see Chapter 5 and Appendix E). Used effectively, these tools can build positive relationships, increase public knowledge, identify and respond to public concerns early, and promote responsible behavior (e.g., discouraging vandalism of line marking devices).

CHAPTER 2

Progress in Dealing with Collision Issues

IN THIS CHAPTER

- North America
- International
- Future Research Priorities

Much progress has been made since the 1970s in understanding and addressing bird collisions with power lines. This chapter recalls the conferences and studies that have occurred in North America and internationally. The major avian power line research organizations are introduced, along with future research priorities.

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NORTH AMERICA

UNITED STATES

The first reported bird collision with overhead lines in the United States was documented in 1876 (Coues 1876); numerous bird carcasses, mostly horned larks (*Eremophilia alpestris*), were reported during one week in a 5.8-kilometer (km) (3-mile [mi]) section of an overhead telegraph line between Cheyenne, Wyoming, and Denver, Colorado. Coues indicated that such collisions had already been reported in Europe, although no references were given. Another early report of collisions with electric wires in the United States was documented in 1904 (Emerson 1904). Emerson reported that shorebirds, as well as a black rail (*Lateralus jamaicensis*), collided with electrical wires over a salt marsh and evaporation ponds in the San Francisco Bay area. Avery et al. (1980) provides an annotated bibliography of other early power line collision literature.

Most collision studies have been published since the late 1970s and have led to a growing awareness among stakeholders. During the 1970s, Bonneville Power Administration conducted studies on reducing collisions with power lines (Lee and Meyer 1977; James and Haak 1980; and Beaulaurier 1981). Lee and Meyer (1977) proposed using devices such as image intensifiers for nocturnal observation and collision detectors that would measure the number of bird strikes on wires. They also suggested using thermal imaging, a relatively new technique at the time, to view birds and bats flying near power lines and wind turbines. Lee and his colleagues set a new scientific standard for studies of the interaction between birds in flight and power lines.

In 1978 bird/power line issues were addressed at a national conference sponsored by the U.S. Fish and Wildlife Service (USFWS),

FIGURE 2.1: APLIC has helped fund studies on the effectiveness of different types of line marking devices in reducing bird collisions with power lines.

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SAMPLE

the Environmental Protection Agency, and the Oak Ridge Associated Universities (Avery 1978).[3] This conference was followed by a 1978 meeting at the Edison Electric Institute (EEI) in Washington, D.C. There, EEI and the Electric Power Research Institute (EPRI) discussed a research program on bird/power line interactions. EPRI funded an assessment of completed, ongoing, and planned research; an analysis of future research needs regarding the impact of power lines on birds in flight; and a series of studies aimed at developing different methods for measuring the impact of power lines on birds in flight.

In 1989, a group of biologists representing a wide range of utility interests, together with representatives from the USFWS and the National Audubon Society, formed the Avian Power Line Interaction Committee (APLIC).[4] APLIC, in cooperation with the USFWS, funded a study on the effectiveness of different types of line markers in the San Luis Valley of Colorado. Such a study was needed because aerial marker spheres were commonly recommended for power lines where bird collision potential existed, although there were no data that established their effectiveness. Further details can be found in Brown and Drewien (1995).

APLIC and EPRI were also instrumental in developing and providing funding for an international conference on bird interactions with utility structures (Miami, September 1992). The proceedings of that workshop included papers and case studies by researchers from various utilities and universities in the United States, Canada, South Africa, and India, and other organizations and agencies including the USFWS, Bureau of Land Management, and U.S. Navy.

[3] Avery 1978 is the citation for the USFWS version of the proceedings; the original proceedings were documented by Oak Ridge Associated Universities. This reference will be noted as Avery 1978 in this document.

[4] Founding APLIC utility members included Bonneville Power Administration, Edison Electric Institute, Central and South West Services (currently American Electric Power), Florida Power & Light Company, Houston Lighting and Power Company (currently CenterPoint), Nebraska Public Power District, Pacific Gas and Electric Company, Pacific Power & Light Company (currently PacifiCorp), Public Service Company of Colorado (currently Xcel Energy), San Luis Rural Electric Cooperatives, Southern California Edison Company, and Virginia Power (currently Dominion). A list of current APLIC members can be found at www.aplic.org.

In 1994, APLIC published *Mitigating Bird Collisions with Power Lines* (APLIC 1994) to compile the research on bird collision issues to date. Since then, research and reviews of this issue have continued. In 1999, EPRI held a workshop sponsored by APLIC and EEI entitled Avian Interactions with Utility and Communication Structures, which included papers and discussions on the bird collision issues these two industries face (see EPRI 2001). Every three to four years since 1976, electric utilities and utility organizations including EEI, EPRI, and APLIC help sponsor the International Symposium on Environmental Concerns in Rights-of-Way Management. This symposium often includes papers on bird collisions. APLIC also conducts avian protection workshops at its semi-annual business meetings and at other times through the year upon request (see www.aplic.org for information on upcoming workshops).

Since the early 2000s, the California Energy Commission (CEC) has sponsored a large number of research projects including identification of research needs on avian collisions with power lines in California: *A Roadmap for PIER Research on Avian Collisions with Power Lines in California* (Hunting 2002). CEC also has a searchable database on avian collision literature, *An Annotated Bibliography of Avian Interactions with Utility Structures* (CEC 2011).

Other CEC, APLIC, and EPRI sponsored studies include:

- *Human-related Causes of Raptor Mortality in Western Montana: Things are not Always as They Seem* (Olson 2001)
- *Bird Strike Indicator/Bird Activity Monitor and Field Assessment of Avian Fatalities* (EPRI 2003)
- *Raptor and Raven Electrocutions in Northwestern Mexico* (Cartron et al. 2004)
- *Corona Testing Devices Used to Mitigate Bird Collisions* (EDM 2004).
- *Assessment of Avian Mortality from Collisions and Electrocutions* (Dorin and Spiegel 2005)
- *Preventing Raptor Electrocutions in an Urban Environment* (Dwyer and Mannan 2007)
- *Evaluating and Reducing Avian Collisions with Distribution Power Lines at Cosumnes River Preserve* (Yee 2007)
- *Bird Strike Indicator Field Deployment at the Audubon National Wildlife Refuge in North Dakota* (Pandey et al. 2008)
- *Raptor and Corvid Response to Power Distribution Line Perch Deterrents in Utah* (Prather and Messmer 2010)
- *Evaluating Diverter Effectiveness in Reducing Avian Collisions with Distribution Lines at San Luis National Wildlife Refuge Complex, Merced County, California* (Ventana Wildlife Society 2009)
- *Contemporary Knowledge and Research Needs Regarding the Potential Effects of Tall Structures on Sage-grouse* (UWIN Cooperative 2010)
- *Protocol for Investigating the Effects of Tall Structures on Sage-grouse (Centrocercus spp.) Within Designated or Proposed Energy Corridors* (UWIN 2011)
- *Line Marking Study near Coleharbor, ND, 2006-2008* (WAPA 2011)

Bibliographies of Collision Literature

Appendix A of this manual includes the literature cited and a bibliography of collision literature. An annotated bibliography of early collision literature was provided by Avery et al. (1980). In addition, the California Energy Commission hosts a searchable database on collisions: *On-Line Annotated Bibliography of Avian Interactions with Utility Structures* (CEC 2011).

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FIGURE 2.2: In Canada, the first reported collision victims were snow geese.

SAMPLE

CANADA

The first reported bird collision in Canada was published by Blokpoel and Hatch (1976) after several thousand snow geese (*Chen caerulescens*) were flushed by an aircraft into a transmission line. The geese had been feeding on a stubble field near Winnipeg, Manitoba. Between 25 and 75 geese were reportedly injured or killed after striking the wires.

Since then, there have been few published accounts of bird collisions in Canada. In 1997, the *Blue Jay* published a discussion on birds and power line risk (Curtis 1997). Other accounts can be found in proceedings from the Canadian hosted 5th and 7th International Symposium on Environmental Concerns in Rights-of-Way Management in Quebec (1993) and Alberta (2000). In 2007, a study on using a landscape-scale model to predict the risk of collisions in Alberta was completed (Heck 2007; Quinn et al. 2011). It examined the practicality of using GIS spatial modeling to predict areas with elevated collision frequency across large, existing electric service territories.

Bird/power line interaction knowledge is growing in Canada and more emphasis is being placed on identifying the root cause in relation to a utility's reliability issues. The cause of many outages has been identified as a direct result of wildlife interactions, including birds. Many utilities are also installing line marking devices in areas where collisions have been reported or suspected.

Depending on the species, collisions with power lines may be violations of federal and provincial wildlife laws (see Chapter 3) and can result in penalties. Most bird species present in Canada are migratory and are very often the same species present in the United States and subject to many of the same collision risks, which stem from the same biological, environmental, and engineering factors outlined in Chapter 4.

Although Canada has wildlife laws in place, as of 2011 there is not a Canadian organization addressing the management of bird interactions with power lines; so Canadian companies have turned to American utilities for support by joining APLIC. In 2012, the first APLIC workshop in Canada was held in Banff. Electric utility representatives, consultants, contractors, and government regulators from across the country attended.

In addition to legal requirements and due diligence, Canadian companies have recognized that bird collisions need to be minimized for environmental, public relations, and public health reasons. Through increased management of avian collision issues, companies have been better able to demonstrate to utility staff, regulators, and the public, their commitment to reducing utility impacts on birds.

MEXICO

In Mexico, the USFWS has been working with officials of the Mexican government through the Trilateral Committee of the North American Free Trade Agreement, the

Migratory Bird Treaty with Mexico, Partners in Flight, and the National Wind Coordinating Collaborative to help Mexico better address avian collision and electrocution issues. These efforts are also tied to Mexico's land-based wind energy development, which includes power line issues (R. Villegas-Patraca, pers. comm.; A. Manville, pers. comm.; Mexico Institute of Ecology and USFWS, unpubl. reports, respectively).

INTERNATIONAL

Important collision research has been conducted in Europe, Asia, and Africa. In 2003, BirdLife International prepared the guide *Protecting Birds from Power Lines: A practical guide on the risks to birds from electricity transmission facilities and how to minimize any such adverse effect* (BirdLife International 2003). It reviewed the risks from power lines, including collisions, and recommended standards to protect birds, siting considerations, use of underground power lines, hiding or obscuring power lines against more prominent landscape features, and the use of line marking devices. In 2007, BirdLife International developed a policy position statement on the risks to birds from transmission lines (BirdLife International 2007). In 2009, the Council of Europe issued *Follow-up Recommendation No 110, 2004* (Schuerenberg et al. 2009) on minimizing adverse effects of power lines on birds. It reviews standards and retrofitting methods and provides an exhaustive list of actions taken by 26 European countries.

In 2011, the United Nations Environment Programme (UNEP) for the African-Eurasian Waterbird Agreement (AEWA) and the Convention on Migratory Species (CMS) released a *Review of the Conflict between Migratory Birds and Electricity Power Grids in the African-Eurasian Region* (CMS 2011a) and the *Guidelines for Mitigating Conflict between Migratory Birds and Electricity Power Grids* (CMS 2011b). CMS (2011a) provides a summary of collision issues and hot spots in Europe, Asia, and Africa. Also in 2011, the *Budapest Declaration on Bird Protection and Power Lines* (MME 2011) was adopted by the participants of the Budapest Conference, Power Lines and Bird Mortality in Europe. The declaration aims for all new construction of power poles to be bird-safe by 2016 and all dangerous poles to be retrofitted by 2020. The conference was attended by 123 participants from 29 European and Central Asian countries, the European Commission, UNEP AWEA, six energy and utility companies, experts, businesses, and non-government organizations.

In Asia, the risk of bird collisions with power lines is being recognized as more studies are conducted on bird electrocutions associated with new power line structures. For example, in Mongolia, while performing a review of raptor electrocutions on new concrete poles with metal crossarms, researchers found that Pallas' sandgrouse (*Syrrhaptes paradoxus*) were killed after colliding with power lines during an unusual seasonal relocation (Gombobaatar et al. 2010).

In Uzbekistan, systematic collision monitoring using standard protocols has not been conducted and therefore reported mortalities can only be considered anecdotal. However, these observations have shown that certain species are more susceptible to collisions and/or electrocutions. It is known that during spring and autumn migration, medium and large size birds collide with or are electrocuted on the power lines, which include rare and declining species like the steppe eagle (*Aquila nipalensis*), golden eagle (*Aquila chrysaetos*), imperial eagle (*Aquila heliaca*), osprey (*Pandion haliaetus*), short-toed eagle (*Circaetus gallicus*), and Saker falcon (*Falco cherrug*) (Abdunazarov 1987; Shernazarov and Lanovenko 1994).

SAMPLE

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FIGURE 2.3: Researchers have studied the effects of power line collisions on vulnerable species, such as the Ludwig's bustard of Europe, Asia, and Africa.

In Kazakhstan, researchers found 409 bird carcasses of 34 different species during a 2006 survey of power line mortality. Many deaths were due to electrocutions and 44% were raptors. Deaths due to collisions were also noted (Lasch et al. 2010).

The great bustard (*Otis tarda*), which once ranged from Manchuria to Portugal, is now extirpated or endangered across much of the continent because of habitat loss, disease, and mortality from power line collisions (Janss and Ferrer 2000; Garcia-Montijanoi et al. 2002; Alonso and Martin 2005). It is one of the world's heaviest flying birds with a maximum weight of 21 kilograms (46 pounds). As a result, great bustards maneuver slowly in flight and are not able to avoid wires spotted at the last moment. Collisions have been observed by researchers in Mongolia (Kessler 2007). The research group notes that great bustard collisions with power lines are a common occurrence in developed Western Europe and are becoming more frequent in China.

In South Africa, The Endangered Wildlife Trust has a Wildlife & Energy Program that coordinates and sponsors research on bird/power line interactions (EWT 2011) (see Appendix E). This includes a study on the vision characteristics of the Ludwig's bustard (*Neotis ludwigii*) and blue crane (*Anthropoides paradiseus*) with respect to their ability to see power lines while in flight and how to reduce the collision risk for these species. It also includes a range-wide study of the collision rates of the Ludwig's bustard.[5]

In Kenya, a 2009 risk assessment of bird interactions with electrical infrastructure identified several sites of high collision risk to birds of conservation concern. These species included the grey-crowned crane (*Balearica regulorum*), lesser flamingo (*Phoeniconaias minor*), white stork (*Ciconia ciconia*), secretary-bird (*Sagittarius serpentarius*), and a number of vultures and raptors (Smallie and Virani 2010).

[5] The range of the Ludwig's bustard includes Angola, Botswana, Lesotho, Namibia, and South Africa.

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FUTURE RESEARCH PRIORITIES

As more power lines are built across the landscape, collision risk is anticipated to increase. Yet, this risk may be offset through assessment of potential avian impacts during siting and route selection, improved line marking devices and study methods, and increased awareness among stakeholders. With the continued growth in power line mileage, more collision research is needed. Because of the susceptibility of some endangered species, such as the whooping crane (*Grus americana*) and California condor (*Gymnogyps californianus*), power lines in these species' ranges will require careful evaluation and routing in addition to line marking devices and/or other collision reduction measures.

National and international collaboration on bird/utility interactions has increased markedly since the late 1990s. Guidelines for the development of Avian Protection Plans are a product of this collaboration (see Chapter 7). Electric utilities are increasingly adopting avian protection policies, plans, and conservation measures, and APLIC will continue to provide guidance on bird collision issues. Cooperation in addressing collision issues will continue between electric utilities and wildlife agencies. This relationship will advance the collision risk reduction measures discussed in this manual (see Chapters 5 and 6).

Regional and species-specific studies of collision mortality and methods for minimizing collisions would be especially helpful. At this time there is no organized attempt to understand the extent and magnitude of collision mortality from power lines. Current knowledge of collisions is geographically, regionally, and site biased because most studies have been conducted on lines with known collision problems. In addition, avian/power line collision risk is not uniformly distributed because it is highly dependent on species and habitat variables. Bevanger (1999) recommended several areas of investigation that combine well-planned observational studies with experimental studies rather than non-standardized collision records that cannot be scientifically or statistically compared. Recent studies on the effectiveness of line markers (e.g., Yee 2008 and Murphy et al. 2009) follow these recommendations. Standardized protocols for monitoring mortality at communication towers (e.g., Manville 2002, 2009b; Gehring et al. 2009) and wind turbines (e.g., CalWEA 2011) could also provide models that could be adapted for power line mortality assessments.

The effectiveness of line marking devices needs further study. In particular, more research is required to determine the device and spacing best suited to different environmental conditions and species. Except for studies sponsored by the CEC and APLIC (e.g., Ventana Wildlife Society 2009; Yee 2008; WAPA 2011) relatively few systematic studies have looked at the comparative effectiveness

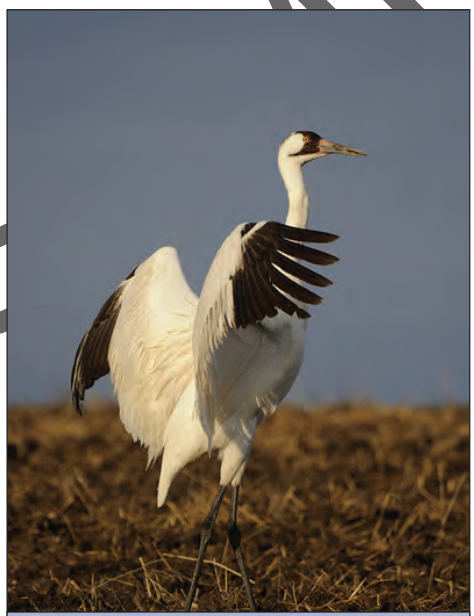

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FIGURE 2.4: Because of the susceptibility of some endangered species, such as the whooping crane, power lines in these species' ranges require careful evaluation and routing.

SAMPLE

of different line marking devices. Barrientos et al. (2011) conducted a meta-analysis of line marking studies, discussed the limitations, and provided recommendations for more scientifically rigorous evaluations. In addition, no systematic comparison of the effectiveness of these devices with different species, in different habitats, or in different weather conditions has been conducted. As new styles of line markers continue to be developed and existing markers are modified, associated effectiveness testing will be needed.

Funding Organizations for Collision Research

APLIC, EPRI, and CEC are three organizations that provide some funding for research on avian/power line interactions (see Appendix E). The USFWS conducts limited primary research and funds state research through Section 6 Endangered Species Act grants.

APLIC funds research projects that further the knowledge of avian/power line interactions including:

- Assessments of collision and/or electrocution rates associated with power lines
- Risk assessments to identify factors contributing to collisions and electrocution mortality risks for different species
- Evaluations of impacts of power line construction on bird species

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FIGURE 2.5: APLIC, EPRI, and CEC are three organizations that provide some funding for research on avian/power line interactions.

EPRI's research priorities emphasize information and monitoring systems that will improve understanding of and mitigating for avian interactions with utility facilities. These include the Bird Activity Monitoring System and avian vision studies that may help develop more effective collision prevention devices.

The CEC (Hunting 2002) identified a number of research priorities that still apply today and need to be considered to better understand avian collisions with power lines. These include:

- Standardizing mortality estimation
- Testing and documenting the efficacy of line marking devices
- Testing and documenting the efficacy and limitations of remote collision detection devices
- Determining collision risk levels associated with potential high avian-use habitats
- Monitoring and reporting over the long term

CHAPTER 3

Avian Regulations and Compliance

IN THIS CHAPTER

Overview of Existing Laws and Policies
Permit Requirements

Most native North American birds are protected by the Migratory Bird Treaty Act. Additional statutes provide further protection for bald and golden eagles *(Haliaeetus leucocephalus* and *Aquila chrysaetos)* and birds that are threatened or endangered. This chapter describes United States' and Canada's federal regulations that protect these birds, their habitat, and the corresponding conservation and permitting measures.

OVERVIEW OF EXISTING LAWS AND POLICIES

UNITED STATES

Migratory Bird Treaty Act

The Migratory Bird Treaty Act of 1918 (MBTA) (16 U.S.C. 703–712) is the legal cornerstone of migratory bird conservation and protection in the United States. It is a strict liability statute, meaning that proof of intent is not required in the prosecution of a taking (injuring or killing) violation. Most actions that result in *taking* or possessing a protected species, its nest, parts, and/or eggs are violations.

The MBTA states: "Unless and except as permitted by regulations…it shall be unlawful at any time, by any means, or in any manner to pursue, hunt, *take*, capture, kill… possess, offer for sale, sell…purchase…ship, export, import…transport or cause to be transported…any migratory bird, any part, nest, or eggs of any such bird, or any product …composed in whole or in part, of any such bird or any part, nest, or egg thereof…."

Generally speaking, the MBTA protects the majority of birds that nest in North America (50 CFR 10.13). As of 2012 there were 1,007 bird species on the list of migratory bird species protected under the MBTA. The list includes waterfowl, shorebirds, seabirds, wading birds, raptors, and songbirds. The 1972 MBTA amendment extended protection to birds of prey—eagles, hawks, falcons, and owls—and to corvids, such as crows and ravens. However, the MBTA does not protect non-migratory upland game birds (such as grouse and quail) or introduced species such as house (English) sparrows (*Passer domesticus*), European starlings (*Sturnus vulgaris*), rock pigeons (common/feral pigeons, *Columba livia*), monk parakeets (*Myiopsitta monachus*), and 121 other less commonly encountered species that have been excluded from protection by the MBTA (USFWS 2005a [70 Fed. Reg. 49, 15 March 2005]).

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FIGURE 3.1: The Migratory Bird Treaty Act of 1918 is the legal cornerstone of bird protection in the United States, protecting more than 1,000 North American bird species such as this cedar waxwing (*Bombycilla cedrorum*).

An individual, which can mean a corporation or other organization, who violates the MBTA may be fined up to $15,000 and/or imprisoned for up to six months for a misdemeanor conviction. An individual who knowingly *takes* any migratory bird with the intent to sell, offer to sell, barter, or offer to barter such bird or who knowingly sells, offers for sale, barters, or offers to barter any migratory bird is subject to a felony violation with fines of up to $250,000 and/or imprisonment for up to two years. The MBTA has no provision for permitting incidental or accidental take.

Federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations are directed by Executive Order 13186 (3 CFR 2001; Office of the President 2001. [66 Fed. Reg. 11, 17 January 2001]) to develop and implement a memorandum of understanding (MOU) with the U.S. Fish and Wildlife Service (USFWS) that shall promote the conservation of migratory bird populations. This includes federal agencies' power line infrastructure-related collisions and electrocutions of protected birds. To date (2012), MOUs have been signed by the Department of Defense, Department of Energy, U.S. Forest Service, National Park Service, Bureau of Land Management, Minerals Management Service/Bureau of Ocean Energy Management, and the Federal Energy Regulatory Commission, with others under development.

Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act of 1940 (BGEPA) (16 U.S.C. 668–668d) provides additional protection to these eagle species. If a proposed project or action would occur in areas where nesting, feeding, or roosting eagles occur, then utilities may need to take additional conservation measures to achieve compliance with the BGEPA.

The BGEPA prohibits the take, possession, sale, purchase, barter, offer to sell, purchase, or barter, transport, export or import, of any bald or golden eagle, alive or dead, including any part, nest, or egg, unless allowed by permit ([16 USC 668(a)]. *Take* under this statute is defined as "to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb" (50 CFR 22.3). *Programmatic take* is defined as "*take* that (1) is recurring, but not caused solely by indirect effects, and (2) occurs over the long-term and/or in a location or locations that cannot be specifically identified" (50 CFR 22.26). *Disturb* is defined as "to agitate, or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, (1) injury to an eagle, (2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or (3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior" (50 CFR 22.3). Violators may be fined up

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to $100,000 and/or imprisoned for up to one year. Individuals with subsequent convictions or who commit intentional *takes* face penalties of up to $250,000 and/or two years imprisonment.

The BGEPA has been amended to provide a permit for non-purposeful *take*, including *take resulting in disturbance* and limited *take resulting in mortality* that may occur as a result of otherwise lawful activities, provided the breeding populations are stable or increasing. Because there are no breeding populations in the eastern United States that can sustain *take*, the USFWS will not authorize *take* for golden eagles east of approximately 100° west longitude, except for *take* of nests for safety emergency situations (USFWS 2009a).

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FIGURE 3.2: Habitat Conservation Plans help landowners incorporate conservation measures for species, such as the wood stork (*Mycteria americana*), into their development plans.

Endangered Species Act

The Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531–1544) protects the United States' native plants and animals that are in danger of becoming extinct and may also protect their habitats. Federal agencies are directed to use their authority to conserve listed and candidate[6] species and to ensure that their actions do not further jeopardize these species or adversely modify designated critical habitat for them. The law is administered by the USFWS and the National Marine Fisheries Service (NMFS). The USFWS has responsibility for terrestrial and freshwater organisms, while the NMFS oversees endangered marine life. These two agencies work with other agencies to plan or modify federal projects to minimize project impacts on listed species and their habitats. Protection is also gained through USFWS' financial and technical assistance partnerships with states, tribes, and private landowners.

Section 9 of the ESA makes it unlawful for a person to *take* a listed species. *Take* under the ESA is defined as "…to harass,[7] harm,[8] pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." The ESA authorizes the USFWS to issue Incidental Take Permits (ITP) for *take* resulting from otherwise legal activity.

Section 10 of the ESA allows Habitat Conservation Plans (HCP) for the con-

[6] *Candidate* species are those in decline which may be added to the list of threatened and endangered species in the near future.

[7] Harass is defined as an intentional or negligent act or omission, which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly impair normal behavioral patterns including breeding, feeding, or sheltering (50 CFR 17.3).

[8] Harm is defined as an act which actually kills or injures wildlife. Such acts may include significant habitat modification or degradation when it actually kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering (50 CFR 17.3).

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struction and management of facilities, e.g., transmission lines, on private lands that are used by endangered species. These plans help landowners incorporate conservation measures into their land and/or water development plans. Landowners who develop and implement HCPs can also receive ITPs that allow their activities to proceed with authorization for limited *take*.

State Policies and Regulations

States have additional bird protection regulations. A utility should consult with its respective state wildlife agency to determine whether more regulations apply and if permits are required.

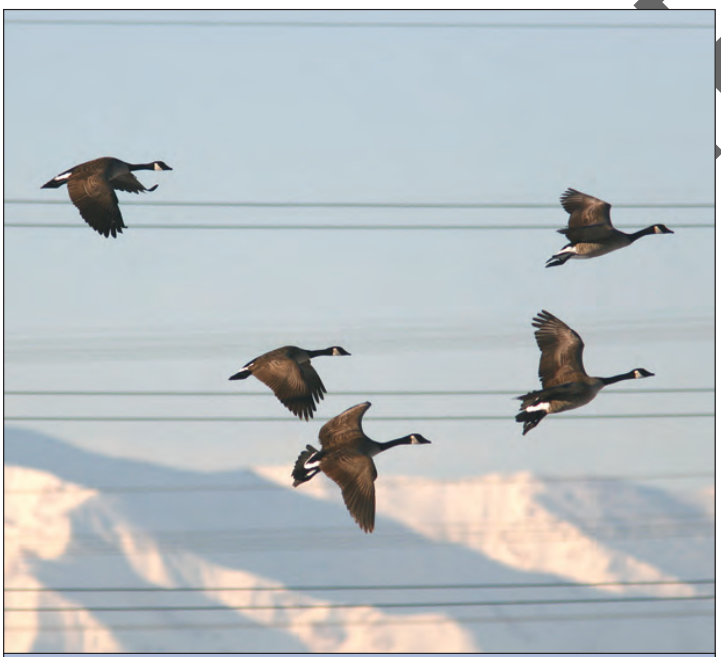

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FIGURE 3.3: Canada geese (*Branta canadensis*) are protected by both the Migratory Bird Treaty Act and Canada's equivalent, the Migratory Birds Convention Act.

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Migratory Birds Convention Act

The Migratory Birds Convention Act (MBCA) of 1917 and amended 1994 (1994, c.22) is Canada's equivalent of the United States' MBTA (1918), which provides legal protection for migratory birds. One notable exception is raptors, which are protected by provincial and territorial wildlife acts instead of MBCA. The MBCA satisfies the terms of the Migratory Birds Convention of 1916, when both countries recognized concerns about overhunting waterfowl and shorebirds. The MBCA recognizes three classifications of protected birds: migratory game birds, migratory insectivorous birds, and migratory non-game birds. It further lists them by family and gives examples.

In Canada, the MBCA is administered by the Wildlife Enforcement Division of Environment Canada in cooperation with provincial and territorial governments. Enforcement of the Act is made in concert with the Canadian Wildlife Service (CWS), Royal Canadian Mounted Police, and provincial and territorial enforcement authorities.

The MBCA and its associated regulations state that "No person shall hunt a migratory bird except under authority of a permit," and "Subject to subsection 5(9), no person shall (a) disturb, destroy, or *take* a nest, egg, nest shelter, eider duck shelter or duck box of a migratory bird, or (b) have in his possession a live migratory bird, or a carcass, skin, nest or egg of a migratory bird."

Individuals, which includes corporations, who violate the MBCA and associated regulations may be subject to a fine of up to $300,000 and/or six months imprisonment. Upon summary conviction or upon indictment, fines of up to $1,000,000 and/or two years imprisonment may be applied.

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Species at Risk Act

The Canadian Species at Risk Act (SARA) was enacted in 2003. The objective of SARA is to protect native species from extinction, ensure measures are taken for the recovery of threatened or endangered species, and encourage best management practices for maintaining healthy populations.

SARA adopted the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as an advisory body to assess potentially at-risk wildlife species, identify existing and potential threats to the species, and classify the status of the species (i.e., extinct, extirpated, endangered, threatened, of special concern, or not currently at risk). Established in 1977, COSEWIC is an independent committee of wildlife experts and scientists from federal, provincial and territorial governments, universities, and non-government organizations that uses the best available science to support its recommendations. Under SARA, the government of Canada will take COSEWIC's designations into consideration when establishing the legal list of wildlife species at risk (COSEWIC 2009).

SARA states that "No person shall kill, harm, harass, capture or *take* an individual of a wildlife species that is listed as an extirpated species, an endangered species or a threatened species." However, SARA does make allowance for the incidental *take* of animals through the issuance of permits (similar to the ESA in the United States).

Provincial Policy and Regulations

Federal and provincial governments have worked together to develop complementary policy and programs to protect species at risk. For example, the Alberta Wildlife Act and Regulations seek to protect wildlife whereby "a person shall not hunt wildlife unless the person holds a licence authorizing the person, or is authorized by or under a licence, to hunt wildlife of that kind." The legislation also states that "a person shall not wilfully molest, disturb or destroy a house,[9] nest or den of prescribed wildlife" where wildlife is defined as "big game, birds of prey, fur bearing animals, migratory game birds, non game animals, non-licence animals and upland game birds." Similarly, other provinces have enacted legislation for the protection of wildlife, including birds.

INTERNATIONAL POLICIES AND AGREEMENTS

Since 2000, there has been an increasing international awareness of the issue of bird collisions for certain species. International conventions and policies (see CMS 2011a) that are relevant to bird collisions include:

- Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA)
- Convention on Biological Diversity (CBD)
- Ramsar Convention on Wetlands, List of Wetlands of International Importance
- Convention on the Conservation of Migratory Species of Wild Animals (CMS)
- MOU on the Convention of Migratory Birds of Prey in Africa and Eurasia
- MOU on the Conservation and Management of the Middle-European Population of the Great Bustard
- Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)
- Various European Union Directives

These agreements have resulted in research, reviews, and guidance on bird collisions that may provide some further insight into bird collisions.

[9] The term "house" includes artificial structures such as bird boxes and nesting platforms.

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PERMIT REQUIREMENTS

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Federal and state permits may be required for activities that may affect species protected by the MBTA, BGEPA, ESA, or state laws. For species protected by the MBTA, utilities are encouraged to contact their regional USFWS Migratory Bird Permit Office and their state wildlife agency to identify permit requirements and, if necessary, obtain permit applications. For species protected by the ESA and BGEPA, utilities must contact their USFWS Ecological Services field office.

Migratory Bird Permits

Migratory bird permits are issued by the regional USFWS Migratory Bird Permit Offices. Permits are issued for falconry, raptor propagation, scientific collection, rehabilitation, conservation education, migratory game bird propagation, salvage, *take* of depredating birds, taxidermy, waterfowl sale and disposal, and special purpose. Annual reporting to the USFWS is required as a condition of each permit. Policy for migratory bird permits is developed by the Division of Migratory Bird Management. The regulations governing migratory bird permits can be found in 50 CFR part 13, General Permit Procedures, and 50 CFR part 21, Migratory Bird Permits.

In 2003, the USFWS issued a memorandum clarifying the definition of *take* under the MBTA as it applies to active nests (nests containing eggs or young). Under the MBTA, the collection, possession, and transfer of inactive bird nests requires a permit, but the destruction of nests that do not contain eggs or birds is permissible. This does not apply to eagles or species listed by the ESA, whose active and inactive nests are protected. The memo also stated that the USFWS may issue permits for the removal of occupied nests when public safety is at risk (see 50 CFR 21.27).

Bald and Golden Eagle Permits

BGEPA permits are administered by the regional USFWS Migratory Bird Permit Offices in coordination with the Division of Migratory Bird Management's Washington, D.C. office and the local Ecological Services field office where an eagle *take* might occur.

Under BGEPA (50 CFR parts 22.26 and 22.27), the USFWS can issue permits to *take* bald eagles and golden eagles or their nests, where the *taking* is associated with, but not the purpose of, the activity and cannot practicably be avoided. Permits may be authorized for non-purposeful *take*, which includes *take resulting in disturbance* or limited *take resulting in mortality* provided the breeding populations are stable or increasing. USFWS will not issue golden eagle *take* permits east of the 100° meridian (see BGEPA discussion on page 22).

USFWS may also issue permits for programmatic *take* (e.g., recurring *take* for an entire power line over a specified amount of time) or for individual *take* (e.g., for disturbance due to one-time construction of a power line where the location of the *take* and when it will occur are known). *Programmatic take* permits may be issued to entities, such as electric utilities or transportation providers, that may currently *take* eagles in the course of

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FIGURE 3.4: Most songbirds, such as these horned larks *(Eremophilia alpestris)*, are protected by the Migratory Bird Treaty Act.

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FIGURE 3.5: Bald eagles are protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act.

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otherwise lawful activities but who can work with the USFWS to develop and implement advanced conservation practices (ACPs). ACPs are defined as "scientifically supportable measures that are approved by the Service and represent the best available techniques to reduce eagle disturbance and ongoing mortalities to a level where remaining *take* is unavoidable" (50 CFR 22.3).

The regulations are intended to provide a mechanism—under carefully considered circumstances—where non-purposeful *take* of bald and golden eagles can be legally authorized. How-ever, BGEPA provides the Secretary of Interior with the authority to issue eagle *take* permits only if it is able to determine that the *take* is compatible with eagle conservation. This must be "…consistent with the goal of increasing or stable breeding populations."

Regulation establishes the issuance of permits for removing eagle nests where (1) necessary to alleviate a safety emergency to people or eagles, (2) necessary to ensure public health and safety, (3) the nest prevents the use of a human-engineered structure, or (4) the activity or mitigation for the activity will provide a net benefit to eagles (50 CFR 22.27). Only inactive nests may be *taken* except in the case of safety emergencies. Inactive eagle nests are defined by the continuous absence of any adult, egg, or dependent young at the nest for at least 10 consecutive days leading up to the time of *taking* the nest.

Special Purpose or Salvage or Miscellaneous Permit

In compliance with federal regulations, utilities may need certain permits to handle or "possess" injured or dead birds found along power lines. Salvaging and possessing carcasses of birds protected under the MBTA requires a Federal Special Purpose or Salvage or Miscellaneous Permit (50 CFR 21.27). This permit allows the burial or incineration of migratory birds found dead on a utility property or temporary possession for transporting to a suitable disposal location, rehabilitation facility, repository, or wildlife pathology laboratory. Permit conditions may vary but if the bird is a federally endangered or threatened species or eagle, most permits require the USFWS to be notified within 48 hours of discovery of the carcass. Depending on permit requirements, a quarterly and/or an annual report must be submitted to the USFWS regional permit office.

Endangered Species Act Consultation, Incidental Take Permit (ITP), and Habitat Conservation Plan (HCP)

When utilities propose the construction of, for example, power generation or transmission facilities where a federal nexus exists (i.e., on federal lands, with federal funding, or requiring federal authorization or permits), they

must first consult with the USFWS through Section 7 of the ESA if any threatened or endangered species may be at risk. Before initiating an action, the federal agency owning the land or providing the funding or the non-federal permit applicant (e.g., an electric utility) should ask the USFWS to provide a list of threatened, endangered, proposed, and candidate species and designated critical habitats that may be present in the project area. The USFWS has developed a handbook that describes the consultation process in detail (USFWS and NMFS 1998). Based on a Biological Assessment, an ITP may be issued under Section 7 of the ESA.

When non-federal activities (i.e., lacking a federal nexus) will or may *take* threatened or endangered species, an ITP is required under Section 10 of the ESA. Approval of an ITP issued in conjunction with an HCP requires the Secretary of the Interior to find, after an opportunity for public comment, that among other things, the *taking* will be incidental and that the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such *taking*. An HCP must accompany the application for an ITP. The HCP associated with the permit is to ensure that conservation measures are adequate for avoiding jeopardy to the species or adversely modifying critical habitat. Information about consultations and HCPs can be obtained by contacting the local USFWS Ecological Services field office.

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Both MBCA and SARA provide for permitting and authorization of incidental *take* of migratory birds and species at risk. However, for MBCA, the Canadian government, through the CWS, has declared that they will not develop the permitting system; instead they recommend that companies use due diligence to prevent incidental impacts to migratory birds through best management practices.

SARA does provide for incidental harm to a species or destruction of its critical habitat under carefully controlled circumstances provided the activity does not jeopardize the survival or recovery of the species. These provisions include permits (three-year duration) or agreements (five-year duration). These authorizations are tied to strictly prescribed conditions. The government continues to work with stakeholders to develop operational policies to better implement SARA.

The requirement to protect critical habitat for migratory birds only applies in federal lands such as national parks, national wildlife areas, and bird sanctuaries. For critical habitat located in federally protected lands, the prohibition on destruction of this habitat applies automatically once the Environment Minister posts a description of the critical habitat in the Canada Gazette (typically within 90 days after the recovery strategy/action plan is posted to the SARA Public Registry).

The Environment Minister can recommend that the Cabinet protect a migratory bird species and/or the critical habitat of a species not on federal land if there is reason to believe the province or territory is not sufficiently protecting the species. However, the decision by the Cabinet to order protection is discretionary. There is also a species and habitat harm exemption clause in SARA for activities that have been authorized by other permits or agreements. This clause has not been implemented to date (2012).

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CHAPTER 4

Understanding Bird Collisions

IN THIS CHAPTER

- Susceptibility of Birds to Power Line Collisions
- Identifying Collision Mortality
- Variability in Reported Mortality Rates
- Biological Significance of Collision Mortality
- Biological Characteristics Influencing Avian Collision Risks
- Environmental Conditions Influencing Avian Collision Risks
- Engineering Aspects Influencing Avian Collision Risks

Understanding the nature of bird collisions is essential for minimizing and mitigating them. This chapter presents what is known about bird collisions including the susceptibility of certain species, variability in reported mortality rates, biological significance of collision mortality, and the biological, environmental, and engineering factors that influence collision risk.

Some bird species have a greater collision risk than others. Because of the need for power lines to deliver electricity, engineering design requirements, and potential interaction of birds with power lines, collisions cannot be eliminated, but they can be reduced. The understanding of bird collisions has grown since 1994 and revolves around the following principles:

- Exposure to collisions is largely a function of behavior. Specific behaviors (such as flushing, courtship displays, and aerial hunting) may distract birds from the presence of power lines.
- Exposure is increased for birds that make regular and repeated flights between nesting, feeding, and roosting areas in proximity to power lines.
- Susceptibility to collisions is partially a function of wing and body size and vision. Larger, heavy-bodied birds with short wing spans and poorer vision are more susceptible to collisions than smaller, lighter-weight birds with relatively large wing spans, agility, and good vision.
- Environmental conditions (such as inclement weather and darkness) may distract birds from the presence of power lines or obscure their visibility.
- Engineering aspects, including design and placement, can increase or decrease the exposure for collisions.

SUSCEPTIBILITY OF BIRDS TO POWER LINE COLLISIONS

Summaries of studies on birds' susceptibility to collisions have primarily come from Europe (see Bevanger 1998; Janss 2000; Rubolini et al. 2005). Based on the Bevanger (1998) summary of risk, the orders of birds reported to be most susceptible to collisions included:

- Gaviforms (e.g., loons)
- Podicipediformes (e.g., grebes)
- Procellariiformes (e.g., shearwaters, albatross, petrels)
- Pelecaniformes (e.g., pelicans, cormorants)
- Ciconiiformes (e.g., storks, ibis, herons)
- Anseriformes (e.g., ducks, geese)
- Falconiformes (e.g., hawks, eagles)
- Galliformes (e.g., grouse)
- Gruiformes (e.g., rails, cranes)
- Charadriformes (e.g., gulls, terns)
- Apodiformes (e.g., swifts)
- Columbiformes (e.g., pigeons, doves)
- Strigiformes (e.g., owls)
- Passeriformes (e.g., song birds)

The reasons for this susceptibility are functions of species characteristics, in particular the birds' body size, weight, wing shape, flight behavior, and nesting habits (see *Biological Characteristics Influencing Avian Collision Risks* on page 36). For example, literature shows that, in general, birds of prey are good fliers, have the ability to avoid obstacles, and are not prone to collisions. It is when they are engaged in certain activities (e.g., territorial defense, pursuing prey) that their collision risk increases (see Harness et al. 2003; Olendorff and Lehman 1986).

IDENTIFYING COLLISION MORTALITY

Reporting bird injuries and mortalities is part of the U.S. Fish and Wildlife Service (USFWS) permit requirements (see Chapter 3) and permits are an element of utility Avian Protection Plans (APPs; see Chapter 7). In order to report mortalities correctly, the affected species and the cause (collision or electrocution) needs to be properly identified. Field guides can be used to identify the bird species, and a guide for identifying raptor remains is also available (CEC 2005). The U.S. Geological Survey's National Wildlife Health Center also provides information and technical assistance for identifying bird carcasses (USGS 2011). See Appendix E for resources.

Table 4.1 lists the typical damage evident in bird carcasses from collision injuries. Electrocution injuries often occur as burn marks on the feathers and feet (see APLIC 2006). Collisions can also lead to electrocutions

TABLE 4.1: Typical evidence of bird injuries or mortalities from power line collisions.*

Evidence	Description
Predominant bone fractures	Fractured wings, legs, shoulder bones, vertebra, or skull; torn off limbs
Damage to plumage	Mechanical damage, such as torn off or broken feathers
Skin injuries	Skin torn open or off, and open muscle, sinew, and bone tissue visible; power line may leave imprint in skin where the bird struck the line; necropsy may reveal internal bleeding and bruising
Secondary damage to extremities	Limited areas of infection at open wounds, bones, sinews, and muscles
General condition of injured birds	State of shock; handicapped by injuries and secondary damage

* Source: Adapted from BirdLife International (2003)

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(called collision-electrocutions) if the bird's size is sufficient to make simultaneous contact with two phase conductors or with a phase conductor and grounded equipment, or if the collision causes two lines to slap together or get close enough to cause an electric arc.

VARIABILITY IN REPORTED MORTALITY RATES

It is difficult to extrapolate collision risk from one study and apply it to other power lines or compare it with other studies because of site-specific conditions and varying study methods and metrics. Likewise, many collision studies have been conducted in high risk areas and would not be applicable to lower risk areas. Numerous authors have summarized collision mortality with power lines (e.g., Faanes 1987; Bevanger 1998; Alonso and Alonso 1999; Rubolini et al. 2005; and Jenkins et al. 2010) and report mortality rates ranging from no birds killed to several hundred birds killed along a given segment of line per year. The California Energy Commission (CEC) study (Hunting 2002) provides a summary of collision mortality rates per unit area per distance. Reported mortality rates are highly variable and do not lend themselves to extrapolation to other lines because of site- and study-specific differences in:

- Species involved, such as ducks and sandhill cranes (*Grus canadensis*)
- Habitats, such as wetlands and agriculture
- Time periods and sampling regimes, such as single seasons versus multiple seasons
- Weather conditions, such as fog, wind, etc.
- Sampling biases, such as scavenger removal rates and searcher efficiency
- Types of power lines

Another limit to extrapolating bird/power line collision mortality estimates is the tendency to select worst-case scenarios as case studies (e.g., Koops 1987; Erickson et al. 2001; Manville 2005a). The CEC study (Hunting 2002) points out the difficulty in generalizing collision rates, and Bevanger (1999) provides an excellent summary of the

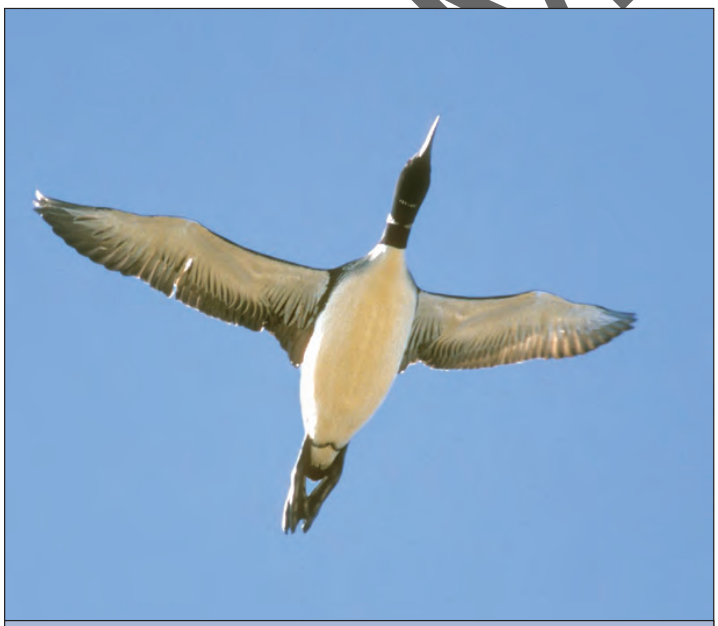

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FIGURE 4.1: Collision risk is highly variable among species, with heavy-bodied birds, such as this common loon (*Gavia immer*), being more vulnerable because they cannot readily maneuver.

Bibliographies of Collision Literature

Appendix A of this manual includes the literature cited and a bibliography of collision literature. An annotated bibliography of early collision literature was provided by Avery et al. (1980). In addition, the California Energy Commission hosts a searchable database on collisions: *On-Line Annotated Bibliography of Avian Interactions with Utility Structures* (CEC 2011).

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methodological issues in calculating these rates. For example, Faanes' (1987) calculation of 125 collisions/kilometer(km)/year (0.62 miles[mi]/year) for a line near a North Dakota wetland with abundant waterfowl during migration periods has been referenced by others including Bevanger (1999) and Erickson et al. (2005). Janss and Ferrer (2000) calculated collision rates of "one of the densest breeding populations of the great bustard (*Otis tarda*) in Spain," and for a large wintering population of common cranes (*Grus grus*) feeding in grain fields. Extrapolations from these studies could lead to exaggerated overestimates.

Adding to the difficulty in providing an overall assessment of collision mortality is that bird collisions do not usually cause power outages and consequently are not usually discovered. On the other hand, electrocutions are more likely to cause power outages and be reported (see APLIC 2006). To generate collision estimates for a particular power line, power line segments have to be selected randomly for mortality monitoring and should represent a diversity of habitats. Collision mortality can be relatively high or low depending upon the species, habitat, and the local circumstances. Appendix B provides recommendations for collision monitoring studies.

BIOLOGICAL SIGNIFICANCE OF COLLISION MORTALITY

Understanding the biological significance of collision mortality is necessary for developing proper reduction strategies. Collision mortality may have significance from social, wildlife policy, and biological points of view. Social and wildlife policy aspects relate to how the public and wildlife agencies consider collision mortality. The biological aspects relate to how the mortality affects bird populations. The social or wildlife policy assumption of significance is not necessarily biologically significant.

From a biological perspective, significance evaluates whether collision mortality will affect the viability of a species' population. Biological significance results from an influence that significantly affects the ability of a species' population to sustain itself or increase its size.

This definition is used by population biologists to understand the influence of an adverse effect on a particular population or species. During site evaluation studies, utility biologists need to be aware of the possible impacts to rare species and to determine if the line would create a biologically significant risk as well as significant risk from a wildlife policy perspective (see Chapter 3).

Drewitt and Langston (2008) conclude that few studies of bird collisions with power lines show that collisions are biologically significant, which means individual losses from collision mortality are unlikely to affect large and robust populations. As an independent mortality factor, the effect of power line collisions on bird populations is generally thought to be compensated for in populations that have high reproductive rates (Bevanger 1998).

Biologically significant risk from collisions may occur in a population that is so small

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FIGURE 4.2: Because of their higher reproductive rates, common bird species are generally at less risk of population effects from power line collisions.

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that the loss of a few individuals may impact local, rare, or endangered populations (Crowder 2000). Power line collisions may be significant to very small and/or declining populations, as they may not be capable of compensating for this loss (Bevanger 1998). Drewitt and Langston (2008) note that low reproductive rates and small populations of some species may further contribute to the likelihood of population effects. In addition, there are examples where collision mortality has occurred locally and concern has been expressed. Although not a federally endangered species, recent studies of sandhill cranes in Nebraska have shown that local populations can be affected by collision mortality (Murphy et al. 2009). Collisions during spring migration stopovers at major night roosts along the Platte River in Buffalo County, Nebraska, have been historically high near two 69-kilovolt (kV) transmission lines. The Newell's shearwater (*Puffinus auricularis newelli*), an endangered species in Hawaii, is an example of a species with a relatively small and restricted population that is threatened by multiple factors including power line collisions (Podolosky et al. 1998). Other threats include ground nest predation by dogs, cats, rats, pigs, and mongooses; collisions with buildings, cars, and other objects; and attraction to lights that may disorient them and cause them to fly around the light until they fall from exhaustion. Power line collisions appear to be a major contributor to the threats to Newell's shearwater's survival (Podolosky et al. 1998; Day et al. 2003; R. Podolosky, pers. comm.).

Outside North America, collision mortality is considered biologically significant for these species with low population numbers:

- Red-crowned cranes (*Grus japonensis*) in Japan (Archibald 1987, cited in Crowder 2000)
- Wattled cranes (*Bugeranus carunculatus*) in South Africa (Van Rooyen and Ledger 1999, cited in Crowder 2000)
- Capercaillie (*Tetrao urogallus*) in Norway (Bevanger 1995; Bevanger and Broseth 2004)
- Dalmatian pelicans (*Pelecanus crispus*) in northern Greece (Crivelli et al. 1988, cited in Drewitt and Langston 2008)
- Bonelli's eagle (*Aquila fasciata*) in Spain (Mañosa and Real 2001)
- Sarus crane (*Grus antigone*) in India (Sundar and Choudury 2005)
- Eagle owl (*Bubo bubo*) in Sweden (Herren 1969)
- Mute swans (*Cygnus olor*) in the United Kingdom (Kelly and Kelly 2005)

In the United States, collision mortality from power lines is considered biologically significant for two species with small populations: the whooping crane (*Grus americana*) and the California condor (*Gymnogyps californianus*).

WHOOPING CRANE

Losses of wild and reintroduced (or experimental) whooping cranes to power line collisions have been reported (Crowder 2000; Brown et al. 1987; Morkill and Anderson 1991; Stehn and Wassenich 2007). The one natural wild population, the Aransas-Wood Buffalo Population (AWBP), has been subjected to significant natural causes of mortality such that additional collision mortality is viewed as a threat to the species. The loss of 57 cranes (21.4% of the flock of 266) that died of starvation and infectious disease in the 12 months following spring 2008 (34 between spring and fall, 23 during the winter) was a serious setback (T. Stehn, pers. comm.). The additional loss of more than 10 birds per year for any reason could destabilize this species' recovery. However, the population has shown resilience with 279 whooping cranes at the Aransas National Wildlife Refuge in the spring of 2011 (T. Stehn, pers. comm.) compared to 247 in the spring of 2009.

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FIGURE 4.3: The United States' population of endangered whooping cranes has had such significant mortality from natural causes that additional power line collision mortality is now viewed as a threat to the species.

SAM

The actual percentage of whooping crane mortality caused by collisions with power lines is hard to extrapolate for the AWBP because monitoring the small population during migration over such a large area (Figure 4.4)[10] is so difficult. In the 1980s, two of nine radio-marked juvenile whooping cranes in the AWBP died within the first 18 months of life as a result of power line collisions; that is 33% of total post-fledging losses (n = 6) of the radio-marked birds during the study (Kuyt 1992). Five of 13 known causes of mortality (38%) for the AWBP between April and November from 1950 to 1987 resulted from collisions with power lines (total mortality from all causes equaled 133 cranes) (Lewis 1992).

Collisions have been reported in other whooping crane populations as well. In the non-migratory Florida population, 20 out of 166 cases with known causes of mortality (12%) were from collisions with power lines, and in the migratory Wisconsin population, 3 out of 18 mortalities (17%) were from collisions with power lines (Stehn and Wassenich 2007). From 1950 to 2008, out of 508 fledged whooping cranes that have died, only 44 (8.7%) of the carcasses were recovered (C. Strobel, USFWS, unpubl. data). Of the 44 carcasses recovered, no cause of death could be determined for 17. Of the remaining 27 carcasses where a cause of death was established, 9 (33%) were from power line strikes and 18 (67%) were from other causes (e.g., disease, predators, and shooting).

[10] The whooping crane migration corridor is 322 km (200 mi) wide and extends 4,023 km (2,500 mi) from Wood Buffalo National Park in the Alberta and Northwest territories in Canada to the Aransas National Wildlife Refuge on the Gulf Coast of Texas (see Stehn and Wassenich 2007).

CALIFORNIA CONDOR

The federally endangered California condor was rescued from extinction when the last remaining wild individuals were captured from the mountains of southern California in 1987 to establish a captive breeding and reintroduction program. In 1991, reintroduction of captive-bred individuals began in select areas of the southwestern United States. As of December 2011, the total wild population of California condors was 210 individuals (NPS 2011). Reintroduced individuals from the captive breeding program have come into contact with power lines and collision mortality has occurred. For example, in a six-month period, three of eight condors that died in the wild died after colliding with power lines (D. Pearson, pers. comm.).

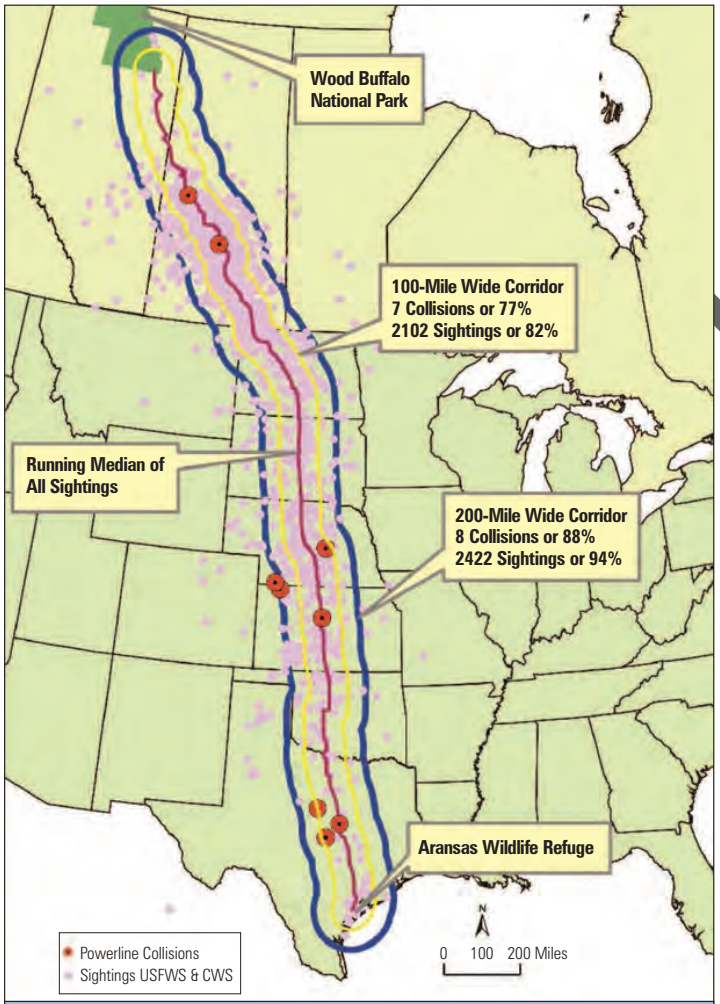

FIGURE 4.4: Whooping crane migration corridor in North America (2005 data from Stehn and Wassenich 2007).

FIGURE 4.5: Collision mortality has occurred with the expansion of the reintroduced population of the endangered California condor.

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DRAFT

BIOLOGICAL CHARACTERISTICS INFLUENCING AVIAN COLLISION RISKS

Different bird species have different collision risks based on their biology, behavior, habitat use, and inherent abilities to avoid risk (e.g., Savereno et al. 1996) (see *Susceptibility of Birds to Power Line Collisions*, page 30). A number of biological characteristics influence the susceptibility of species to collisions with power lines:

- Body size, weight, and maneuverability
- Flight behavior
- Vision
- Age and sex
- Health
- Time of day and season
- Habitat and habitat use

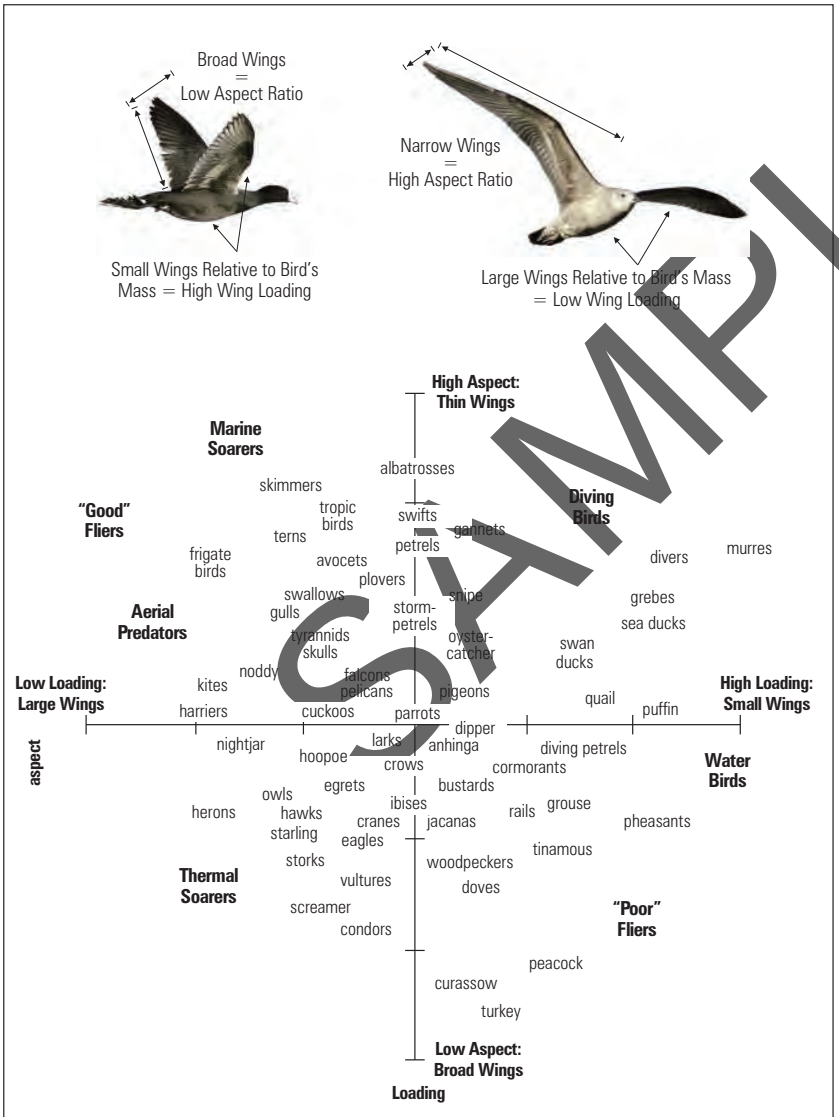

FIGURE 4.6: Wing loading and aspect ratio, among other factors, influence susceptibility to collisions (after Bevanger 1998).

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Knowing what avian species are involved, when they are present, and how they use the habitat along a power line route will help to estimate risk.

BODY SIZE, WEIGHT, AND MANEUVERABILITY

Several studies of collision vulnerability have addressed the relationship between bird size and maneuverability (e.g., Bevanger 1994, 1998; Janss 2000; Crowder and Rhodes 2002; and Rubolini et al. 2005). They classified birds based on weight and with these characteristics quantified wing loading (the ratio of body weight to wing area) and wing aspect ratio (ratio of the square of the wing span to the wing area) (Figure 4.6). Using Rayner's characterization (Rayner 1988), bird species were grouped according to the relationship of wing loading and wing aspect ratio and analyzed for collision susceptibility (Bevanger 1998). He developed six categories: poor flyers, waterbirds, diving birds, marine soarers, aerial predators, and thermal soarers. Bevanger (1994, 1998), Janss (2000), Crowder and Rhodes (2002), and Rubolini et al. (2005) have also evaluated different species and their collision susceptibility using wing loading and wing aspect ratio. They found in general that birds

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with high wing loading are more susceptible to collisions than birds with low wing loading; and that birds with low aspect ratios are more susceptible than birds with high aspect ratios. Birds with high wing loading and low aspect ratios represent poor fliers. Bevanger (1998), supported by Janss (2000) and Rubolini et al. (2005), also found this to be true.

High wing loading birds are frequently reported as collision casualties, including large, heavy-bodied birds with large wing spans such as herons (Mead et al. 1979), cranes (Walkinshaw 1956; Tacha et al. 1979; Brown et al. 1987), swans (Banko 1956; Beer and Ogilvie 1972), pelicans (Willard et al. 1977), and condors (D. Pearson, pers. comm.). These and similar species generally lack the maneuverability to quickly avoid obstacles.

Heavy-bodied, fast fliers are also vulnerable to collision. This characteristic is typical of most waterfowl, coots, rails, grebes, pigeons and doves, and many shorebirds (e.g., sandpipers and plovers). For example, waterfowl accounted for the majority of collision mortality at a site in the San Luis Valley, Colorado (Brown and Drewein 1995). Researchers have also noted that species with long legs and necks collide more often than those with more compact profiles (NUS Corporation 1979, unpubl., cited in Hunting 2002).

In comparison, terns with low wing loading and smaller body size are considered agile fliers and have a keen ability to avoid lines despite their high potential exposure. Henderson et al. (1996) found only two casualties beneath wires in a study of a common tern (*Sterna hirundo*) colony located within an industrial complex, where birds of all age classes and both sexes were making hundreds of flybys per hour (>10,000 flybys observed).

Body size and maneuverability do not explain all collision risk. Other factors can also contribute. For example, gulls and terns have low wing loading, yet they can be subject to collisions because of behavioral

FIGURE 4.7: Birds with high wing loading, such as swans, are more susceptible to collisions.

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characteristics, such as flocking, spending large amounts of time in the air, and flying at night. Although the low wing loading (light body) gives gulls and terns a more buoyant, graceful, and potentially slow flight speed, they are over-represented in Janss' mortality data set because of their large abundance at his study sites. This point is also made by Bevanger (1998) who cites observational studies by Meyer (1978), James and Haak (1980), and Beaulaurier (1981) to assert that gulls were 50 to 100 times less likely to collide with power lines when compared with ducks.

Passerines (songbirds) were reported in Bevanger (1998) to have a great deal of variation in flight morphology, yet most are not particularly heavy bodied or thin winged. Certain songbirds such as European starlings (*Sternus vulgaris*) may be so abundant that their representation among power line collision casualties may actually be attributed to abundance rather than susceptibility (Janss 2000). On the other hand, passerine carcasses are so small that they are much more difficult to discover and may be under-reported (Scott et al. 1972, cited in Drewitt and Langston 2008).

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FLIGHT BEHAVIOR

Understanding the flight behavior of birds active near a power line can be useful in identifying the potential risk for collisions and how those risks might be reduced. The following flight behaviors have been reported in the literature (e.g., Drewitt and Langston 2008) as influencing collision risk:

- Flocking
- Flight altitude patterns of migrating and non-migrating birds
- Courtship, nest building, and feeding flights to and from and around the nest, especially for colonial species
- Flight ability of fledglings and juveniles
- Flights between nesting/roosting and foraging areas

Flocking species, such as waterfowl and wading birds, are more vulnerable to collisions than solitary species (Bevanger 1998; Crowder 2000; Crowder and Rhodes 2002; Drewitt and Langston 2008). The density of large flocks leaves little room to maneuver around obstacles; in fact, birds sometimes collide with each other when panicked (Brown 1993). Bevanger (1998) and Drewitt and Langston (2008), citing several studies, conclude that flocking behavior may lead to greater susceptibility, as trailing birds have obstructed views of an upcoming obstacle. Crowder (2000) and Crowder and Rhodes (2002) observed that flocks react to power lines at a greater distance from the line than do solitary birds. Scott et al. (1972) and James and Haak (1980) stated that flocking behavior was an important factor in starling collisions, as did Blokpoel and Hatch (1976) for snow geese (*Chen caerulescens*). A number of birds within large flocks of sandhill cranes were involved in power line collisions in the Platte River area, Nebraska; in several instances collisions of some birds within flocks were observed (Murphy et al. 2009).

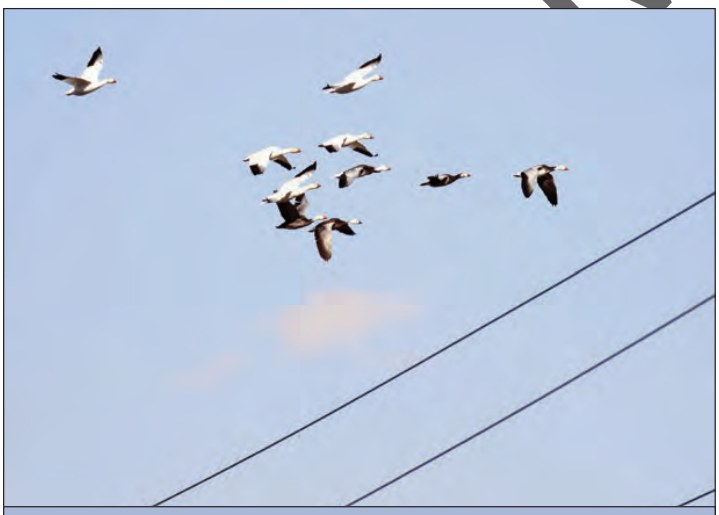

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FIGURE 4.8: Flocking species, such as these snow geese, can be more vulnerable to collisions.

Flight altitude is a function of species and environmental conditions such as winds, thermal conditions, visibility, precipitation, and time of day, as well as the type of flight (Newton 2008). Two types of bird flight altitude are observed: migrating or non-migrating.

Migrating birds take advantage of thermals and stronger tail winds when conditions permit, allowing them to conserve energy (Newton 2008) while staying well above power lines. In general, flight altitudes of migrating birds range from a couple hundred meters (m) (several hundred feet [ft]) to more than 6,000 m (20,000 ft). Weather conditions (e.g., wind speed and direction) influence flight altitude of migrants (see *Weather Conditions and Visibility*, page 48). Most transmission towers in the United States range from 15.2 m (50 ft) to less than 60.9 m (200 ft)[11] high depending upon design and voltage. If a

[11] Some structures exceed 61 m (200 ft) in height especially at river crossings and to clear other lines that might otherwise intersect (M. Schriner, pers. comm.; D. Bouchard, pers. comm.).

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bird's flight altitude is at or below the height of power lines, collision risk can increase.

There are two basic types of migrating birds: long distance and daily migrants. Long distance migrants can fly thousands of kilometers (miles) without stopping and will have the least exposure to power lines during migration (e.g., some shorebirds, swallows, swifts, and terns). Most long distance migrants migrate at night, resting and feeding during the day (Manville 2007a). Daily migrants take shorter flights and make numerous stops to rest and feed (Newton 2008). Daily migrants include cranes, ducks, geese, and raptors. If power lines are in their landing or take-off paths, collision risk increases.

For non-migrating birds, flight altitude is likely to be within the range of power line height. Their flight is a function of their feeding, reproductive, and foraging behaviors. These behaviors usually occur within approximately 200 m (660 ft) of the ground, which can expose birds to collision risk when in the proximity of power lines. For predatory birds, the exposure to collision risk can be related, in part, to the pursuit of prey. Bevanger (1994) suggests that aerial hunters such as swifts, swallows, and certain raptors, such as the peregrine falcon (*Falco peregrines*), golden eagle (*Aquila chrysaetos*), and goshawk (*Accipiter gentilis*), typically have excellent maneuverability and very good vision. Yet because they chase prey at high speeds, the presence of a power line may not be perceived soon enough to avoid a collision with it.

Flight related to nesting behavior can increase collision risk if nests occur in close proximity to power lines. Such behavior includes courtship (e.g., aerial displays and pursuit), nest building, fledgling flights, feeding flights to and from the nest, territorial defense, and general flying around the nest or colony. These behaviors are most important for birds that nest in colonies, such as herons and egrets. Risks can also be associated with the age of a bird (i.e., adults and juveniles). Older birds are often acclimated to the presence of a line and will exhibit lower collision risk through well-developed flight patterns. Fledgling birds have less control of the flights and are more vulnerable to collisions than adults (see *Age and Sex*, page 41). There may also be risks for birds crossing a power line from the nesting site to a foraging area. Again, this is most important for colonial birds that will travel together to feed (see also *Habitat and Habitat Use*, page 44). Collision risks to foraging birds will occur when birds departing from and returning to a colony have to cross power lines. Their risk will be a function of the direction of foraging flights and the frequency of crossings. Mojica et al. (2009) reported 21 bald eagle (*Haliaeetus leucocephalus*) mortalities attributed to power line collisions in a study in Maryland conducted from 1985 to 2007.

FIGURE 4.9: Aerial hunters that forage in flight within a couple hundred meters (several hundred feet) of the ground, such as swallows, can become collision victims.

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VISION

Information on the visual acuity of birds relative to power lines is generally lacking (Bevanger 1998). However, when they are able to see power lines, birds do exhibit avoidance behavior. The use of line marking devices that increase the visibility of lines has confirmed this (see Chapter 6).

For birds, detecting power lines depends on the visibility of the wires and on the characteristics of their vision. Compared to humans, the frontal vision of many bird species is not high-resolution, and many species mainly use their lateral vision to detect details (Martin 2011). Birds often tend to look downwards when in flight (e.g., to look for conspecifics [their own kind] or food), which for some species puts the direction of flight completely inside their blind zone (Martin and Shaw 2010; Martin 2011; CMS 2011a).

Some birds have highly developed vision that they use to capture prey and avoid predators (Gill 1995). The eyes of most birds are on the sides of their heads, which allows them to see things on each side at the same time as well as in front of them. This wide field of vision enables birds to spot predators and obstacles. However, widely spaced eyes can make judging distances and depth perception more difficult, except in the area where the eyes' fields-of-view overlap.

In addition, birds have blind spots caused by the length, width, and position of their bills. For some species, depending upon the size and movement of their bill, these blind spots can reduce the visual field. Researchers have noted that swans' poor frontal vision makes them more susceptible to collision (Martin and Shaw 2010). Martin and Shaw (2010) provided evidence that some species, such as bustards and cranes, have extensive blind spots in the frontal hemisphere and that downward head movement (forward pitch) greater than 25 degrees and 35 degrees, respectively, can render them blind in the direction of travel. If this occurs, objects directly ahead of the bird may not be detected during flight regardless of the visual capacities of the bird's eyes or the size and contrast of the object.

Raptors' eyes are closer to the front of their heads, giving them binocular vision, which is important for making distance judgments while pursuing prey. Having depth perception also makes them less vulnerable to collisions than birds with eyes on the sides of their head.

Birds with eyes adapted to underwater vision, such as ducks, tend to be emmetropic (objects are in sharp focus) in water and slightly myopic (nearsighted) in air (Jones et al. 2007). This may affect their ability to detect small diameter wires as they approach them at high speeds. A red-breasted merganser (*Mergus serrator*) was observed colliding with a shield wire with no reaction prior to the collision, and other mergansers were observed flying within 30.5 cm (12 in) of the shield wire with no reaction (N. Turley, pers. comm.). These observations suggest that the

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FIGURE 4.10: Swans' poor frontal vision, along with their large size, increases their susceptibility to collisions.

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mergansers were not aware of the wire, which indicates that vision characteristics may play a role in collision risk. Examples of other birds in this group with eyes adapted to underwater vision include loons, grebes, other diving ducks (buffleheads, scoters, and eiders), gannets, and kingfishers.

Some species have the ability to keep objects at different distances in focus simultaneously. For example, they are able to scan the horizon while keeping the ground in focus during flight, regardless of changes in elevation. This is believed to be achieved by asymmetry of the lens and cornea about an optical axis (Jones et al. 2007). This results in the eye being emmetropic in some parts of the visual field (the lateral and upper lateral visual fields) and myopic in others (lower lateral visual fields). For prey species such as pigeons, these characteristics allow the bird to scan the horizon for predators and conspecifics while foraging for objects on the ground. This same ability is also found in quail and sandhill cranes (Jones et al. 2007), but is generally not possessed by raptors or other species that must capture mobile prey.

In the last two decades, research on avian vision has indicated that ultraviolet sensitivity is an important component of avian vision. Birds detect a wider bandwidth of light in the violet and ultraviolet (UV) spectrum (440 nanometers [nm] to 10 nm) than humans do. This difference in sensitivity may relate to many different aspects of bird behavior including prey detection, foraging, display and mating, navigation, and circadian rhythm (Hart et al 1998; Bennett and Thery 2007). Based on this research, UV materials have been applied to line marking devices to help birds detect hazards that otherwise would not be seen. However, these UV materials have not been systematically tested in collision studies.

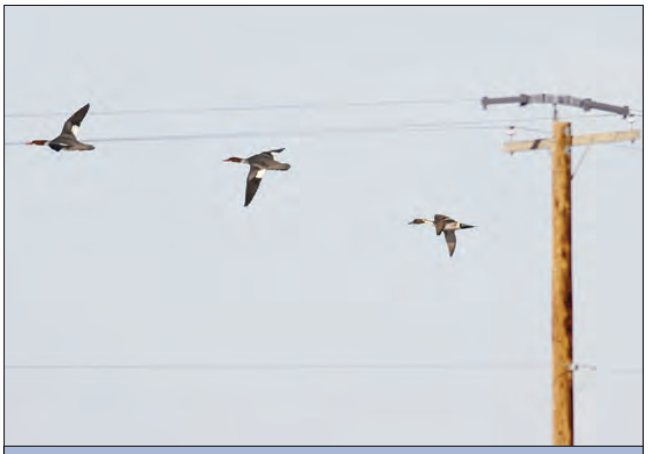

FIGURE 4.11: Because they are nearsighted and fly at high speeds, mergansers may be unable to readily detect small diameter wires as they approach them.

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Regardless of a bird's vision, environmental conditions such as inclement weather and the time of day (e.g., low light or dark) can reduce a bird's ability to see even marked power lines. A number of line modification and marking strategies can be used to reduce the effect of these factors (see Chapter 5 and Chapter 6).

AGE AND SEX

Age and sex have a species-specific influence on collision risk. Crowder (2000) cites numerous studies showing that juveniles are more susceptible than adults (Thompson 1978; McNeil et al. 1985; Brown et al. 1987; Crivelli 1988; Savereno et al. 1996; Mathiasson 1999) but also notes two examples where adults are more susceptible (Ogilvie 1966; Anderson 1978). Brown et al. (1987) and Morkill and Anderson (1991) demonstrated statistically that juvenile sandhill cranes col-

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lided with power lines more frequently than their proportion of the population would indicate. Conversely, Anderson (1978) found that adult mallards (*Anas platyrhynchos*) were more vulnerable to collisions than juveniles. Ogilvie (1966) suggested that age was not a factor in collision susceptibility for mute swans.

Many authors suggest that young birds or those unfamiliar with the area are more vulnerable than experienced birds (Anderson 1978; Thompson 1978; McNeil et al. 1985). The less-controlled flight of young birds also increases their collision risk. These birds are generally believed to be more susceptible to both electrocution and collision, though this may be confounded by the greater proportion of young birds in the population (Bevanger 1998). Most (11 of 14 = 78.6%) of Newell's shearwater collisions at a Kauai, Hawaii, power line were non-breeding birds, though many of those were likely subadults. The proportions of non-breeding adults and subadults in the population were not reported (Cooper and Day 1998). Juveniles of many migratory species are especially at risk because they have not yet encountered nor learned to avoid the assortment of risks they face.

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FIGURE 4.13: Endangered Newell's shearwater mortalities at a Kauai power line were mostly non-breeding adult and subadult birds.

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FIGURE 4.12: Some juvenile birds, such as sandhill cranes, collide with power lines more frequently than their adult counterparts.

Less information about the differing vulnerability of sexes exists because comparative data are rarely available. However, several studies have presented evidence that male ducks are more prone to collisions than females (Boyd 1961; Avery et al. 1977; Willard et al. 1977; Brown and Drewien 1995). The courtship and pursuit behaviors of male ducks greatly increase their frequency of local flights and can distract them from seeing and avoiding power lines. Distractions for other species also include pursuit of mates, competitors, or prey, which can increase collision risk (Willard et al. 1977; Anderson 1978).

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HEALTH AND CONDITION OF THE BIRD

Studies of birds killed by power line collisions indicate that poor health may increase collision risk. Mute swans with elevated blood lead levels had higher collision risk than did healthier birds (Kelly and Kelly 2005). Low weight swans and swans with heavy burdens of toxins were over-represented among swans killed by collisions in Sweden (Mathiasson 1999).

The ability of the bird to maneuver can also be impaired by entanglement with fishing lines and other anthropogenic materials. Manville (2005b) reported on entanglement issues involving Canada geese (*Branta canadensis*) and other waterbird species with six-pack beverage rings and monofilament fishing line, along with plastic debris ingestion, all of which may increase their susceptibility to power line collisions due to weakened conditions, altered aero-dynamics, and impaired health.

Collision mortality can also lead to health effects in populations of birds. In rare instances, collisions that occur in high enough numbers can indirectly contribute to some diseases, such as botulism. Malcom (1982) reported the deaths of several thousand grebes and ducks from botulism that were initiated by the victims of collisions with a transmission line in south central Montana. The collision victims fell into a wetland where their carcasses provided the energy substrate in which dormant *Clostridium botulinum* spores became active. These bacteria produce a toxin that invertebrates consume and concentrate without ill effects. Those toxin-laden invertebrates (e.g., fly-egg-maggot) become food for other ducks and a vicious cycle can develop and become protracted (Rocke and Friend 1999), much as Malcom observed.

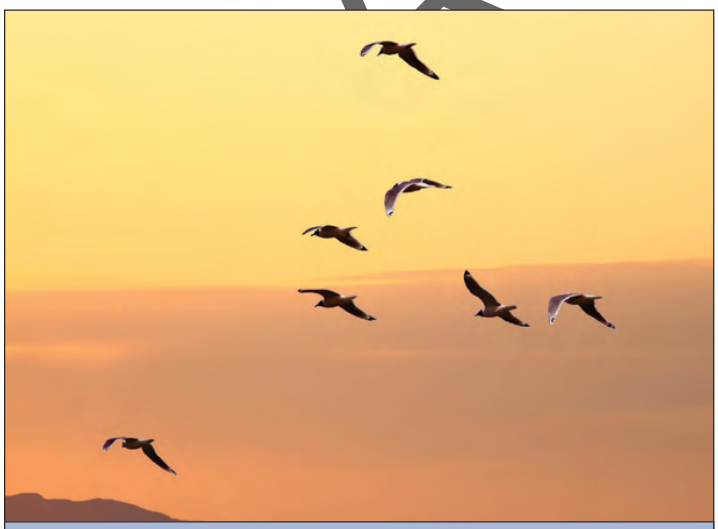

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FIGURE 4.14: Gulls (pictured) and waterfowl tend to make feeding flights at dusk and dawn, when reduced light increases collision risk.

TIME OF DAY AND SEASON

Time of Day

Studies have shown that time of day is important to collision frequency in daily flights and during migration. Different species generally feed at different times of day. Non-breeding birds, including migrating species, generally feed continuously during the day and are considered to have continuous exposure to power lines in the vicinity of their feeding areas. When birds are nesting, they often show a periodicity in feeding.

Collisions are much more likely during the night than the day (Scott et al. 1972; Krapu 1974; Anderson 1978; and James and Haak 1980; all cited in Crowder 2000; Pandey et al. 2008). Gulls and waterfowl tend to make feeding flights after sunset and before sunrise. Many waterbird species regularly fly at night in response to tidal cycles or prey activity (Black and Collopy 1982; Erwin 1977; Robert et al. 1989; Dodd and Colwell 1998) or predator avoidance. Inability to see the wires due to low light conditions probably raises the collision risk for these species (Scott et al. 1972; Krapu 1974; James and Haak 1980; Brown and Drewien 1995). At the San Luis National Wildlife Refuge Complex in California, bird flight diverters were effective on waterfowl but not on coots, which authors attribute to the fact that coots

fly at night and cannot see the diverters (Ventana Wildlife Society 2009).

Species that migrate at night, such as songbirds and herons, may be vulnerable to collisions if weather forces them to fly at low altitudes. However, generalizing from one species to another or one habitat to another that nocturnal flight behavior may be more risky than diurnal flight behavior needs to be cautioned. Deng and Frederick (2001) investigated nocturnal bird flights of wading birds in the vicinity of a 550-kV transmission line adjacent to the Everglades in south Florida. They observed nine species of wading birds including herons, egrets, and wood storks (*Mycteria americana*). The investigation showed that nocturnal-flying wading birds were less responsive to the power lines than diurnal-flying birds; however, the birds generally flew higher over the power lines at night than during the day. No collisions were observed but the authors stated that the sampling period was short (118 hours). One of the suggested reasons for the lack of collisions was that the birds were acclimated to the presence of the line.

Similarly, radar data collected by Harmata et al. (1997) along the Missouri River indicated that birds flying at night flew at heights well above power lines. By flying higher at night, waterbirds and other species may lower collision risk with natural and anthropogenic obstacles. However, there may be risks from lines that occur in the departing and arriving zones for roosting or foraging habitats. For example, dark-rumped petrels (*Pterodroma phaeopygia*) and Newell's shearwaters in Kauai, Hawaii, crossed much closer to power lines in morning seaward flights than in evening landward flights, and all recorded Newell's shearwater collisions occurred during morning flights (Cooper and Day 1998).

Season

Seasonal bird abundance is also correlated with collision mortality. For example, seasonal flight behavior differences resulted in more wintertime collisions for ptarmigan in Norway (Bevanger and Broseth 2004). Migration seasons generally pose a greater risk to migrating birds because of both higher flyover frequency and unfamiliarity with local landscapes. The nighttime proportion of crane and waterfowl collision mortality versus total collision mortality was 31.8% in the fall (1990) during migration and 7.7% in the spring (1991) in San Luis Valley, Colorado (Brown and Drewein 1995).

Willard (1978) described a situation in the Klamath Basin, Oregon, that illustrates how both collision mortality and its population effects can increase during the breeding season. At Lower Klamath Lake National Wildlife Refuge, adult American white pelicans (*Pelecanus erythrorhynchos*) flew low over canals and collided with power lines while searching for food. For this species, this meant a double loss: first, the loss of the adult that collided with the line, and second, the loss of the young, which rarely fledge after one parent is lost because both parents must forage extensively to feed them.

HABITAT AND HABITAT USE

Power lines located near habitats with high avian use (such as nesting, foraging, roosting, and resting sites) may pose greater exposure to collisions for some species. For example, power lines between foraging and roosting sites of wading birds will be frequently crossed, which increases the collision risk potential. This is especially true when only a short distance separates the two habitats. Birds in these situations typically fly at low altitudes, potentially putting them at the height of power lines. Willard et al. (1977) suggested that overhead wires within a single habitat (e.g., within a wetland) are more likely to cause collisions than those between two habitats (e.g., wetlands and uplands); other studies have found the opposite to be true (e.g., Faanes 1987; Brown et al. 1987; Morkill and Anderson 1991).

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The critical questions are how often, and in what numbers, do birds fly across a power line during their daily routines? For example, in a study in the San Luis Valley of Colorado, Brown et al. (1987) found that power lines dividing wetlands (used for roosting) from grain fields (used for feeding) caused the most collisions for sandhill cranes and field-feeding waterfowl. This occurred because these habitats encouraged the birds to cross the lines at low altitudes several times each day. However, the same power lines had little effect on diving ducks, which had restricted their activities to wetlands. Thus, the risk of a particular power line depends in part upon the way each species uses the adjacent habitat.

FIGURE 4.15: Power lines located between the foraging and roosting sites of wading birds, such as this white ibis *(Eudocimus albus)*, may result in higher collision risk.

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FIGURE 4.16: Research conflicts on whether or not overhead wires within a single habitat, such as this wetland, are more likely to cause collisions than those between two habitats.

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Power lines, including those that border habitat such as a wetland used by many birds, may present little risk if the adjacent habitat separated by the power lines is not attractive to birds (e.g., a city rail yard). Conversely, if the adjacent habitat is a grain field, collisions may result in fall and winter for field-feeding birds that make daily flights between wetland roosts and foraging sites, including sandhill cranes, Canada geese, mallards, and pintails (*Anas acuta*) (Thompson 1978; Brown et al. 1987; Morkill and Anderson 1991). The same line may represent lower risk during the breeding season when these birds remain in wetlands throughout the day. Although forested habitats located near power lines can

CAMM

sometimes reduce collision risk (see *Managing Surrounding Lands* on page 58), in some forested habitats where there are open clearings for the power lines, collision risk may be higher for birds that fly across the open corridor while going between forested areas.

During migration, birds make stopovers in their preferred habitats. When migratory birds' staging, roosting, resting, and foraging areas are located near power lines, especially when ingress or egress coincides with inclement weather, collision risk increases (Manville 2005a, 2009a). This can be especially true when there are large concentrations of birds; for example, sandhill cranes that number in the tens of thousands along the Platte River in Nebraska (Murphy et al. 2009).

Some habitats, such as lakes and ponds, have seasonal use patterns. Proximity to shoreline habitat was linked to bald eagle collisions (21) and electrocutions (24) at Aberdeen Proving Grounds, Maryland (Mojica et al. 2009). Higher collision mortality was found at power lines near shorelines used as feeding areas. The 16,000 hectare (39,537 acre) area on Chesapeake Bay had 42 resident pairs and seven known communal roosts used by migrants from the north and south during the winter and summer months, respectively. In a high bird concentration area along Lake Ontario, double-crested cormorants (*Phalacrocorax auritus*) were the most commonly reported collision victim, although they were over-represented relative to their abundance in the area, and gulls and waterfowl were the next most commonly reported species to collide with lines (Barrett and Weseloh 2008). A PacifiCorp study calculated the distance of collision mortalities to the nearest water body using survey data collected in Oregon, California, Idaho, Utah, and Wyoming from 2004 to 2009 (S. Liguori, PacifiCorp, unpubl. data) (Table 4.2).

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TABLE 4.2: Average distance of collision mortalities from nearest water body.*

Species	Sample Size	Average Distance
Snow goose *(Chen caerulescens)*	37	82.3 m (270 ft)
American white pelican *(Pelecanus erythrorhynchos)*	17	82.6 m (271 ft)
Tundra swan *(Cygnus columbianus)*	3	89.3 m (293 ft)
Sandhill crane *(Grus canadensis)*	7	119.8 (393 ft)
Great blue heron *(Ardea herodias)*	7	154 m (505 ft)
Mallard *(Anas platyrhynchos)*	5	213.4 m (700 ft)

* Source: PacifiCorp, unpubl. data

ENVIRONMENTAL CONDITIONS INFLUENCING AVIAN COLLISION RISKS

Environmental conditions that can increase the risk for collisions with power lines include:

- Land uses
- Weather conditions and visibility
- Sudden disturbances

The relative importance of these conditions varies with location, season, species, and different populations of the same species.

LAND USES

Land uses, such as conservation, recreational, residential, agricultural, and industrial, have

habitats and management practices that can attract or discourage bird use. Collision risk depends on the location of power lines within these areas and the bird species that are drawn to them.

Conservation and Nature-Based Recreation Lands

Conservation areas and wildlife refuges vary greatly in size and habitat type and are often managed for specific types of wildlife and/or nature-based recreation uses. Many conservation lands have distribution lines that supply their power needs and may also be crossed by transmission lines. These lines may present collision risk depending on the habitats, species, and human activities present. The potential for disturbing and flushing birds into nearby power lines can be higher in recreation areas due to increased human activity or lower if resident birds are acclimated to human activity. Power lines that cross high avian-use habitats such as wetlands or are placed between foraging and roosting areas may also result in a higher risk of bird collisions (see *Habitat and Habitat Use* on page 44). Although a proposed power line route may not be able to avoid such conservation areas, managers need to be aware of the potential risks so they may be minimized (see Chapter 5).

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FIGURE 4.17: Power lines crossing agricultural fields with seasonally attractive crops or residue can contribute to collision risk for some flocking species, such as cranes, waterfowl, songbirds, and these trumpeter swans (*Cygnus buccinator*).

Residential and Urban Recreation Lands

Residential and urban recreation lands vary widely in their attractiveness to birds (e.g., Chace and Walsh 2006). Generally, urban recreation lands such as parks and golf courses are interspersed within or between densely populated residential areas. These lands often become habitat islands. For example, they may have small wetlands that are used by various protected birds. Distribution lines may be especially plentiful in residential and recreational areas and can pose a collision risk, depending on the susceptibility of the species, when situated in the flight patterns of birds.

Agricultural Lands

Agricultural fields and ponds can attract birds; for example, grain crops are seasonally attractive to many flocking species such as cranes, waterfowl, and blackbirds, along with rodents that attract raptors. Because grain fields are used only as feeding areas by these species, they may be attractive when they are in close proximity to nesting, roosting, or wintering habitat. Agricultural fields, especially those that are managed with burning or flooding or have nearby wetlands, can also attract a variety of bird species during staging and migration and may even result in shortstopping, i.e., drawing birds to these attractive sites for the winter rather than their historical wintering sites (Viverette et al. 1996). Collision problems may develop when birds must cross power lines to make daily, low-altitude flights between feeding areas and nesting or roosting sites. See also *Habitat and Habitat Use* (page 44).

Industrial Lands

Industrial lands sometimes provide attractive bird habitat. Gulls, vultures, crows, ravens, and

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other scavengers often gather at landfills in large numbers. Cooling ponds at electricity generation facilities, municipal sewage ponds, settling ponds at mines, and other industrial water bodies can attract waterbirds, shorebirds, and raptors. As with other types of land use, the degree of hazard posed by power lines will vary depending upon the proximity of the lines to these avian-use areas (see *Habitat and Habitat Use* on page 44). If bird collisions become a problem, property managers may be able to choose from a variety of options to modify or discourage bird use of the area (see *Managing Surrounding Lands* on page 58).

WEATHER CONDITIONS AND VISIBILITY

Weather conditions play a very important role in both the visibility of power lines and in the behavior of birds in flight during migration and local movements, such as daily foraging activity. When weather conditions interact with biological characteristics (e.g., flight behavior, wing loading and aspect ratio, and season), collision risk may be dramatically affected.

Adverse weather conditions, such as fog, dense cloud cover, high and variable wind speeds, precipitation, and reduced or zero visibility are associated with greater collision risk. Reduced visibility and high wind speeds can also cause birds to fly at lower altitudes, potentially putting them at the same height as power lines. The influence of weather on flight altitude was reviewed in depth by Shamoun-Baranes et al. (2006), and the effect of weather on flight height and behavior has been observed in many bird species (Drewitt and Langston 2008; Newton 2008).

Weather and biological factors are often interrelated and may affect flights within high bird-use areas. The timing of daily flights may subject certain species to adverse weather conditions associated with collisions, such as fog (Scott et al. 1972; Tacha et al. 1979) or wind (Brown 1993). This is especially true in coastal and low-lying areas that are frequently foggy or windy. When possible, birds will avoid flying in heavy precipitation or fog. Problems most often occur when birds unexpectedly encounter these conditions. Storms or fog can arise quickly and birds may collide with power lines when attempting to leave feeding areas for protected roosts (Wheeler 1966; Tacha et al. 1979). In foul weather, birds may be attracted to lighted areas on the ground (Manville 2007a). If power lines are also in or near those areas they could be in the landing approach of the attracted birds and become a collision risk (see *Lighting*, page 52).

Wind, wind shear, and turbulence most often appear to influence collisions when birds fly at power line heights. Some birds decrease flight altitude in high winds (Scott et al. 1972; Raevel and Tombal 1991). Poor conditions—wet feathers, precipitation, high winds, wind gusts, and turbulence—also hamper birds' ability to control flight and further increase collision risk (Walkinshaw 1956; Avery et al. 1977; Willard et al. 1977; Anderson 1978). In high-velocity winds, birds may collide with other birds, buffeting them into fully visible and familiar power lines (Brown et al. 1987; Morkill and Anderson 1991; Raevel and Tombal 1991; Brown and Drewien 1995).

In the San Luis Valley, Colorado, collisions occurred more frequently on days with winds >24 km per hour (15 mi per hour) (Brown and Drewein 1995). Collisions were also more likely with tailwinds, which increase a bird's ground speed, than with headwinds, which have the opposite effect (Savereno et al. 1996). Crowder (2000) reviewed older evidence of power line collisions resulting from stormy (Wheeler 1966), foggy (Tacha et al. 1979), or windy (Brown et al. 1987; Morkill and Anderson 1991) conditions. These studies showed that wind, especially associated with stormy weather, is an important contributor to collisions. It has been suggested that birds, such as gulls, with a high aspect ratio and low wing loading are more susceptible to being blown into lines than other bird

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FIGURE 4.18: Birds usually initiate migration in favorable weather conditions, but when they encounter inclement weather they may decrease their flight altitude, which increases collision risk when power lines are present.

species without these physical characteristics (Bevanger 1998).

The impact of weather is also related to season, as adverse weather may pose a greater risk during migration (APLIC 2007) and can influence the initiation of migration (Shamoun-Baranes et al. 2010). Songbirds usually begin migration in favorable conditions, but may encounter inclement weather en route. The weather hazard may be worsened when migratory birds respond to fog and precipitation by decreasing their flight altitude (Gauthreaux 1978a) or by attempting to land (Manville 2007a). In known or historic staging, roosting, resting, feeding, or stopover areas for migratory birds located in immediate proximity to power lines, there can be a substantial increase in collision risk, especially when bird ingress or egress coincides with inclement weather (Manville 2005a, 2009a). This effect is magnified when flocks are very large, as with migrating sandhill cranes in the Platte River area of Nebraska (Murphy et al. 2009).

The flight altitudes of migratory birds can vary greatly and are strongly correlated with winds aloft, air clarity, turbulence, thermals, and weather, both day and night. In particular, thunderstorms and low cloud ceiling conditions are known to cause nocturnally migrating songbirds to land or to fly at lower altitudes that increase collision risk, particularly with illuminated structures (Winkelman 1995; Gill et al. 1996; Erickson et al. 2001; Johnson et al. 2002; Kerlinger 2003). Various radar studies have estimated that under normal weather conditions, 84% to 97% of nocturnally migrating songbirds fly at altitudes of 125 m (410 ft) or more above ground level where they are not exposed to risk of collision with power lines (Mabee and Cooper 2002; Cooper 2004; Mabee 2004).

SUDDEN DISTURBANCES

Sudden disturbance can panic and flush birds, especially flocks of birds, into nearby power lines and has been well documented as a contributing factor to collisions (Krapu 1974; Blokpoel and Hatch 1976; Anderson 1978; Brown et al. 1984; Archibald 1987). Birds may be flushed by vehicles, trains, pedestrians, aircraft, farm equipment, hazing, hunters, predators, etc., along ROWs and may collide with power lines in their effort to escape (APLIC 2007). Crowder (2000) reviewed older evidence of power line collisions resulting from sudden disturbance of geese by vehicles (Schroeder 1977) or airplanes (Blokpoel and Hatch 1976). One such disturbance resulted in a collision event with mallards during Crowder's (2000) field study. Murphy et al. (2009) support the idea that most sandhill crane collisions at Platte River, Nebraska, occur when closely congregated birds are flushed after dark. In Washington, roosting American white pelicans collided with an adjacent distribution line when flushed during the night by a passing train, even though line marking devices were installed (S. Liguori, PacifiCorp, pers. comm.).

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ENGINEERING ASPECTS INFLUENCING AVIAN COLLISION RISKS

The following engineering aspects can influence the risk of collisions with power lines:

- Diameter of lines (shield wires versus phase conductors)
- Line placement (proximity to avian habitat)
- Line orientation (relative to biological and environmental factors)
- Line configuration (aligned vertically or horizontally and the number of lines)
- Structure type (guyed versus self-supporting)
- Lighting (steady burning versus blinking)

DIAMETER OF LINES

The smaller diameter of transmission line shield wires compared to phase conductors influences the risk of collisions, with shield wires being the lines most often involved (Scott et al. 1972; Willard et al. 1977; Brown et al. 1987; Faanes 1987; APLIC 1994; Savereno et al. 1996; Jenkins et al. 2010). Because of their smaller diameter (1 to 1.3 centimeters [0.4 to 0.5 inches]) compared to phase conductors (2.5 to 5 cm [1 to 2 in]) and their position above the phase conductors, shield wires are the least visible type of power lines and they are in the flight path of birds that gain altitude to avoid the more obvious phase conductors. The shield wire protects, or shields, the phase conductors from lightning strikes.

Distribution lines consist of phase conductors and a neutral wire, which is at the same level or below the phase conductors. Though it is not absolute, most birds gain altitude to avoid an obvious line, which implies that neutral lines are less likely to be involved in collisions.

LINE PLACEMENT

The proximity of power lines to bird take-off and landing areas can affect collision risk (Lee 1978; Thompson 1978; Faanes 1987), but no specific setback distance has been found in the literature. Brown et al. (1984, 1987) found that no sandhill crane or waterfowl collisions occurred where distances from power lines to bird-use areas were ≥1.6 km (1 mi). Faanes (1987) found that collision rates dropped off dramatically after 400 m (1,312 ft). Faanes (1987) stated that "among the sites I examined, power lines situated 400 m (1,312 ft) or more from the edge of the water generally had lower observed mortality than sites where the power line was within this distance." Quinn et al. (2011) found no bird carcasses under power lines that were situated more than 500 m (1,640 ft) from the edge of the water; at distances of 60 m (197 ft), collision mortality dropped off dramatically ($p = 0.0012$, $df = 3$). See also *Habitat and Habitat Use* on page 44. See Chapter 5 for examples of risk and reduced risk situations.

LINE ORIENTATION

Orientation of power lines relative to biological characteristics (e.g., flight behavior, season, habitat, and habitat use) and environmental conditions (e.g., topographical features and weather patterns) can influence collision risk. When planning power line routes, features that are traditional flight corridors, such as mountain ridges, river valleys, and shorelines, should be considered (Colson and Yeoman 1978; Faanes 1987). Power lines that parallel primary bird flight paths pose less risk than a perpendicular orientation (Crowder 2000; Scott et al. 1972; McNeil et al. 1985). For example, the perpendicular orientation of a line relative to a topographical feature poses a greater collision risk to local and migrating birds than a parallel orientation (see Figure 4.19).

Lines that are at or below the height of nearby trees rarely present a problem to small tree-dwelling birds because of their maneuverability; furthermore, large birds will gain altitude to fly over the tree line and consequently avoid the power line (Thompson 1978; Raevel and Tombal 1991). For example,

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FIGURE 4.19: Orientation of power lines parallel to ridges or narrow, low altitude flyways presents a lower risk of collision than perpendicular orientation.

a power line that crosses a narrow river bordered by trees that are taller than the line is likely to have a lower collision risk than lines crossing broad rivers because most birds will fly over the tree tops to cross the narrow river valley (CMS 2011a).

Strong tail winds can be detrimental to birds' ability to execute avoidance maneuvers. Brown (1993) suggested that north-south orientation of lines increased collision frequency for cranes and waterfowl in the San Luis Valley, Colorado, because birds crossing them on an easterly heading were often subjected to prevailing westerly winds. See also *Biological Characteristics*, on page 36, and *Weather Conditions and Visibility* on page 48.

LINE CONFIGURATION

Line configuration—phase conductors aligned vertically or horizontally, and the number of conductors—is a collision factor that intuitively makes sense, but there are too few studies to draw conclusions. Most researchers agree that keeping the vertical arrangement of multi-conductor transmission lines to a minimum is beneficial because it reduces the height of the collision zone. However, a single-pole vertical structure is often esthetically more acceptable and requires less ROW width.

Thompson (1978) and others (Bevanger 1998; Crowder 2000; Drewitt and Langston 2008) have suggested that clustering lines (i.e., several power lines sharing the same ROW) may reduce the risk of collisions because the resulting network of wires is confined to a smaller area and is more visible. Birds only have to make a single ascent to cross lines before resuming their preferred altitude. However, when there is decreased visibility, collision risk for birds may increase where several lines are clustered together. In addition, when there are two shield wires at different heights, and only the higher one is marked, there may be collisions at the lower unmarked shield wire, thus both shield wires may need to be marked (S. Liguori, pers. comm.). See Chapter 5 for examples of risk and reduced risk situations.

STRUCTURE TYPE

Because of the collision risk posed by guyed communication towers (e.g., Shire et al. 2000; Manville 2007a; Gehring et al. 2009; Gehring et al. 2011; Longcore et al. 2012), the question of collision risk associated with guyed power line structures has occasionally been asked. Guy wires on power line structures are used for support and stability especially where a line ends (deadend structure) or changes direction (e.g., makes a 90-degree turn). There is no published information to suggest that guyed power line structures pose a significant collision risk for birds. PacifiCorp has surveyed over 120,000 poles in six states and has not found collision victims at any of the guyed structures (S. Liguori, pers. comm.). Based on exposure alone, the relative short lengths of the guy wires and the low heights on power lines pose much less risk to birds than do the longer, multiple guy wires on communication towers whose height can

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exceed 300 m (>1,000 ft; Gehring et al. 2011). In addition, some types of lighting on communication towers can attract birds into the collision zone in low visibility weather. Because transmission towers are, with very few exceptions, unlit, they are not expected to have the same risk.

LIGHTING

Studies of bird collisions with communication towers and other tall structures have shown that steady-burning white or red lights can disorient migrating birds at night especially when migration coincides with inclement weather (Manville 2007a, 2009; Gehring et al. 2009, 2011). This disorientation can cause birds to collide with the lighted structure, guy wires on a communication tower, or each other. It can also cause the birds to circle the light source, which may also result in exhaustion and injury or death. Collision incidence on lighted communication towers, for example, depends on the type and intensity of the lights (i.e., steady burning, blinking, or strobe) as well as whether the birds are navigating visually or magnetically. In a Michigan communication tower study, extinguishing steady-burning, L-810, red side lights, while leaving on the red, blinking incandescent pilot warning lights, reduced bird collision mortality by up to 72% (Manville 2007a; Gehring et al. 2009). However, any light, including blinking incandescent and strobe lights, can cause some bird attraction, even during clear weather (Manville 2009a).

In the United States, any structure that is ≥60.9 m (200 ft) above ground level is subject to Federal Aviation Administration (FAA) lighting requirements for aviation safety. Transmission towers in the United States are typically <60.9 m (200 ft) tall[12] and do not have lights. However, shorter structures may also require lighting depending on their location (e.g., in proximity to airports). If lighting is used on transmission lines, it should be compatible with FAA regulations, the Canadian Aviation Regulation, and USFWS bird protection guidelines, and these agencies should be consulted on lighting. The FAA no longer recommends using L-810 steady-burning red lights.[13] In general, the USFWS recommends avoiding lights, particularly steady-burning lights, and using motion- and heat-sensitive lighting where feasible (e.g., for infrastructure security lighting).

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[12] Some structures exceed 60.1 m (200 ft) in height, especially at river crossings and to clear other lines that might otherwise intersect (M. Schriner, pers. comm.; D. Bouchard, pers. comm.).

[13] This change is expected to be included in the revision to the FAA's 2007 lighting circular, which is underway at this time (2012). As a preliminary step, in June 2012 the FAA published the results of its pilot conspicuity studies on the elimination of steady-burning red (L-810) side lights at communication towers.

CHAPTER 5

Minimizing Collision Risks

IN THIS CHAPTER

- Opportunities for Minimizing Collision Risks
- Modifying Existing Power Lines
- Planning New Power Lines
- Public Participation to Address Social and Cultural Issues

There are a number of design and engineering strategies for minimizing collision risk with power lines. This chapter introduces evaluation studies and risk reduction strategies for modifying existing lines and planning new lines. This chapter also discusses how to address social and cultural issues through public participation programs.

OPPORTUNITIES FOR MINIMIZING COLLISION RISKS

By working together, engineers and biologists can identify and address collision issues when modifying existing lines and planning new lines (Figure 5.1). Collision issues typically develop or are discovered long after a power line is built, which makes minimizing collision risk more difficult. However, early evaluation of factors that influence collisions (see Chapter 4) can reduce collision potential and may reduce the need for costly modifications later.

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Engineers and biologists can reduce collisions when…

Modifying Existing Power Lines	Planning New Power Lines
Evaluation studies include: • Collision monitoring to examine the causes and conditions associated with the risk and to help determine the type and effectiveness of modifications. • Avian risk assessment and spatial analysis to prioritize line segments for modification.	*Evaluation studies include:* • Spatial analysis that considers habitat variables, species, behavior, and other factors to help choose the optimal route. • Field assessment to identify species, abundance, and high bird-use areas. • Avian risk assessment to evaluate collision risk along potential routes.
Risk reduction options include: • Line marking to increase the visibility of the line. • Managing surrounding land to influence bird use. • Removing the shield wire if lightning is not an issue or if lightning arresters can be used instead. • Increasing the diameter or changing the configuration of wires when a line is being rebuilt. • Rerouting the line if all other attempts have been exhausted and populations are significantly impacted. • Burying the lines if feasible and warranted.	*Risk reduction options include:* • Line placement that takes migratory patterns and high bird-use areas into account. • Line orientation that considers biological and environmental factors such as bird flight paths, prevailing winds, and topographical features. • Line configuration that reduces vertical spread of lines, clusters multiple lines in the same right-of-way (ROW), increases the visibility of lines, and/or decreases the span length if such options are feasible. • Line marking to increase the visibility of the line. • Burying lines if feasible and warranted.

FIGURE 5.1: Opportunities and strategies for minimizing collision risks.

MODIFYING EXISTING POWER LINES

EVALUATION STUDIES FOR LINE MODIFICATIONS

If a significant collision risk has been observed along a segment of line, it may be possible to eliminate or minimize the risk by modifying the line in various ways. Line modifications should be supported by collision monitoring studies that examine the causes and conditions associated with a high collision rate (e.g., bird species involved, avian use patterns, mortality rates, weather, and biological significance of mortality levels). Although collision monitoring study methods must be tailored to site-specific biological, environmental, and engineering factors (see Chapter 4), basic, standardized ornithological field survey procedures should be used to produce results that would be comparable to other studies. Appendix B presents considerations and issues for designing site-specific

Comparing the Effectiveness of Line Modifications

Assessments of line modification effectiveness are often based on pre- and post-modification mortality (Rigby 1978; Beaulaurier 1981; Archibald 1987; Brown et al. 1987). Although evaluations based on casual observations or limited sampling of collisions contribute to the knowledge of line modification effectiveness, more rigorous studies are necessary to adequately compare the effectiveness of various measures (e.g., Crowder 2000; Yee 2007, 2008; Ventana Wildlife Society 2009; and Pandey et al. 2008).

study methods for collision monitoring. Once monitoring data are collected, line modification options can be evaluated to identify, quantify, and balance existing risks with the effectiveness and risks posed by the modifications.

Collision Monitoring Studies

To design a collision monitoring study, a number of key questions need to be answered:

- What species is/are at risk?
- What is the magnitude of risk?
- Does this risk contribute to population level impacts?
- What biological, environmental, and engineering factors contribute to collision risk?
- Is the study protocol scientifically sound?
- What are the regulatory and policy considerations of collisions?
- What methods effectively minimize collisions for new and existing power lines?

Collision monitoring results should include the following information:

- Collision rates among species and between sexes and ages (if known) within a single species
- Collision rates expressed as the number of bird collisions relative to the number of birds that are exposed to the line in the strike zone, i.e., collisions/flybys
- Biological, environmental, and engineering factors affecting collision risks (see Chapter 4)
- Mortality corrected for site-specific sampling bias (see Appendix B)
- Behavioral responses of different species to the lines and to line marking devices or other modifications
- Effectiveness of line marking devices based on changes in mortality after marking devices were installed or other line modifications were made

These and other monitoring considerations are discussed in greater detail in Appendix B.

To understand the mortality risk for an entire line, it is essential to study representative segments of the line rather than focusing only on high collision segments, since doing so will overestimate the overall mortality risk. The study method should ensure that test and control segments are of comparable length and that they have as much environmental homogeneity as possible (see Appendix B). On lines with high environmental variability across their length, stratified random sampling may allow the investigator to treat the segments similarly enough to collect meaningful data.

The greatest problem faced by researchers in most field studies is controlling for external variables (e.g., Alonso and Alonso 1999; Jenkins et al. 2010; Barrientos et al. 2011). The results of Brown and Drewien (1995) support the hypothesis of Thompson (1978) that collision rates are not predictable from one study to another and one season to another. They found that rates varied among species, seasons, and years and attributed much of the variability to changes in the local environment, which, in turn, influenced bird densities (see also Blair 1996). This suggests that, ideally, studies should compare test

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and control line segments within the same time period.

Regardless of whether assessments are made before or after line modification or by using test and control segments, collision risk comparisons are most meaningful if collisions are expressed in relation to bird numbers or, preferably, flybys. This allows a collision rate to be calculated. Where feasible, observations of birds' avoidance behavior when crossing the lines are valuable in understanding how a line affects flight behavior. Actual mortality may be low, which presents a statistical challenge in comparing retrofitting options. This condition should be anticipated and integrated into the study design (see Appendix B).

Collision monitoring studies should incorporate the basic methods used in other mortality evaluations (see Appendix B) including:

- Defining the collision zone for birds crossing lines
- Establishing an adequate search area for mortalities (increasing with the height of the line)
- Obtaining sampling bias estimates for injuries, searcher efficiency, scavenger removal, and habitat differences

Evaluation of bird behavior at marked and unmarked lines provides insight to collision rates. Morkill and Anderson (1991) and Brown and Drewien (1995) demonstrated that bird responses varied with marked and unmarked lines. Observations should be made on marked and unmarked portions simultaneously to minimize environmental variability. For example, Deng and Frederick (2001) showed that the number of birds flying above or below marked and unmarked lines was not statistically significant; however, they observed that the birds approaching a marked line reacted earlier than birds approaching an unmarked line.

Behavioral criteria evaluated may include:

- Type of reaction to lines
- Distance from the line that the reaction occurred
- Height above the line when crossing

Because these estimates require evaluations by observers, it is important to standardize survey procedures (see Appendix B). All observers should be given training and practice time before the study begins and, when possible, the same observers should be used throughout the study. Brown and Drewien (1995) found that most observers required about 12 hours of practice before they became consistent. As an alternative to field observers, the Bird Strike Indicator (BSI), a vibration sensing and recording tool, can be installed on lines to detect bird strikes (see box, page 57). However, the BSI does not identify what species struck the line; hence, mortality monitoring or field observations, which would also reveal pre-strike behavior, would be required.

Avian Risk Assessment and Spatial Analysis

Avian risk assessment and spatial analysis can be used to prioritize segments of line for modification. See *Evaluation Studies for Siting New Power Lines* on page 64.

OPTIONS FOR MODIFYING EXISTING LINES

Potential options for line modification include line marking, managing surrounding land, removing the shield wire, changing the diameter or configuration of wires, and rerouting or burying existing lines where feasible. Utilities are encouraged to work with wildlife agencies (see Chapter 3) to evaluate collision risks to species of concern and options for reducing those risks. Typically, the first option is marking high risk segments of the line and/or managing the surrounding lands. Redesigning, reframing, relocating, or

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Remote Sensing with the Bird Strike Indicator

The Bird Strike Indicator (BSI) is an automated vibration sensing and recording tool designed by Electric Power Research Institute (EPRI) to detect bird strikes on overhead lines. Previously, the only means for identifying whether collisions were occurring was for observers to monitor lines and to conduct ground surveys for bird carcasses. Manually monitoring bird collisions is labor-intensive, expensive, and its effectiveness is limited to daylight hours. Carcass surveys may correct for lack of monitoring during low-light periods, but these are often associated with vegetation, water, and scavenger detection biases (see Appendix B). Some birds also may fly beyond the search zone after the collision. If the collision itself was not observed then this type of contact would be missed by standard monitoring methods.

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FIGURE 5.2: The Bird Strike Indicator, a tool used to detect bird strikes with power lines, can be installed from a bucket truck or helicopter.

BSI sensors can be installed on phase conductors or shield wires. Each installation will be unique to the surrounding environment. For example, the lightweight accelerometers in BSIs are meant to detect stress waves caused by avian collisions, but in one study, BSIs also picked up the vibrations from daily trains (M. Schriner, pers. comm.). For a horizontal line configuration, the BSI is only needed on the outside wires (M. Schriner, pers. comm.). The BSI generates a collision log including the wire struck along with the date, time, and temperature. The BSI wirelessly transmits these data to a base station in real time. Base stations serve multiple sensors simultaneously and are accessible through an interface. Each sensor is designed for up to six months of autonomous operation between battery replacements. The units check and report their health each morning and can be reprogrammed remotely.

Research during the development of the BSI (Pandey et al. 2008) and independent trials conducted afterwards (Murphy et al. 2009) demonstrated that the BSI is as reliable as human observers for detecting collisions during daylight. The technology is especially useful for monitoring collisions in low-light or no-light conditions and over-water crossings where carcass recovery is compromised. However, unlike human observations, BSI does not identify the species that struck the line; mortality monitoring or field observations would be required to determine this. The BSI has also been successfully used to monitor communication tower guy wire collisions in Cold Bay, Alaska, which demonstrated that the BSI allows continuous line monitoring under all lighting and weather conditions (R. Harness, pers. comm.).

As of 2012, a new companion technology to the BSI, called the Bird Activity Monitoring System (BAMS), is in its technical development phase with EPRI funding and is envisioned as an intelligent, image-based, sensing and recording tool that will assist with detailed study of wildlife interactions with various types of structures including power lines.

burying power lines may not be economically or technically feasible. Such options are usually a last resort and only contemplated when an avian resource has been documented to be seriously affected.

Line Marking

Most studies have shown a reduction in collisions and/or an increase in behavioral avoidance at marked lines when compared to unmarked lines, but this can vary with location, type of line marking device, and bird species (Jenkins et al. 2010; Barrientos et al. 2011; see Chapter 6 for detailed information on devices and effectiveness). There are three general categories of line marking devices: aerial marker spheres, spirals, and suspended devices (swinging, flapping, and fixed). Large diameter wire may also improve line visibility and has been used with line marking devices to reduce risk of collision-electrocutions and collisions (see Chapter 6). Line marking devices are selected based on product availability and durability, cost, ease of installation, compliance and legal issues, spacing and positioning, safety codes related to ice and wind loading, corona effects, esthetics, and potential for vandalism.

Lighting has also been successfully used to reduce collisions. In Washington, a spot light (using the line as a power source) was installed in an uninhabited area to illuminate a section of marked distribution line at night. This effectively reduced collisions of American white pelicans (*Pelecanus erythrorhynchos*) that roost adjacent to the distribution line. The pelicans had collided with the line when flushed during the night by passing trains, even though line marking devices were installed (S. Liguori, PacifiCorp, pers. comm.). In Botswana and South Africa, the Mace Bird Lite, a spiral device with a fluorescent light, has been used to reduce flamingo collisions (Eskom 2003; Eskom Transmission 2009; see *Devices Available in Other Countries* on page 97).

When using lighting, the effects of lighting on birds as well as applicable regulations for lighting should be considered (see *Lighting* on page 52).

Managing Surrounding Lands

The location and condition of habitat and the surrounding or nearby land uses, such as wetlands and agriculture, and their proximity to power lines influences collision risk (see Chapter 4). Modifying habitat, land uses, or management practices to influence bird use in strategic areas can reduce collision risk where there is a willing agency or landowner. Sometimes, land management can be less costly and more effective than other line modifications. Options are discussed for conservation, recreation, residential, agricultural, and industrial land uses.

Planting Trees

Where climate and location will allow, planting native trees that will grow to or above the height of nearby power lines, without interfering with line operations, may prevent collisions by forcing birds to gain enough altitude to clear the more visible tree line (Thompson 1978; Raevel and Tombal 1991). For instance, greater white-fronted geese (*Anser albifrons*) flew over power lines more in woodlands than over lines in rice fields in Japan (Shimada 2001), and areas with shorter trees had higher collision rates than areas with taller trees for ptarmigan in Norway (Bevanger and Broseth 2004). For mitigation purposes, tree planting is a long-term strategy because of the time it takes for trees to grow to the desired height; thus, short-term mitigation would likely be necessary in the interim. Because trees can potentially cause operational and reliability problems with lines, a design engineer and a forester should be consulted concerning minimum clearances and line maintenance requirements so appropriate tree species and planting locations can be determined.

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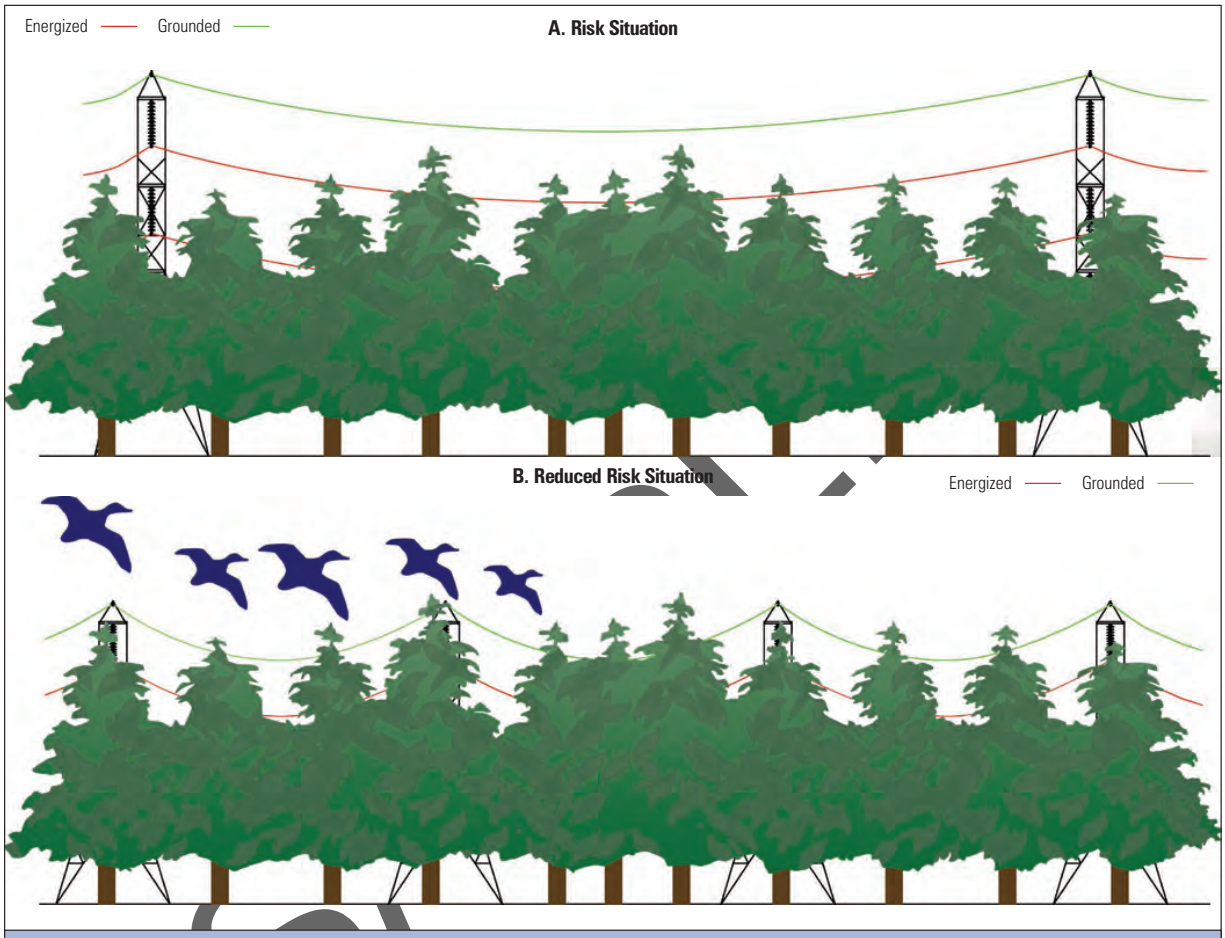

FIGURE 5.3: Reducing collisions in wooded areas. A tree line or other obvious obstacle at the appropriate height warns birds to gain altitude, which results in birds flying over the power line screened by the trees (after Thompson 1978).

Removing Disturbances

Reducing and modifying human access points to decrease the likelihood that human activities will disturb birds where they congregate near power lines can reduce collisions caused by frightening and flushing birds into the power lines (see *Sudden Disturbances* on page 49). Restricting access roads on power line ROWs to utility-related activities is an option that may be open to landowners or land managers. Conservation area managers and private landowners can limit or prohibit hunting or other high-disturbance activities near power lines. On public access roads, speed limit restrictions and signage indicating bird-use areas may reduce flushing of birds. Crane and waterfowl collisions at Bosque del Apache National Wildlife Refuge in New Mexico were reduced simply by having personnel drive slowly and stop when birds

were on refuge roads, which allowed the birds to leave the area without panic. However, this was not successful enough and the lines were eventually buried. (J. Bradenburg, pers. comm.)

Habitat Modification on Conservation, Recreation, and Residential Lands

Land managers and landowners may be able to manipulate bird habitat to minimize collision risk. For example, when waterfowl need to use two distinct habitat types (e.g., one for feeding and one for roosting), they will generally select those that are closest to each other. If a power line divides those habitats, the collision risk is greater. It may be possible to create both habitat types on one side of the line to reduce the crossing frequency (see *Line Placement* on page 66).

Management Practices on Agricultural Lands

Sometimes it is possible to enlist the help of landowners to modify management practices, including the timing of practices that may be attractive to birds, such as burning or flooding fields, where a line is experiencing a high collision rate. For example, in the San Luis Valley, Colorado, farmers plow barley stubble into the ground in preparation for planting in late fall and early spring—times when sandhill and, in the past, whooping cranes (*Grus canadensis* and *Grus americana*) forage in the stubble. The cranes may collide with power lines that border these fields, especially when feeding very close to the line. Through a program sponsored by utility companies, farmers were encouraged to begin plowing the stubble closest to the lines before the birds arrived. This reduced the risk of collisions by causing

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FIGURE 5.4: Habitat modifications, such as cooperative programs to encourage earlier plowing of grain stubble, which is attractive to migrating sandhill cranes, may help to reduce collision risk.

the birds to forage farther from the lines where the stubble remained standing (C. Bryant, pers. comm.).

Discourage Bird Use of Industrial Lands

For industrial features such as landfills, cooling ponds, municipal sewage ponds, settling ponds at mines, and other industrial water bodies, property managers can choose from a variety of options that will discourage bird use, such as covering garbage, placing nets over a pond, and using visual or sonic deterrents. Cost, effectiveness, and maintenance should be considered when evaluating bird dissuasion options.

Removing the Shield Wire

Removal of the shield wire from transmission structures (AC or DC) can reduce bird collisions (Beaulaurier 1981; Brown et al. 1987), but is rarely a viable option because it exposes the lines to lightning strikes, which jeopardize service reliability (Figure 5.5). Shield wires are typically installed on the top of transmission structures to protect the phase conductors from lightning strikes and the electric grid from lightning related power outages. This overhead shielding has proven to be the most effective and economical lightning protection for transmission lines.

The lightning arrester system, one alternative to the shield wire, is effective when used on lines with distribution voltages from 4.2 to 35 kilovolts (kV) and provides sufficient protection to the line and associated equipment. However, lightning arresters may not be a viable option due to cost, design characteristics, and effectiveness for transmission voltages. Their presence would also increase the electrocution risk to birds that perch on power line structures. Because the shield wire often incorporates a fiberoptic communication line, the cost of modifications to the communications system would also need to be included in the analysis.

FIGURE 5.5: Removing shield wires can reduce bird collisions but leaves the lines unprotected from lightning strikes and jeopardizes service reliability.

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Changing the Line Configuration

When collisions cannot be reduced by another method such as line marking or managing surrounding lands, the configuration of an existing line can sometimes be changed to minimize collisions. This is usually only possible for new construction or when a line is being rebuilt. Effective design changes would need to be based on studies of the flight behaviors of the bird species at risk (see *Evaluation Studies for Line Modifications*, page 54). In addition, the redesigned section(s) of line would need to be compatible with the rest of the line. Options for changes might include:

- Lowering the height of the lines (e.g., below the tree line)
- Changing the wire diameter
- Bundling wires
- Using spacers to improve visibility

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- Rearranging wire configuration (e.g., converting from vertical to horizontal)
- Changing the structure type to increase its visibility
- Decreasing span length (e.g., by adding a pole mid-span)

Rerouting Existing Lines

If all other attempts to reduce significant collision risks to an acceptable level have been exhausted, rerouting may need to be considered. This option would require routing analysis, acquisition of a new or additional ROW, removal and relocation of existing structures, and a scheduled outage for the work. The rerouting analysis should include a comparative risk assessment to evaluate the collision risk for the new line (i.e., whether its risk is measurably lower than that of the existing line) to determine if the rerouting is justified (see *Avian Risk Assessment* on page 65). Environmental benefits and economic cost should be part of the risk analysis. Given the potential land costs and limited options for ROW , together with the cost of structure changes, the economics and logistics of rerouting make this option rarely possible.

Burying Power Lines

Burying power lines with voltages less than 345 kV have been proposed to reduce collisions. However, there are innate characteristics of buried lines that make them only rarely feasible. These include voltage and type of cable, land use patterns, soil conditions, regulatory acceptance, outage risk and reliability requirements, termination facility requirements, length and operating limits, and other environmental concerns. Depending on these characteristics, the cost of buried power lines can vary from 3 to 20 times that of an overhead line (Bumby et al. 2009).

Voltage and Type of Cable

As the voltage increases, costs increase. The type of cable (power line) used also affects the cost. Current options include paper-insulated cable installed in oil-filled pipes, and solid dielectric cables installed in conduits or buried directly in the earth with selected backfill (see *Soil Conditions*, page 63).

Lines ≥69 kV are normally installed in pressurized, oil-filled pipes in order to eliminate voids and moisture pockets in the cable insulation. They have an excellent reliability record when properly designed, installed, and maintained. The oil also tends to dissipate the heat generated by the current flow in the cables. If the oil can be circulated under pressure, the capacity and reliability of the cable will be enhanced.

Solid dielectric cables are currently being used for 115-kV and 230-kV applications. They are less reliable than oil-filled pipes. The preferred design is to place them in a conduit so that construction in highly developed areas may move rapidly and the necessary excavation can be covered quickly to reduce the impact and inconvenience to the public. The conduit also provides some physical protection to the cable from accidental excavations.

Land Use Patterns (Urban, Rural, etc.)

In highly developed areas where other utilities are buried (e.g., water, sewer, gas, communication), costs and space are at a premium. In rural areas, some conflict may exist with pipelines, rivers, and lakes (see Figure 5.6 and *Environmental Concerns* on page 63). In undeveloped areas, geologic formations may prevent economical trenching. In addition, underground lines require termination areas at both ends, similar to small substations, to accommodate the overhead-to-underground transitions.

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FIGURE 5.6: Buried power lines may be a solution to bird collisions in some instances, but can cost from 3 to 20 times more than overhead lines and have other environmental impacts.

Soil Conditions

The soils must be able to dissipate heat during periods of high electricity demand. Soil condition also directly affects construction cost (i.e., sandy soils are more easily trenched than rocky soils). In many cases, the spoils from the cable trench have to be hauled away and replaced with heat-dissipating sands to meet the cable design standards.

Regulatory Acceptance

Utility regulatory commissions set rates and control costs. This can have a direct bearing on the feasibility of an underground project. There are documented projects where regulatory commissions have instructed the parties requesting underground construction to pay the difference in installation cost (e.g., Colorado Public Utility Commission Decision No. R82-93).

Outage Risk and Reliability Requirements

Cable failures are difficult to locate and the line must be dug up for repairs and maintenance. Extended outages normally result because of the length of time it takes to locate and repair a fault in the cable. Certain customers, such as hospitals and large industrial or mining operations, have higher reliability requirements than others.

Requirements for Termination Facilities

These include access for large equipment, a fenced area, transition structures, switches and other protective equipment, a transmission line tower or distribution structure, and in some cases a pumping station. Such overhead electrical facilities should be designed to minimize avian electrocution risk (see *Suggested Practices for Avian Protection on Power Lines*, APLIC 2006).

Length and Operating Limitations

As the length of the line increases, the operating limitations are approached and the options to address this will further increase costs.

Environmental Concerns

Environmental damage can result if a buried power line is near or crosses a waterway or is in wetlands or other sensitive habitats (Figure 5.6). If an oil-filled pipe leaks, the oil would contaminate the water and surrounding soils. Ground disturbance during construction, repairs, and maintenance can result in large, permanent displacement of excavated soil and subsequent issues with re-establishing native vegetation and preventing the overgrowth of invasive species. A University of California study (Bumby et al. 2009) found that underground power lines have more environmental impacts than overhead power lines for all categories and most scenarios in southern California.

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PLANNING NEW POWER LINES

EVALUATION STUDIES FOR SITING NEW POWER LINES

The potential for avian/power line interactions can be identified and addressed during corridor and routing evaluations such as spatial analysis, field assessment, and avian risk assessment. Methods for these evaluations differ because every route is unique with regard to the species, habitat, and line design. Ornithologists or wildlife biologists knowledgeable in local bird issues should be consulted for pertinent information on bird movement patterns and the presence of species of concern that could be affected by collisions with power lines. Habitats that influence bird presence and movement may present a collision risk and should be identified. Other biological, environmental, and engineering factors that contribute to collision risk should be understood (see Chapter 4) and considered as well.

Spatial Analysis

The siting process for new lines is in large part a geospatial analysis that facilitates the selection of a route that is compatible with regulatory, land use and availability, environmental, economic, and engineering considerations. Spatial analysis of habitats has been aided by the development of GIS software, which can help identify and characterize risk. GIS is often preferred because it can predict the optimal route by incorporating all the variables under consideration. Features in some GIS software systems can apply segment weighting to help determine the optimal route. GIS software specifically for siting and routing power lines has been developed by the Transmission Line Siting Methodology research project (see EPRI 2006). It uses a multi-step approach that starts with a large study area (corridor) and through various levels of evaluation selects potential routes and a preferred route. GIS software can also be used to create maps, which may be used to rank habitats for their prospective bird use within potential line routes. This approach is especially useful when species of concern occur along a proposed route.

About GIS

GIS (geographic information systems) software incorporates, stores, analyzes, manages, and presents data linked to a specific geographical location. It merges cartography, statistical analysis, and database technology. As a tool, GIS software helps decision-makers understand and predict the relationships between human uses and natural resources such as wildlife and habitat.

Field Assessment

Field assessment can often minimize collision risks (see Chapter 4) by identifying high-use bird habitats to avoid during route evaluation. Study designs should be scientifically defensible and developed to meet the needs of the project. Ideally, the following information should be obtained during the field assessment:

- Presence and abundance of bird species in the vicinity of the alternative routes
- Occurrence of species of concern, such as endangered species
- Location of habitat used by birds of concern
- Daily and seasonal use patterns for each species, including a differentiation between migration and daily use

This information can be obtained by using standard bird survey techniques, such as point counts, and from existing avian databases, such as the Christmas Bird Count and eBird (see Appendix E).

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Avian Risk Assessment

Avian risk assessment can be used to characterize the collision risk of a planned or existing line and to prioritize the segments that need to be modified. Risk assessment is a systematic process for characterizing the probability of an adverse effect occurring (USEPA 1998). It has been adapted for a

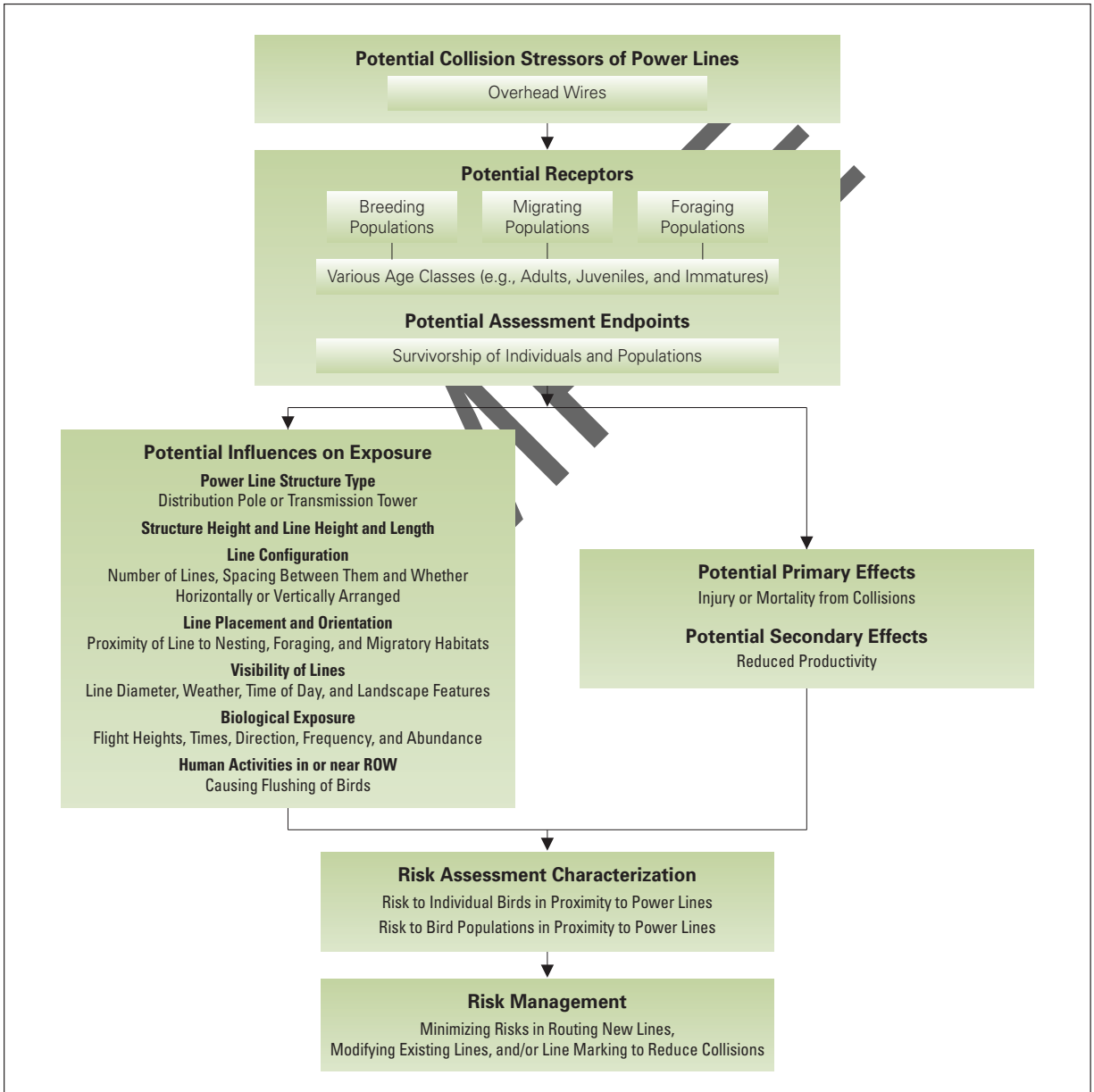

FIGURE 5.7: Conceptual model of avian collision risk assessment.

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wide range of applications, including avian/power line interactions. Avian risk assessment in this context evaluates the collision risk that a power line may pose to birds. It includes several steps: problem formulation (e.g., identifying species affected and specific collision issues), characterization of exposure and effects, risk assessment, and risk management. Figure 5.7 presents a conceptual model of avian collision risk assessment.

Both qualitative and quantitative estimates of risk can be used. One or both of these approaches may be appropriate depending upon the type of risk characterization required and the data available.

Qualitative risk assessment provides a non-numeric narrative description of risks. The resulting risk statement is descriptive (not mathematically quantifiable) and provides an estimate of risk, such as low, moderate, high, etc. This approach uses existing information about the proposed site, its ecological resources, literature on the physiology and behavior of species of concern, and reported effects (e.g., accounts of known collision mortality at existing power line projects). Implementing a qualitative methodology does not generally require field studies before construction, but uses site visits to confirm conditions and supplement available information.

Quantitative risk assessments provide estimates of the number of birds anticipated to be at risk to collisions. A quantitative approach accounts for, among other things, the spatial configuration of the stressor (power lines) and the spatial and temporal exposure of the receptor (birds) (i.e., the number of receptors that interact with the stressors in question).[14] Quantitative risk assessments can be developed using literature and other data but, because this method is typically used when greater precision is needed, it is frequently supplemented by site-specific data on power line engineering and/or design and site-specific observations and studies to further assess collision potential.

Sometimes a tiered risk assessment can be used starting with a qualitative assessment and proceeding to a quantitative assessment. For example, if more than one route is being compared for risks, a higher or lower risk ranking may be appropriate using a qualitative approach. If a specific prediction of the amount of mortality is required, a quantitative or modeled approach may be appropriate. Spatial analyses have been used with quantitative modeling to identify and prioritize high risk bird collision areas with varying degrees of success depending upon the quality and quantity of the data (see Heck 2007; Shaw et al. 2010; and Quinn et al. 2011).

OPTIONS FOR MINIMIZING COLLISION RISK DURING ROUTE EVALUATION

Engineering aspects such as line placement, line orientation, and line configuration all contribute to either increasing or decreasing the level of collision risk relative to biological and environmental factors (see Chapter 4). However, line routing is primarily a function of the origin and destination of the power being carried by these lines (see Figure 5.8), so other options such as line marking in areas where there is unavoidable collision risk and burying power lines where feasible and warranted may need to be considered.

Line Placement

Broadly, line routing should consider migratory patterns, areas of high bird use, and, if available, historical bird abundance information. On a finer scale, proximity to bird habitats (e.g., wetlands, trees, and other roosting, nesting, and foraging sites) is an important

[14] A stressor is a hazard in the environment that is capable of causing an adverse effect on a receptor. A wildlife receptor can be wildlife individuals, populations, or habitats that are subject to the potential impacts of a stressor.

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Terminology Used When Planning New Transmission Lines

For transmission line planning, the following terms may have different meanings to various stakeholders. Figure 5.8 illustrates these terms, which will be used in this manual in the following way.

Planning is the process that identifies the need for a transmission line to deliver electricity from the generation facility to a load or demand center.

Siting determines where the ends of the line need to be—Point A and Point B.

Corridor or study area is usually a rectangular boundary between Points A and B within which the alternative and preferred transmission line routes are plotted.

Alternative routes through the corridor are identified based on a long list of considerations that include endangered species and wildlife habitat. Examples of additional considerations are:

- Cities and towns
- Landowner agreement
- Crossings, such as highway, water, other power lines
- Airports
- Heliports
- Cemeteries
- Communication towers
- Historic places and archaeological sites
- Wetlands
- Land availability
- Land use
- Homes/businesses/schools
- Hospitals
- Parks/recreation
- Pipelines
- Churches
- Wells
- Bridges
- Topography
- Line voltage, design, engineering, and construction

Determining a route through public land is distinctly different than through private land. On public land, an agreement with only a few landowners is necessary; whereas on private land, hundreds of landowners may be involved along with a diversity of land uses and concerns to consider.

The **preferred route** is suggested by the utility. After stakeholder participation, the public utility commission determines the final route, which may be the preferred route, an alternative route, or a combination of the preferred and alternative routes.

The **right-of-way (ROW)** is the land that will be used for the power line. Easements along the ROW give utility crews access to the line for maintenance and are legal agreements, including compensation, between the utility and the landowner.

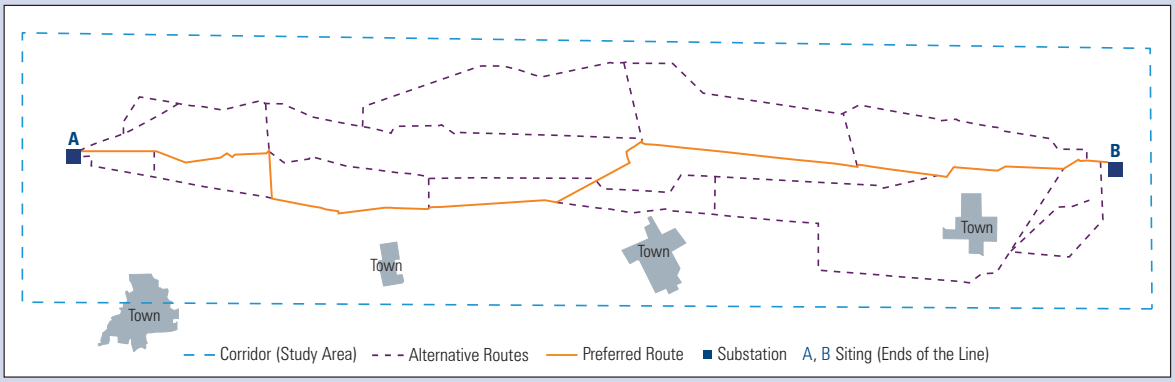

FIGURE 5.8: Schematic of the terminology used when planning new transmission lines.

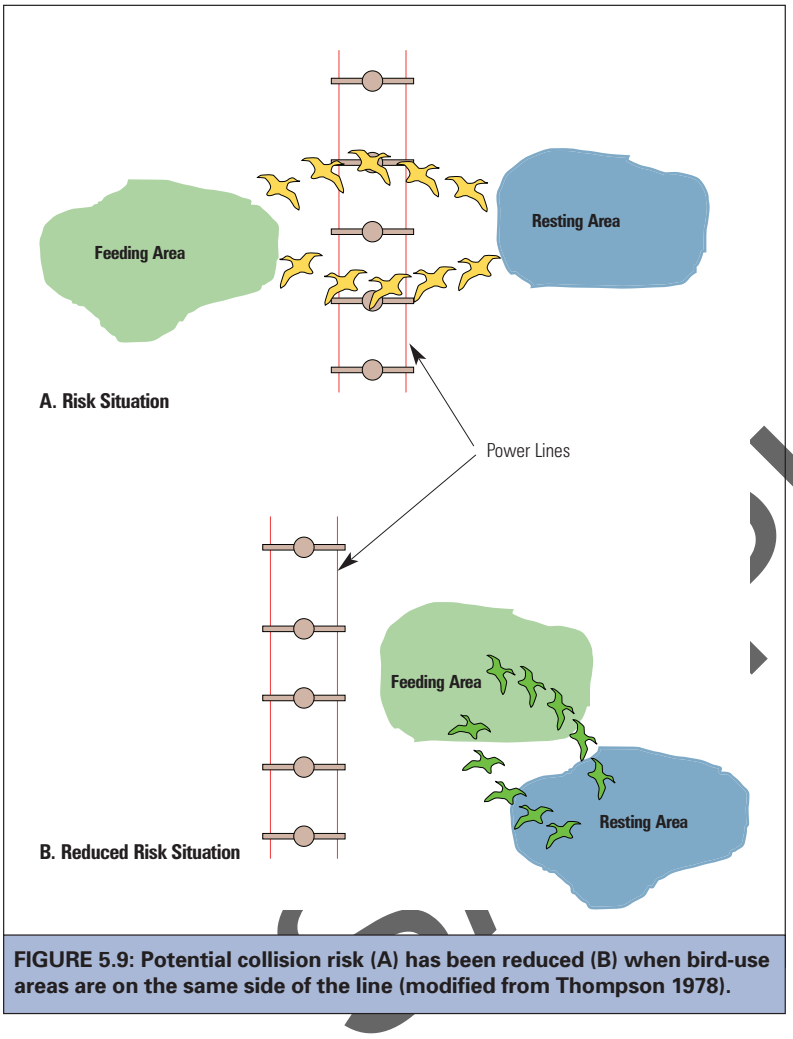

FIGURE 5.9: Potential collision risk (A) has been reduced (B) when bird-use areas are on the same side of the line (modified from Thompson 1978).

consideration when selecting a line route (see Chapter 4). The proximity of power lines to bird take-off and landing areas can affect the risk of collision (Lee 1978; Thompson 1978; Faanes 1987; Brown et al. 1984, 1987; Heck 2007; Quinn et al. 2011). For results of studies on distance of collision mortalities from specific areas, see *Habitat and Habitat Use* (page 44) and *Line Placement* (page 50). Spatial analysis with GIS is useful for evaluating different power line placement options relative to bird migration and habitat use patterns (see *Spatial Analysis* on page 64).

Line Orientation

Orientation of power lines relative to biological characteristics (e.g., flight behavior, season, and habitat use) and environmental conditions (e.g., weather patterns and topographical features) can influence collision risk. When planning power line routes, features such as mountain ridges, river valleys, and shorelines that are in traditional flight corridors should be considered (Colson and Yeoman 1978; Faanes 1987; Figure 5.10). Power lines that parallel primary bird flight paths pose less risk than a perpendicular orientation (Crowder 2000; Scott et al. 1972; McNeil et al. 1985). For example, the perpendicular orientation of a line relative to a topographical feature poses a greater collision risk to local and migrating birds, whereas a parallel orientation reduces risk.

Where perpendicular orientation cannot be avoided, forest habitats located near power lines can sometimes reduce collision risk (see Figure 5.3) Lines that are at or below the height of nearby trees rarely present a problem to small tree-dwelling birds because of their maneuverability; furthermore, large birds will gain altitude to fly over the tree line and will consequently avoid the power line (Thompson 1978; Raevel and Tombal 1991). For example, a power line crossing a narrow river bordered by trees that are taller than the line is likely to pose a lower collision risk than a broad river crossing because most birds will fly over the tree tops to cross the narrow river valley (CMS 2011a).

Strong tail winds can be detrimental to birds' ability to maneuver. Brown (1993) suggested that north-south orientation of lines increased collision frequency for cranes and waterfowl in the San Luis Valley, Colorado, because birds crossing them on an easterly heading were often subjected to prevailing westerly winds.

Line Configuration

Line configuration—phase conductors aligned vertically or horizontally and the number of conductors—is a collision factor that intuitively makes sense, but there are too few studies to draw conclusions. Most researchers agree that keeping the vertical arrangement of multi-conductor transmission lines to a minimum is beneficial because it reduces the height of the collision zone. However, a single-pole, vertical structure is often esthetically more acceptable and requires less ROW width.

Thompson (1978) and others (Bevanger 1998; Crowder 2000; Drewitt and Langston

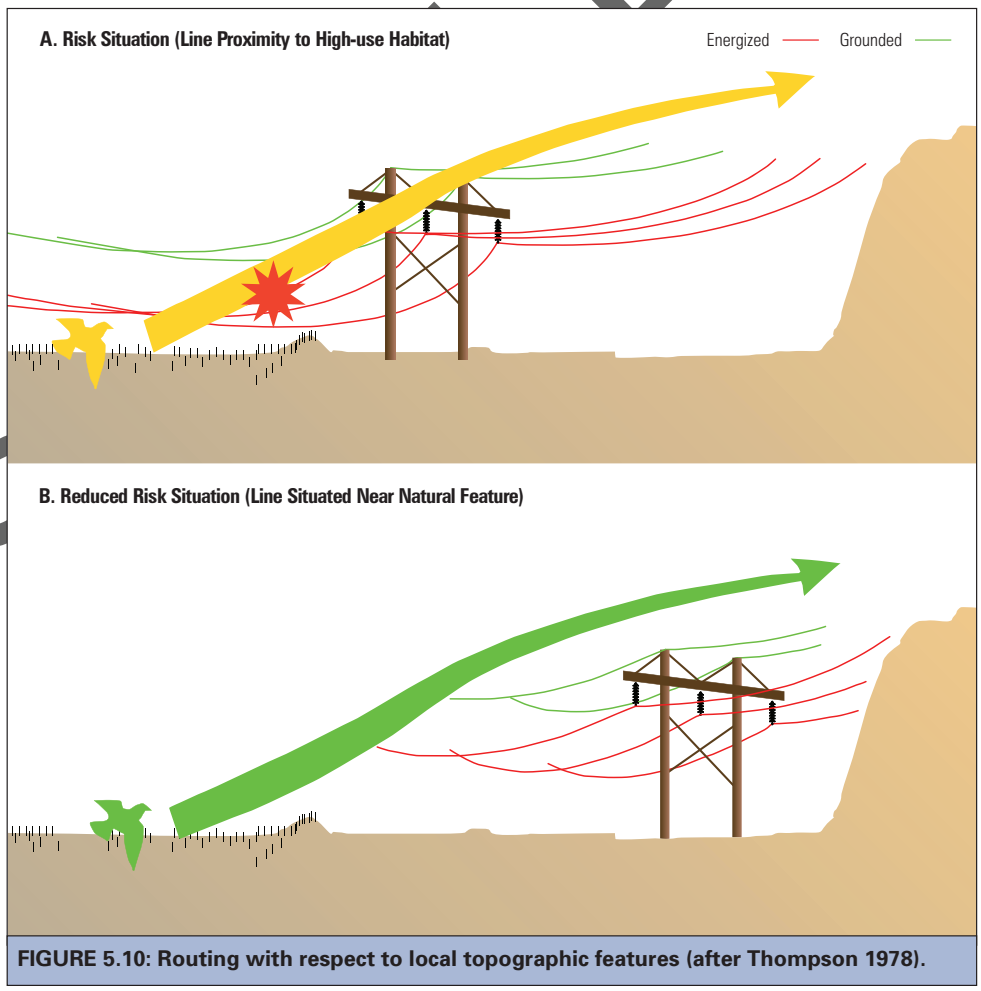

FIGURE 5.10: Routing with respect to local topographic features (after Thompson 1978).

2008) have suggested that clustering lines (i.e., several power lines sharing the same ROW) may reduce collision risk because the resulting network of wires is confined to a smaller area and is more visible. Birds only have to make a single ascent and descent to cross lines in this arrangement (Figure 5.11 and Figure 5.12). However, when there is decreased visibility, collision risk for birds may increase where several lines are clustered. When there are two shield wires at different heights, and only the higher one is marked, there may be collisions at the lower unmarked shield wire; both shield wires may need to be marked (S. Liguori, pers. comm.).

Other configuration options include:

- Lowering the height of the lines (e.g., below the tree line)
- Changing the wire diameter
- Bundling wires
- Using spacers to improve visibility

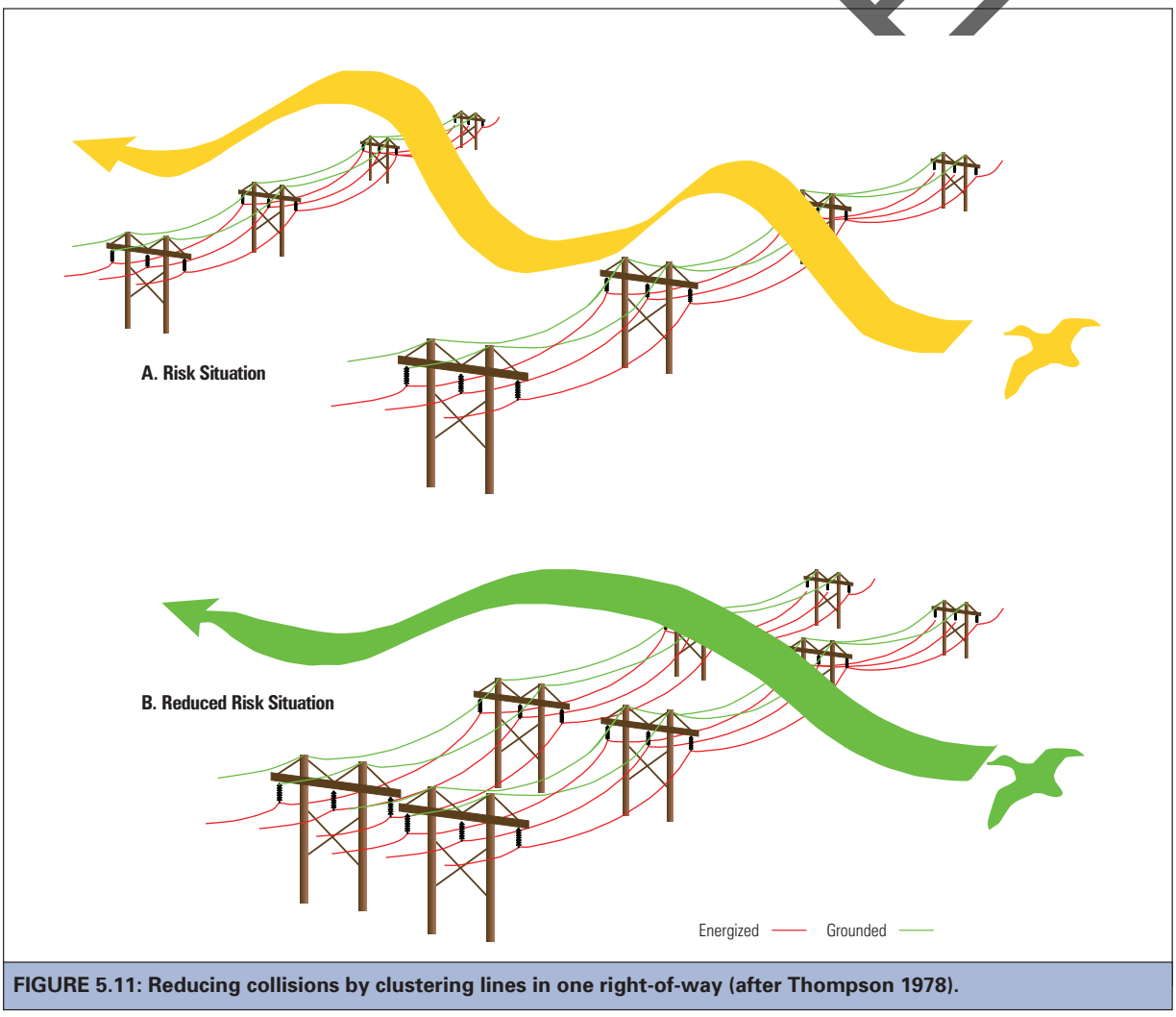

FIGURE 5.11: Reducing collisions by clustering lines in one right-of-way (after Thompson 1978).

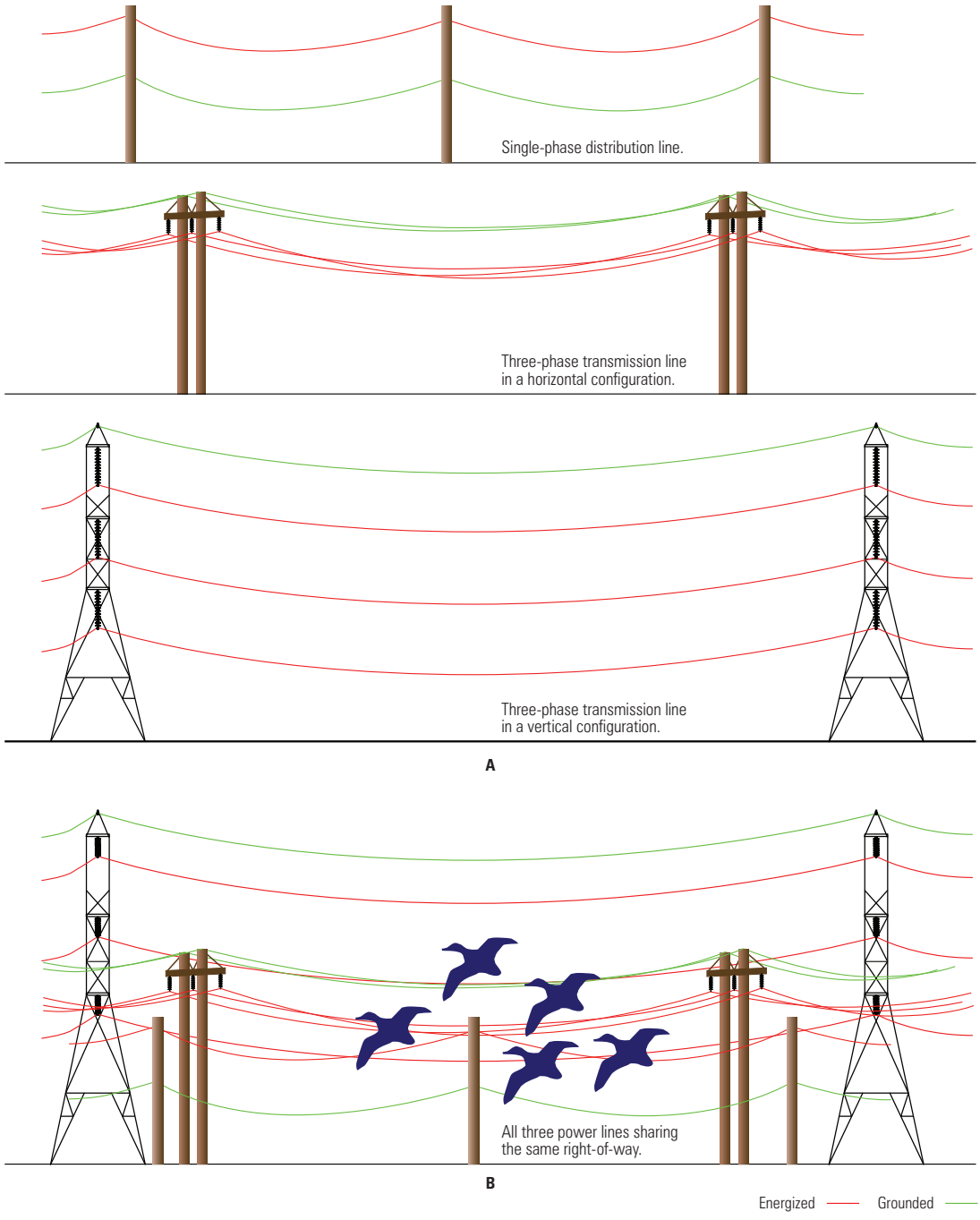

FIGURE 5.12: Collision risks for separate (A) and clustered (B) lines (after Thompson 1978).

- Rearranging wire configuration (e.g., converting from vertical to horizontal)
- Changing the structure type to increase its visibility
- Decreasing span length (e.g., by adding a pole mid-span)

Line Marking

In areas where there is collision risk, line marking devices should be considered. Most studies have shown a reduction in collisions and/or an increase in behavioral avoidance at marked lines when compared to unmarked lines, but this can vary with location, type of line marking device, and bird species (Jenkins et al. 2010; Barrientos et al. 2011; see Chapter 6 for detailed information on devices and effectiveness).There are three general categories of line marking devices: aerial marker spheres, spirals, and suspended devices (swinging, flapping, and fixed). Large diameter wire may also improve line visibility and has been used with line marking devices to reduce risk of collision-electrocutions and collisions (see Chapter 6). Line marking options are based on accessibility of the line, product availability and durability, ease of installation, cost, compliance and legal issues, spacing and positioning, safety codes related to ice and wind loading, corona effects, esthetics, and potential for vandalism.

Burying Power Lines

See the discussion on *Burying Power Lines* under *Options for Modifying Existing Lines* (page 62).

PUBLIC PARTICIPATION TO ADDRESS SOCIAL AND CULTURAL ISSUES

The public may have concerns about power line design and placement, including esthetics, environmental effects, wildlife, and safety. Vandalism is also a persistent problem—electrical equipment and line marking devices can become targets. When a utility is taking steps to minimize collision risk, a public participation program can help build positive relationships, increase public knowledge, identify and respond to public concerns, and promote responsible behavior (e.g., discouraging vandalism of line marking devices).

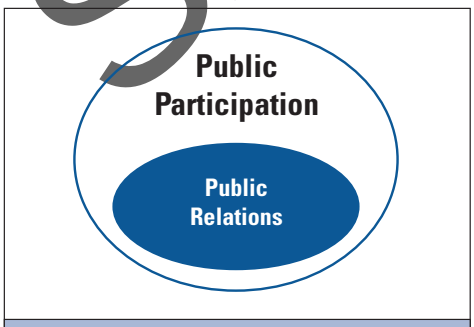

FIGURE 5.13: Public participation programs may provide information through a public relations campaign, but they also go further to engage the public in discussions and decision making (after EEI 2001).

WHAT IS PUBLIC PARTICIPATION?

Public participation is different from public relations or public information programs. While a public relations campaign provides information to the public, public participation programs actively engage the public in discussions and decision making. A well-designed public participation program requires the expertise of someone who can communicate technical information in an easily accessible way, facilitate groups, and cultivate trust with stakeholders. For a public participation program to succeed, the commitment and involvement of top management including the key decision makers is essential.

Utilities can use a variety of public participation tools to address social and cultural aspects of collision risk (see EEI 2001 and Appendix E for resources). Exhibits, signs, publications, web pages, and public announcements can be used to inform the public. Other techniques, such as webcasts, public

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forums, interviews, polls, retreats, citizen advisory panels, social media communications, and workshops promote engagement in the process. All efforts should be based on knowledge of the target audiences, consistent messages, audience participation in building a shared understanding, complete and objective information, and partnerships with supportive organizations and businesses. Edison Electric Institute's (EEI) *Introduction to Public Participation* (EEI 2001) is an excellent source of practical information for electric utilities.

Case Study: How Public Participation Benefitted Transmission Line Routing

The Project: Florida Power & Light (FPL) Crane-Bridge-Plumosis Transmission Line in southeast Florida (Martin and Palm Beach counties).

The Issue: FPL sought licensing for a 64.4-kilometer (40-mile) transmission line that traversed two densely populated counties. The route chosen for the power line generated some controversy because it included residential areas and a sensitive environmental tract. Alternative routes were proposed and submitted by various non-governmental and neighborhood groups as well as individuals. Continued opposition was expected.

Public Participation: A Citizens Advisory Panel (CAP) was appointed that included members from many different interest groups. The CAP recommended a route that was similar to the one originally recommended by FPL staff and consultants. FPL chose the panel's route.

The Result: The chosen route was initially rejected by the permitting agency but formed the basis of the final approved route.

Benefits of Public Participation: By establishing and working with the CAP, FPL precluded numerous separate meetings with different interest groups. The CAP increased understanding and support for the project despite initial opposition by individual parties. The discussions led to acceptable compromises, and costly appeals and reviews were avoided. In the end, FPL had an approved route that was similar to their preferred route and many members of the CAP felt positive that their input resulted in an improved project. The goodwill developed in the community benefited FPL's public image and set the stage for better relations on future projects.

(Modified from a case study that originally appeared in EEI 2001)

BENEFITS OF EFFECTIVE PUBLIC PARTICIPATION

Past experience shows that public participation has a record of creating cooperative working relationships (EEI 2001). According to EEI (2001), public participation:

- Reduces delays and costs associated with controversy and litigation. It often reduces implementation time because the public already supports or accepts the decision.
- Builds a positive relationship with the public, which is important even when it is necessary to make an unpopular decision.
- Develops and maintains credibility even with those who disagree with a given decision. A negative public image in one arena can affect a company's bottom line and trigger opposition in other arenas.
- Creates collaborative problem solving for achieving better and more acceptable decisions. When people believe that utility decisions are being imposed on them, they are more likely to increase their opposition.
- Gathers information from the public that the utility needs to make informed decisions.
- Can improve programs and policies, which will enjoy greater support.
- Can help management understand that technical issues have important social components. Some decisions appear to be technical, but are actually decisions about values.

CREATING A STRUCTURED PROGRAM

There are three phases to establishing a successful public participation program: decision analysis, program planning, and implementation. For case studies and a thorough description of how to plan and implement a public participation program use *Introduction to Public Participation* (EEI 2001) as your guide.

Phase 1: Decision Analysis

Clearly identify the decision-making process for the project and establish what role the public will play. Consider who will be affected by the project and if public support for the project is needed. Determine whether regulatory requirements or constraints may limit the opportunities for public participation. A thorough decision analysis will ensure that you engage the public for the right reasons and are not promising something that is not in your power to provide.

Phase 2: Program Planning

Successful participation plans address the needs and goals of both the utility and the public. The steps in creating a participation plan are:

- Identify the issues that will be important and assess the level of controversy of each. Issues and concerns typically focus on one or more of the following: mandate, economics, health, proximity, values, and existing uses of the property or area.
- Identify the parties (stakeholders) that need to be represented in the process. Invite a cross-section of the public including those who will be affected, those with a vested interest, and those who have decision-making power.
- Determine the goals for your public participation program. Goals provide focus and a course of action for the process. Clearly defined goals also make it easier to evaluate the success of the process.
- Define the level of public participation needed and state this clearly when inviting participants. In some cases, the public may be making decisions, while in other cases they may be providing support or recommendations.
- Select appropriate techniques of public participation based on the issues, level of controversy, and audience. Techniques, such as newsletters, web pages, exhibits or news releases provide information, whereas focus groups, meetings, workshops, polls, and interviews foster active public participation and collaboration.
- Outline the decision-making process including all steps from identifying the problem to formulating, evaluating, and selecting alternative approaches.

Phase 3: Implementation

Implement the program according to the collaboratively developed plan. During implementation, participants may see the need to make adjustments or changes, so be flexible and prepared.

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Characteristics of Successful Public Participation

Successful public participation programs often do the following:

- Make public participation an integral part of the project, rather than an afterthought.
- Commit to a decision-making process at the outset and maintain that commitment.
- Ensure that the interested public is involved in all phases of decision making: definition of the problem, range of possible alternatives, criteria used to evaluate alternatives, and selection of the final course of action.
- Carefully assess the needs of different audiences and choose techniques appropriate for all groups and for the information that will be collected.
- Ensure that management is engaged and has endorsed the program. This will create a climate of acceptance, which is essential to meaningful public participation.

CHAPTER 6

Line Marking to Reduce Collisions

IN THIS CHAPTER

- Overview of Line Marking Devices
- Effectiveness of Designs
- Marking Constraints and Considerations
- Line Marking Devices
- Large Diameter Wire

A common observation in collision studies is that birds show the ability to avoid a power line if they see the lines early enough. Many of these studies indicate that collision risk can be lowered by more than half and, in some cases, by as much as 80% after lines have been marked. This chapter discusses what is known about line marking, including the different devices, their reported effectiveness, and considerations in their use.

OVERVIEW OF LINE MARKING DEVICES

Studies suggest that the majority of bird collisions occur with the smallest diameter wire, which is typically the shield wire located above the phase conductors on transmission lines (e.g., Savereno et al. 1996) or the phase conductor and neutral wire on distribution lines. Most collisions occur mid-span (e.g., Eskom Transmission 2009). As a result, most of the efforts to reduce bird collisions have focused on marking the shield wires on transmission lines and the phase conductors on distribution lines. As discussed in Chapter 4, different biological, environmental, and engineering factors contribute to birds' ability to see and avoid a power line; each should be considered when choosing among line marking options.

There are three general types of line marking devices: aerial marker spheres, spirals, and suspended devices (swinging, flapping, and fixed). In addition, large diameter wire, though not a marking device, may also improve line visibility and has been used with line marking devices to reduce risk of collision-electrocutions and collisions (see *Large Diameter Wire* on page 100). Since 1994, aerial marker spheres, spirals, and suspended devices have been further developed. Advances include changes to shape, colors and color patterns, and attachments, along with UV resistance, which improves durability and colorfastness. Other designs have been developed, but are not currently available in the United States (see *Devices Available in Other Countries* on page 97).

Because there are few comparative studies, no single device is considered to be the best performing. However, Jenkins et al. (2010) concluded that any sufficiently large line marking device that thickens the appearance of the line for at least 20 centimeters (cm) (7.8 inches [in]) in length and is placed with at least 5 to 10 meters (m) (16.4 to 32.8 feet [ft]) spacing is likely to lower collision rates by 50% to 80%. In addition, the South African Electric Supply Commission (Eskom Transmission 2009) describes its use of spirals and suspended devices on transmission lines and recommends suspended devices over small-diameter spirals because their swinging or flapping motion makes them more visible and more effective.

Devices can be purchased in a variety of colors, which may be important but there are insufficient comparative studies to provide firm conclusions. In general, what seems to be effective is to alternate the colors to make the lines more obvious (Eskom Transmission 2009). For aerial marker spheres, yellow seems to be the preferred choice over international orange because they provide better contrast in poor light conditions.

Table 6.1 provides a general description of the most commonly used devices that are available in the United States.

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TABLE 6.1: Summary of data on line marking devices available in the United States.*

Name†	Description	Dimensions	Spacing§	General Comments on Effectiveness§
Aerial Marker Spheres				
Aerial Marker Spheres or Aviation Balls	Large, colored spheres that attach to wires.	Diameter ranges from 23 cm (9 in) to 137 cm (54 in). The 23 cm (9 in) and 30.5 cm (12 in) are most often used for line marking.	Up to 100 m (328 ft) apart. See Table 6.3 for details.	Reduction in collisions noted in certain situations. Sometimes this marker is used in conjunction with other line marking devices. See Table 6.4 for details.
Spirals				
Spiral Vibration Damper (SVD)	Extruded plastic (PVC) spiral device that fits over the shield wire and distribution conductors.	Various lengths, ranging from 112 to 165 cm (46 to 65 in), to fit different conductor sizes.	Often placed about 3 m (9.8 ft) apart on the shield wire. Stagger on distribution lines to prevent interphase contact.	Reduction in collisions noted. Not as commonly studied as other line marking devices. See Table 6.6 for details.
Bird-Flight™ Diverter (BFD)	Spiral device made from high impact PVC that attaches at one end to the shield wire or distribution conductor and increases in diameter at the other end.	Lengths range from 17.8 to 59.7 cm (7 to 23.5 in). Diameter at the large end ranges from 3.8 to 12.7 cm (1.5 to 5 in).	Ranges from 4.6 to 21 m (15 to 68.9 ft) apart. See Table 6.7 for details.	Shows varying amounts of effectiveness in collision risk reduction and flight behavior alteration. Commonly included in collision studies. See Table 6.8 for details.
Swan-Flight™ Diverter (SFD)	Similar to the BFD, but this device attaches at both ends with the larger diameter spirals in the center.	Lengths range from 50.8 to 116.8 cm (20 to 46 in). Diameter of central spiral ranges from 17.8 to 20.3 cm (7 to 8 in).	Ranges from 15 to 30 m (49.2 to 98.4 ft) apart. See Table 6.9 for details.	Shows varying amounts of effectiveness in collision risk reduction and flight behavior alteration. Commonly included in collision studies. See Table 6.10 for details.

Continued

TABLE 6.1: Summary of data on line marking devices available in the United States.* (cont.)

Name†	Description	Dimensions	Spacing§	General Comments on Effectiveness§
Suspended Devices				
General Designs	Swinging and fixed devices; plastic flapper of various shapes and colors with reflective and glowing surfaces; connected to a clamp that attaches to the power line.	Size and shape varies with device and design.	5 to 30 m (16.4 to 98.4 ft) apart. Staggering devices on parallel lines is recommended. See Table 6.11 for details.	Shows varying amounts of effectiveness in collision risk reduction and flight behavior alteration. Commonly included in collision studies. See Table 6.12 for details.
FireFly™	Swinging and fixed models; rectangular devices with reflective and glowing surfaces; connected to a clamp that attaches to the power line.	Acrylic plastic tag measures 9 cm x 15 cm (3.5 in x 6 in).	4.6 to 15.2 m (15 to 50 ft) apart. See Table 6.13 for details.	Shows varying amounts of effectiveness in collision risk reduction and flight behavior alteration. See Table 6.14 for details.
BirdMark BM-AG	Swinging perforated disk has a reflective center and spins and flutters, it also glows; connected to a clamp that attaches to the power line; perforations allow device more wear resistance in high wind locations.	29.21 cm (11.5 in) long with a 13.33-cm (5.25-in) diameter disk.	4.6 m (15 ft) apart	Mentioned in reviews, but no scientific studies were found.

* Source: Summarized from available literature and Hunting (2002); see *Line Marking Devices* on page 85 for detailed information and sources.
† This table only includes devices that are available in the United States; see *Devices Available in Other Countries* on page 97.
§ Summarized from different sources and studies with varying methodologies, environments, and species; see tables in *Line Marking Devices* for detailed information and sources.

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EFFECTIVENESS OF DESIGNS

EARLY STUDIES (1960 TO 1994)

In Europe during the 1960s and 1970s, numerous studies addressed the effectiveness of different devices to make power lines more visible so collision rates could be reduced. Most of these studies tested aerial marker spheres (aviation balls) and various types of plastic or rubber strips attached to the lines. These studies found that increasing the visibility of lines resulted in a statistically significant reduction of collision risk.

In 1964, a 275-kilovolt (kV) line near Teeside, England, was marked with 15-cm (6-in) black vanes (flags). Koops and de Jong (1982) reported that this effort was successful in reducing bird collisions, although no quantitative data were given. Renssen et al. (1975, cited in Beaulaurier 1981) investigated several marking schemes: black, white, and orange aerial marker spheres on the shield wire.

Overall, the dozen or more studies during this period (see lists in Beaulaurier 1981 and Hunting 2002) found that marking devices ranged from no effect to a 60% reduction in collisions. The limitation of these early studies was that most were conducted over a short period of time or they were not held to rigorous experimental protocols. Often, quantifying and comparing flight intensities over marked and unmarked lines were not done.

In addition, the durability of these devices was often very limited because of the plastic and cloth materials used.

LATER STUDIES (1995 TO 2012)

Testing and reporting on the effectiveness of line marking devices have broadened to include the behavioral responses of birds approaching power lines. Hunting (2002), Lislevand (2004), Jenkins et al. (2010), and Barrientos et al. (2011) identified approximately two dozen studies that have focused on the effectiveness of certain devices for selected species. However, most of these studies involved transmission lines, and relatively few have looked at the comparative effectiveness of different devices. Hunting (2002) also concluded that making recommendations on the comparative device effectiveness is not possible due to the variation in study designs.

Barrientos et al. (2011) conducted a meta-analysis of published and unpublished collision studies to evaluate whether line marking reduced the number of collisions and which devices might be more effective. Although they showed that line marking reduced collision rates by 78%, the variability in study designs made it impossible to compare the effectiveness of these devices with different species, in different habitats, in different weather conditions, or on different line configurations. Barrientos et al. (2012), a before-after-control-impact (BACI) study of the effectiveness of two spiral devices (the smaller bird flight diverter and the larger swan flight diverter), concluded that line marking is an effective way of reducing mortality on distribution and transmission lines. Their estimate of overall effectiveness was significant, but not as high as others have reported; more definitive predictions were not possible because of study design and data limitations.

Comparison studies that use the same monitoring time intervals, control for habitat differences, and standardization of the periodicity of carcass searches are necessary to determine the device best suited to a given set of environmental conditions and species intended for protection. The following examples reflect various approaches to studying the effectiveness of line marking devices. (For studies on the effectiveness of each device, see *Line Marking Devices* on page 85.)

In San Luis Valley, Colorado, Brown and Drewien (1995) evaluated the effectiveness of two devices: yellow spiral vibration dampers (SVDs) and yellow swinging fiberglass plates with a diagonal black stripe (30.5 cm × 30.5 cm [12 in × 12 in]). Marked segments 0.8 kilometers (km) (0.5 mile [mi]) long were compared with unmarked segments of equal length during spring and fall seasons over a three-year period. They found that SVDs reduced sandhill crane (*Grus canadensis*) and waterfowl mortality by 60% and the swinging plates reduced mortality by 63%. Flight intensities were quantified. Evaluation of the flight behavior of sandhill cranes, Canada geese (*Branta canadensis*), and ducks at marked and unmarked lines indicated that birds reacted to marked lines by increasing their altitude and reaction distance. Although both devices significantly reduced mortality, the swinging plates damaged power lines.[15] The authors suggested that the silhouette of the swinging plate also provided an important benefit in low-light conditions.

In west-central Spain, Janss and Ferrer (1998) studied the effectiveness of three devices (white spiral, series of crossed bands, and thin black strips) on marked and unmarked transmission (380 kV and 132 kV) and distribution (13 kV) lines over a four-year period. The three devices were examined by comparing marked to unmarked spans

[15] The concept of swinging plates has developed into a variety of suspended devices. This new generation of suspended devices has reduced the line-wear problem while maintaining effectiveness.

SAMPLE

along the same power line. Monthly carcass searches were conducted without correcting for monitoring biases (see Appendix B). The species exhibiting the highest mortality included bustards, cranes, and shorebirds. The white spiral devices (30 cm × 100 cm [11.8 in × 39.4 in]), similar to a Swan-Flight™ Diverter (SFD), reduced expected mortality by 81% for all birds. The series of two black, crossed bands (35 cm × 5 cm [13.8 in × 1.9 in]) reduced expected mortality by 76% for all birds but not for great bustard (*Otis tarda*). The thin black strips (70 cm × 0.8 cm [28.6 in × 0.3 in]) placed at 12-m (39.4 ft) intervals from the central conductor did not reduce mortality. The authors state that the data could not be used for statistical comparison of effectiveness of the different diverters for specific species.

The Ventana Wildlife Society (2009) conducted a comparative effectiveness study of Bird Flight™ Diverters (BFD) and SFDs at six sites at San Luis National Wildlife Refuge Complex in California. Although approximately 800 hours of observation were made during three winter seasons from 2005 to 2008, few collisions were observed. However, many reactions to power lines were documented, such as altitude changes or sudden changes in flight direction called flutter or flare. The birds exhibited reactions at greater distances from power lines after flight diverters were installed, especially on lines with SFDs. Estimated total collisions were significantly higher for the unmarked control lines than for the lines marked with BFDs or SFDs. The difference in estimated total collisions between control lines and marked lines was even greater when the analysis excluded the American coot (*Fulica americana*), which primarily flies at night and accounted for approximately half of all carcasses found. The study concluded that both diverters were ineffective for the American coot. The study also suggested that site-specific differences can influence the effectiveness of diverters.

FIGURE 6.1: Studies at the San Luis National Wildlife Refuge show that the line marking devices tested work well for most species, the exception being the American coot, which is more vulnerable to collisions because it primarily flies at night.

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Western Area Power Administration conducted a line marking study along 3.2 km (2 mi) of line in 2006, 2007, and 2008 (WAPA 2011). Three line marking devices were used: SFD, BirdMark (solid orange), and FireFly™. The study occurred near Coleharbor, North Dakota, along the Audubon causeway, which separates Lake Audubon on the east from Lake Sakakawea on the west. More than 1,000 bird carcasses (from road mortality and collisions with power lines) and 300 hours of observational data were collected. The results indicated that marking the line decreased the number of observed flyovers for the majority of species; rather than flying over the lines, birds turned and flew parallel to the line. The study also indicated that the differences in device efficacy were minimal.

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Regardless of the variability in studies on the effectiveness of devices, most studies have shown a reduction in collisions and/or an increase in behavioral avoidance when compared to unmarked sections of a line.

MARKING CONSTRAINTS AND CONSIDERATIONS

The choice of marking device is often based on consideration of product availability and durability, cost, ease of product installation, compliance and legal issues, spacing and positioning, safety codes related to ice and wind loading, corona effects, esthetics, and vandalism. Utilities are encouraged to investigate and test products before installing them on a large scale. A general discussion of these considerations is presented here. For specific considerations on each device, see *Line Marking Devices* on page 85. For additional information on what devices may be appropriate, utility companies can consult with the manufacturer and with other utilities.

PRODUCT AVAILABILITY AND DURABILITY

Three general types of devices are available in North America: aerial marker spheres, spirals, and suspended devices. In addition, larger diameter wire can be considered for increasing line visibility. Several distributors supply these devices, so utility managers should consult with their suppliers for available options. Other devices have been developed, but are not currently available in the United States (see *Devices Available in other Countries*, page 97).

The durability of line marking devices and diverters was a commonly reported concern in the 1990s and 2000s. Since then most manufacturers have redesigned these devices to withstand ultraviolet (UV) light degradation, and they have improved the attachment clamps on suspended devices so that damage to the power line is reduced or eliminated—device specifications can be obtained from the manufacturer.

Static devices (such as spirals) and dynamic devices (such as some suspended devices) have different durability. Static devices have been more durable since they do not have moving parts. However, they have had limited success in South Africa since they can be less visible than dynamic devices. It is assumed that the motion is what makes the dynamic devices more visible. The disadvantage of dynamic devices is that they are subject to wear and have a more limited useful life than static devices. Some dynamic devices can also cause wear damage on the power line (Eskom Transmission 2009). In high wind areas, some devices with moving parts broke within several months (PacifiCorp, unpubl. data).

COST CONSIDERATIONS

Costs will vary with power line access, installation method, type of device, spacing, number of devices needed, and durability of the device. These depend in part on the line design, voltage, and length of line to be marked. Cost will also vary if the marking is done during construction of new lines or retrofitting existing lines. Power lines that are higher or over a water body (e.g., rivers, lakes, etc.) can be difficult to access and require more costly installation methods, such as a boat or helicopter. The durability of each device also varies, which makes long-term maintenance and impacts on line reliability additional considerations in cost estimates. Product cost contributes the least to the overall cost of line marking.

EASE OF INSTALLATION

The various types of line marking devices require different installation techniques: from the ground, bucket truck, boat, helicopter, line trolley, or other means. Some devices can be attached by hand and others need to be attached by a hot stick. Devices that coil onto

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FIGURE 6.2: A helicopter crew installing line marking devices on a power line.

lines may be easier to install by hand, if possible, than by hot stick. Some, such as suspended devices, may be installed by either one or two people, and a tool may be required for one-person installation.[16] In areas where access to the power line is difficult, product durability may be a more important consideration than ease of installation. For products with a shorter lifespan, the ease of product removal for repairs or replacement should also be considered.

COMPLIANCE AND LEGAL ISSUES

Associated issues must be considered to ensure that the line marking system complies with all applicable company, industry, and legal requirements. Installation must not reduce National Electrical Safety Code (NESC) clearance requirements, cause damage to standard power line hardware, conductors, and/or supporting structures, or affect the line or system reliability. Attachment procedures must adhere to worker and industry safety standards and be compatible with standard industry tools and equipment. Where facilities are shared, the easement documents may have restrictions concerning additions or modifications. In addition, legal counsel of some utility companies may object to the use of aerial marker spheres for preventing bird collisions because they prefer that the spheres only be used in compliance with Federal Aviation Administration (FAA) regulations to mark hazards to aircraft.

SPACING AND POSITIONING

Spacing and positioning determine the ability of marking devices to increase line visibility, the number of devices needed to mark each span, and how much the marking will add to the ice and wind loading. Over the years, studies have discussed spacing and positioning of devices on power lines. However, there have been no systematic comparisons of devices and their spacing and positioning. The following are general recommendations for spacing and positioning. For specific recommendations on each device, see *Line Marking Devices* on page 85.

Spacing recommendations vary depending on species considerations, environmental conditions, line location, and engineering specifications (e.g., wind and ice loading, conductor size, and the presence or absence of the shield wire). In general, intervals of 5 to 30 m (16 to 98 ft) have been most commonly used and recommended for all but the aerial marker spheres (aviation balls), where a greater spacing is used, and SVDs, where less spacing is used (see Table 6.1). Jenkins et al. (2010) concluded that any sufficiently large line marking device that increases the diameter of the line by at least 20 cm (8 in) for a length of at least 10 to 20 cm (4 to 8 in) and is placed at intervals of 5 to 10 m (16 to 32 ft) is likely to lower general collision rates by 50% to 80%.

For positioning, Eskom Transmission (2009) recommends marking only 60% of a span, the central portion of the shield wires on transmission lines, since this is where

[16] A utility should consult with its safety department to determine appropriate practices for individual or crew work.

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TABLE 6.2: Distance of collision mortalities from the nearest pole (parallel to distribution lines in the right-of-way).*

Taxa or Species	Sample Size	Distance	
		Mean Std Dev	Range
Geese	43	11.9 ± 10.7 m (39 ± 35 ft)	0.6 to 45.7 m (2 to 150 ft)
Ducks	25	16.2 ± 13.1 m (53 ± 43 ft)	0.6 to 48.8 m (2 to 160 ft)
Swans	5	18.6 ± 9.4 m (61 ± 31 ft)	6.1 to 60.9 m (20 to 200 ft)
Raptors	12	37.5 ± 11.9 m (123 ± 39 ft)	18.3 to 54.9 m (60 to 180 ft)
Great blue heron (*Ardea herodias*)	7	17.4 ± 12.8 m (57 ± 42 ft)	1.5 to 33.5 m (5 to 110 ft)
American white pelican (*Pelecanus erythrorhynchos*)	16	19.8 ± 15.2 m (65 ± 50 ft)	1.8 to 45.7 m (6 to 150 ft)
Sandhill crane (*Grus canadensis*)	6	21.9 ± 16.5 m (72 ± 54 ft)	6.1 to 45.7 m (20 to 150 ft)

* Source: PacifiCorp, unpubl. data

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most collisions occur. In surveys conducted from 2004 to 2009 in Oregon, California, Idaho, Utah, and Wyoming, PacifiCorp (unpubl. data) found that most waterfowl collision mortalities were found mid-span in the right-of-way (ROW), parallel to distribution lines, at distances of 12 to 18 m (39 to 61 ft) from the nearest pole (Table 6.2); typical span lengths were 91.5 to 121.9 m (300 to 400 ft). Sandhill cranes (*Grus canadensis*), American white pelicans (*Pelecanus erythrorhynchos*), and raptors were found farther from the nearest pole than were other species (PacifiCorp, unpubl. data.). These distances can help direct the placement of line marking devices (Figure 6.3).

Another commonly recommended strategy is to stagger the devices on parallel lines in the same plane to increase the visual density of the marked power line (Figure 6.4 and Figure 6.5). This would also reduce the number of markers on each individual line and each line's ice and wind loading.

SAFETY CODES: ICE AND WIND LOADING

The NESC identifies minimum safety and engineering standards for power lines within the United States. The NESC ice and wind loading and safety criteria for conductors and supporting structures must be reviewed prior to marking. These guidelines are used when designing a line so the constructed power lines meet or exceed NESC criteria. In addition, some states have adopted additional codes and regulations that further specify design criteria.

When any device is added to an overhead power line, it adds to the weight or loading of the line. Ice or wind adds still more loading to the line and supporting structures. The added weight of the devices and the extra wind and ice loading must not exceed line

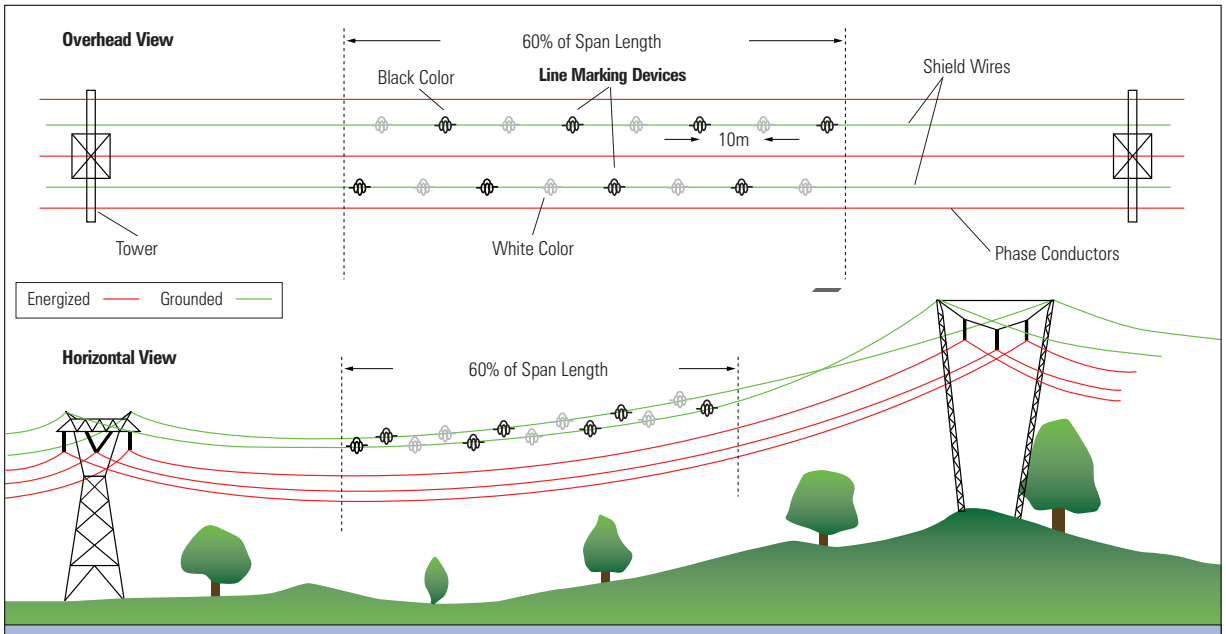

FIGURE 6.3: Positioning of line marking devices on the central portion of two shield wires on transmission lines (after Eskom Transmission [South Africa] 2009).

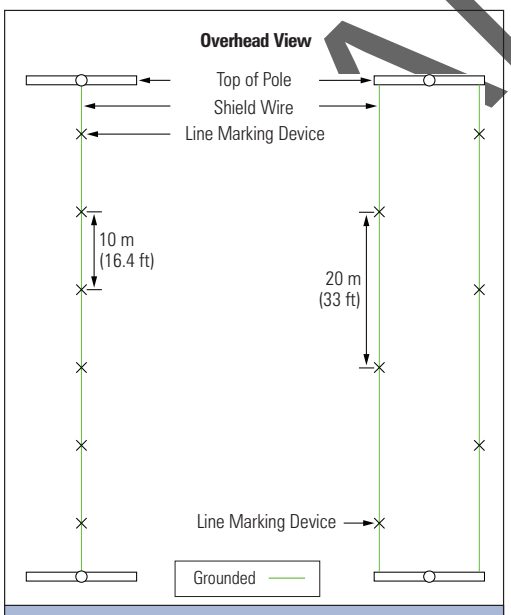

FIGURE 6.4: Positioning of line marking devices on one shield wire or staggered on two parallel shield wires.

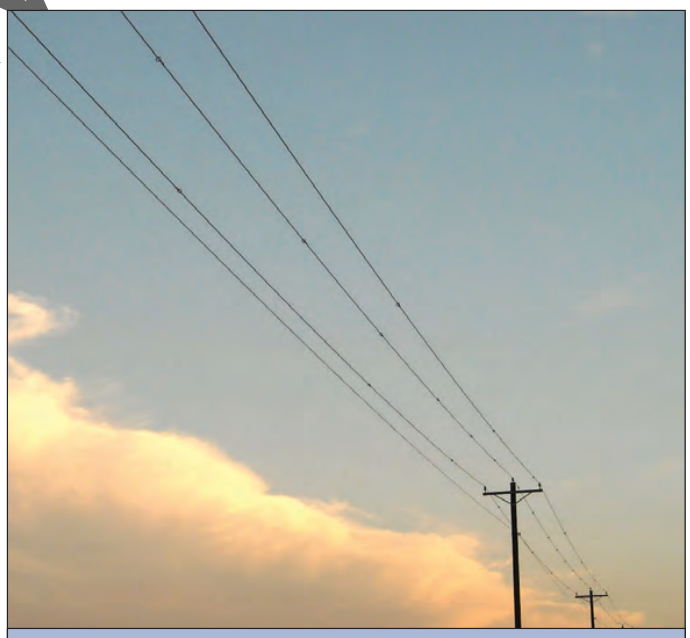

FIGURE 6.5: Line marking devices staggered on a distribution line.

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FIGURE 6.6: When a device is added to a power line, it may add to the loading of the line, which further increases under icy or windy conditions and may also cause problems for deicing operations.

design limits and code requirements or cause additional sag that could lead to interphase contact (one conductor contacting another) and an outage. Consultation with the design engineers is imperative to ensure that adding any type of line marking device will not exceed design criteria. For existing lines, additional loading must be considered when retrofitting with line marking devices. When designing new power lines that may require marking, include allowances for the additional loading of those marking systems to prevent safety criteria from being exceeded.

CORONA EFFECTS

Electric corona occurs when the voltage of a phase conductor, typically 115 kV or greater, ionizes the surrounding air, which also becomes a conductor (Hurst 2004). Corona can degrade certain materials over time (Hurst 2004). Corona discharges appear as bluish tufts or streamers around the phase conductor, generally concentrated at irregularities on the conductor surface. A hissing sound, an odor of ozone, and local radio interference often occurs. Sharp corners of energized parts and voids, bubbles, and other heterogeneous components within solid materials (e.g., diverters) can cause corona effects.

Hurst (2004) tested several devices (Bird Flapper, FireFly™, BirdMark BM-AG, BFD, and SFD) at three simulated voltages. The study found that most of the devices had very little or no corona at 115 kV (except for some of the suspended devices) but did have corona effects at 230 kV and 345 kV. The best-performing devices at 115 kV were the BFD and the SFD, neither of which had any detectable corona discharge. At 230 kV, the BFD and the SFD had a medium level of corona, whereas suspended devices were characterized with a high level. At 345 kV, all of the devices had a very high level of corona. The corona generally occurred at the point of attachment to the phase conductor and at the top of the Bird Flapper and FireFly.

ESTHETICS

Visual management and esthetics have become concerns related to the construction or modification of power lines. With appearance as a consideration, dull rather than shiny materials are now widely used for overhead lines. Consequently, power lines were designed to blend with the background and be as invisible as possible, particularly in heavily forested areas. However, with growing concern about bird collisions, design goals are changing toward making the line acceptable to people but not invisible to birds.

If the power line is located where the viewshed is an environmental value, such as on or near public land or in residential areas, the addition of line marking devices may become an esthetic issue. For public lands and resi-

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Using Public Participation to Address Social Constraints of Line Marking

FIGURE 6.7: Power structures and line markers can become targets for vandalism and a detriment to service reliability. Public participation and outreach programs, like this hotline, may reduce vandalism.

Participation and outreach programs can increase public support for strategies such as line marking and can change or reduce behaviors such as vandalism. This can make it easier for a utility to meet requirements for electrical reliability and customer satisfaction while reducing risks to birds. See Chapter 5 for a discussion on using public participation to address social issues that influence collision risk. Appendix E includes resources.

dential areas, the marking system should be effective and acceptable in appearance. Public participation and outreach programs can increase support for line marking in areas where viewshed or esthetics are concerns, which could avoid the need for making a trade-off between esthetics and collisions (see *Public Participation* in Chapter 5).

VANDALISM

Vandalism is a persistent problem with overhead power lines, particularly from irresponsible shooters. In general, the poles, insulators, towers, signs, and line marking devices can become targets when lines traverse sparsely populated areas. As a result, electrical conductors have been damaged or severed, and extensive outages have resulted. Repair and replacement costs are ultimately borne by the utility companies and ratepayers. In addition, some customers with critical electricity needs, such as hospitals and mining operations, have had to rely on emergency back-up measures in order to maintain safety levels (A. D. Miller, pers. comm.). When evaluating any line marking system, the potential for vandalism should be addressed. Public participation and outreach programs may help reduce or prevent vandalism (see *Public Participation* in Chapter 5).

LINE MARKING DEVICES

AERIAL MARKER SPHERES (AVIATION BALLS)

Aerial marker spheres (or aviation balls) were one of the earliest devices used in an attempt to reduce bird collisions (Figure 6.8 and Figure 6.9). Originally they were used to warn aircraft pilots of power lines. These large, colored balls are usually attached to distribution phase conductors or transmission shield wires. They are available in a variety of diameters: 23 cm (9 in) to 137 cm (54 in). The most often used sizes for line marking are 23 cm (9 in) and 30.5 cm (12 in).

Aerial marker spheres are available in a variety of colors, including international orange, gloss white, or gloss yellow. Studies

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FIGURE 6.8: Aerial marker spheres, also known as aviation balls, were designed to make power lines more visible to aircraft operators.

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FIGURE 6.9: Aerial marker spheres in use on a power line above a wetland habitat.

SAMPLE

regarding the effectiveness of color for warning pilots have shown that international orange is not the most effective color for all lighting conditions (Electrical World 1986). The FAA suggests a combination of international orange, gloss white, or gloss yellow for marking lines for aircraft. In bird collision studies, yellow has been shown useful because it reflects light better at dawn and dusk, and it does not blend in with the background colors as readily as international orange.

Recommended spacing between spheres generally ranges from 30 to 100 m (100 to 328 ft) (Table 6.3 and Table 6.4). For an existing line that crosses water, where the addition of aerial marker spheres may not be suitable, a separate (non-energized) cable for the purpose of holding the aerial markers could be installed. In this application, a larger size cable (visible to birds) should be used so that it does not contribute to bird collisions. This may provide adequate marking to reduce collisions.

TABLE 6.3: Spacing and positioning for aerial marker spheres (aviation balls).*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies†
Aerial Marker Spheres (Aviation Balls)	30 to 100 m (98.4 to 328 ft) apart (APLIC)	Spacing is not critical and will depend upon local conditions. The general rule is 20 m (65.6 ft) apart (Preformed Line Products)	Up to 100 m (328 ft) apart. Some studies staggered devices on parallel lines to increase visual density.

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions.
† See Table 6.4 for study details and sources.

TABLE 6.4: Representative studies for aerial marker spheres (aviation balls).

Description/Spacing	Location/ Species	Power Line Characteristics	Effectiveness		Reference
			Behavioral Avoidance	Reduction in Collisions	
Yellow spheres with black vertical stripe, 30 cm (11.8 in)/spacing: irregular intervals	Nebraska/ sandhill cranes	Transmission, 69 kV to 345 kV	Behavioral avoidance was greater (birds flew higher and reacted sooner) for marked versus unmarked line	Significantly reduced collisions	Morkill and Anderson 1991
Yellow aviation balls with black stripes, 30 cm (11.8 in)/spacing: 100 m (328 ft); staggered on opposing shield wires for a visual effect of 50 m (164 ft)	South Carolina/ various waterfowl species	Transmission, 115 kV	Behavioral avoidance was greater (birds reacted sooner) for marked versus unmarked line	Collision rate was 53% lower at marked line	Savereno et al. 1996
Yellow aviation marker ball with 20.3 cm (8 in) black dots/spacing: not provided	Hawaii/ shearwaters	–	–	Reduced collisions	Telfer 1999 cited in Bridges et al. 2008

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Considerations for Aerial Marker Spheres (Aviation Balls)

- Improper design or installation of aerial marker spheres on phase conductors or shield wires can cause spheres to work loose and slide to the center of the span or be pushed by wind to the end of a span. Line damage from this may cause an outage.
- Aerial marker sphere size should be compatible with the design constraints of the line. For example, very large spheres can be heavy and should only be used on lines that can handle this weight.
- Adding aerial marker spheres can affect line tension and structure design more than other devices, particularly in areas where heavy ice and wind loading occurs. Accommodating the additional loading could affect construction costs.
- When installed on higher voltage conductors, there can be corona damage (depending on the type of marker balls). To avoid corona damage, marker balls designed for installation on higher voltage lines, though more costly, should be used.
- Spheres are moderately labor-intensive to install on an existing line, but less costly when added to a new line during construction.
- Although aerial marker spheres are more costly per unit than spirals, the overall cost of marking new or existing lines would be about the same because fewer spheres would be required.
- The legal counsel of some utility companies objects to the use of aerial marker spheres to prevent bird collisions. They prefer that spheres be used only in compliance with FAA regulations to mark hazards to aircraft.
- Depending upon the location, aerial marker spheres can be targets for irresponsible shooters.
- The size and number of aerial marker spheres used may result in visual degradation of environments where esthetics are important (tourist areas, scenic mountain views, historic areas, etc.)

SPIRALS

Spirals available in the United States include spiral vibration dampers (SVDs), Bird-Flight™ Diverters (BFDs), and Swan-Flight™ Diverters (SFDs).

Spiral Vibration Damper (SVD)

Spiral vibration dampers (SVDs) are pre-formed PVC spirals that were designed to reduce line vibration (aeolian vibration), but were also found to increase line visibility and

to reduce collision risk. Aeolian vibration is induced by low-velocity winds of 4.8 to 12.9 km per hour (3 to 8 mi per hour)

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FIGURE 6.10: Spiral vibration dampers act to reduce line vibration, and they also make power lines more visible to birds.

(Figure 6.10). SVDs change the airfoil of a power line under normal and icing conditions to reduce conductor gallop.

SVDs are available in various lengths, ranging from 112 to 165 cm (46 to 65 in), to fit different wire sizes. Standard SVDs are made of solid thermal plastic. They are available in gray or yellow with UV stabilizers that help the devices retain color, flexibility, and durability when exposed to extreme sunlight and weather conditions. They are also available in a yellow, high-impact PVC.

SVDs are often placed about 3 m (9.8 ft) apart on transmission line shield wires (Table 6.5 and Table 6.6). For distribution lines, to prevent interphase contact and increase line visibility, SVDs should be staggered so that every third one is on an alternate phase conductor.

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TABLE 6.5: Spacing and positioning for spiral vibration dampers (SVDs).*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies†
Spiral Vibration Damper (SVD)	2.7 m (9 ft) on the shield wire. On distribution phase conductors, stagger SVDs to prevent interphase contact. (APLIC)	–	3.3 m (10.8 ft) apart (Brown and Drewien 1995)

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions.
† See Table 6.6 for study details and sources.

TABLE 6.6: Representative studies for spiral vibration dampers (SVDs).

Description/Spacing	Location/ Species	Power Line Characteristics	Effectiveness		Reference
			Behavioral Avoidance	Reduction in Collisions	
Yellow spiral vibration dampers, 1.27 cm × 112 to 125 cm (0.5 in × 44 to 49.2 in) / spacing: 3.3 m (10.8 ft)	Colorado/ waterfowl and sandhill cranes	Distribution, 7.2 kV Transmission, 69 to 115 kV	Reacted sooner and changed flight patterns in marked versus unmarked lines	Reduced mortality by 60%	Brown and Drewien 1995

Considerations for Spiral Vibration Dampers

- When installed on triangularly spaced distribution lines, SVDs should be staggered on all three phase conductors. Despite their light weight, if they are only applied on the top or ridge phase conductor, wind or ice may make the top phase sag, which may cause interphase contact.
- When installed on a single shield wire, given the relatively light weight of SVDs, the rate of coverage, and the distance between the shield wire and the phase conductors, line sag on the shield wire would rarely present an issue.
- SVDs are not recommended for use on transmission phase conductors (AC or DC) with voltage ≥230 kV because of corona effects (see *Corona Effects*, page 84). However, future design materials may address this issue.
- Installation of SVDs is moderately labor intensive on lower-height distribution lines and more so on transmission lines that range from 15.2 to 59 m (50 to 195 ft) above the ground.

FIGURE 6.11: The Bird-Flight™ Diverter is a spiral device made of PVC.

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Bird-Flight™ Diverter (BFD)

BFDs are preformed, increasing-radius spirals made of extruded, high-impact PVC (Figure 6.11 and Figure 6.12). One end of the spiral grips the power line while the radius quickly increases toward the other end of the spiral. BFDs were developed in Great Britain and have been used in Europe since the early 1970s and more recently in the United States and South Africa. They are also called "small pigtails" in South Africa (Eskom Transmission 2009). Since 1994, more designs have become available.

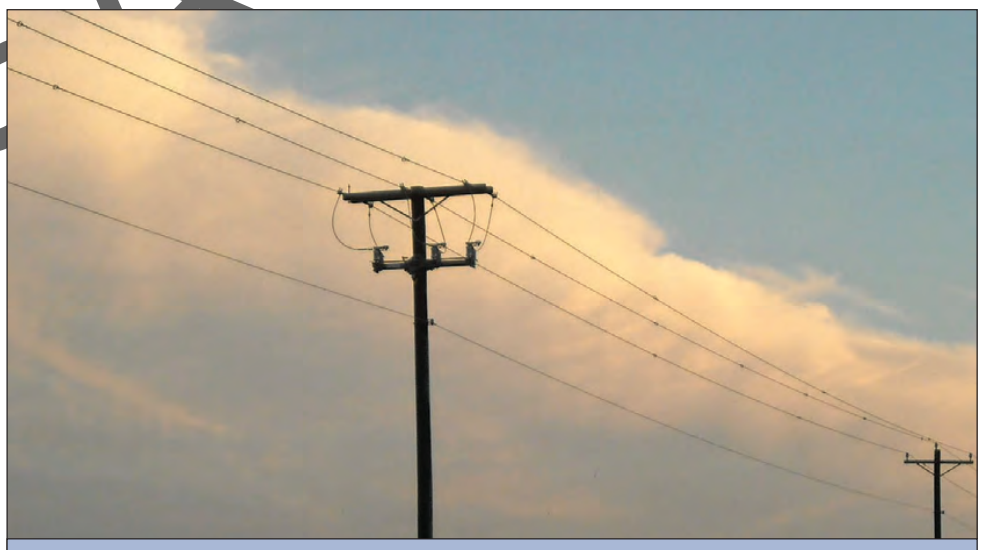

FIGURE 6.12: Bird-Flight™ Diverters installed on a distribution line.

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SAMPLE

TABLE 6.7: Spacing and positioning for Bird-Flight Diverters (BFDs).*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies†
Bird-Flight Diverter (BFD)	4.9 to 15.2 m (16 to 50 ft) (APLIC) 10 m (32.8 ft), staggered (Eskom) 21 m (68.9 ft) (Iberdrola)	4.6 m (15 ft) apart depending upon local conditions (Preformed Line Products)	5 m (16.4 ft), 10 m (32.8 ft), 15 m (49.2 ft), and 20 m (65.6 ft). Some studies staggered devices on parallel lines to increase or maintain visual density and to reduce and distribute loading equally.

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions. Manufacturer recommendations are the closest spacing that would be required.
† See Table 6.8 for study details and sources.

Various sizes of BFDs are available to fit different line diameters. The lengths can range from 17.8 to 59.7 cm (7 to 23.5 in). The diameter of the spiral at the large end of the diverter ranges from 3.8 to 12.7 cm (1.5 to 5 in). UV stabilizers are added to the PVC to protect BFDs from sunlight. They are produced in a variety of colors, such as yellow, orange, red, green, brown, gray, and black, and some glow.

Spacing recommendations for BFDs vary (Table 6.7 and Table 6.8). In the Netherlands, wires have been marked in bird-collision zones using 10 cm (3.9 in) spirals at 5 m (16.4 ft) intervals. This reportedly has an average mortality reduction of approximately 90% (Koops 1993). For the United States, one manufacturer (Preformed™ Line Products) recommends 4.6 m (15 ft) spacing intervals depending upon local conditions. In studies conducted in the Netherlands, marking devices have been staggered on parallel shield wires so that the line marking devices appear to be 5 m (16.4 ft) apart (Koops 1979; Koops and de Jong 1982; Koops 1987). On each shield wire, however, they are 10 m (32.8 ft) apart. Staggering line marking devices on alternate lines reduces the loading that a single marked line would otherwise have to bear.

Considerations for Bird-Flight Diverters

- BFDs add some aeolian vibration stabilization since their profile changes the airflow over the line.
- BFDs are not recommended for use on transmission line phase conductors (AC or DC) with voltage ≥230 kV because of corona effects (see *Corona Effects*, page 84). However, future design materials may address this issue.
- Eskom has used BFDs in South Africa for years with no reports of mechanical failure (van Rooyen 2000) although some red PVC devices have faded.
- BFD installation is labor intensive whether by bucket truck, boat, helicopter, or line trolley. Robotic installation devices are being developed.

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TABLE 6.8: Representative studies for Bird-Flight Diverters (BFDs).

Description/Spacing	Location/ Species	Power Line Characteristics	Effectiveness		Reference
			Behavioral Avoidance	Reduction in Collisions	
White BFD, 5 cm (1.9 in) diameter/ spacing: 5 m, 10 m, and 20 m (16.5, 32.8, and 65.6 ft) White BFD, 10 cm (3.9 in) diameter/spacing: 15 m (49.2 ft)	Netherlands/ various species	–	–	When spaced at 20 m (32.8 ft), they reduced collisions by 58%. Total mortality was reduced by 57% to 89%, depending upon the size and spacing	Koops 1987; Koops and de Jong 1982; Koops 1993 (cited in Janss and Ferrer 1998)
Red spiral BFD, 30 cm (11.8 in) maximum diameter, 1 m (3.3 ft) long/spacing:10 m (32.8 ft)	Spain/various species including cranes and bustards	Transmission, 380 kV with dual shield wires	61% reduction in birds crossing the lines, more birds flying over, fewer flying through lines	60% reduction in collisions	Alonso et al. 1994
Yellow and gray BFD	Indiana/ waterfowl	Transmission, 345 kV		Reduced bird collision by 73.3% compared to unmarked lines	Crowder 2000
Yellow PVC BFD spirals, 25 cm (9.8 in) diameter, 80 cm (31.5 in) length /spacing: 10 m (32.3 ft); staggered on both shield wires	Colombia/ night flying rallids, herons, and ducks	Transmission, 500 kV	Birds detected BFD line at a greater distance than unmarked line, fewer flew at conductor height	Reduction in collision frequency for marked versus unmarked lines, but collision rate was highly variable regardless of line condition	De La Zerda and Roselli 2003
Yellow and gray BFD/ spacing: 4.6 m (15 ft); staggered on 3 phase conductors	California/ waterfowl	Distribution	Birds exhibited greater reactive distances	Reduced waterfowl collisions, but not coot collisions (coots fly at night)	Ventana Wildlife Society 2009
Small spirals, 10 cm (3.9 in) diameter, 24 cm (9.4 in) long/ spacing was not provided	Spain/various species including bustards, storks, and doves	Distribution and transmission	–	Reduced collisions overall after line marking (9.6%)	Barrientos et al. 2012

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Swan-Flight™ Diverter (SFD)

The SFD is another spiral design, which is also called a Double Loop Bird Flight Diverter (Figure 6.13 and Figure 6.14). SFDs have two gripping ends and a central spiral with a larger diameter.

Sizes are available to fit different conductor diameters. The lengths can range from 50.8 to 116.8 cm (20 to 46 in). The diameter of the central spiral can range from 17.8 to 20.3 cm (7 to 8 in). SFDs are extruded in yellow and gray high-impact PVC with UV

FIGURE 6.13: The Swan-Flight™ Diverter is a double-ended spiral device.

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FIGURE 6.14: Swan-Flight™ Diverters installed on the phase conductors of a distribution line.

stabilization. Gray is the standard color but SFDs are available in: black, blue, brown, green, purple, red, orange, and pink, and some that glow.

Spacing depends upon local conditions (Table 6.9 and Table 6.10).

Considerations for Swan-Flight Diverters

- SFDs can be used on the shield wires of high-voltage lines.
- SFDs on the line add some aeolian vibration stabilization since their profile changes the airflow over the line.
- SFDs are not recommended for use on transmission line phase conductors (AC or DC) with voltages ≥230 kV because of corona effects (see *Corona Effects*, page 84). However, future design materials may address this issue.
- Wind and ice loading should be considered, as these have been a concern in Canada and the northern United States (N. Heck, pers. comm.).
- Colors of some SFDs may fade.
- Installation is labor intensive whether done from bucket truck, boat, helicopter, or line trolley. Robotic installation devices are also being developed.

TABLE 6.9: Spacing and positioning for Swan-Flight Diverters (SFDs).*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies†
Swan-Flight Diverter (SFD)	15.2 m (50 ft) (APLIC) 21 m (68.9 ft) (Iberdrola)	Spacing is not critical and will depend upon local conditions. The recommended ranges are 10 to 15 m (32.8 to 49.2 ft) (Preformed Line Products) up to 30 m (98.4 ft) (FCI)	5 m (16.4 ft), 10 m (32.8 ft), and 15 m (49.2 ft). Some studies staggered devices on parallel lines to increase visual density and distribute loading equally.

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions.
† See Table 6.10 for study details and sources.

SAMPLE

TABLE 6.10: Representative studies for Swan-Flight Diverters (SFDs).

Description/Spacing	Location/ Species	Power Line Characteristics	Effectiveness		Reference
			Behavioral Avoidance	Reduction in Collisions	
White spirals (SFD), 30 cm (11.8 in) diameter/ spacing: 10 m (32.8 ft)	Spain/various species including cranes, storks, and bustards	Various size distribution and transmission lines	–	Effective at reducing collisions	Roig-Soles and Navazo-Lopez 1997
White polypropylene spirals, 1 m (3.3 ft) long, 30 cm (11.8 in) maximum diameter/spacing: 10 m (32.8 ft); staggered on 2 shield wires for a visual effect of 5-m (16.4-ft) intervals	Spain/cranes	Transmission, 380 kV and 132 kV Distribution, 13 kV	–	Small sample size did not permit specific species evaluation. Reduced mortality for common cranes. The reduction in actual versus predicted mortality for all birds was 81%	Janss and Ferrer 1998
Yellow and gray SFD/spacing was not provided	Indiana/ waterfowl	Transmission, 345 kV	–	Reduced collisions by 37.5% on marked lines compared to unmarked lines	Crowder 2000
Yellow SFD/ spacing: 15.2 m (50 ft); staggered on parallel wires for a visual effect of 7.6-m (25-ft) spacing	Wisconsin/ trumpeter swans (*Cygnus buccinator*)	Distribution, 23.9 kV	–	Eliminated collisions completely	Rasmussen 2001, cited in Hunting 2002
Red SFD, 32 cm (12.6 in) for the gripping section and 17.5 cm (6.9 in) for the outside diameter of the central spiral/spacing: 5-m (16.4-ft) intervals on shield wire	England/ mute swans (*Cygnus olor*)	Transmission, 132 kV	–	Reduced collisions	Frost 2008
Gray SFD/ spacing: 4.6 m (15 ft); staggered on 3 phase conductors	California/ waterfowl	Distribution	Birds exhibited greater reactive distances	Reduced waterfowl collisions, but not coot collisions (coots fly at night)	Ventana Wildlife Society 2009
Large spirals, 35 cm (13.8 in) diameter, 1 m (3.3 ft) long/ spacing was not provided	Spain/various species including bustards, storks, and doves	Distribution and transmission	–	Reduced collisions overall after line marking (9.6%)	Barrientos et al. 2012

SAMPLE

ESKOM 2009

FIGURE 6.15: Examples of suspended devices (swinging and fixed).

SUSPENDED DEVICES (SWINGING, FLAPPING, AND FIXED)

There are several types of suspended devices including general designs and branded designs (e.g., FireFly™ and BirdMark BM-AG), which are discussed separately on page 95 and page 96. They have a clamp that attaches to the power line so that the device can move in the wind. Some are designed to swing, flap, and spin, while others, for use in high wind locations, are nearly immobile but do allow some motion. Some have reflective and glow-in-the-dark properties.

General Designs

Suspended devices have a polycarbonate, UV stabilized, plastic flapper (swinging or fixed) connected to a clamp that attaches to the power line (Figure 6.15). The movement and reflectivity of the device enhances the visibility of the line. Suspended devices are available in many colors and shapes with panels that reflect visible and UV light and glow. They can be attached to distribution phase conductors up to 40 kV and to shield wires up to a diameter of 1.9 cm (0.75 in) (Table 6.11 and Table 6.12).

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TABLE 6.11: Spacing and positioning for general designs of suspended devices.*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies†
Swinging or fixed device	5 m (16.4 ft), staggered (Eskom)	Staggering devices on parallel lines is recommended. The general spacing rule is 10 to 15 m (32.8 to 49.2 ft) (Preformed Line Products).	–

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions.

TABLE 6.12: Representative studies for general designs of suspended devices.

Description/Spacing	Location/ Species	Power Line Characteristics	Effectiveness		Reference
			Behavioral Avoidance	Reduction in Collisions	
Swinging or fixed device (specifications and spacing not provided)	South Africa/ bustards and cranes	Distribution, 22 kV Transmission, up to 440 kV	– –	Reduced collisions More effective than the BFD	van Rooyen 2000; Anderson 2001; McCann 2001
Yellow fiberglass swinging plate, 30.5 x 30.5 cm, (12 × 12 in) with a black stripe/ spacing: 20 to 30 m (65.6 to 98.4 ft) on shield wires or center phase conductor	Colorado/ sandhill cranes and waterfowl	Distribution, 7.2 kV Transmission, 69 kV to 115 kV	Birds reacted earlier and flew higher over marked lines than unmarked lines	63% reduction in mortality rates overall, but there was considerable seasonal variation. Over 30% of collisions in fall occurred at night.	Brown and Drewien 1995

FireFly™

There are several types of FireFlys, two of which (the FireFly FF and the FireFly HW) are designed as suspended devices (Figure 6.16). FireFlys have a strong spring-loaded clamp that attaches to the line so that the device can swing. The device increases the line profile slightly, but its motion and reflectivity attract attention and alert birds of the line's presence.

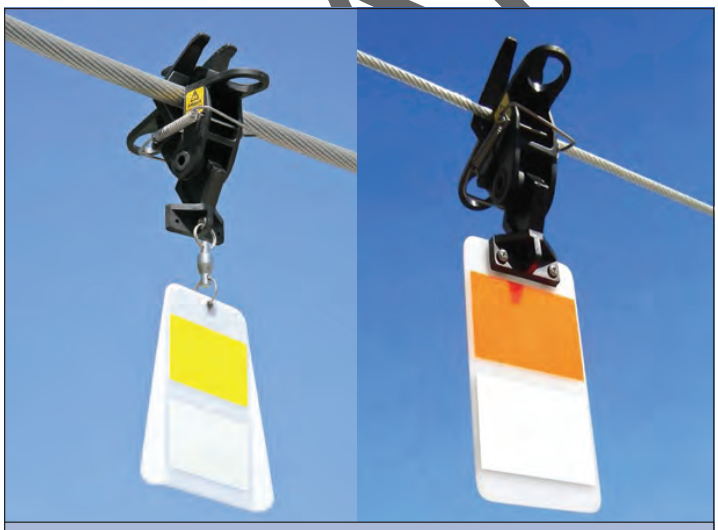

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FIGURE 6.16: The FireFly™ FF (left) has a swinging tag for use in light winds and the FireFly™ HW (right) has a fixed tag to withstand higher, sustained winds.

The FireFly FF has an acrylic plastic tag that measures 9 cm × 15 cm (3.5 in × 6 in), is 3 mm (0.13 in) thick, and is covered with yellow and orange reflective tape and photo-reactive coatings. They are UV light stabilized and constructed to be highly reflective during the day. According to the manufacturer they glow for up to 10 to 12 hours after sunset. They are attached to the clamp by swivels so they swing and spin in the wind.

The FireFly HW is similar in size to the FireFly FF but the HW model's plastic tag does not swivel and is designed to withstand higher, sustained winds. The manufacturer claims similar effectiveness. Results from installation in a high raptor use area on a new power line in central California have shown these devices to be effective without any damage to the line or failure of the devices (M. Schriner, pers. comm.).

FireFlys have been attached 4.6 to 15.2 m (15 to 50 ft) apart. For lines with parallel shield wires, they can be staggered so that the device density appears greater, e.g., when spaced at 12.2 m (40 ft) on each shield wire and staggered, they appear to be 6.1 m (20 ft) apart (Table 6.13 and Table 6.14).

SAMPLE

TABLE 6.13: Spacing and positioning for FireFlys.*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies†
FireFly™	15.2 m (50 ft) spacing, staggered on alternating wires (PacifiCorp)	Recommendations depend on the tower height: 4.6 m (15 ft) apart for towers less than 30.5 m (100 ft) and 9.1 m (30 ft) apart for towers that are greater than 30.5 m (100 ft) tall (Birdbusters).	5 to 12 m (16.4 to 39.3 ft) apart. Some studies staggered devices on parallel lines to either increase visual density or distribute loading equally.

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions.
† See Table 6.14 for study details and sources.

TABLE 6.14: Representative studies for FireFlys.

Description/Spacing	Location/ Species	Power Line Characteristics	Effectiveness		Reference
			Behavioral Avoidance	Reduction in Collisions	
FireFly™, 9 cm × 15 cm (3.5 in × 6 in), 3 mm (0.13 in) thick, luminescent strip, spinning swivel, contrasting reflective colors on opposite sides/spacing: 5 m (16.4 ft); staggered on conductors	California/ sandhill crane, song birds, other species	Distribution, 12 kV	No changes in flight height or reaction distance	60% reduction in collision frequency on marked lines, collision frequency also decreased on adjacent spans	Yee 2008
FireFly™, acrylic plastic tag measures 9 cm × 15 cm (3.5 in × 6 in), 3 mm (0.13 in) thick, yellow and orange reflective tape and photo-reactive coatings/ spacing: 12-m (39.3-ft) intervals	Nebraska/ sandhill cranes	Transmission, 69 kV	Cranes reacted more quickly (mainly by gradually gaining altitude) to avoid the marked line than they did to unmarked lines	Reduced collisions by half	Murphy et al. 2009

SAMPLE

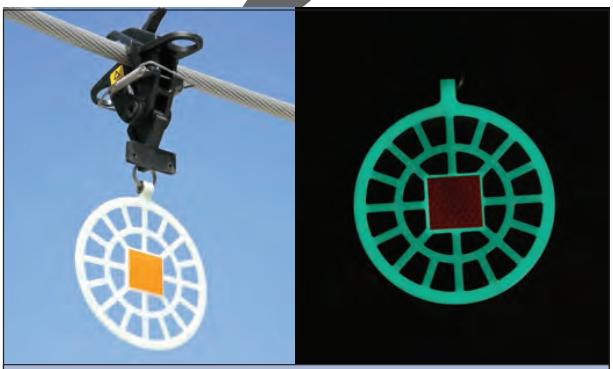

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FIGURE 6.17: BirdMark BM-AG (After Glow) in daylight (left) and darkness (right).

BirdMark BM-AG (After Glow)

The BirdMark BM-AG (After Glow) has a perforated swinging disk that spins and flutters (Figure 6.17). This device is 29.21 cm (11.5 in) long with a 13.33 cm (5.25 in) diameter disk with a reflective center. The BirdMark BM-AG is designed with a strong spring-loaded clamp that attaches to wires up to a diameter of 6.4 cm (2.5 in). The reflective disks glow for up to 10 hours after sunset and are available in orange, white, and red.

The manufacturer recommends 4.6 m (15 ft) spacing (Table 6.15). The movement of the device adds to the visibility of the line.

TABLE 6.15: Spacing and positioning for BirdMark BM-AG.*

Device	Utility Industry Practices	Manufacturer Recommendations	Spacing Lengths Used in Experimental Studies
BirdMark BM-AG	–	4.6 m (15 ft) (P&R Technologies)	No scientific studies on the BirdMark BM-AG were found.

* Actual spacing depends on engineering requirements, manufacturer specifications, species involved, and site-specific conditions.

Considerations for Suspended Devices

- In some of the earlier versions, there were problems with the device shifting (van Rooyen 2000).
- Depending upon the location, suspended devices can be targets for irresponsible shooters.
- The devices can be installed and removed from the ground or bucket truck with a hot stick. Two people are required for installation unless a special tool is used; homemade tools have worked better than some manufactured tools (S. Liguori, pers. comm.). New manufactured tools are being made and tested.
- Corona effects can occur depending upon the voltage (see *Corona Effects*, page 84).
- Installation cost increases with line height and in areas that are difficult to access such as river and lake crossings.
- Swivels have failed prematurely in high wind locations.

DEVICES AVAILABLE IN OTHER COUNTRIES

The following devices are not distributed in the United States at this time (2012).

Baliza Avifauna

The Baliza Avifauna is manufactured in Spain by Saprem. It is a variation of hanging strips that consists of two black neoprene crossed bands (measuring 6 cm × 28 cm [2.4 in × 11 in]). Some versions have a phosphorescent stripe.

Janss and Ferrer (1998) describe a similar device (with crossed bands measuring 5 cm × 35 cm [1.9 in × 13.8 in]) that was staggered on the conductors every 24 m (78.7 ft) (a visual effect of 12 m [39.3 ft] intervals). The device consisted of two black neoprene crossed bands slightly shorter than the com-

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FIGURE 6.18: Hanging strips of neoprene, such as this Spanish-made Baliza Avifauna, are being used as line marking devices in Europe and South Africa.

© SAPREM

FIGURE 6.19: Baliza Avifauna installed on a power line in Europe.

© ETIENNE FOLLET/RTE

FIGURE 6.20: The Avifaune Spiral is commonly used in France and other parts of Europe.

© DR/RTE

FIGURE 6.21: Avifaune Spirals installed.

© MACE TECHNOLOGIES

FIGURE 6.22: The Mace Bird Lite is a spiral device with a central fluorescent tube that is illuminated by the ambient electrical field.

mercially available strips. Janss and Ferrer (1998) found the device reduced collisions by 76% on transmission (380 kV and 132 kV) and distribution (13 kV) lines. The device pictured here is widely used in Europe and South Africa.

Avifaune Spiral

The Avifaune Spiral is used in France and other parts of Europe. These are preformed PVC similar to the SFDs described previously. Avifaune Spirals are 91 cm (36 in) long and have two 36-cm (14-in) spirals in the middle. They are produced in two UV light protected colors: red and white. French researchers recommend alternating the colors. Raevel and Tombal (1991) indicate that the color combination is effective in variable light conditions on transmission lines. Avifaune Spirals have been used on phase conductors and shield wires with a recommended spacing of 7 to 10 m (23 to 32.8 ft).

Mace Bird Lite

The Mace Bird Lite is a spiral vibration damper with a fluorescent light attached inside a plastic tube. The light is energized by a phase conductor's electrical field and can be seen at night. These were designed specifically for 132-kV lines, but it should be possible to use them with other voltages. Although no precise scientific data are available on its effectiveness, this technology has been successfully used in Botswana and South Africa (Eskom 2003) in reducing flamingo collisions (Eskom Transmission 2009). The potential issue of the light attracting birds to a line was not addressed.

RIBE Bird Flight Diverter Fittings

RIBE bird flight diverter fittings are available in two versions: a swinging rectangular tag and a series of 10 alternating black-and-white, rigid plastic pieces that swing on a rod attached at both ends to a shield wire or phase conductor.

PREVIOUS VIEW

© RIBE

FIGURE 6.23: The RIBE line marking device is available as a swinging triangular tag or as a series of black-and-white, rigid plastic pieces that swing (pictured).

© INOTEC

FIGURE 6.24: The Inotec BFD 88, a South African device, is a reflective stainless steel sphere reported to be visible from all angles and in low-light conditions.

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According to the manufacturer, results from a three-year field trial on the Bernbrug-Susigke 110-kV line in South Africa showed that these are effective at reducing bird collisions with power lines when compared to lines without diverters. The information suggests that closer spacing (20 m versus 40 m [65.6 ft versus 131.2 ft] apart) is more effective. However no description of the study design nor specific data was provided.

Inotec BFD 88

The Inotec BFD 88 is a relatively new device with characteristics of both suspended devices and spheres. It is a reflective stainless steel sphere, 7 cm (2.8 in) in diameter, attached to a metal spiral, which is attached to the wire. When installed they appear as small metal spheres suspended from the wire.

This device is made of 316-grade stainless steel and is naturally reflective and corrosion resistant. The crimp is made from marine-grade aluminum, a highly durable adhesive, and conductive rubber. According to the manufacturer, the clamp does not come into contact with the phase conductor, so there is no chance of galvanic cell reaction or mechanical damage to the power line. The stainless steel sphere does not sway and cannot touch the power line.

Eskom Transmission (2009) indicates that these metal spheres are visibly superior to colored (red, yellow, white, or black) objects in low light, especially at dawn and dusk when birds are flying between roosting and feeding areas. The spherical shape reflects available light and is claimed to be visible from all directions including above or below the diverter. When viewed during low-light conditions, the device is visible against dark backgrounds such as the ground, trees, or high ground. It is also visible against bright clouds when viewed from below (Eskom Transmission 2009).

The diverter can be attached while a line is energized and installed from the ground with a hot stick. Because of the spherical design, it does not display corona. It was developed in South Africa for use on shield wires and phase conductors up to 88 kV, and no radio interference was detected up to 88 kV.

PLASTIC TUBES

Archibald (1987) reported that yellow plastic tubes placed on power lines near Hokkaido, Japan, in 1982 reduced mortality of red-crowned cranes (*Grus japonensis*). Plastic tubes along with various versions of ribbons, however, are not durable enough for use.

LARGE DIAMETER WIRE

OVERSIZED SHIELD WIRE FOR TRANSMISSION LINES

A limited study compared the use of an oversized shield wire with a conventional shield wire (Brown et al. 1987; Miller 1990). The oversized wire was 2.52 cm (1 in) in diameter, or 2.6 times greater than standard shield wire (0.95 cm [0.4 in]). Researchers found that there was no significant difference between these wires. Other studies have identified the conventional, small-diameter shield wire as the highest risk wire for collisions with transmission lines (e.g., Savereno et al. 1996), which suggests that diameter and distance visibility are factors involved in collision risk. The use of larger-diameter shield wire is considerably more expensive. Though anecdotal reports suggest larger diameter shield wire is effective, studies of its effectiveness are needed before it can be recommended for reducing collision risk.

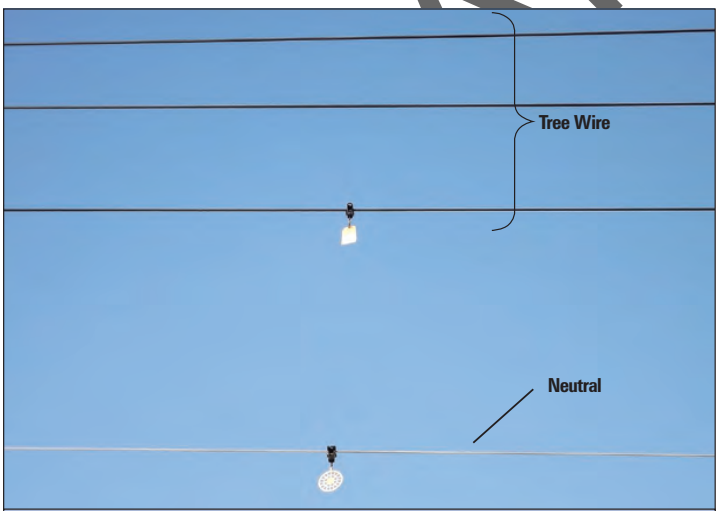

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FIGURE 6.25: Tree wire on all three phases of a distribution line marked with suspended devices.

TREE WIRE TO PREVENT COLLISION-ELECTROCUTIONS ON DISTRIBUTION LINES

Tree wire is a type of insulated phase conductor used on distribution lines to provide protection from momentary contact with tree branches, which would otherwise cause an electric arc (Figure 6.25, Figure 6.26, and Figure 6.27). The insulation is also sufficient[17] to protect birds from collision-electrocutions, which are caused by phase-to-phase contact when large birds, such as eagles and swans, brush phase conductors while flying between them. The electric arc created in collision-electrocutions can kill multiple birds in a flock, even if only one bird makes phase-to-phase contact. Because tree wire can prevent collision-electrocutions, it has even been used in some open areas for rebuilt and new distribution lines (M. Walters, pers. comm.).

Tree wire may also be an effective means of reducing collision incidence because the insulated covering increases the diameter of the wire, making the line more visible. However, no scientific studies were found to verify this.

Retrofitting a line with tree wire is usually only a consideration when outages are caused by tree branches. It would be unusual to retrofit an existing line with tree wire to prevent collisions because line marking devices are more cost effective. However, when a distribution line is being upgraded or a new line is being built, tree wire may be a cost-effective option when used for the center

[17] The insulation on tree wire is not considered protective for human safety.

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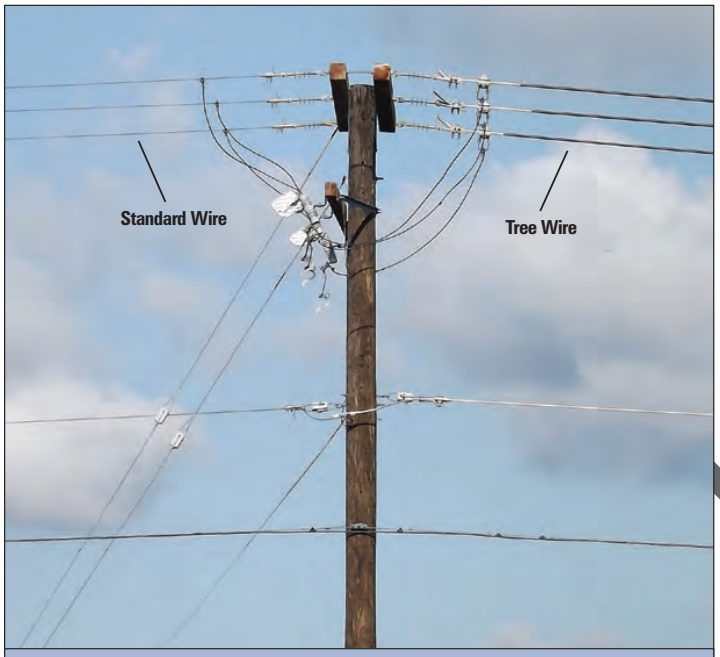

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FIGURE 6.26: Tree wire (right of pole) and standard wire (left of pole) on a distribution line.

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FIGURE 6.27: Collision-electrocutions cause an electrical short, like this one caused by tree branches, and can kill two or three birds in a flock even if only one bird makes phase-to-phase contact.

phase. The difference in cost (2011 $) between tree wire (336ACSR TW= $0.89 per 30.5 cm [12 in]) and standard wire (397KCM = $0.77 per 30.5 cm [12 in]) is approximately $0.12 per 30.5 cm (12 in) or $1,900 per 1.6 km (1 mi) for a standard three-phase distribution feeder. Tree wire is also heavier than standard wire and may require higher class poles, more poles (1 to 2 per 1.6 km [1 mi]), and possibly additional guying. The average lifespan of tree wire is 40 years. The advantages to tree wire are that it reduces the risk of collision-electrocution at mid-span for flying birds, reduces the risk of electrocution for perching birds, and reduces the maintenance requirements usually associated with suspended devices.

Unpublished observations show that tree wire used in conjunction with line marking devices, such as the FireFly™ and/or Bird-Mark BM-AG, is effective at reducing collision-electrocutions and collisions for trumpeter swans (*Cygnus buccinator*), waterfowl, and raptors (M. Walters, pers. comm.). When rebuilding lines already equipped with flight diverters, the diverters are reinstalled on the new tree wire lines. The increased visibility of tree wire reduces the risk, which is further reduced by installing FireFlys (M. Walters, pers. comm.).

In the Chimacum Valley, Washington, from 2000 to 2007, an eight-span lateral line averaged three bird-caused outages per year due to swan and waterfowl collisions, including 10 swan mortalities in 2006 alone. In 2007, the line was modified with tree wire to prevent collision-electrocutions and with FireFlys to reduce collision risk. No swan mortalities or outages have occurred since the line was modified in spite of increasing swan populations and their continued use of this flight corridor. The landowner reported that the swan flight path is much higher over the lines since these modifications were made (M. Walters, pers. comm).

LIVE

At another site in western Washington's Skagit Valley, five swan mortalities occurred on a single-phase line in the winter of 2008–2009, and others had been documented in previous years. The line was rebuilt in a three-phase configuration during the summer of 2009, which included tree wire on the center phase along with alternating FireFly™ and BirdMark BM-AG devices on all three phase conductors. In the following winter season, no mortalities or outages occurred, although swan populations continue to increase. Between 1,000 and 2,000 swans forage in this area throughout the winter (M. Walters, pers. comm.).

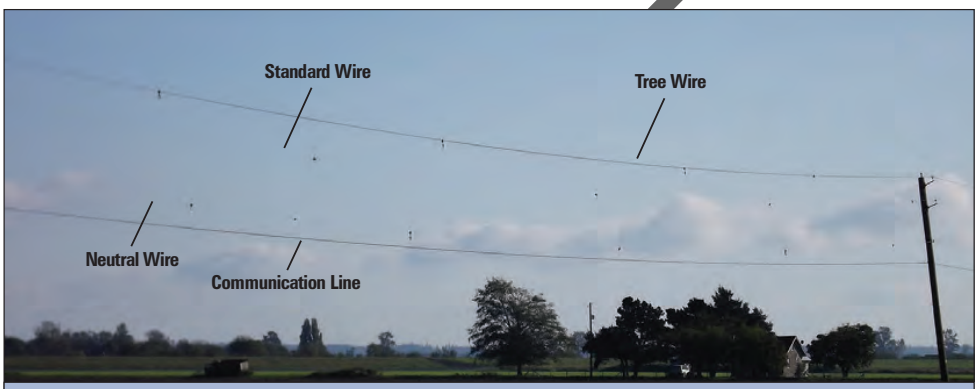

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FIGURE 6.28: Tree wire on the top phase conductor of a two-phase distribution line (vertical configuration) with line marking devices.

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CHAPTER 7

Avian Protection Plans

IN THIS CHAPTER

- Overview of Avian Protection Plans
- Components of an Avian Protection Plan
- Creating and Implementing an Avian Protection Plan

An Avian Protection Plan is a voluntary, utility-specific plan that provides a framework for reducing bird mortalities, documenting utility actions, and improving service reliability. In 2005, the U.S. Fish and Wildlife Service and the Avian Power Line Interaction Committee jointly published Avian Protection Plan Guidelines to provide utilities with resources and guidance for developing Avian Protection Plans. This chapter is based on those guidelines.

OVERVIEW OF AVIAN PROTECTION PLANS

An Avian Protection Plan (APP) is a utility-specific program for reducing the operational and avian risks that result from avian interactions with electric utility facilities. In 2005, the Avian Power Line Interaction Committee (APLIC) and the U.S. Fish and Wildlife Service (USFWS) announced their jointly developed Avian Protection Plan Guidelines (*Guidelines*) that are intended to help utilities manage their avian/power line issues. The *Guidelines* offer resources for developing APPs and provide a toolbox from which utilities may select and tailor APP components to fit their needs. An APP should provide the framework necessary for developing a program to reduce bird mortalities, document utility actions, and improve service reliability. The APP components are summarized in this section. The complete version of the *Guidelines* can be obtained from either the APLIC (www.aplic.org) or USFWS (www.fws.gov) websites.

An APP represents a utility's commitment to reducing its avian impacts. Since they are created by a utility, APPs are more easily modified to address newly developing or unforeseen problems. Despite the fact that APPs are generally initiated by utilities, a cooperative dialog between the utility and the USFWS is encouraged during development and implementation. This sets the tenor for those conversations that will inevitably follow as the APP is implemented and refined over time.

Implementing the *Guidelines* will reduce avian collision and electrocution risks. An APP represents responsible environmental practices to all stakeholders, and a utility that creates an APP to address its specific avian issues can benefit through regulatory compliance, reliability improvements, potential long-term cost savings, and positive recognition from regulators, employees, and customers.

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COMPONENTS OF AN AVIAN PROTECTION PLAN

Although each utility's APP will be different, the overall goal of reducing avian mortality is the same. The *Guidelines* provide a framework along with principles and examples to help a utility craft an APP to best fit its needs. Because of utility-specific circumstances, some of the *Guidelines*' elements may not be applicable. The *Guidelines* present a comprehensive overview of the elements that should be considered in an APP. The APP should also be a "living document" that is modified over time to improve its effectiveness. Some or all of the following elements may be implemented:

- Corporate policy
- Training
- Permit compliance
- Construction design standards
- Nest management
- Avian reporting system
- Risk assessment methodology
- Mortality reduction measures
- Avian enhancement options
- Quality control
- Public awareness
- Key resources

Details on the nature of these elements and how they may be developed by a utility are discussed on the following pages.

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FIGURE 7.1: Utility employee training should include the reasons and methods for reporting bird mortalities, nest management protocols, proper disposal of carcasses, applicable regulations, and the consequences of non-compliance.

CORPORATE POLICY

An APP usually includes a statement that balances the company's commitment to minimizing its impact on migratory birds, complying with bird-protection regulations, and providing reliable, cost-effective electrical service. To do this, it will comply with all necessary permits, monitor avian mortality incidents, and make reasonable efforts to construct and alter infrastructure to reduce the incidence of avian mortality.

TRAINING

Training is an integral component of an APP. Workshops and short courses on avian/power line interactions are provided by APLIC (www.aplic.org) and Edison Electric Institute (EEI) (www.eei.org). A two-hour overview of avian electrocutions and collisions intended for training use is also available to APLIC members through the APLIC website as part of the APP toolbox. Each company will have its own approach to training. All appropriate utility personnel, including managers, supervisors, line crews, engineering, dispatch, design personnel, and vegetation management personnel should be trained in avian issues. This training should encompass the reasons, needs, and methods for reporting avian mortalities, following nest management protocols, disposing of carcasses, complying with applicable

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regulations, and understanding the potential consequences of non-compliance. Supplemental training also may be appropriate when there are changes in regulations, personnel, permit conditions, construction standards, bird protection materials, or internal policies.

PERMIT COMPLIANCE

Each utility developing an APP should familiarize itself with the different avian regulations and permit types and should work with wildlife agencies to determine whether permits are required for operational activities that may affect protected avian species (see Chapter 3). An APP should discuss how this is done and identify company permits. Particular attention should be given to activities that may require special purpose or related permits, including but not limited to nest relocation, temporary possession, depredation, salvage or disposal, scientific collection, and miscellaneous. State permits may also be required to manage protected bird nests or for temporary possession of nests, birds, or their parts.

CONSTRUCTION DESIGN STANDARDS

To improve system reliability, avian interactions should be considered when siting and designing new facilities and when operating and maintaining existing facilities. For those reasons the accepted standards for both new construction and retrofitting for risk minimization should be included in an APP. Companies can either rely upon the recommendations in APLIC documents for electrocutions and collisions or develop their own standards that meet or exceed these guidelines.

An APP may indicate that all new or rebuilt lines in identified avian-use areas or potential problem areas be built to current standards for minimizing electrocutions and collisions. Employing avian-safe construction standards in such areas will reduce future legal and public relations problems and will enhance service reliability.

NEST MANAGEMENT

An APP may include procedures for managing nests on utility structures and in power line rights-of-way (ROW). This could include procedures for handling problem nests (ones that need to be relocated or removed) as well as for creating safe nest sites. These procedures should be explained to company employees during training to ensure uniform treatment of avian nest issues and compliance with regulations or permits related to nest management. For more detailed guidance regarding nest management, see *Suggested Practices for Avian Protection on Power Lines* (APLIC 2006).

AVIAN REPORTING SYSTEM

An avian reporting system is used for documenting bird injuries, fatalities, and nest management activities. This system should be described in the APP and designed to meet the needs of the utility and applicable avian permit reporting requirements. The reporting system should be compatible with a utility's other data management and analysis programs so this information can be effectively collected and recorded. The system could be based on paper forms or may be an internal web-based program. The information collected should be used to help a utility conduct risk assessments of avian problem areas and high risk structures or lines. To protect birds and minimize outages, these data can be prioritized for corrective actions. Avian information collected by a utility should be maintained internally. Reporting is required as a condition of the USFWS permit for direct *take* of birds or their nests (see Chapter 3).

The USFWS Office of Law Enforcement also maintains a voluntary, internet-based Bird Fatality/Injury Reporting Program.[18]

[18] The USFWS (2012) has been internally referring to this as the Bird Information and Mortality Reporting System. The title on the web page may assume this title as well (A. Manville pers. comm.).

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This program provides a clearinghouse of useful information for the electric utility industry to mitigate the impacts of energy delivery systems on birds and to address specific bird/power line problems on an incident-specific basis (USFWS 2009b). This database was designed to collect information about bird collisions and electrocutions to help with preventing future bird/power line incidents. It is also intended for utilities to see which structures pose a greater risk than others and under what conditions they occur. Utilities can establish a password-protected account with this voluntary program, and privacy and confidentiality are protected including several exemptions from the Freedom of Information Act (FOIA). The data collected include the characteristics of the fatality or injury, location, configuration of the equipment, environmental conditions, etc. To date (2012), at least 33 electric utilities have been voluntarily reporting through this program.

RISK ASSESSMENT METHODOLOGY

A utility can cost-effectively reduce avian mortalities by focusing its efforts on the areas of greatest risk. Therefore, an APP should include a method for evaluating and prioritizing the risks that a company's operations pose to migratory birds. A risk assessment will often begin with a review of available data that address areas of high avian use, avian mortality, problem nests, established flyways, migration corridors, concentration and staging areas, other preferred habitats, prey populations, perch availability, effectiveness of existing procedures, remedial actions, and other factors that can increase avian interactions with utility facilities. The avian reporting system discussed in the previous section is an integral component of this risk assessment, as is the use of avian experts, birders, and biologists who can provide additional information on avian distribution. A risk assessment can be used to develop models that will enable a company to use biological and electrical design information to choose an optimal route during corridor and ROW siting and to prioritize existing poles and lines most in need of modification. A risk assessment may also provide data about the various causes of avian mortality as well as the benefits birds receive from utility structures. For more discussion on avian risk assessment, see Chapter 5.

MORTALITY REDUCTION MEASURES

As a part of an APP, a mortality reduction process is described. A utility can use the results of an avian risk assessment to focus its efforts on areas of concern, ensure that its responses are not out of proportion to the risks presented to protected birds, and determine whether avian mortality reduction plans need to be implemented.

Mortality reduction plans may use strategies that include preventive, reactive, and proactive measures that focus on issues, risks, and reliability commitments facing a utility. The following are examples of how this multi-faceted approach may be used.

- **Preventive**: Construct all new or rebuilt lines in high avian-use areas to avian-safe standards. Apply collision minimization measures for new construction in high risk areas. Ensure that the APP is in compliance with applicable laws, regulations, and permits.
- **Reactive**: Document bird mortalities and problem nests, conduct assessment of problems, and apply remedial measures where appropriate. Notify resource agencies in accordance with the utility's permits and policies.
- **Proactive**: Provide resources and training to improve employees' knowledge and awareness. Partner with organizations that conduct research on effects of bird interactions with power lines. Evaluate risks of existing lines in high avian-use areas and prioritize structures or lines for retrofitting or mitigation according to their risk level.

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A successful APP and mortality reduction plan requires management support as well as the following:

- Assessment of facilities to identify risks
- Allocation of resources
- Standards for new or retrofit construction
- Budget for operation and maintenance and capital investment
- System for tracking remedial actions and associated costs
- Timely implementation of remedial measures
- Positive working relationships with agencies

An APP should be reviewed annually in the context of risk assessment and modified as appropriate, ideally with wildlife agency input.

AVIAN ENHANCEMENT OPTIONS

In addition to reducing avian mortality risk, an APP also may include descriptions of opportunities for a utility to enhance avian populations or habitat. These opportunities may include installing nest platforms, managing habitats to benefit migratory birds, or working with agencies or organizations in these efforts. Where feasible, new ideas and methods for protecting migratory birds should be encouraged and explored.

There are also opportunities to collaborate with agencies or organizations and to educate the public about the company's APP and its partnerships. USFWS and state wildlife agencies, as well as other experts, can be consulted for recommendations on habitat enhancement projects. Nest box construction, maintenance, and monitoring can be done in conjunction with volunteers, such as Boy Scouts, Girl Scouts, and avian/wildlife conservation organizations.

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FIGURE 7.2: An Avian Protection Plan may include opportunities to enhance avian populations or habitat with nesting structures, habitat restoration, or other projects.

QUALITY CONTROL

A quality control mechanism can and should be incorporated into an APP to evaluate the effectiveness of a company's avian protection procedures. Some examples of quality control include the following:

- Effectiveness of remedial actions in reducing avian mortality
- Effectiveness of avian protection devices as well as their ease of application and durability
- Mortality reporting procedures to ensure that discoveries of avian mortalities are properly documented
- Response to avian mortalities to ensure that appropriate and timely actions are taken
- Compliance with company policy to ensure that personnel are consistently following company procedures for avian-safe construction, mortality reporting, nest management, training, etc.
- Public and agency feedback and opinions on system reliability and avian protection

The quality control component of an APP is a continuous process that is used to ensure that a company's APP is accomplishing what

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it is intended to do. Information gathered during assessments of existing practices should be used to improve the effectiveness and timeliness of avian protection efforts, which, in turn, can help to reduce costs associated with such efforts.

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FIGURE 7.3: Raising public awareness about avian collisions and the utility's commitment to avian protection can increase support for an Avian Protection Plan.

PUBLIC AWARENESS

An APP may include a method for educating the public about avian collision issues, the company's avian protection program, and its successes in avian protection. A public awareness program can be an integral part of an APP and can be used to enhance public awareness and support for a company's APP. Public participation allows stakeholders such as government agencies, tribes, non-profit organizations, wildlife rehabilitators, and other interested parties an opportunity to provide input to the decision-making process, enabling all parties to work openly and collaboratively towards recommendations that can be effectively implemented. This collaboration often leads to improved relationships within the community and to more efficient and positive projects (see Chapter 5). The relationships developed through this process may also encourage the public to report bird mortalities and encourage them to seek assistance for birds that have been injured in power line-related accidents.

Communicating an APP can be accomplished through a variety of public outreach tools, including fact sheets, newsletters, brochures, videos, websites, public workshops, short courses, special training sessions, and speaker bureau presentations. These tools can also be used to record the success of an APP, thereby documenting the utility and electric industry's efforts to reduce avian mortalities. The goal of these outreach efforts is to convey to the public that electric utilities are responsible environmental stewards working cooperatively with wildlife agencies towards reducing avian mortalities while continuing to provide safe, reliable, and affordable electricity to their customers.

Many utilities have examples of their environmental stewardship and of the innovative ways they have reduced environmental impacts through their business decisions. A company's efforts to minimize avian mortalities should

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be shared with the public and resource agencies. For more information, see *Public Participation* in Chapter 5.

KEY RESOURCES

An APP should identify the key resources that address avian protection issues. Key resources include utility personnel and external contacts. This would include a list of experts who may be called upon to help resolve avian-caused problems. Experts could include company specialists, consultants, state and federal resource agents, university faculty, or other biologists. Internal personnel may include representatives from environmental, engineering, operations and maintenance, standards, procurement, outage management, etc. Engineers may find that company personnel such as environmental specialists (or biologists) can help find creative solutions to avian interaction problems. An understanding of avian behavior can also influence how and when avian protection should be provided. An APP that connects biologists with utility decision-makers may reduce bird mortality and improve system reliability.

Members of organizations like APLIC can help with workshops, materials, and contacts. External resources may include biologists and law enforcement agents from wildlife agencies, avian specialists from NGOs or universities, wildlife rehabilitators, and industry consultants. Utility industry resources include APLIC, EEI, Electric Power Research Institute, Institute of Electrical and Electronics Engineers, National Rural Electric Cooperative Association, and the Rural Utilities Service. Contact information and websites for a number of resources are available in the *Guidelines* (see www.aplic.org).

CREATING AND IMPLEMENTING AN AVIAN PROTECTION PLAN

Integrating an APP into an electric utility's operations will help the utility meet demands for reliable, cost-efficient, and environmentally compatible power delivery. A utility that creates and manages an APP will quickly become familiar with the avian-related science, engineering, and laws. It will also need to satisfy utility employees, utility customers, investors, and other stakeholders.

The case of creating and implementing an APP will depend on a utility's size, the location of its transmission and distribution system, the range of avian species in the service area, and the frequency of bird/power line interactions. The extent of bird/power line interactions may not be realized until several years into a fully implemented reporting program. Thus, APP implementation and operation is a long-term commitment and a process of continual evaluation and improvement.

Depending on the company's culture, the rate of adoption may vary. An APP may be the first species-oriented environmental compliance initiative to which utility employees are exposed. High-profile endorsements by corporate officers and managers can facilitate a program's implementation. Some larger utilities have effectively linked APP compliance with financial incentives, similar to more common budget, schedule, and safety incentives. Compliance with an APP will reduce utility costs in the long term through improved reliability and reduced regulatory risk.

Creating and implementing an APP will be more successful if all the affected departments within the utility also support it. An effective way to build a broad consensus during APP preparation is to form a team within the utility that includes representatives from standards, engineering, environmental services, vegetation management, construction, operations and maintenance, public relations, customer service, and other departments that will be impacted by the APP. Considerable input and assistance from team members are needed to understand how APP implementation will

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FIGURE 7.4: Integrating an Avian Protection Plan into an electric utility's operations will help the utility meet demands for reliable, cost-efficient, and environmentally compatible power delivery while protecting and enhancing bird populations.

best fit the operations of each department. Solutions to reduce avian mortality can be developed that are responsive to the work requirements of each functional unit. In this manner, individuals from each department will feel invested in the mortality reduction solutions they helped develop and will have an interest in assuring APP effectiveness.

Beyond developing and communicating a corporate APP policy, the most important component of an APP is a consistent and mandatory reporting process. An electronic or paper form of documenting bird/power line conflicts (e.g., time, place, equipment) becomes the foundation for appropriate corrective action—both to correct unsafe situations and to build a dataset to guide future engineering/construction needs. Managing data for these purposes, as well as for meeting any state and federal agency reporting requirements, is an important function of APP administration. Using GIS technology to track and report bird mortalities, remedial actions, outages, and avian risks enables a utility to identify problems and to track the effectiveness of its APP.

Use of existing processes and systems (e.g., outage reporting, environmental review, asset management, and accounting) will help control costs of developing and implementing an APP. Whether an APP is driven by an environmental, engineering, or operations department, cooperation will be necessary across all departments to reduce actual and potential avian/power line conflicts. As with any project, better planning yields better results. The goals of an APP are a measurable decrease in avian/power line injuries and mortalities and an increase in electric service reliability—ultimately benefiting the birds, the utility, its customers, the regulators, and the affected public.

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APPENDIX A

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APPENDIX B

Designing Site-Specific Studies for Collision Monitoring

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With any study design for collision monitoring it is important that the resulting data can be compared to similar studies (see *Variability of Reported Mortality Rates* in Chapter 4 and *Effectiveness of Designs* in Chapter 6). The information in this appendix will help you design site-specific study methods that produce useful and comparable results. Table B.1 summarizes the considerations and issues presented in this appendix.

TABLE B.1: Summary of considerations and issues for designing site-specific collision monitoring.

Considerations for Site-Specific Collision Monitoring	Issues Related to Estimating Mortality Rates
Behavioral Monitoring • Bird density • Evaluation criteria • Estimating bird flight height • Radar observation and detection • Metrics • Study segments	Equations for Calculating Mortality Rate • Accuracy • Variability in methods
Mortality Monitoring • Differences in sampling design • Questions to ask • Data to record • Remote sensing	Sampling Biases • Crippling loss • Searcher efficiency • Scavenger removal • Habitat differences

CONSIDERATIONS FOR SITE-SPECIFIC COLLISION MONITORING

BEHAVIORAL MONITORING SURVEYS

The most direct way to determine how collisions are occurring is to observe behavior as birds are approaching, crossing, or colliding with power lines. Behavioral monitoring is used to characterize the birds' reaction to lines by giving each reaction a behavioral avoidance value. In line modification studies, behavioral monitoring can be used to measure the effectiveness of line marking devices.

Bird Density

Past studies (e.g., Bevanger 1999; Janss 2000) have counted collisions per flyby (observed collisions per number of birds flying by a line). With high bird density, counting collisions per flyby is feasible. But with low bird density, counting flybys is not practical because so few observations can be made, even over an extended period of time. Direct observation can be especially time consuming with low bird density or intermittent high bird density. Observations may also be restricted by poor visibility due to weather or time of day. In such cases, the most feasible method may be to conduct mortality monitoring to estimate collisions (see *Mortality Monitoring Surveys* on page 141). Bird collisions with power lines can also be detected with remote sensing devices (see *Remote Sensing* on page 142), although they do not yield behavioral and species data.

Evaluation Criteria

A study's behavioral criteria may include the type of reaction to lines, distance from the line when the reaction occurred, and height above the line when crossing. Because estimates are provided by different observers, all observers must be trained and given time to practice before the study begins, and the same observers should be used throughout the study when possible to minimize observer bias. Records of approach, crossing, and departure heights should be kept. If behavioral avoidance is observed, the reaction to and distance from the line should be recorded. The following are possible reaction categories and definitions:

- No reaction—Birds maintain constant altitude and unaltered flight
- Swerve and over—Birds turn from course, flying up and over line
- Swerve and under—Birds turn from course, flying down and under line
- Over and swerve—Birds flying over line swerve immediately after crossing the lines
- Turn and leave—Birds turn and retreat from the line after approaching within 50 meters (m) (164 feet [ft]) of the line
- Collision and fly—Birds in flight hit a line but keep flying outside of the transect boundaries
- Collision and fall—Birds in flight hit a line and drop within the study transect (the specific line should be noted in the comments section)
- Land on line—Birds land on line or pole

Estimating Bird Flight Height

Bird flight altitude information should be estimated relative to the structure height and the height of phase conductors, neutral wires, and shield wires. Height classes will vary depending on the type of power line (e.g., conductor arrangement, voltage) and the species studied. Figure B.1 provides an example of altitude classes for transmission lines. Since power lines will vary in design, site-specific altitude criteria should be developed.

The manner of recording flight altitude should be modified according to line configuration and the species studied. If the wires are in the same horizontal plane, then the area included in the study is above and below the line for a certain number of meters (feet). If the wires are in a vertical configuration, then the area observed is above and below the multiple planes including the shield wire and a distribution underbuild if present. If the structure type is an H-frame, then the obser-

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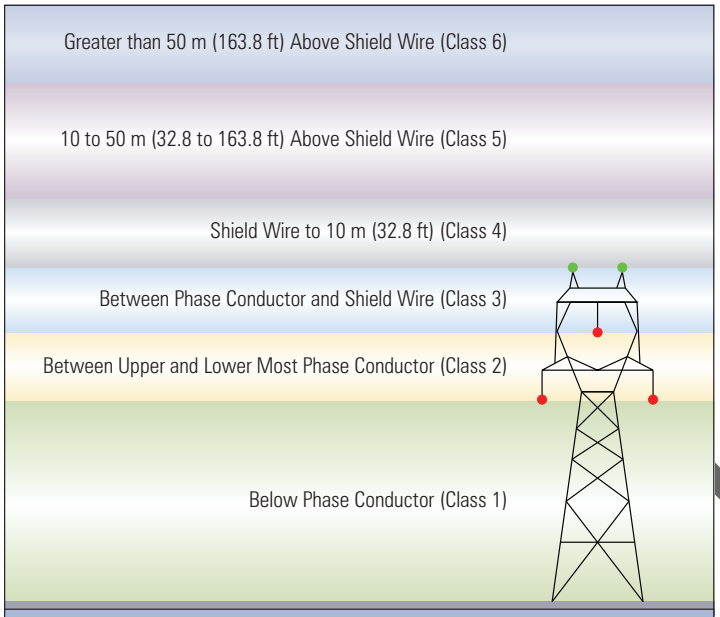

FIGURE B.1: Classes used to describe birds' approach, crossing, and departure altitudes in collision studies on transmission lines (after James and Haak 1979).

vational box might be different than if the tower is steel lattice or a V-shape supported by guy wires. The size of the line structure may warrant extending the observational area farther from the poles (i.e., begin recording at 30.5 m (100 ft) away from a distribution single pole, but 152.4 m (500 ft) from a steel lattice transmission tower) in order to account for reaction times related to the size of the structure and the height and arrangement of the lines.

Bird flight height can be estimated and measured in various ways with varying degrees of expense, effort, accuracy, and efficiency. Visual categorization, rangefinders, and radar systems can all collect data on the flight height and each approach has its advantages and disadvantages (see *Radar Observation and Detection* on page 140). When choosing which techniques to use, the following must be considered: project goals, species identification and concentration, migration data, and project budget. For example, if the major bird migration occurs in spring, data needs to be collected for a sufficient period in the spring to characterize bird movement and behavior. If you need to estimate the overall impacts of the mortality to the local bird population, you will need an understanding of that population in the area surrounding the study site throughout its seasonal fluctuations including breeding, migration, and wintering.

One of the simplest field techniques for estimating flight height is to visually categorize height, such as above the lines, below the lines, etc. This approach only requires a known reference point in the field. Survey flags and reaction zones can help observers estimate the distance from the line and the section of the line as they record behavioral avoidance. For example, survey flags can be placed 5 m (16.4 ft), 5 to 25 m (16.4 to 82 ft), and >25 m (>82 ft) from the line (Brown and Drewien 1995). This technique works well in terrestrial situations and eliminates the need for a rangefinder. In another approach, a reaction zone of 200 m (656.2 ft) on each side of a 500-kV transmission line has been used (Willdan Associates 1981, 1982).

This approach can be expanded by using visual estimation in conjunction with electronic rangefinders, which are used to measure the height of reference structures in the field. Electronic rangefinders come equipped with a laser and built in clinometers, which measure straight line distance to the bird and the angle of the measurement above horizontal. The measurements can be used to estimate an object's (bird's) height above ground. Height is calculated as:

SIN([Angle[1]])*[Distance to Object] = Flight height

[1] if calculating in Excel use the radian function to convert degree units into radians so the number will be compatible with the SIN function

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Once the heights are known for several tall objects in the area, bird flight heights can be estimated. This approach can be further expanded by directly measuring the flight heights of birds using an electronic rangefinder. This approach can be effective if birds are in close range and are big and reflective enough to bounce a signal back to the rangefinder. Other factors that affect successful measuring of flight height using the rangefinder include:

- Distance of the observer to the bird (shorter distances reflect better signals)
- Size of the bird (larger birds reflect the laser better than smaller birds)
- Reflectivity of the bird (white birds reflect the signal better than dark birds; Klimentjew et al. 2010; M. Schriner, pers. comm.)

A limitation of measuring bird flight height directly is that it is difficult to record multiple heights simultaneously. In areas where bird passage rates are high, multiple observers, digital tape recorders, or video cameras may be needed to adequately capture multiple measurements of flight height.

Radar Observation and Detection

Although the use of radar in power line studies is not common, it is a useful tool for characterizing bird movements. Two types of radar, Nexrad and portable radar, have been used in bird studies to collect data on nocturnal movements and broad front migrations, which may be missed by field observations. Nexrad radar (Next-Generation Radar) is a network of Doppler weather radars operated by the National Weather Service. Nexrad radar has the advantage of being able to collect data on the density of targets within an area and examine the temporal variation in target activity over many years. Portable radars are smaller and include systems such as modified marine, pencil beam tracking, and other specialized radar systems. Portable radar collects data on flight height, direction, and speed of targets and can distinguish different size classes of targets which provides some level of certainty as to what is being detected (e.g., songbirds versus herons).

Despite the unique information that radar can collect, it does have limitations. Nexrad cannot distinguish between birds, bats, and insects, and the height of airspace that is surveyed is dependent on the distance from the Nexrad station. Portable radar detects targets (e.g., birds, bats, insects, weather, etc.) in flight and can classify them by size and speed and movement patterns (R. Larkin, pers. comm.). Software filters can help refine target specificity by removing weather images, leaving images of desired targets. While size classes can be used to indicate species groups to some extent, distinguishing between species groups that are of similar size is not possible. Ground clutter, visual obstructions, and inclement weather can also limit the ability of radar to detect objects at a distance. The longer the distance between radar and subject, the more likely ground clutter will interfere. Finally, the cost of radar systems can be high, which limits their applicability.

Metrics

Metrics used in behavioral observations of collisions are generally expressed as the number of observed collisions per number of birds flying by a line (flybys), often expressed as a percentage. For example, Meyer (1978, cited in Bevanger 1998) observed the number of collisions to be 0.003% to 0.07% of flybys for waders and gulls. Janss and Ferrer (2000) reported collisions per flyby as 3.93×10^{-5} for the common crane (*Grus grus*) and 6.34×10^{-3} for the great bustard (*Otis tarda*).

Study Segments

It is essential that study segments represent the line as a whole (unless there is a need to identify high risk areas), that test and control segments be of comparable length, and that

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they have as much environmental homogeneity as possible. Variability will be reduced by including an adequate number of test and control segments. Contiguous segments are convenient but not essential. Koops and de Jong (1982) marked alternating spans, and Brown and Drewien (1995) marked alternate 0.8-kilometer (km) (0.5-mile [mi]) segments of eight different test lines. The length of study segments may vary according to bird density, seasonal use, habitat type, size of the power line, etc. However, in line modification studies it is important that test and control segments are separated sufficiently so control segments are not affected by the presence of markers on the test segments. Thus, when evaluating markers on small distribution lines that have short spans (pole to pole distance), each test and control segment should consist of several spans. Barrientos et al. (2011) provides recommendations on reasons for standardizing segment length.

MORTALITY MONITORING SURVEYS

The most common way to determine if collisions have occurred is to survey the power line right-or-way (ROW) for dead and injured birds and attempt to identify the cause of injury or death. Mortality monitoring surveys provide a more accurate assessment of collision mortality.

Differences in Sampling Design

There are numerous monitoring approaches and each has different strengths and weaknesses (e.g., APLIC 1994; Bevanger 1999; Hunting 2002). Mortality surveys conducted through 2011 generally differ in sampling design including:

- Segment selection
- Lengths of lines sampled
- Width of the area sampled
- Duration and intensity of the study
- Seasonal sampling

The fact that all these considerations are not routinely included leads to difficulty in comparing studies (Hunting 2002; Barrientos et al. 2011). Typically the sampling biases (i.e., searcher efficiency, crippling loss, scavenger removal, and habitat differences; see *Sampling Biases* on page 143), which need to be accounted for to correct the estimated mortality rates, are not implemented systematically or in a manner that is consistent with the expected monitoring program survey designs. In addition, because of sampling uncertainty, a variety of statistical methods are applied to estimate the actual number of birds affected based on the number of birds found.

Site-specific study designs and correction factors need to be developed for mortality monitoring to account for these variables. Bevanger (1999) concluded that, given the site-specific factors and local conditions (e.g., biological, environmental, and engineering) that influence collision and mortality estimation, it is not expedient to develop a set of standard study design methods or use general correction factors. Barrientos et al. (2011) presented three recommendations for conducting line marking device effectiveness studies that also apply to mortality monitoring:

1. Collecting data on carcass counts and flight frequency for the same length of time and at the same time of the year at marked and unmarked wire segments
2. Studying marked (test segment) and unmarked (control segment) lines in areas with similar vegetation and topography, with similar lengths of time spent searching for carcasses, and with transects of equal lengths and widths
3. Standardizing the timing of carcass searches and search area widths

For search area width, searches should cover the width of ROW with reference to the height of the power line (James and Haak 1979; Raevel and Tombal 1991) and the zone in which carcasses are expected to fall.

Questions to Ask

The study design phase should focus on the questions being asked, the data needed to answer these questions, and the appropriate methods, including duration and intensity, to provide those data. A series of hierarchical questions that need to be considered may include the following:

1. Are collision injuries and/or mortalities occurring?
2. What species of birds are involved? Are they protected species?
3. Where along the power line are the birds colliding?
4. When are they being killed?
5. Under what circumstances (e.g., weather, time of day) are they being killed?
6. What biological, environmental, and engineering factors appear to be important in influencing collisions?
7. What line modification actions can be taken to reduce these collisions?

Questions 1 and 2 are the simplest to answer if the carcasses are detected. Many of the past studies have focused on answering the first two questions and sometimes 3 and 4. More recent studies have attempted to address questions 5, 6, and 7. There is a tendency to focus on sampling worst-case situations or locations where high numbers of collisions have occurred as opposed to sampling representative locations along a given power line to understand the overall collision risk. Although results from worst-case situations may skew general mortality risk, determining this information is still important because it provides data needed for reducing risk.

Data to Record

For each bird found, the following information should be gathered when possible:

- Location of the carcass in proximity to the power line (e.g., GPS position)
- Species
- Sex
- Age: adult or juvenile
- Date or approximate time of death
- Physical injuries and conditions (e.g., broken bones, lacerations, abrasions, blood, discolorations, gunshot wounds, decomposition, feather spots, feeding by scavengers)
- Probable cause of death
- Necropsy[19]

Environmental conditions should also be recorded, especially visibility, wind speed and direction, weather events, avian habitats, as well as the type and abundance of bird species in the study area.

Remote Sensing

An alternative to directly observing bird collisions is to use a Bird Strike Indicator (BSI). BSI is a vibration sensing and recording tool that is fitted to a power line to detect collisions with that line. It is especially useful for monitoring collisions in low-light or no-light conditions. However, BSI does not identify what species struck the line; mortality monitoring or field observations would be required to determine this. See Chapter 5 for a discussion on the BSI.

[19] In the United States, the possession of any protected migratory bird will require a Special Purpose or Scientific Collecting permit (see Chapter 3), unless otherwise instructed by an agent of U.S. Fish and Wildlife Service Office of Law Enforcement.

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ISSUES RELATED TO ESTIMATING MORTALITY RATES

EQUATIONS FOR CALCULATING MORTALITY RATE

Accuracy

Few mathematical equations for estimating mortality have been tested for accuracy using experimentally designed, rigorous field studies (Bevanger 1999). Furthermore, there are no agreed upon methods that link the equation to the type of field trials necessary for site-specific calculation of mortality, nor are methods for incorporating uncertainty often provided.

These issues are not unique to power lines. Similar uncertainty is found in calculating actual mortality from estimates of bird carcasses collected from wind turbine collisions, building window collisions, pesticide application, and avian diseases. Although the causes of mortality are different, the ability to find bird carcasses in the field is affected by the same sampling biases (i.e., crippling loss, searcher efficiency, scavenger removal, and habitat differences; see discussion on this page). Huso (2011) evaluated the accuracy and precision of mortality estimators for power lines and other structures and proposed one that improves reliability. This limitation in calculating mortality rates is also presently being investigated by the wind industry, U.S. Fish and Wildlife Service, U.S. Geological Survey, and others. The California Energy Commission (CEC) is funding a controlled field study through the California Wind Energy Association strictly looking at the mathematical relationships of scavenger removal and searcher efficiency as they relate to calculating actual mortality rates. The study report should be available in 2012 (J. Newman, pers. comm.).

Variability in Methods

While designing a study, the most recent literature on mortality rate calculations should be reviewed before selecting a particular method. Bevanger (1999) and Hunting (2002) provide an excellent review of collision mortality for power lines. A mortality rate of the number of carcasses/distance of line surveyed/time period is the most commonly used metric found in the literature. However, the search area (i.e., estimated annual mortality/hectare/kilometer [/acre/mile]) also needs to be included (Hunting 2002).

Finally, as mentioned earlier, there is great variability in monitoring methods, which prevents useful comparison of mortality rates and effectiveness of markers to reduce collisions.

SAMPLING BIASES

When conducting mortality monitoring, the mortality rate calculation must take a number of sampling biases into account, including the following:

- Crippling loss
- Searcher efficiency
- Scavenger removal
- Habitat differences

Crippling Loss Bias

The crippling loss bias occurs when birds strike a line and fall outside the search area or when injured birds move out of the search area and are not observed by searchers. Bevanger (1999) cites several studies that found 22% (Hiltunen 1953) to 50% (Renssen et al. 1975) to 74% (Beaulaurier 1981) of birds fatally injured in power line collisions move far enough away from the power line before dying that they are not found during carcass searches.

In Beaulaurier's (1981) study, crippling loss bias was defined as the percent of observed collisions in which birds continued flying out of the study area after the collision. Because she did not observe a collision during her study, she used an estimate of 74%—the average measure of crippling loss bias calculated by Meyer (1978) as 75% and James and Haak (1980) as 73%. These authors assume

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a worst-case estimate with all injured birds dying from their injuries. The estimates were also based on collisions with shield wires.

Because great time and effort are involved in monitoring flights and recording collisions, crippling loss bias estimates are extremely difficult to obtain and they are the least likely to be calculated in a study. Application of estimates from other studies is inappropriate, and, in fact, very misleading. Once again, the size of the bird may make a significant difference because of flight dynamics. A crane or swan that just tips a line is more likely to tumble to the ground and sustain fatal injuries than is a smaller, lighter bird that may be able to recover its flight mid-air and die later at some distance from the line (W. Brown, pers. comm.). Consequently, smaller birds might have a higher crippling loss bias than larger birds. This may need to be examined in future research.

Searcher Efficiency Bias

During carcass searches, some of the carcasses will be missed depending on several variables (e.g., number of observers, their skill and experience, and how the surveys are conducted). This is called searcher efficiency bias or searcher bias. Searcher bias is also influenced by vegetation type, height, and density, search pattern, presence of waterbodies, bird size, and other factors (Bevanger 1999; Erickson et al. 2005). Searcher bias in carcass detection must be carefully controlled (Bevanger 1999; Erickson et al. 2005). Searcher efficiency biases are specific to the site and the season. Bias needs to be determined while the mortality monitoring is taking place and not extrapolated from or to other locations, seasons, or studies (Bevanger 1999; Barrientos et al. 2011). APLIC (1994) and Bevanger (1999) give examples of the calculations for determining searcher bias. CEC is also studying searcher efficiency factors for calculating wind turbine-caused bird mortality.

The use of trained dogs in mortality monitoring studies can increase carcass recovery, particularly of small carcasses in dense vegetation (Homan et al. 2001; Anderson 1978; Rusz et al. 1986; Bevanger 1995, cited in Bevanger 1999). However, the availability of trained dogs is limited and their efficiency varies with individuals, seasons, weather conditions, vegetation structure, breed, length of use, and level of fatigue.

Scavenger Removal Bias

Scavengers may remove carcasses before a search is completed, which results in underestimating mortality. Scavenging rates are very important to include in mortality rate estimation (Bevanger 1999; Rivera-Milan et al. 2004; Erickson et al. 2005; Gehring et al. 2009). Bevanger (1999) gives an example of the calculation. Scavenging rate varies by habitat, season, time of day, scavenger type, bird size, bird species, etc. (Bevanger 1999; Erickson et al. 2005). Evidence of seasonal variation in scavenging rates in United Kingdom farmland is presented by Prosser et al. (2008).

In some cases scavenging can be a quick process, occurring in a matter of minutes depending on the scavenger species as well as the bird species involved. A review of the scavenging studies from various mortality monitoring studies (including power lines, communication towers, wind turbines, pesticide application, and bird disease) indicates that the majority of scavenging takes place within a short period of time after death for many species. For example, preliminary results of a scavenging removal study at one communication tower location on the Alaska Peninsula suggest that carcass removal from scavenging is as high as 50% removal per day (P. Flint, USGS pers. comm.; E. Lance, USFWS pers. comm.; USFWS 2007 unpubl. Data, cited in Manville 2007a); scavenged carcasses included eiders, waterfowl, and shorebirds,

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among others. This degree of scavenging is consistent with what Herbert Stoddard (Crawford and Engstrom 2001) found in a 29-year study of a communication tower in Florida where about 92% of carcasses were removed by scavengers within 24 hours. Peterson et al. (2001) reported that in British Columbia, Canada, 52/54 poisoned waterfowl carcasses were discovered by avian scavengers within 72 hours. Kostecke et al. (2001) reported carcasses scavenged mostly by skunks with 66% of carcasses scavenged within five days in a South Dakota study. Erickson et al. (2005) cites a number of case studies with average carcass persistence times ranging from less than one to 28 days. In other cases it can be longer (Brown and Drewien 1995). They found that crane carcasses sometimes remained for as much as a year after death and that no crane carcasses were removed by scavengers during the removal studies. Likewise, large bird carcasses (e.g., raptors, pelicans) may persist for extended periods (several months to 32 months) without scavenger removal (S. Liguori, pers. comm.). Raevel and Tombal (1991) and others have noted that removal bias varies with the size of the birds (i.e., smaller birds usually disappear more quickly and more frequently). Consequently, the effects of size and perhaps species must be included in calculations of removal bias for a study. In controlled studies where a known number of carcasses were placed in the field showed that many carcasses were removed within a short period time, e.g. days; however, even small birds can persist in the field for long periods of time as they become desiccated and less preferred for scavenging.

Scavenger removal bias is site-specific and needs to be determined when the mortality monitoring is taking place rather than extrapolating it from other locations, seasons, or studies (Bevanger 1999). Scavengers can quickly learn where carcasses or injured birds are readily available, suggesting the need to update these bias correction factors throughout the study, as needed, to account for learning behavior.

Habitat Differences Bias

Habitat bias is used to account for unsearchable areas. Some portions of a study area may not be searchable because of water, bogs, dense vegetation, or topography. Researchers should not extrapolate beyond the area sampled because the rate of collision may vary with habitat type. Habitat bias should be used only in situations where unsearchable habitat is finely interspersed with searchable habitat and where researchers can demonstrate that the numbers of birds found in searchable and unsearchable habitats are similar.

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APPENDIX C

Glossary

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adult
A bird that has acquired its final plumage.

aspect ratio
Aspect ratio is the wing breadth divided by wing length. A low aspect ratio generally correlates with relatively thin wings and high aspect ratio with relatively wide wings.

avian-safe
A power pole configuration designed to minimize avian electrocution risk.

circuit (multiple)
A configuration that supports more than one circuit.

circuit (single)
A conductor or system of conductors through which an electric current is intended to flow. The circuit is energized at a specified voltage.

conductivity
The capacity to transmit electrical energy.

conductor
The material (usually copper or aluminum)—usually in the form of a wire, cable, or bus bar—suitable for carrying an electric current (AC, DC, and shield); a material that offers little resistance to the flow of electricity.

conductor gallop
Also known as galloping. The high-amplitude, low-frequency oscillation of overhead power lines often due to wind. The movement of the wires occurs most commonly in the vertical plane, although horizontal or rotational motion is also possible. Galloping can cause power lines to slap together, which results in outages and damage to the lines and equipment. Icing conditions, wind velocity, and conductor tension are some of the factors that interact to cause galloping.

configuration
The arrangement of parts or equipment. A distribution configuration would include the necessary arrangement of crossarms, braces, insulators, etc. to support one or more electrical circuits.

conspecific
Members of the same species.

corona
A process by which current in a conductor with a high potential ionizes the air surrounding it to create a plasma. The ions generated eventually pass charge to nearby areas of lower potential or recombine to form neutral gas molecules.

corridor
The broad area between the origin and termination of a new line, within which the potential routes lie. The area in which a new line's routing alternatives are proposed and evaluated before the final route is determined.

corvid
Birds belonging to the family Corvidae; includes crows, ravens, magpies, and jays.

crossarm
A horizontal supporting member used to support electrical conductors and equipment for the purpose of distributing electrical energy. Usually made of wood, fiberglass, or steel, and manufactured in various lengths.

current
A movement or flow of electricity passing through a conductor. Current is measured in amperes.

distribution line
Lower-voltage wires, energized at voltages from 2.4 kV to 60 kV, and used to distribute electricity to residential, industrial, and commercial customers, i.e., end users.

facility
As used in this manual, this term refers to all the equipment, wires, structures (e.g., poles and towers), etc., that are involved in carrying electricity.

fault
A power disturbance that interrupts the quality of electrical supply. A fault can have a variety of causes including fires, ice storms, lightning, animal collisions/electrocutions, or equipment failures. Also known as arc, short circuit, or flash.

flappers
Suspended collision reduction devices that clamp to and hang from a line and swing and spin in the wind. There are variations on this theme that have little or no motion, which are used when high winds cause moving parts to wear rapidly.

flaring
A sudden panic avoidance reaction to power lines, in which birds ascend almost vertically with rapid wing beats or fold their wings and fall down and backwards away from the obstacle.

fledgling
A bird that has recently learned to fly and left the nest, but may still be dependent on its parents for food.

ground
Material that conducts electricity and makes an electrical connection with the earth.

ground rod
Normally a copper-clad steel rod or galvanized steel rod, driven into the ground so that the necessary parts of a facility can be physically connected to ground potential.

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grounding conductor
A conductor used to ground the shield and neutral wires. Grounding conductors may be copper-clad, solid copper, or stranded galvanized wires and are attached to the structure. Sometimes also called a down wire. When steel structures are used the structure becomes the grounding conductor.

guy
Secures the upright position of a pole and offsets physical loads imposed by conductors, wind, ice, etc. Guys are normally attached to anchors that are securely placed in the ground.

immature
All plumages other than adult.

juvenile
(Plumage)—first plumage of a bird.
(Bird)—a bird in its first year of life.

Kilovolt (kV)
1,000 volts.

latticework
The combination of steel members connected together to make complete structures, such as transmission towers or substation structures.

lightning arrester
An electrical protection device used to divert the energy of lightning strikes to the earth.

lightning days
Lightning or thunderstorm days. A day with one or more lightning storms would be classified as a lightning day.

maneuvering
Any change in flight behavior, height, or direction, and in this context, in response to obstacles such as power lines.

necropsy
Postmortem examination of wildlife often used to determine cause of death.

nestling
A young bird that has not yet reached sufficient size and maturity to leave the nest.

neutral wire
A non-energized conductor that carries the primary current back to its substation. The neutral is at ground potential (i.e., it grounds a distribution power line system).

outage
Event that occurs when the energy source is cut off from the load.

overhead ground wire
See **shield wire**.

phase conductor
An energized power line that carries alternating current electricity.

phase-to-ground
The contact of an energized conductor to ground potential. A bird can cause a phase-to-ground fault when fleshy parts of its body touch an energized phase and ground simultaneously.

phase-to-phase
The contact of two energized conductors. Birds can cause a phase-to-phase fault when the fleshy part of their wings or other body parts contact two energized conductors of different phases at the same time.

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pole

1. A vertical structure used to support electrical conductors and equipment for the purpose of transporting electrical energy. It can be made of wood, fiberglass, concrete, or steel and manufactured in various heights.

2. DC transmission lines use bundled conductors also known as poles, which refers to the positively and negatively charged conductors in a DC design.

power generation facility

The location where electricity is generated, which may be a power plant, station, wind turbines, solar farm, or hydro-electric dam, among others.

power line

A line made of conductive material that transmits electricity from its source to its point of use.

ramping

A contemplated maneuver frequently seen in wading birds approaching a power line at or below conductor levels. During their approach waders swerve and continue parallel to the power line until sufficient altitude is reached for crossing. Ramping is most frequently observed on clear days with moderate winds and apparently allows birds to assess and negotiate the power line before crossing.

raptor

Bird of prey. Raptors are members of the orders Falconiformes (diurnal raptors) and Strigiformes (owls). Raptors have a sharp hooked bill and sharp talons used for killing and eating prey.

rebuild

The act of upgrading an existing line by replacing its wires and/or structures.

reliability

The percentage of time a line is delivering uninterrupted electricity.

reroute

The act of removing an existing line from the original right-of-way and rebuilding it along another route that will avoid the interactions encountered in the original route.

retrofit

The modification of an existing electrical power line structure to make it avian-safe.

right-of-way (ROW)

The strip of land that has been acquired by an agreement between two or more parties for the purpose of constructing and maintaining a utility easement. The width of right-of-way required by each voltage level is generally dictated by state statutes and the National Electrical Safety Code (NESC) and is a function of span length, the conductor height above ground, and the conductor's low point of sag.

route

The pathway on which a right-of-way will be cleared and the new line constructed.

sailing

Crossing of conductors and shield wires with wings set. Most frequently seen in birds flying through or close to the conductor-shield wire complex.

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separation
The physical distance between energized conductors or between energized and non-energized conductors.

shield wire
Also called static wire or overhead ground wire. A conductor that provides a path to ground for static electricity. Lightning is its most common source of static electricity. Since lightning follows pathways to ground, the shield wire protects phase (AC) and pole (DC) conductors from lightning strikes.

shortstopping
Wintering in more northerly latitudes than has been historic for the species.

siting
The process of identifying the points in the electrical system that need new lines of connection to deliver electricity to growing or new demand centers.

span
The pole-to-pole or tower-to-tower distance of a power line.

static wire
See **shield wire**.

structure
A pole or lattice assembly that supports electrical conductors and equipment for the transmission or distribution of electricity.

subadult
Stage of a bird between juvenile and adult.

substation
A transitional point (where voltage is increased or decreased) in transmission and distribution systems.

transmission line
Power line that delivers electricity from its source over long distances to substations where the voltage is reduced for distribution. Transmission voltages range from 60 to 765 kV in the United States.

trust resource
Wildlife held in the public trust and managed and protected by federal and state agencies. These trust agencies are designated by statute and regulations as responsible for upholding the protection, conservation, and management of these resources.

underbuild
Refers to a circuit that is placed on the same pole but underneath another circuit of a higher voltage. The lower circuit is often referred to as the underbuilt circuit.

volt
The measure of electrical potential.

voltage
Electromotive force can be expressed in volts. Power lines are rated and categorized by voltage.

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voltage rating

The voltage rating of a transmission line depends on the utility's existing transmission system voltages, interconnections with other utilities, potential delivery points, and the amount of power that must be transmitted to meet load requirements. As voltages increase, the amount of power that can be transmitted increases. Various line-design parameters such as conductor size and configuration, spacing, and the number of conductors per phase (bundling) allow for increased transmission capability. Transmission voltages for carrying energy long distances are generally in the 115- to 765-kV range in North America.

wing loading

Wing loading is a bird's mass divided by its wing surface area. High wing loading describes a bird that is heavy relative to its wing area. Low wing loading describes a bird that is light relative to its wing area.

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APPENDIX D

Acronyms

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AC	Alternating Current
ACP	Advanced Conservation Practice
APLIC	Avian Power Line Interaction Committee
APP	Avian Protection Plan
AWBP	Aransas-Wood Buffalo Population (whooping cranes)
BAMS	Bird Activity Monitoring System
BFD	Bird-Flight™ Diverter
BGEPA	Bald and Golden Eagle Protection Act (United States)
BSI	Bird Strike Indicator
CAP	Citizens Advisory Panel
CEC	California Energy Commission
cm	centimeter
CFR	Code of Federal Regulations (United States)
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWS	Canadian Wildlife Service
DC	Direct Current
EEI	Edison Electric Institute
EPRI	Electric Power Research Institute
ESA	Endangered Species Act (United States)
FAA	Federal Aviation Administration
ft	feet
GIS	Geographic Information Systems
GPS	Global Positioning System
HCP	Habitat Conservation Plan
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
in	inch
ITP	Incidental Take Permit
km	kilometer
kV	kilovolt
m	meter
mi	mile
MBCA	Migratory Birds Convention Act (Canada)
MBTA	Migratory Bird Treaty Act (United States)
MOU	Memorandum of Understanding
NESC	National Electrical Safety Code
NMFS	National Marine Fisheries Service (United States)
NRECA	National Rural Electric Cooperative Association
PVC	Polyvinyl Chloride
ROW	Right-of-Way (singular), Rights-of-Way (plural)
SARA	Species at Risk Act (Canada)
SFD	Swan-Flight™ Diverter
SVD	Spiral Vibration Damper

USEPA	U.S. Environmental Protection Agency	USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service	UV	Ultraviolet
		V	Volt

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APPENDIX E

Resources

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BIRD IDENTIFICATION AND NATURAL HISTORY

All About Birds
Cornell Lab of Ornithology
Includes bird identification information and bird songs.
www.allaboutbirds.org/Page.aspx?pid=1189

Birds of North America
Cornell Lab of Ornithology
Comprehensive reference covering the life histories of North America's breeding birds.
http://bna.birds.cornell.edu/bna

Tools for Learning About Birds
USGS Patuxent Wildlife Research Center
Includes bird pictures and songs.
www.mbr-pwrc.usgs.gov/bbs/ident.html

Bird Identification Pages
Idaho Museum of Natural History
Includes a visual key with silhouettes.
http://imnh.isu.edu/digitalatlas/bio/birds/main/birdid.htm

Florida Bird Sounds
Florida Museum of Natural History
www.flmnh.ufl.edu/birds/sounds.htm

BIRD DATABASES AND CONSERVATION INFORMATION

Migratory Bird Program
USFWS Division of Migratory Birds
Resources and regulations for the conservation and management of migratory birds.
www.fws.gov/migratorybirds

Migratory Bird Treaty Act (MBTA)
USFWS Division of Migratory Birds
www.fws.gov/laws/lawsdigest/migtrea.html

Bald and Golden Eagle Protection Act (BGEPA)
USFWS Division of Migratory Birds
www.fws.gov/laws/lawsdigest/baldegl.html

Endangered Species Act of 1973 (ESA)
USFWS Division of Migratory Birds
www.fws.gov/laws/lawsdigest/esact.html

Endangered Species Consultation Handbook (1998)
USFWS and NMFS
Procedures for conducting consultation and conference activities under Section 7 of the Endangered Species Act.
www.fws.gov/midwest/endangered/section7/index.html

North American Waterfowl Management Plan
USFWS Division of Bird Habitat Conservation
Includes waterfowl status reports.
www.fws.gov/birdhabitat/NAWMP/index.shtm

Bird Conservation Initiatives
U.S. Environmental Protection Agency
Portal to major United States bird conservation plans and organizations.
www.epa.gov/owow/birds/bird.html

Conservation Plans, Databases, Strategies, and Assessments
Partners in Flight—U.S.
www.partnersinflight.org

North American Landbird Conservation Plan (2004)
Partners in Flight
www.pwrc.usgs.gov/pif/cont_plan

U.S. Shorebird Conservation Plan (2001)
USFWS
www.fws.gov/shorebirdplan

North American Waterbird Conservation Plan (2002)
Waterbird Conservation for the Americas
www.pwrc.usgs.gov/nacwcp/nawcp.html

Migratory Birds (Canada)
Environment Canada
Conservation, monitoring and reporting, and regulations for Canadian migratory birds.
www.ec.gc.ca/nature/default.asp?lang=En&n=FDF836EF-1

Migratory Birds Convention Act and Regulations (Canada)
Environment Canada
Polices, regulations, and list of birds protected in Canada under the MBCA.
www.ec.gc.ca/nature/default.asp?lang=En&n=7CEBB77D-1

Species at Risk Public Registry (Canada)
Government of Canada
Information and regulations for at-risk species in Canada.
www.sararegistry.gc.ca/default_e.cfm

Committee on the Status of Endangered Wildlife in Canada
Committee of experts that assesses wildlife species in danger of disappearing.
www.cosewic.gc.ca/eng/sct5/index_e.cfm

North American Bird Conservation Initiative
Bird Studies Canada
Describes and maps the North American bird conservation regions.
www.bsc-eoc.org/nabci.html

Christmas Bird Counts
National Audubon Society
Annual "snapshot" of North American bird populations over many decades. Because of issues with detection and database limitations, this database should only be used for indications of species presence and season of use.
http://birds.audubon.org/christmas-bird-count

eBird
Audubon and Cornell Lab of Ornithology
International database of bird observations with graphs and range maps. Because of issues with detection and database limitations, this database should only be used for indications of species presence and season of use.
http://ebird.org/content/ebird

Avian Knowledge Network (AKN)
Downloadable version of the eBird reference dataset for the Western Hemisphere.
www.avianknowledge.net/content

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National Biological Information Infrastructure: Bird Conservation
USGS Biological Informatics Program
Portal to maps, data, and bird conservation procedures for conservation of bird populations and their habitats in North America.
www.nbii.gov/portal/server.pt/community/bird_conservation/460

Ornithological Information System (ORNIS)
National Science Foundation
Data from collections of a network of museum and academic partners.
www.ornisnet.org

North American Breeding Bird Survey
U.S. Geological Survey
Data since 1966 on the status and trends of North American bird populations. Because of issues with detection and database limitations, this database should only be used for indications of species presence and season of use.
www.pwrc.usgs.gov/BBS

Landbird Population Estimates Database
Partners in Flight/Rocky Mountain Bird Observatory
Based on the Breeding Bird Survey data of the 1990s.
www.rmbo.org/pif_db/laped/default.aspx

Raptor Information System
U.S. Geological Survey
Keyword catalog of over 32,000 references on the biology and management of raptors.
http://ris.wr.usgs.gov

BIRD/ENERGY PROGRAMS AND AVIAN PROTECTION PLANNING

Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006
Avian Power Line Interaction Committee
www.aplic.org/documents.php

Avian Protection Plan Guidelines 2005
Avian Power Line Interaction Committee and USFWS
www.aplic.org/uploads/files/2634/APPguidelines_final-draft_Aprl2005.pdf

Short Courses and Workshops on Avian-Power Line Interactions
Avian Power Line Interaction Committee
www.aplic.org (see Upcoming Events)

California Energy Commission
www.energy.ca.gov/index.html

On-Line Annotated Bibliography of Avian Interactions with Utility Structures
California Energy Commission
www.energy.ca.gov/research/environmental/avian_bibliography

Right-of-Way Siting, Vegetation Management, and Avian Issues—Program 57
Electric Power Research Institute
http://portfolio.epri.com/ProgramTab.aspx?sId=ENV&rId=134&pId=5117

Conserving Birds and Their Habitats on Department of Defense Lands
U.S. Department of Defense and Partners in Flight
Includes a variety of resources such as bird conservation maps and avian protection planning guidelines.
www.dodpif.org

Materials on Bird-Power Line Interactions for Electric Utilities and their Employees
New Mexico Avian Protection Working Group
http://nmavianprotection.org//resources.html

Wildlife and Energy Programme
Endangered Wildlife Trust
www.ewt.org.za/WHATWEDO/OurProgrammes/WildlifeEnergyProgramme.aspx

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HIGH VOLTAGE DIRECT CURRENT (HVDC) TRANSMISSION SYSTEMS

Technology Information, Resource Library, and Student/Teacher Education
Clean Line Energy Partners
www.cleanlineenergy.com

AVIAN HEALTH, MORTALITY, AND CARCASS IDENTIFICATION

National Wildlife Health Center
U.S. Geological Survey
www.nwhc.usgs.gov

Field Manual of Wildlife Diseases, General Field Procedures and Diseases of Birds
U.S. Geological Survey
www.nwhc.usgs.gov/publications/field_manual

Wildlife Health Bulletin #06-02: Wild bird mortality reporting
U.S. Geological Survey
www.nwhc.usgs.gov/publications/wildlife_health_bulletins/WHB_06_02.jsp

Avian Necropsy Manual for Biologists in Remote Refuges
U.S. Geological Survey
http://www.nwhc.usgs.gov/publications/necropsy_manuals/index.jsp

Causes of Mortality in Common Loons
U.S. Geological Survey
www.nwhc.usgs.gov/publications/documents/92JCF.CLE01.pdf

Field Guide to Raptor Remains
California Energy Commission
www.energy.ca.gov/index.html

Wing and Tail Image Collection (Useful for Carcass Identification)
University of Puget Sound
www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/birds/wing-image-collection

PUBLIC PARTICIPATION RESOURCES

Introduction to Public Participation
Edison Electric Institute
Practical information for working with the public as a partner.
www2.eei.org/products_and_services/descriptions_and_access/intro_pub_partic.htm

Bird Education Network
Council for Environmental Education
Coalition developing a national strategy for bird education.
www.birdeducation.org

Flying Wild
Council for Environmental Education
Classroom bird education resources.
www.flyingwild.org

International Migratory Bird Day
Environment for the Americas
Annual event focusing on migratory birds of the Americas.
www.birdday.org

Project BEAK (Bird Education and Awareness for Kids)
Nebraska Partnership for All-Bird Conservation, Nebraska Environmental Trust, Nebraska Game and Fish Commission, U.S. Environmental Protection Agency
Exemplary bird education program.
http://projectbeak.org

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National Wildlife Refuge System
U.S. Fish and Wildlife Service
552 refuges, many of which focus on bird conservation and public outreach.
www.fws.gov/refuges

FUNDING ORGANIZATIONS

Avian Power Line Interaction Committee
APLIC funds research projects that further the knowledge of avian/power line interactions, including causes and solutions to avian mortalities due to power line electrocutions and collisions.
www.aplic.org/proposals.php

California Energy Commission
CEC funds various programs; see their website for a complete list.
www.energy.ca.gov/contracts/index.html

Electric Power Research Institute
EPRI funds research and development through competitive selection of contractors.
http://my.epri.com
(see About EPRI and Contractor Resources)

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Edison Electric Institute
Power by Association℠

Avian Power Line Interaction Committee

EXHIBIT G.1
SUBMITTAL SCHEDULE

Each Contractor Deliverable shall meet the minimum requirements for submittals prescribed in Exhibit G.1 (*Submittal Requirements*). Prior to finalizing a contract agreement, Contractor and Owner shall review this submittal schedule and update if for including in the contract agreement.

Unless defined in this Exhibit G.1, terms that begin with an upper case shall have the meaning defined in the Agreement.

Item	Name of Submittal	Date Due
Regular Submittals		
01	Plan of the Day Report [NTD: reconcile with defined terms]	8 AM daily during construction
02	Weekly Progress Report [NTD: reconcile with defined terms]	Each Monday during construction
03	Monthly Progress Report [NTD: reconcile with defined terms]	10th day of each month during construction
04	Weekly updates to Project Schedule [NTD: reconcile with defined terms]	As set forth in the Agreement
05	Notice to Owner of safety recordable, OSHA (or equivalent) visits and/or fines, reportable spills, visits by any environmental organization, any take of an environmentally-sensitive species, and/or any security breach, including theft or vandalism	Within 24 hours of occurrence
06	Requests for Payment and copies of Lien Waivers [NTD: reconcile with defined terms]	As set forth in the Agreement
Pre-Construction Submittals		
07	Document control plan, including transmittal protocol, document naming, web-based submittal management, and other similar items	30 days after Execution Date
08	Project execution plan, as described in Exhibit A (*Scope of Work*)	30 days after Execution Date
09	Quality assurance plan, as described in Exhibit A (*Scope of Work*)	30 days after Execution Date
10	Health and safety plan, as described in Exhibit A (*Scope of Work*)	30 days after Execution Date
11	Security plan, as described in Exhibit A (*Scope of Work*)	30 days after Execution Date
12	Site environmental plan, as described in Exhibit A (*Scope of Work*)	30 days after Execution Date
13	Traffic management plan, as described in Exhibit A (Scope of Work)	Prior to Contractor mobilization
14	Fire management plan, as described in Exhibit A (Scope of Work)	Prior to Contractor mobilization
15	Project Site rules / regulations	Prior to Contractor mobilization
16	Offloading plans and procedures	90 days prior to delivery of first Turbine to Project Site
17	Crane mobilization plans	90 days prior to delivery of first Turbine to Project Site
18	Spill prevention, control, and countermeasure (SPCC) plan	Prior to Contractor mobilization
19	List of all Hazardous Material to be brought onto or generated at the Project Site by Contractor or any Subcontractor (per Section TBD of the Agreement)	Prior to bringing or generating such Hazardous Material onto or at the Project Site
20	Hazardous waste management and control plan	Prior to Contractor mobilization
21	For each Contractor-Acquired Permit, copy of application and other documentation to be submitted to any Governmental Authority	[Pending]
22	Certificates of insurance	As set forth in the Agreement
23	Parent Guarantee	As set forth in the Agreement
24	Escrow Agreement	As set forth in the Agreement

Item	Name of Submittal	Date Due
25	Storage and maintenance invoice (TSA ONLY)	As set forth in the Agreement
26	Delivery Certificate (TSA ONLY)	As set forth in the Agreement
Manufacturing / Design Submittals (TSA ONLY)		
27	Tentative manufacturing and testing schedule specifying the date and where the Major Components are going to be manufactured and any special tests to be performed.	30 days after Notice to Proceed
28	Tentative Work schedule, including anticipated production / manufacturing dates of Turbine Nacelles, and anticipated Ex Works and delivery dates for Main Components.	As set forth in the Agreement
29	Detailed engineering drawings for the foundation bolt template for the Turbine, sufficient in detail to allow Buyer or Buyer's Contractors to independently fabricate a within-tolerance Tower Foundation bolt template.	30 days after Effective Date
30	Factory acceptance test reports or final test reports, including all minimum required testing, as described in Exhibit TBD (*TBD*)	As set forth in the Agreement
31	Manufacturing documentation for every Turbine, as described in Exhibit TBD (*TBD*)	As set forth in the Agreement
32	Design Certificate	As set forth in the Agreement
33	Type Certificate	As set forth in the Agreement
Engineering Submittals and Design Documents, Geotechnical Services		
34	Name and qualifications for proposed geotechnical engineer, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating subsurface investigations
35	Proposed scope of subsurface investigation, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating subsurface investigations
36	Geotechnical engineering report, as described in Exhibit A (*Scope of Work*)	[Pending]
Engineering Submittals and Design Documents, Civil Works		
37	Civil works Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • 30% Design Documents • 60% Design Documents • 90% Design Documents • Issued-for-construction Design Documents	 [Pending] [Pending] [Pending] [Pending] [Pending]
38	Hydrology study, as described in Exhibit A (*Scope of Work*)	[Pending]
39	Stormwater pollution prevention plan (SWPPP), as described in Exhibit A (*Scope of Work*)	[Pending]
40	Blasting plans and procedures, as described in Exhibit A (*Scope of Work*)	[Pending]
41	Aggregate job mix formula, as described in Exhibit A (*Scope of Work*)	30 days prior to placing material
42	Name and qualifications for proposed civil works testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
43	Recurring test reports: compaction, sieve, wet ball mill	Copy to on-site job books within 48 hours of completing test
44	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material

Item	Name of Submittal	Date Due
Engineering Submittals and Design Documents, Turbine Foundations		
45	Turbine Foundation Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • Preliminary Design Documents • Issued-for-review (IFR) Design Documents • Issued-for-construction Design Documents • Structural calculation package	[Pending] [Pending] [Pending] [Pending] With IFR Design Documents
46	Shop drawings, Turbine Foundation rebar	30 days prior to installation of first rebar cage
47	Shop drawings, embedment ring	30 days prior to installation of first rebar cage
48	Name and qualifications for proposed Turbine Foundation testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
49	Concrete mix designs and concrete placement procedures, as described in Exhibit A (*Scope of Work*)	30 days prior to performing concrete work
50	Grout specification sheets and grout placement procedures, as described in Exhibit A (*Scope of Work*)	30 days prior to performing grouting work
51	Laboratory tension test reports for anchor bolts, as described in Exhibit A (*Scope of Work*)	30 days prior to ordering anchor bolts
52	Mass concrete temperature control plan	14 days prior to first concrete placement
53	Hot / cold weather concreting plan	14 days prior to first concrete placement
54	Turbine Foundation subgrade evaluation procedure	14 days prior to first concrete placement
55	Recurring test reports: compaction, concrete, grout	Copy to on-site job books within 48 hours of completing test
56	Foundation Inspection Report, as described in Exhibit A (*Scope of Work*)	30 days prior to commencing erection of the applicable Turbine
57	Third-party certification of Foundation integrity, including test results, as described in Exhibit A (*Scope of Work*)	30 days prior to commencing erection of the applicable Turbine
58	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material

Item	Name of Submittal	Date Due
Engineering Submittals and Design Documents, Collection System Circuits		
59	Collection System Circuit Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • 30% Design Documents • 60% Design Documents • 90% Design Documents • Issued-for-construction Design Documents	 [Pending] [Pending] [Pending] [Pending] [Pending]
60	Project Electrical Studies, as defined in Exhibit A (*Scope of Work*): • Load flow study • Short circuit study • Annual energy loss report • Reactive compensation study • Harmonic analysis report • Concentric induced voltage report • Insulation coordination report • Transient overvoltage report • Wind Turbine ground grid report	 [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending]
61	Name and qualifications for proposed Collection System Circuit testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
62	Recurring test reports: compaction, electrical, pad-mount transformer (if any)	Copy to on-site job books within 48 hours of completing test
63	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material
Engineering Submittals and Design Documents, Project Substation		
64	Project Substation Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • 30% Design Documents • 60% Design Documents • 90% Design Documents • Issued-for-construction Design Documents • Points list	 [Pending] [Pending] [Pending] [Pending] [Pending] [Pending]
65	Project Electrical Studies, as defined in Exhibit A (*Scope of Work*): • Substation grounding report • Effectively grounded report • Substation AC system study • Substation DC system study • Substation bus ampacity study • Substation bus structural analysis study • Substation bus design study • Substation lighting study • Substation lightning study • Arc flash study • Protection coordination study	 [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending] [Pending]

Item	Name of Submittal	Date Due
66	NERC Compliance Studies, as defined in Exhibit A (*Scope of Work*): • FAC-002-2: Facility Interconnect Studies • FAC-008-3: Facility Ratings • MOD-025-2: Verification and Data Reporting … • MOD-026-1: Verification of Models and Data … • MOD-027-1: Verification of Models and Data … • PRC-001-1.1: System Protection Coordination • PRC-005-3(i): Protection System and Automatic Reclosing Maintenance • PRC-019-2: Voltage Regulating Controls • PRC-024-2: Frequency and Voltage Relays • PRC-025-1: Generation Relay Loadability	 Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization Prior to synchronization
67	Name and qualifications for proposed Project Substation testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
68	Concrete mix designs and concrete placement procedures, as described in Exhibit A (*Scope of Work*)	30 days prior to performing concrete work
69	Recurring test reports: compaction, concrete, electrical	Copy to on-site job books within 48 hours of completing test
70	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material
Engineering Submittals and Design Documents, Interconnection Line		
71	Interconnection Line Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • 30% Design Documents • 60% Design Documents • 90% Design Documents • Issued-for-construction Design Documents	 [Pending] [Pending] [Pending] [Pending] [Pending]
72	Name and qualifications for proposed Interconnection Line testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
73	Recurring test reports: compaction, concrete, electrical	Copy to on-site job books within 48 hours of completing test
74	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material
Engineering Submittals and Design Documents, Maintenance Building		
75	Maintenance Building Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • 30% Design Documents • 60% Design Documents • 90% Design Documents • Issued-for-construction Design Documents	 [Pending] [Pending] [Pending] [Pending] [Pending]
76	Shop drawings, Maintenance Building foundation rebar	30 days prior to installation
77	Name and qualifications for proposed Maintenance Building testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
78	Concrete mix designs and concrete placement procedures, as described in Exhibit A (*Scope of Work*)	30 days prior to performing concrete work
79	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material

Item	Name of Submittal	Date Due
Engineering Submittals and Design Documents, Meteorological Towers		
80	Meteorological tower Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • Preliminary Design Documents • Issued-for-review Design Documents • Issued-for-construction Design Documents	 [Pending] [Pending] [Pending] [Pending]
81	Name and qualifications for proposed Meteorological Tower testing agency, as described in Exhibit A (*Scope of Work*)	14 days prior to initiating investigations
82	Concrete mix designs and concrete placement procedures, as described in Exhibit A (*Scope of Work*)	30 days prior to performing concrete work
83	Manufacturer's product sheets (material cut sheets) for all permanently-installed equipment and materials as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material
84	Calibration and installation records for all permanently-installed equipment, as applicable	Within 14 days of installation of such equipment
Engineering Submittals and Design Documents, Other		
85	Documentation list for the Project, including drawing list and submittal logs, as described in Exhibit A (*Scope of Work*)	Updated concurrent with each Contractor Deliverable
86	RFI log, as described in Exhibit A (*Scope of Work*)	Updated concurrent with each RFI
87	Communications System Design Documents, as described in Exhibit A (*Scope of Work*): • Design basis • 30% Design Documents • 90% Design Documents • Issued-for-construction Design Documents	 [Pending] [Pending] [Pending] [Pending]
88	Manufacturer's product sheets for all permanently-installed equipment and materials, as described in Exhibit A (*Scope of Work*)	14 days prior to installation of applicable equipment / material
89	Recommended spare parts list for the Project's electrical works, as described in Exhibit A (*Scope of Work*)	[Pending]
90	Preliminary schedule for all factory acceptance tests	45 days prior to the first occurrence of any such test or 60 days after the Execution Date, whichever occurs first
91	Copies of factory acceptance test reports, as described in Exhibit A (*Scope of Work*)	Within 14 days of completion of any factory acceptance test
Construction-Related Submittals		
92	Critical lift plans and procedures, as described in Exhibit A (*Scope of Work*)	No less than 14 days prior to beginning critical lift
93	Energization plans and procedures, as described in Exhibit A (*Scope of Work*)	90 days prior to Project energization date
94	Project electrical testing and energization results, including results for all required testing (including that noted in Exhibit A (*Scope of Work*)) for the Project Substation, Collection System Circuits, SCADA System, Turbines (tower wiring, Turbine grounding grid resistance tests), Interconnection Line, and other relevant systems.	Within 5 days of completing the applicable test
95	Receipt, inspection, and inventory reports for all Equipment and Owner-Supplied Equipment deliveries (*including* Turbine deliveries but *excluding* only the main step-up transformer), as described in Exhibit A (*Scope of Work*)	As set forth in Exhibit A
96	Milestone Certificates	As set forth in the Agreement

Commented [RED1]: List design documents to be submitted in a single package or just keep to IFR and IFC drawings. Can we combine issuing the instrumentation and the structural drawings together?

Item	Name of Submittal	Date Due
97	Proposed training schedule, training course outline, and training manual for Contractor-Provided Training, as described in Exhibit TBD (*TBD*)	[Pending]
98	Operating Manuals in soft copy format. The Operating Manuals shall be provided in the languages of English and Spanish, respectively. (TSA ONLY)	3 months prior to Commissioning Completion Date of first Turbine
Post-Construction Submittals		
99	Controlled redline drawings showing all Owner-approved changes made during construction, as described in Exhibit A (*Scope of Work*)	Substantial Completion Date
100	Draft version of Job Books (electronic format only)	Substantial Completion Date
101	Draft version of As-Built Drawings (electronic format only)	Substantial Completion Date
102	Draft version of Operating Manuals (electronic format only)	Substantial Completion Date
103	Final version of Job Books, including hard copy format and electronic format, as described in Exhibit A (*Scope of Work*)	Final Completion Date
104	Final version of As-Built Drawings, including hard copy format and electronic format, as described in Exhibit A (*Scope of Work*)	Final Completion Date
105	Final version of Operating Manuals	Final Completion Date
106	Final Punch List	5 days prior to proposed Substantial Completion Date
107	Copies of all Subcontractor guarantees and warranties	As set forth in the Agreement
108	Wind Turbine serial numbers (TSA ONLY)	As set forth in the Agreement

EXHIBIT G.2
HOLIDAY SCHEDULE

Holiday	Date(s)
2024 Holidays	
New Year's Day	Monday, January 1, 2024
Martin Luther King Jr Birthday	Monday, January 15, 2024
Washington's Birthday (observed)	Monday, February 19, 2024
Good Friday	March 29, 2024
Memorial Day	Monday, May 27, 2024
Independence Day	Thursday, July 4, 2024
Labor Day	Monday, September 2, 2024
Thanksgiving Day	Thursday, November 28, 2024
Day after Thanksgiving	Friday, November 29, 2024
Christmas Eve	Tuesday, December 24, 2024
Christmas Day	Wednesday, December 25, 2024

In certain years, New Year's Day will be an Xcel Energy observed holiday during the previous year at the end of December. Xcel Energy determines actual dates for observing holidays on an annual basis.

Small & Diverse Businesses Subcontracting Plan

Xcel Energy is a prime contractor to the Federal Government and must comply with specific laws and regulations. We are required to flow down certain requirements to our contractors and suppliers to ensure utilization of small & diverse businesses in all contracts that offer further subcontracting opportunities. As a contractor or supplier to Xcel Energy, you are required to adopt a subcontracting plan that complies with the requirements of FAR clause 52.219-9.

Contractor Name:		City:			
Address:		State:		Zip Code:	
Contract Number:		Contract Start Date:		Contract End Date:	
Contract Value:		Total value of project subcontracts (both small & diverse businesses):			
Service/Material:					

1. Description of Products and/or Services to be Subcontracted to Small & Diverse Companies:

Provide a description of all the products and/or services to be subcontracted to companies under this contract, indicating the types of businesses supplying them: disability-owned small business, HUBZone small business, LGBT-owned small business, minority-owned small business, service disabled veteran-owned small business, small business, small disadvantaged business, veteran-owned small business or women-owned small business.

Subcontractor Name:		Type of Business:			
Subcontractor Website:		Percent of Total Subcontracting:		Dollar Value:	
Product and/or Services to be Subcontracted:					

Subcontractor Name:		Type of Business:			
Subcontractor Website:		Percent of Total Subcontracting:		Dollar Value:	
Product and/or Services to be Subcontracted:					

Subcontractor Name:		Type of Business:			
Subcontractor Website:		Percent of Total Subcontracting:		Dollar Value:	
Product and/or Services to be Subcontracted:					

Subcontractor Name:		Type of Business:			
Subcontractor Website:		Percent of Total Subcontracting:		Dollar Value:	
Product and/or Services to be Subcontracted:					

Subcontractor Name:		Type of Business:			
Subcontractor Website:		Percent of Total Subcontracting:		Dollar Value:	
Product and/or Services to be Subcontracted:					

Subcontractor Name:		Type of Business:			
Subcontractor Website:		Percent of Total Subcontracting:		Dollar Value:	
Product and/or Services to be Subcontracted:					

Subcontractor Name: | Type of Business:
Subcontractor Website: | Percent of Total Subcontracting: | Dollar Value:
Product and/or Services to be Subcontracted:

Subcontractor Name: | Type of Business:
Subcontractor Website: | Percent of Total Subcontracting: | Dollar Value:
Product and/or Services to be Subcontracted:

Subcontractor Name: | Type of Business:
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Subcontractor Name: | Type of Business:
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Subcontractor Name: | Type of Business:
Subcontractor Website: | Percent of Total Subcontracting: | Dollar Value:
Product and/or Services to be Subcontracted:

Subcontractor Name: | Type of Business:
Subcontractor Website: | Percent of Total Subcontracting: | Dollar Value:
Product and/or Services to be Subcontracted:

2. Goal Development:

The following method was used in developing the subcontracting goals:

3. Identifying Potential Sources:

The following methods were used to identify potential sources for solicitation purposes (see FAR 52.219-9(d)(5) for examples of methods that may be used):

4. Indirect Costs:

Indirect costs are not directly related to Xcel Energy material or projects. Examples of indirect cost could include janitorial services, office supplies or marketing costs.

Indirect costs have/have not been included in the dollar and percentage subcontracting goals stated above:

If "have been" is checked, explain the method used in determining the proportionate share of indirect costs to be incurred with small and diverse businesses:

5. Program Administrator:

Name:		Address:	
Title:		City:	
Phone Number:		State:	
Email:		Zip Code:	

This individual's specific duties, as they relate to the firm's subcontracting program, are as follows:

6. Equitable Opportunity:

The following good faith efforts (internal and external) will be taken to assure that small business, veteran-owned small business, service-disabled small business, small disadvantaged business, women-owned small business, HUBZone small business, LGBT-owned small business, and minority-owned small business concerns will have an equitable opportunity to complete for subcontracts:

7. Reporting and Cooperation:

The offeror agrees to

(i) Cooperate in any studies or surveys as may be required;

(ii) Submit periodic reports so that the Government can determine the extent of compliance by the offeror with the subcontracting plan;

(iii) After November 30, 2017, include subcontracting data for each order when reporting subcontracting achievements for indefinite-delivery, indefinite-quantity contracts intended for use by multiple agencies;

(iv) Submit the Individual Subcontract Report (ISR) and/or the Summary Subcontract Report (SSR), in accordance with paragraph (l) of this clause using the Electronic Subcontracting Reporting System (eSRS) at http://www.esrs.gov. The reports shall provide information on subcontract awards to small business concerns (including ANCs and Indian tribes that are not small businesses), veteran-owned small business concerns, service-disabled veteran-owned small business concerns, HUBZone small business concerns, small disadvantaged business concerns (including ANCs and Indian tribes that have not been certified by SBA as small disadvantaged businesses), women-owned small business concerns, and for NASA only, Historically Black Colleges and Universities and Minority Institutions. Reporting shall be in accordance with this clause, or as provided in agency regulations;

(v) Ensure that its subcontractors with subcontracting plans agree to submit the ISR and/or the SSR using eSRS;

(vi) Provide its prime contract number, its DUNS number, and the e-mail address of the Offeror's official responsible for acknowledging receipt of or rejecting the ISRs, to all first-tier subcontractors with subcontracting plans so they can enter this information into the eSRS when submitting their ISRs; and

(vii) Require that each subcontractor with a subcontracting plan provide the prime contract number, its own DUNS number, and the email address of the subcontractor's official responsible for acknowledging receipt of or rejecting the ISRs, to its subcontractors with subcontracting plans.

The contractor's designated Program Administrator will be solicited by Xcel Energy on a quarterly basis to report all spend with diverse and small businesses, both direct and indirect. This reporting is required per the terms and conditions of the Contractor's agreement with Xcel Energy.

8. Record Keeping:

The following is a description of the types of records that will be maintained concerning procedures that have been adopted to comply with the requirements and goals in the plan, including establishing source lists; and a description of the offeror's efforts to locate small business, veteran-owned small business, service-disabled veteran-owned small business, HUBZone small business, small disadvantaged business, women-owned small business, LGBT-owned small business, and minority-owned small business concerns and award subcontracts to them. The records shall include at least the following (on a plant-wide or company-wide basis, unless otherwise indicated):

(i) Source lists (e.g., SAM), guides, and other data that identify small business, veteran-owned small business, service-disabled veteran-owned small business, HUBZone small business, small disadvantaged business, women-owned small business, LGBT-owned small business, and minority-owned small business concerns.

(ii) Organizations contacted in an attempt to locate sources that are small business, veteran-owned small business, service-disabled veteran-owned small business, HUBZone small business, small disadvantaged business, women-owned small business, LGBT-owned small business, or minority-owned small business concerns.

(iii) Records on each subcontract solicitation resulting in an award of more than $150,000, indicating --

(A) Whether small business concerns were solicited and, if not, why not;

(B) Whether veteran-owned small business concerns were solicited and, if not, why not;

(C) Whether service-disabled veteran-owned small business concerns were solicited and, if not, why not;
(D) Whether HUBZone small business concerns were solicited and, if not, why not;
(E) Whether small disadvantaged business concerns were solicited and, if not, why not;
(F) Whether women-owned small business concerns were solicited and, if not, why not; and
(G) If applicable, the reason award was not made to a small business concern.

(iv) Records of any outreach efforts to contact --
(A) Trade associations;
(B) Business development organizations;
(C) Conferences and trade fairs to locate small, HUBZone small, small disadvantaged, service-disabled veteran-owned, women-owned small business, LGBT-owned small business, and minority-owned small business sources; and
(D) Veterans service organizations.

(v) Records of internal guidance and encouragement provided to buyers through -
(A) Workshops, seminars, training, etc.; and
(B) Monitoring performance to evaluate compliance with the program's requirements.

(vi) On a contract-by-contract basis, records to support award data submitted by the offeror to the Government, including the name, address, and business size of each subcontractor. Contractors having commercial plans need not comply with this requirement.

9. Utilization of Small & Diverse Businesses Concerns Used in Bid/Proposal:

The offeror agrees to make a good faith effort to acquire articles, equipment, supplies, services, or materials, or obtain the performance of construction work from the small business concerns that it used in preparing the bid or proposal, in the same or greater scope, amount, and quality used in preparing and submitting the bid or proposal. Responding to a request for a quote does not constitute use in preparing a bid or proposal. The Offeror used a small business concern in preparing the bid or proposal if -

(i) The Offeror identifies the small business concern as a subcontractor in the bid or proposal or associated small & diverse businesses subcontracting plan, to furnish certain supplies or perform a portion of the subcontract; or

(ii) The Offeror used the small business concern's pricing or cost information or technical expertise in preparing the bid or proposal, where there is written evidence of an intent or understanding that the small business concern will be awarded a subcontract for the related work if the Offeror is awarded the contract.

The Contractor agrees to provide the Contracting Officer with a written explanation if the Contractor fails to acquire articles, equipment, supplies, services or materials or obtain the performance of construction work as described above. This written explanation must be submitted to the Contracting Officer within 30 days of contract completion.

10. Subcontractor Discussions with Contracting Officer:

The Contractor agrees not to prohibit a subcontractor from discussing with the Contracting Officer any material matter pertaining to payment to or utilization of a subcontractor.

11. Prompt Payment of Small & Diverse Business Subcontractors:

The Contractor agrees to pay its small and diverse business subcontractors on time and in accordance with the terms and conditions of the underlying subcontract, and notify the contracting officer when the prime contractor makes either a reduced or an untimely payment to small and diverse business subcontractors (see FAR 52.242-5).

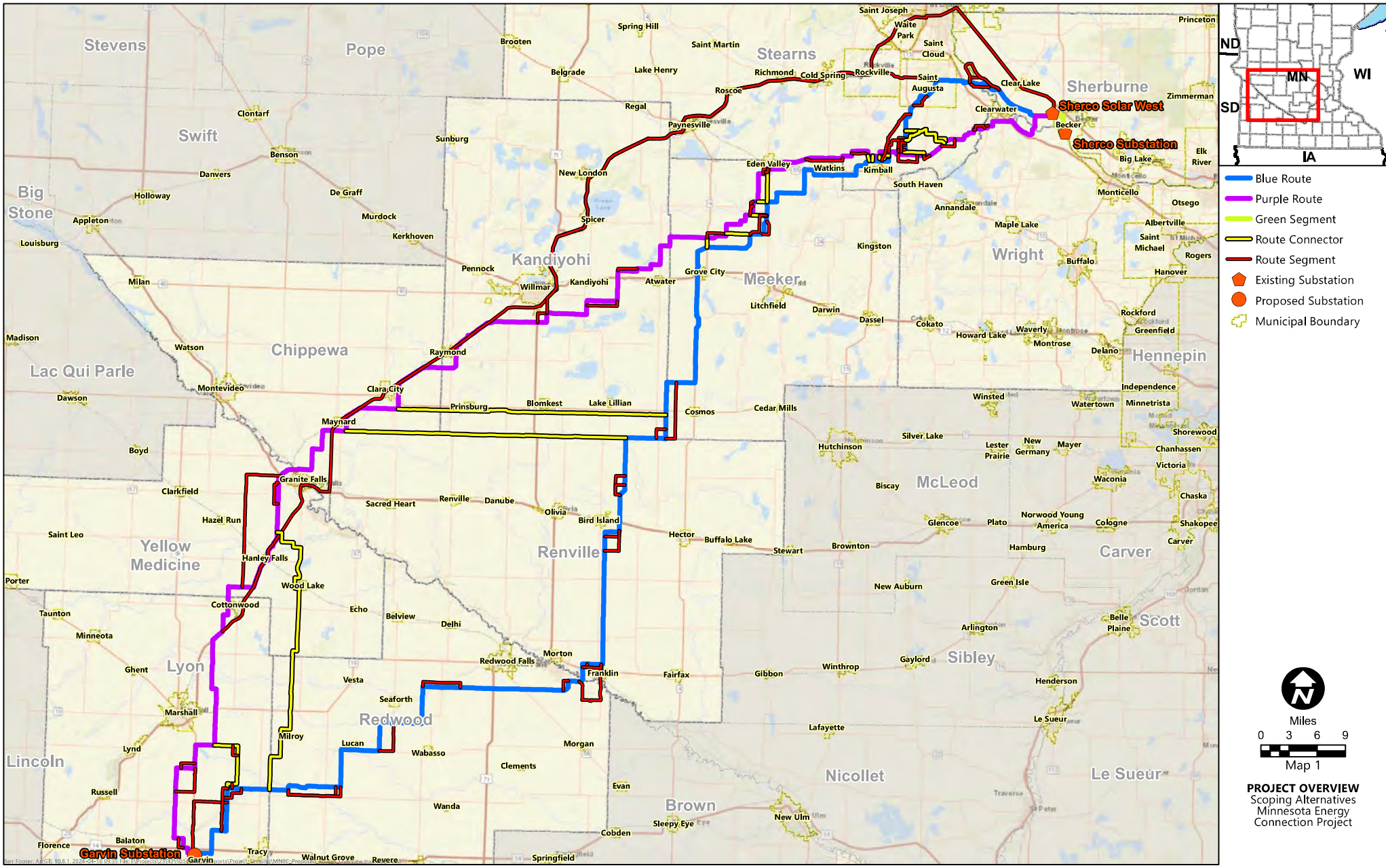
Subcontracting Plan submitted by:

Name:		Phone Number:	
Title:		Email:	

☐ By checking this box you certify that all reported information submitted in this form has been provided by a duly authorized company representative and is accurate.

Date: Digital Signature:

Xcel Energy strives to broaden our business partnerships to be inclusive of the diverse communities we serve. To learn more about our Supplier Diversity program visit https://www.xcelenergy.com/working_with_us/suppliers/supplier_diversity.


Stevens
Pope
Stearns
Sherburne
Swift
Big Stone
Lac Qui Parle
Chippewa
Kandiyohi
Meeker
Wright
Hennepin
Yellow Medicine
Renville
McLeod
Carver
Lyon
Redwood
Lincoln
Nicollet
Le Sueur
Brown
Scott
Sibley
Sherco Solar West
Sherco Substation
Garvin Substation
Saint Joseph
Waite Park
Saint Cloud
Princeton
Spring Hill
Saint Martin
Brooten
Belgrade
Lake Henry
Richmond
Cold Spring
Rockville
Saint Augusta
Clear Lake
Zimmerman
Roscoe
Regal
Paynesville
Clearwater
Becker
Clontarf
Sunburg
Benson
Danvers
Holloway
De Graff
Appleton
Murdock
Kerkhoven
Louisburg
Spicer
New London
Eden Valley
Watkins
Kimball
South Haven
Big Lake
Elk River
Monticello
Otsego
Annandale
Maple Lake
Albertville
Saint Michael
Rogers
Hanover
Buffalo
Kingston
Pennock
Willmar
Kandiyohi
Atwater
Grove City
Litchfield
Darwin
Dassel
Cokato
Howard Lake
Waverly
Montrose
Delano
Rockford
Greenfield
Milan
Madison
Watson
Raymond
Montevideo
Clara City
Dawson
Prinsburg
Blomkest
Lake Lillian
Cosmos
Cedar Mills
Maynard
Winsted
Watertown
Minnetrista
Independence
Shorewood
Chanhassen
Victoria
Waconia
Chaska
Boyd
Granite Falls
Clarkfield
Sacred Heart
Renville
Danube
Olivia
Bird Island
Hutchinson
Silver Lake
Lester Prairie
New Germany
Mayer
Biscay
Hazel Run
Saint Leo
Hector
Buffalo Lake
Stewart
Brownton
Glencoe
Plato
Norwood Young America
Cologne
Shakopee
Carver
Hamburg
Hanley Falls
Porter
Wood Lake
New Auburn
Green Isle
Cottonwood
Taunton
Echo
Belview
Delhi
Minneota
Arlington
Belle Plaine
Redwood Falls
Morton
Franklin
Fairfax
Gibbon
Winthrop
Gaylord
Ghent
Vesta
Seaforth
Marshall
Milroy
Lucan
Wabasso
Lafayette
Henderson
Le Sueur
Lynd
Morgan
Clements
Russell
Evan
Wanda
Florence
Balaton
Tracy
Walnut Grove
Revere
Springfield
Cobden
Sleepy Eye
New Ulm
ND
SD
MN
WI
IA
Blue Route
Purple Route
Green Segment
Route Connector
Route Segment
Existing Substation
Proposed Substation
Municipal Boundary
Miles
0 3 6 9
Map 1
PROJECT OVERVIEW
Scoping Alternatives
Minnesota Energy
Connection Project

Form 0 - Notice of Intent to Respond (NOIR)

2024 NSP RFP

While this Form is not required to submit a proposal, submitting it helps the Company prepare for the RFP evaluation period. Additionally, those bids pursuing the MN Energy Connection Contingent Option Bid should submit a NOIR to avoid a deduction of points as described in Section 5.3 of the RFP. This form will be collected up until the RFP closes on September 17 (self-build) and September 18 (build-transfer and PPA proposals), but the Company's preference is for this form to be submitted by August 15, 2024. Please submit to NSP24RFP@xcelenergy.com. *Please use a separate form for each separate RFP Project.*

BIDDING COMPANY INFORMATION

1) **Company Name**

2) **Company Location**
Street Address, City, State, Zip

3) **Company Representative**
Name & Title

4) **Signature of Representative**

5) **Email of Representative**

6) **Phone # of Representative**

PROJECT INFORMATION

7) **Project Name**

8) **Generation Technology**
Wind, solar, storage, or [wind or solar] + storage ("hybrid")

9) **Nameplate Capacity (MW-ac)**
If project contains multiple technologies, list each capacity separately

10) **Storage Capacity (MWh)**
Nameplate of Storage Component of Hybrid project (e.g. solar + storage)

11) **Capacity Factor (%)**
Annual as a % of Nameplate (MW-ac)

12) **Location**
(City, County, State)

13) **COD (mm/dd/yyyy)**
Proposed Commercial Operation Date (COD)

14) **Point of Delivery is on the:**

- ☐ Transmission System (MISO Zone 1)
- ☐ Reuse of Sherco point of interconnection (MN Energy ConnectionGen Tie)
- ☐ NSP Distribution System
- ☐

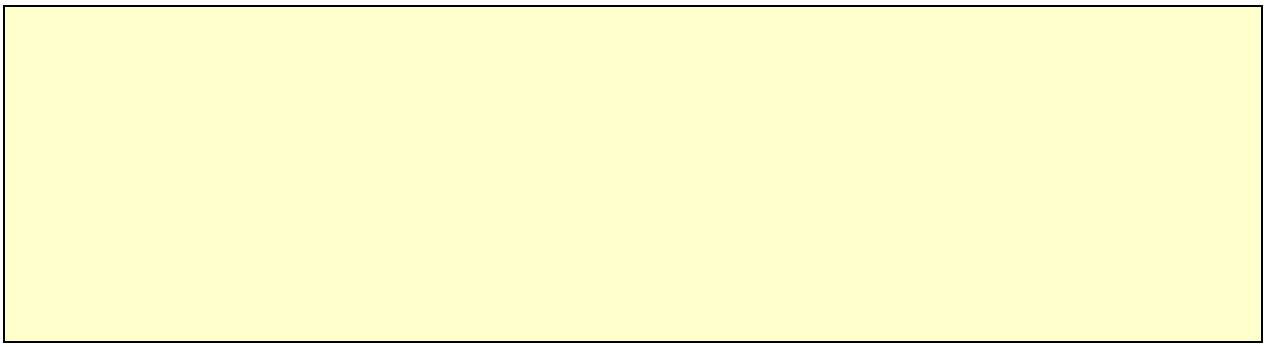
15) **Ownership/Contract Type**

- ☐ Build-Transfer or Self-Build
- ☐ Power Purchase Agreement (PPA)

16) **Diverse/Diversity Suppliers**

☐ Please contact me at the information in 1) - 6) above to help me identify diverse/diversity suppliers

17) **Notes to NOIR**



1 - Confidentiality

2024 NSP RFP

I hereby state that I will not disclose or disseminate any confidential information (as will be marked/labelled by NSP) I receive as part of the 2024 NSP Request for Proposals or during the negotiations of a Power Purchase Agreement or Purchase and Sale Agreement to any third party other than to those who are specifically authorized to review such confidential information and who have signed Form 1: Confidentiality Agreement. At the conclusion of the 2024 NSP Request for Proposals process, I agree to return all confidential information to Northern States Power Company, if requested by the Company. *New to NSP 2024 RFP:* I have also read and understand the data confidentiality provisions at the bottom of this form below the signatures.

Name

Title

Employer or Firm

Business Address

Bidder Represented

Date

Signature

2 - Bid Certification | Build-Transfer and Self-Build Bids

2024 NSP RFP

The bidder hereby certifies that all of the statements and representations made in this proposal are true to the best of the bidder's knowledge and belief, and agrees to be bound by the representations, terms, and conditions contained in the Solicitation including restrictions on the bidder's claims of confidentiality. The bidder agrees to move forward with negotiation of a Purchase & Sale Agreement based on the terms and conditions noted in the applicable Term Sheet except as specifically noted in writing.

The bidder certifies that the proposal pricing submitted includes use of union labor for the construction of the RFP Project as per the Union Labor Provision below. Bidder understands that the proposal pricing submitted for Traditional Option Bids includes the full cost for all transmission and distribution interconnection and system upgrade costs previously identified or that will be identified by MISO and all transmission costs from the RFP Project associated with delivery to the POD, except as specifically noted in Section (D) of the Pricing Form. Bidder understands that for MN Energy Connection Contingent Option Bids, cost of interconnection to the MN Energy Connection will be estimated by qualified NSP personnel.

If the project includes a solar component, the bidder has included the solar site pollinator habitat assessment state form with its bid documents, and the bidder certifies that the project will comply with applicable state permitting requirements.

BT Bidder acknowledges that as detailed in the RFP document, BT bidder will pay a second bid fee to begin contract negotiations, if the bid is shortlisted for negotiations.

The bidder agrees to abide by the Conduct Code posted below and agrees to indemnify, defend, hold harmless and reimburse Xcel Energy, its affiliates and their respective successors and assigns for, from, and against any and all losses, expenses, damages, fees or the like of whatever nature, which may be incurred as a result of or arising out of or in connection with this RFP due to: (i) bidder's breach of these terms, (ii) bidder's negligent acts or omissions; or (iii) bidder's reckless or intentional misconduct.

The bidder acknowledges that the officer whose signature appears below is able to contractually commit the bidder for its proposal.

Submitted by:	
Bidder:	
Signature of an Officer of Bidder:	
Name of Officer:	
Title:	
Date Signed:	
List of Addenda issued by NSP:	Union Labor Provision, expected July 24, 2024

Conduct Code:

All parties will prohibit unethical behavior and are expected to notify the RFP Manager if they witness practices that are counter-productive to the RFP process. Participant is required to disclose any existing or potential conflict of interest, and all parties will act in such a way to avoid the perception of a conflict of interest before, during and after the RFP has closed (September 17, 2024 for self-build bids; September 18, 2024 for build-transfer bids). If Participant is aware of unethical behavior, an existing or potential conflict of interest or experiences any difficulties that would be counter-productive to the fair operation of the RFP process, Participant must notify the RFP Manager immediately.

Union Labor Provision:

To be updated with RFP Addendum by July 24 Bidder's Conference

Current Provision Language: subject to RFP Addenda by July 24. The use of Union Labor for the construction of the RFP Project means that an officer of Seller, authorized to bind Seller and who is familiar with the Facility, shall certify in writing that all Construction Craft Employees were covered by a collective bargaining agreement with a union affiliated with the local council of North America's Building Trades Unions ("Building Trades CBA"). If Seller cannot provide such certification as to a specified portion of the work, then an officer of Seller, authorized to bind Seller and who is familiar with the Facility shall certify in writing that Seller met and conferred, in good faith, with the local council of North America's Building Trades Unions and attempted to find and hire those trade(s) of Construction Craft Employee(s) covered by a Building Trades CBA for that portion of the work, and, if such Construction Craft Employee(s) covered by a Building Trades CBA were not available, that Seller (or Seller's construction contractor) entered into a site-specific building trades collective bargaining agreement covering that portion of the work.

2 - Bid Certifica

2024 NSP RFP

The bidder hereby certif
The bidder certifies that
Labor Provision below,
or that will be identified

If the project includes a

PPA Bidder acknowledg

The bidder certifies that
take all steps to enable

The bidder certifies that
and that, to the bidder's
Company

The bidder agrees to ab
Energy, its affiliates and
like of whatever nature,
these terms, (ii) bidder's

The bidder acknowledg

Submitted by:

Bidder:

Signature of an
Officer of Bidder:

Name of Officer:

Title:

Date Signed:

List of Addenda
issued by NSP:

Conduct Code:

Union Labor Provision:

To be updated with RFP Addendum by July 24 Bidder's Conference

tion | Power Purchase Agreement Bid

ies that all of the statements and representations made in this proposal are true to the best of the bidder's
: the proposal pricing submitted includes use of union labor for the construction of the RFP Project as per the Union
and the full cost for all transmission and distribution interconnection and system upgrade costs previously identified
by MISO and all transmission costs from the RFP Project associated with delivery to the POD.

solar component, the bidder has included the solar site pollinator habitat assessment state form with its bid

ges that as detailed in the RFP document, PPA bidder will pay a second bid fee to begin contract negotiations, if the

, in the event that the Company needs to communicate with MISO regarding interconnection specifics, that they will
such communication.

the bidder has considered applicable accounting standards in regard to finance lease and variable interest entities
knowledge, the bidder's proposal will not result in finance lease or variable interest entity treatment to the

ide by the Conduct Code posted below and agrees to indemnify, defend, hold harmless and reimburse Xcel
l their respective successors and assigns for, from, and against any and all losses, expenses, damages, fees or the
which may be incurred as a result of or arising out of or in connection with this RFP due to: (i) bidder's breach of
s negligent acts or omissions; or (iii) bidder's reckless or intentional misconduct.

es that the officer whose signature appears below is able to contractually commit the bidder for its proposal.

Union Labor Provision, expected July 24, 2024

All parties will prohibit unethical behavior and are expected to notify the RFP Manager if they witness practices that are counter-productive to the RFP process. Participant is required to disclose any existing or potential conflict of interest, and all parties will act in such a way to avoid the perception of a conflict of interest before, during and after the RFP has closed (September 18, 2024 for PPA bids). If Participant is aware of unethical behavior, an existing or potential conflict of interest or experiences any difficulties that would be counter-productive to the fair operation of the RFP process, Participant must notify the RFP Manager immediately.

Current Provision Language: subject to RFP Addenda by July 24. The use of Union Labor for the construction of the RFP Project means that an officer of Seller, authorized to bind Seller and who is familiar with the Facility, shall certify in writing that all Construction Craft Employees were covered by a collective bargaining agreement with a union affiliated with the local council of North America's Building Trades Unions ("Building Trades CBA"). If Seller cannot provide such certification as to a specified portion of the work, then an officer of Seller, authorized to bind Seller and who is familiar with the Facility shall certify in writing that Seller met and conferred, in good faith, with the local council of North America's Building Trades Unions and attempted to find and hire those trade(s) of Construction Craft Employee(s) covered by a Building Trades CBA for that portion of the work, and, if such Construction Craft Employee(s) covered by a Building Trades CBA were not available, that Seller (or Seller's construction contractor) entered into a site-specific building trades collective bargaining agreement covering that portion of the work.

3 - Applicant Info and References

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all bid types to complete.

Does this Bidder Form represent the only bid for this project into the NSPM 2024 RFP? *(if more than one bid is being submitted for this project, please complete the next question)*	
If more than one bid is being submitted for this project, please identify which bid this Bidder Form response is intended to be used for. *Please submit a separate Bid Form for each option.*	

Company Information

Name	
Headquarter Address	
Organization Type (Corp, LLC, Partnership, etc)	

Company Representative

Name	
Title	
Address	
Phone	
Email	

Contact for Transmission Information

Name	
Phone	
Email	

3 - Applicant Info and References

NSP 2024 RFP

Contact for Environmental/Permitting Information

Name	
Phone	
Email	

Contact for Interconnection Information

Name	
Phone	
Email	

Previous Experience

List the five largest developed and fully operational projects in the United States and/or Canada that are similar to the bid technology

Project Name and Location	Bidder's Role	Size (MW)

3 - Applicant Info and References

NSP 2024 RFP

Project Overview (All Applications)

Name		
Facility Category		(select from drop-down)
Description if Facility Category is "Other"		
RFP Bid Option Selected		
Type of Financial Contract Proposed		(select from drop-down)
Does the project contain multiple resource types/hybrid project (example: solar + battery)		(select from drop-down)
If proposal is a hybrid project, indicate the number of resource types		(select from drop-down)
Commercial Operation Date (COD)		

Project Location(s)

There are multiple locations proposed within this bid (i.e., portfolio bid)		(select from drop-down)
City or Cities proposed		
County (or counties)		
State		
Latitude (center of (each) project)		(decimal degrees)
Longitude (center of (each) project)		(decimal degrees)

AD/CVD Cost, Delay and Risk Assessment (Check one; see section 4.9 of the RFP for details)

	My project does not include a solar component
	My solar project is not at risk from determinations or rulings regarding AD/CVD
	My project is at risk from determinations or rulings regarding AD/CVD

3 - Applicant Info and References

NSP 2024 RFP

Website Acknowledgment

	Bidder understands that the most updated version of this Standard Bidder Form, and other RFP materials, are online at www.xcelenergy.com.

BT Bids Only - Demonstrated Understanding of Standard Bids & Confirmation of Term Sheet Exceptions

(all other bid types leave blank)

	Bidder understands a Standard Bid, with pricing that makes no exceptions to the applicable BOT Term Sheet in Appendix A and accepts all terms herein, is required for all BT Bids.
	Bidder has opted to provide pricing for an optional Alternative Bid in addition to the Standard Bid. Redlined exceptions to the applicable Term Sheet have been provided and as per Form 2 bidder accepts all other terms in the BT Term Sheet to which no exception has been made.

Automatic Generator Control

	Can the RFP Project as bid be controlled by Automatic Generator Control (AGC)?
	If the RFP Project cannot be controlled by AGC, is the RFP Project as bid compatible with AGC, should it be added later?

Additional Information

Please provide any additional socioeconomic factors or information that should be considered with this proposal.

Please provide evidence of any local stakeholder support of the planned project.

3 - Applicant Info and References

NSP 2024 RFP

Jobs - Please provide a) the number of estimated construction jobs that would be generated by this project; and b) the number of estimated ongoing operational jobs that would be sustained by this project.

a)

b)

Payments - Please provide an estimate of the a) total payments landowners will receive during the proposed project term; and b) total estimated tax payments the proposed project would generate over the term.

a)

b)

Please provide the assumptions you used to answer the Jobs question above or enclose an attachment with these details and indicate the attachment name here.

Environmental Justice

If the Project is located in Minnesota: is the Project located in an “Environmental Justice Area” as defined in Minn. Stat. 216B.1691, Subd. 1(e)? A map of U.S. Census tracts meeting the criteria in this statute can be found at the link below. Enter your Project location in the "Find address or place" box to determine if it is within an Environmental Justice Area.

Environmental Justice Areas (MPCA map)

If the Project is not located in Minnesota, please confirm whether it is located in an area meeting at least one of the Minn. Stat. 216B.1691, Subd. 1(e) criteria below.

If the Project is not located in Minnesota and is located in an area meeting at least one of the four criteria below, identify which criteria (one or more) are met by the location of the Project.

If the Project is not located in Minnesota and is located in an area meeting at least one of the four criteria below, identify which public source(s) of data were used to evaluate whether these criteria are met (i.e., US Census, etc). *The Company may ask you to provide links or copies of such data.*

3 - Applicant Info and References

NSP 2024 RFP

Minn. Stat. 216B.1691, Subd. 1(e) criteria, based on the most recent data published by the United States Census Bureau:

(1) 40 percent or more of the area's total population is nonwhite;

(2) 35 percent or more of households in the area have an income that is at or below 200 percent of the federal poverty level;

(3) 40 percent or more of the area's residents over the age of five have limited English proficiency; or

(4) the area is located within Indian country, as defined in United State Code, title 18, section 1151.

Notes

4 - Generator, Storage, and Balance of Plant Info ("GenTech&BOP")

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all bid types to complete. Each technology being bid into the RFP, *even an asset already in existence,* must have information completed below. If a project is a portfolio project, composed of multiple locations, please make additional copies of this Form 4-GenTech&BOP until every proposed location is represented by a separate Tech Type.

Directions: Report details on each resource type as a different technology type below. For example, for a solar + storage bid, report the solar component as "Tech Type 1" and the storage component as "Tech Type 2".

	Tech Type 1	Tech Type 2	Tech Type 3	Tech Type 4
1) Generation Technology Type				(select from drop-down)
Additional Description				
Primary Fuel Type				
Wind Only: Gross Nameplate Capacity (MW)				
Solar/Battery Only: Gross Nameplate Capacity (MWdc)				
Point of Delivery Net Nameplate Capacity (MW-AC)				
Capacity Factor (%)				
Storage Duration of Nameplate Capacity (hours)				
2) Collection Sub & Generator Tie-Line				
Collection Substation Quantity				
Main Power Transformer Quantity				
MPT Manufacturer				
MPT Power Rating (MW) (ONAN/ONAF/ONAF)				
MPT Voltage Ratings (kV) (Low/High)				
MPT Planned Order Date				
MPT Planned Delivery Date				
Capacitor Bank Quantity & Total Rating (kVAR)				
Utility Providing Retail Service at Collection Substation				
Length of Gen-Tie to Point of Interconnect (miles)				
Gen-Tie Line Status				

Describe MPT procurement plan including existing supply agreements, planned solicitations, procurement schedule, etc:

3) Estimated Substantial Completion Date (hybrid proposals only) *(e.g., common date of overall project substantial completion since project contains multiple generation types/may contain multiple CODs)*				
4) Estimated Useful Life of Resource at COD (years)				

4 - Generator, Storage, and Balance of Plant Info ("GenTech&BOP")

NSP 2024 RFP

5) Notes

4 - Generator, Storage, and Balance of Plant Info ("GenTech&BOP")

NSP 2024 RFP

5 - Energy Production Profile - Annual ("GenAnnual")

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all applications with physical generation or energy injection facilities (i.e., Generation or Storage systems).

Use the prompts in the orange cells below to complete the applicable annual energy summary for each commercially operable resource type in the proposal.

For Physical Generation Facilities (Wind, Solar): Enter Generation in each Tech Type as it corresponds to the Tech Type identified on Form "4-GenTech&BOP". The "Expected Generation at POI" columns in question 3) below are to be calculated at the Point of Interconnection for each year of the project's expected life (or for Power Purchase Agreements, each year of the proposed contract term). For Power Purchase Agreements, the MWH reported below must align with the Committed Energy in the proposed contract and will also correspond with the Energy Payment Rate ($/MWH) proposed on the "Renew Storage PPA Pricing" tab. Year 1 of Wind and Solar systems proposed must be set at the estimates provided on the WPower Curve and WResource tabs of this document (for wind) or

Instructions for the "Table for Storage Systems" below:

Round Trip Efficiency (RTE) is the amount of Battery Energy discharged by the BESS relative to the amount of Charging Energy, measured at the Battery Storage System Electric Metering Device. All proposal types: Power Purchase Agreement (PPA), Build-Transfer, and Company Self-Build, must complete the RTE column.

Storage Systems in Proposals for Company Owned projects (either Build-Transfer or Company Self-Build): Complete both the "With Augmentation" and "Without Augmentation" columns. Sufficient initial overbuild shall be included to maintain capacity at 100% of design for the first 36 months in the Without Augmentation column. In the With Augmentation column, include a recomended augmentation schedule even though the augmentation cost would be the Company's responsibility.

Storage Systems in Proposals for Power Purchase Agreements: Please complete either the "With Augmentation" column or the "Without Augmentation" column to correspond with the planned design for the proposed storage application of your application (both may be completed if both design options are to be offered as separately priced options). Should "Without Augmentation" be chosen, sufficient initial overbuild shall be included to maintain capacity at 100% of design for the first 36 months in the Without Augmentation column. Both columns will align with the pricing options on the Renew Storage PPA Pricing tab and may not exceed 15 years in length. For any hybrid proposals (i.e., solar + storage, wind + storage, etc), the "Expected Generation at POI" MWH provided below for the physical generation component of your application (i.e., wind or solar component) should correspond to the Committed Energy in the proposed the Power Purchase Agreement and the Energy Payment Rate on the "Renew Storage PPA Pricing" tab.

5 - Energy Production Profile - Annual ("GenAnnual")

NSP 2024 RFP

1) Post COD Generation and Storage Capacity

	Tech Type 1	Tech Type 2	Tech Type 3	Tech Type 4			
	Not Used	*Not Used*	*Not Used*	*Not Used*	Table for Storage Systems Only *(see instructions above)*		
Operational Year	Expected Generation at POI - Include Degradation (MWh)	Expected Generation at POI - Include Degradation (MWh)	Expected Generation at POI - Include Degradation (MWh)	Expected Generation at POI - Include Degradation (MWh)	Storage Capacity at POI - Without Augmentation (MWh)	Storage Capacity at POI - With Augmentation (MWh)	Round Trip Efficiency (%)
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3							
4							
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2) Notes

6 - D1 Technology 1 - Build-Transfer and Self-Build Bid Standard Pricing (Pre-COD)

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build bids. This is for a Standard Bid Price that assumes no exceptions from the applicable Term Sheet as defined on Form 3-Applicant Info and References. See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the application.

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases and post-closing land costs and report them on 6-D2_Expenses instead.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology.

1) Pre-COD Construction & Milestone Standard Bid Payments for Technology 1:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	Payment Date (mm/dd/yyyy)	Generation Equipment Related Payments ($)	Electrical Equipment Related Payments ($)	Transmission Interconnection Related Payments ($)	Land Purchase Payments ($)	All Other Project-Related Payments ($) *(see instructions above)*	Total Payments ($)
							$ -
							$ -
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6 - D1 Technology 1 - Build-Transfer and Self-Build Bid Standard Pricing (Pre-COD)

NSP 2024 RFP

							$ -
							$ -
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							$ -
							$ -
							$ -
							$ -
							$ -
							$ -

2) Notes to Pricing Assumptions for Technology 1

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) ITC/PTC questions - Answer these questions for Technology 1 only

Is the Technology 1 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab for Technology 1. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation for Technology 1. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 1, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

Tax Credit Adders

6 - D1 Technology 1 - Build-Transfer and Self-Build Bid Standard Pricing (Pre-COD)

NSP 2024 RFP

Does bidder intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind and solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date

Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or Grants

Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing

Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

6) Notes to ITC/PTC Assumptions and Documentation for Technology 1

6 - D1 Technology 1 - Build-Transfer and Self-Build Bid Standard Pricing (Pre-COD)

NSP 2024 RFP

6 - D1 Technology 1 - Build-Transfer and Self-Build Application Alternate Pricing (Pre-COD)

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build bids. This is for an Alternate Bid Price that assumes the exceptions proposed by BT bidder to the Term Sheet (Appendix A) and/or the Technical Specifications (Appendix C). See the instructions below for further

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the application.

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases and post-closing land costs and report them on 6-D2_Expenses instead.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology.

1) Pre-COD Construction & Milestone Alternate Bid Payments for Technology 1:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	Payment Date (mm/dd/yyyy)	Generation Equipment Related Payments ($)	Electrical Equipment Related Payments ($)	Transmission Interconnection Related Payments ($)	Land Purchase Payments ($)	All Other Project-Related Payments ($) *(see instructions above)*	Total Payments ($)
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6 - D1 Technology 1 - Build-Transfer and Self-Build Application Alternate Pricing (Pre-COD)

NSP 2024 RFP

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2) Notes to Pricing Assumptions for Technology 1

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) ITC/PTC questions - Answer these questions for Technology 1 only

Is the Technology 1 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab for Technology 1. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation for Technology 1. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 1, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

Tax Credit Adders

6 - D1 Technology 1 - Build-Transfer and Self-Build Application Alternate Pricing (Pre-COD)

NSP 2024 RFP

Does bidder intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind and solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date — Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or Grants — Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing — Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

6) Notes to ITC/PTC Assumptions and Documentation for Technology 1

6 - D1 Technology 1 - Build-Transfer and Self-Build Application Alternate Pricing (Pre-COD)

NSP 2024 RFP

6 - D1 Technology 2 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build applications that are proposing multiple Technology Types on the Form 4-GenTech&BOP. This is for a Standard Bid Price that assumes no exceptions from the applicable Term Sheet as defined on Form 3-Applicant Info and References. See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology. NOTE: If the costs of the gas interconnection are included in the proposal, provide the proposed payments in this column and mention this inclusion in the Notes section below. Do not include gas interconnection costs in the "Generation Equipment Related Payments" or "Electrical Equipment Related Payments" categories.

1) Pre-COD Construction & Milestone Standard Bid Payments for Technology 2:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	**Payment Date (mm/dd/yyyy)**	**Generation Equipment Related Payments ($)**	**Electrical Equipment Related Payments ($)**	**Transmission Interconnection Related Payments ($)**	**Land Purchase Payments ($)**	**All Other Project-Related Payments ($)** *(see instructions above)*	**Total Payments ($)**
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2) **Notes to Pricing Assumptions for Technology 2**

3) Non-ITC/PTC Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) **ITC/PTC questions - Answer these questions for Technology 2 only**

Is the Technology 1 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation for Technology 2. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 2, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

Tax Credit Adders

Does bidder intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind or solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date — Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or Grants — Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing — Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

4) Notes to ITC/PTC Assumptions and Documentation

6 - D1 Technology 2 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build applications that are proposing multiple Technology Types on the Form 4-GenTech&BOP. This is for an Alternate Bid Price that assumes the exceptions proposed by BT bidder to the Term Sheet (Appendix A) and/or the Technical Specifications (Appendix C). See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology. NOTE: If the costs of the gas interconnection are included in the proposal, provide the proposed payments in this column and mention this inclusion in the Notes section below. Do not include gas interconnection costs in the "Generation Equipment Related Payments" or "Electrical Equipment Related Payments" categories.

1) Pre-COD Construction & Milestone Alternate Bid Payments for Technology 2:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	**Payment Date (mm/dd/yyyy)**	**Generation Equipment Related Payments ($)**	**Electrical Equipment Related Payments ($)**	**Transmission Interconnection Related Payments ($)**	**Land Purchase Payments ($)**	**All Other Project-Related Payments ($)** *(see instructions above)*	**Total Payments ($)**
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2) **Notes to Pricing Assumptions for Technology 2**

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) **ITC/PTC questions - Answer these questions for Technology 2 only**

Is the Technology 1 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation for Technology 2. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 2, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

Tax Credit Adders

Does bidder intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind or solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date

Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or Grants

Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing

Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

4) Notes to ITC/PTC Assumptions and Documentation

6 - D1 Technology 3 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build applications that are proposing three or more Technology Types on the Form 4-GenTech&BOP. This is for a Standard Bid Price that assumes no exceptions from the applicable Term Sheet as defined on Form 3-Applicant Info and References. See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the application.

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology.

1) Pre-COD Construction & Milestone Standard Bid Payments for Technology 3:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	Payment Date (mm/dd/yyyy)	Generation Equipment Related Payments ($)	Electrical Equipment Related Payments ($)	Transmission Interconnection Related Payments ($)	Land Purchase Payments ($)	All Other Project-Related Payments ($) *(see instructions above)*	Total Payments ($)
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6 - D1 Technology 3 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

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2) Notes for Pricing Assumptions for Technology 3

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) ITC/PTC questions - Answer these questions for Technology 3 only

Is the Technology 3 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 3, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

Tax Credit Adders

6 - D1 Technology 3 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

Does bidder intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind or solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date — Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or Grants — Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing — Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

4) Notes to ITC/PTC Assumptions and Documentation for Technology 3

6 - D1 Technology 3 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

6 - D1 Technology 3 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build applications that are proposing three or more Technology Types on the Form 4-GenTech&BOP. This is for an Alternate Bid Price that assumes the exceptions proposed by BT bidder to the Term Sheet (Appendix A) and/or the Technical Specifications (Appendix C). See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the application.

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology.

1) Pre-COD Construction & Milestone Alternate Bid Payments for Technology 3:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	Payment Date (mm/dd/yyyy)	Generation Equipment Related Payments ($)	Electrical Equipment Related Payments ($)	Transmission Interconnection Related Payments ($)	Land Purchase Payments ($)	All Other Project-Related Payments ($) *(see instructions above)*	Total Payments ($)
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6 - D1 Technology 3 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

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2) Notes for Pricing Assumptions for Technology 3

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) ITC/PTC questions - Answer these questions for Technology 3 only

Is the Technology 3 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 3, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

Tax Credit Adders

6 - D1 Technology 3 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

Does bidder intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind or solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date — Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or Grants — Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing — Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

4) Notes to ITC/PTC Assumptions and Documentation for Technology 3

6 - D1 Technology 3 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

6 - D1 Technology 4 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build applications that are proposing four Technology Types on the Form 4-GenTech&BOP. This is for a Standard Bid Price that assumes no exceptions from the applicable Term Sheet as defined on Form 3-Applicant Info and References. See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the application.

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology.

1) Pre-COD Construction & Milestone Standard Bid Payments for Technology 4:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	Payment Date (mm/dd/yyyy)	Generation Equipment Related Payments ($)	Electrical Equipment Related Payments ($)	Transmission Interconnection Related Payments ($)	Land Purchase Payments ($)	All Other Project-Related Payments ($) *(see instructions above)*	Total Payments ($)
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6 - D1 Technology 4 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

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2) Notes to Pricing Assumptions for Technology 4

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) ITC/PTC questions - Answer these questions for Technology 4 only

Is the Technology 1 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab for Technology 4. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation for Technology 4. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 1, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

6 - D1 Technology 4 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

Tax Credit Adders

Does applicant intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind and solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date

Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or

Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing

Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

4) Notes to ITC/PTC Assumptions and Documentation for Technology 4

6 - D1 Technology 4 - Build Transfers and Self-Build Bid Standard Pricing

NSP 2024 RFP

6 - D1 Technology 4 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all Build-Transfer and Company Self-Build applications that are proposing four Technology Types on the Form 4-GenTech&BOP. This is for an Alternate Bid Price that assumes the exceptions proposed by BT bidder to the Term Sheet (Appendix A) and/or the Technical Specifications (Appendix C). See the instructions below for further details.

General Directions & Pricing Assumptions

For Hybrid projects (projects involving more than one resource type) a separate sheet is required for each resource type/technology; however if some costs are not able to be itemized by resource type (i.e., some interconnection costs), provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs.

All dollar amounts should be entered in nominal dollars. Notes should include all pricing assumptions, including federal tax incentives applicable to the proposed project that would transfer upon sale of the asset. Subjects covered in the "Notes" should also be included in the application.

Progress Payments - Depending upon whether a PTC or ITC applies, the Company prefers to make one lump-sum payment at closing (in the PTC context) or to make a one installment payment at closing and one installment on the substantial completion date (in the ITC context). Please see Section 2.4 of the RFP and applicable BT Term Sheet in Appendix A for more details. *If bidder is interested in receiving installment/progress payments, include a proposed schedule of installment/progress payments below for the Company to consider. Otherwise, provide the proposed pricing in the form of a single lump-sum payment for each of the different payment categories below.*

MN Energy Connection Contingent Bids: only provide Generation Equipment Related Payments, Land Purchase Payments, and "Other Project-Related Payments in the Table in 1) below. *Do not include Transmission Interconnection Related Payments or Electrical Equipment Related Payments.*

Payment Categories in Table 1) below are as follows:

1) Generation Equipment Related Payments - All project costs up to the collection substation.

2) Electrical Equipment Related Payments - All project costs from the collection substation to the POI (i.e., Collector sub + step up transformer cost + any gen ties to POI). Note: if some electrical equipment costs are not able to be itemized for a type for a hybrid application, provide these costs on the tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

3) Transmission Interconnection Related Payments - Known or estimated MISO upgrade/interconnection costs. Note; if some interconnection costs are not able to be itemized by resource type for a hybrid application, provide the interconnection costs on the Tab for Technology 1 only; do not repeat the same cost in subsequent D1 tabs. *MN Energy Connection Contingent Bids: do not provide this cost.*

4) Land Purchase Payments - Cost of any purchased land, i.e. O&M building lot. Exclude all leases.

5) All Other Project-Related Payments - Any other costs to be incurred by Xcel Energy prior to the commercial operation data of the proposed technology.

1) Pre-COD Construction & Milestone Alternate Bid Payments for Technology 4:

		All Bids	Traditional Bids Only	Traditional Bids Only	All Bids	All Bids	
Description	Payment Date (mm/dd/yyyy)	Generation Equipment Related Payments ($)	Electrical Equipment Related Payments ($)	Transmission Interconnection Related Payments ($)	Land Purchase Payments ($)	All Other Project-Related Payments ($) *(see instructions above)*	Total Payments ($)
							$ -
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6 - D1 Technology 4 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

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2) Notes to Pricing Assumptions for Technology 4

3) Non-ITC/PTC — Describe generally the Non-ITC/PTC tax representation and warranties, and covenants to be provided.

4) Special Purpose Vehicle — Is a newly formed special purpose vehicle (SPV) planned to hold the project? If so, state whether a transfer of that SPV is contemplated.

5) ITC/PTC questions - Answer these questions for Technology 4 only

Is the Technology 1 as reported on this tab expected to qualify for federal tax credits (Investment Tax Credit (ITC) and/or Production Tax Credit (PTC))? _____ (select from drop down)

If project is not expected to qualify for tax credits, the rest of the ITC/PTC section may be left blank.

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret start of construction as the date provided on the Construction Milestone tab for Technology 4. _____ (select from drop down)

Bidder understands that unless specified otherwise in the Notes to Tax Credits below on this tab, for modeling purposes the Company will interpret the placed in service date as the date provided on the Construction Milestone tab for commercial operation for Technology 4. _____ (select from drop down)

Which beginning of construction criteria will be satisfied for Technology 1, the physical work test or the 5% safe harbor? _____ (select from drop down)

Repowering — Does the bidder plan to repower the facility? _____ (select from drop down)

If repowering is planned, describe how bidder will meet the 80/20 test discussed in IRS Notices 2016-31 and 2017-04.

Prevailing Wage & Apprenticeship Requirements:

Confirm how the prevailing wage and apprenticeship requirements will be met in order to receive the full credit.

6 - D1 Technology 4 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

Tax Credit Adders

Does applicant intend for the project to qualify for the domestic content tax credit adder? _____ (select from drop down)

If qualification for the domestic content tax credit adder is intended, describe how the domestic content requirements will be met in order to receive the increased credit.

If bidder asserts the project qualifies for the domestic content bonus, does bidder confirm that the qualification is based on the IRS safe harbor rules for manufactured products/manufactured product components in Notice 2023-38 and based on the new elective safe harbor to determine cost percentages in Notice 2024-21?

Is the project expected to be in an energy community in order to receive the increased tax credit? _____ (select from drop down)

If qualification for the energy community adder is expected, describe which energy community criteria will be met.

Is the project expected to be eligible for an allocation for wind and solar projects constructed in low income communities? _____ (select from drop down)

If the project is expected to be eligible for an allocation for wind or solar projects constructed in low income communities, please describe.

Transfer Date

Confirm the stage of the project at which, and the target date on which, the project is expected to be transferred for federal income tax purposes.

Other Tax Credits or

Confirm whether any other tax credits or grants have been claimed with respect to the project.

Financing

Identify any tax exempt bonds, subsidized energy financings, private activity bonds or other financing be used that may impact the ITC/PTC or depreciation for the project.

4) Notes to ITC/PTC Assumptions and Documentation for Technology 4

6 - D1 Technology 4 - Build Transfers and Self-Build Bid Alternate Pricing

NSP 2024 RFP

6 - D2 - Post COD Expenses for BTs, Self-Builds

NSP 2024 RFP

Who Should Complete this Form: This form is intended for Build-Transfer and Company Self-Build applications of all resource types. See the instructions below for further details.

These are expenses that bidder expects the proposed project will occur after the resource has attained COD. All dollar amounts should be entered in nominal dollars.

If an Original Equipment Manufacturer (OEM) service agreement ("LTSA") is required as part of the equipment sale, select Y in section 2 and enter pricing in section 3 in the "Contract Payments" column for the applicable Tech Type. If an agreement is optional, select N in section 2 but as required in section 2.4 of the main RFP document, enter the estimated pricing in section 3 in the "Contract Payments" column for the applicable Tech Type.

Land & Easement Payments shall incorporate inflation, step changes, production payments, etc in accordance with the executed easement agreements

1) **Is an OEM service contract required with equipment?** _____ (select from drop-down)

2) **Post COD Generation & Expenses**

Operational Year	OEM O&M Contract Payments Tech 1 ($)	Land & Easement Payments Tech 1 ($)	OEM O&M Contract Payments Tech 2 ($)	Land & Easement Payments Tech 2 ($)	OEM O&M Contract Payments Tech 3 ($)	Land & Easement Payments Tech 3 ($)	OEM O&M Contract Payments Tech 4 ($)	Land & Easement Payments Tech 4 ($)
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3) **Notes**

6 - Pricing for Renewable and/or Storage Power Purchase Agreement

NSP 2024 RFP

Who Should Complete this Form: This form is intended for applications proposing the following types of Power Purchase Agreements (PPAs): wind, solar, wind + storage, solar + storage, standalone storage, and other combination of these technologies.

Finance Lease Consideration - The Company is aware that certain contract approaches – especially with respect to battery energy storage – could result in either (i) a contract that must be accounted for by the Company as a finance lease or an operating lease pursuant to Financial Accounting Standards Board ("FASB") Accounting Standards Codification ("ASC") 842, or (ii) consolidation of the seller or assets owned by the seller onto the Company's balance sheet pursuant to the variable interest entity requirements of FASB ASC 810.

The Company is unwilling to be subject to any accounting or tax treatment that results from a PPA's finance lease or consolidated variable interest entity classification. As a result, in their data intake form below(s), applicants may (i) state that the applicant has considered applicable accounting standards in regard to finance leases and variable interest entities, (ii) summarize the applicant's proposal to address these issues, and (iii) state that, to the applicant's knowledge and belief, the application will not result in such treatment as of the date of the proposal.

General Directions & Pricing Assumptions: All dollar amounts should be entered in nominal dollars. Prices must contain a fixed base price. Do not submit proposals with variable base year pricing or variable escalators. All tax assumptions included in the rates below should be described in the Notes section on this form. Please complete the pricing table below that align with the proposed PPA type:

Solar, Hydro, and Wind PPAs: Please complete the Energy Payment Rate for the number of years in the proposed PPA term. The Committed Energy corresponding to this Energy Payment Rate is on the GenAnnual tab in the "Expected Generation at POI" column for the proposed solar or wind generator.

Standalone Storage PPAs: Please complete Capacity Payment Rate #1 (if the project is overbuilt and assumes no augmentation during the proposed term) and/or Capacity Payment Rate #2 (if the project assumes augmentation). Only one payment rate is necessary; although both may be completed as different proposed options for the project as discussed in the GenAnnual tab instructions. The proposed contract term may not exceed 15 years.

Hybrid (Solar + Storage or Wind + Storage) PPAs: Please complete the Energy Payment Rate with pricing in $/MWH for energy from the renewable (solar, hydro, or wind) generation component of the hybrid asset only. For the storage component of the renewable asset, please complete Capacity Payment Rate #1 (if the project is overbuilt and assumes no augmentation during the proposed term) and/or Capacity Payment Rate #2 (if the project assumes augmentation). Only one payment rate is necessary; although both may be completed as different proposed options for the project. The proposed contract term for the storage component may not exceed 15 years.

2)	**Does the pricing below include an assumption that the project will qualify for the domestic content federal tax credit adder?**	(select from drop down)
3)	**Does the pricing below include an assumption that the project will qualify for the energy community federal tax credit adder?**	(select from drop down)
4)	**Does the pricing below include an assumption that the project will qualify for the low income communities tax credit adder?**	(select from drop down)

6 - Pricing for Renewable and/or Storage Power Purchase Agreement

NSP 2024 RFP

5) PPA Rates

	PPA Types: Wind, Solar, renewable component of Hybrid PPAs (*see Hybrid PPA instructions above*)		PPA Types: Standalone Storage, storage component of Hybrid PPAs (*see Hybrid PPA instructions above*)	
Operation Year	**Energy Payment Rate ($/MWh)**		**Capacity Payment Rate #1 ($/kW-mo)**	**Capacity Payment Rate #2 ($/kW-mo)**
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6) Notes

7) Finance Lease (See the Finance Lease Consideration section at beginning of Form for details)

Has the bidder considered applicable accounting standards in regard to finance leases and variable interest entities?

Please summarize how the application addresses these issues.

7 - Construction Milestones

NSP 2024 RFP

Who Should Complete this Form: This form is intended for any projects - PPAs, Company Self-Builds, or Build-Transfer bids - proposing the construction of one or more new resources, or proposing repowers at existing MISO POIs. See the instructions below for further details.

Insert the proposed or estimated date for each milestone shown here. Milestone estimates should be based on the requirements to achieve the proposed commercial operation date. Hybrid proposals may provide dates corresponding to each resource type within this form.

Date	Construction Milestones
	Estimated date by which Seller has obtained all required permits needed to construct the Facility. *Hybrid proposals: if dates differ by each resource type included in the application, please see directions above and provide separate dates for each resource type in the application.*
	Estimated date by which panels/WTGs/battery/CT contract(s) or reservation agreements are in place.
	Estimated date by which MPT contract(s) or reservation agreements are in place.
	Seller shall have achieved closing on financing for the Facility or provided the Company with proof of financial capability to construct the Facility.
	Estimated date by which issues construction drawings complete (IFC set). *Hyprid proposals: if dates differ by each resource type included in the application, please see directions above and provide separately for each resource type in the application.*
	Commencement of construction of the Facility. *Hybrid proposals: see directions above and provide commencement date for each resource type included in the application.*
	Seller shall have constructed necessary Seller's Interconnection Facilities; such facilities are capable of being energized
	Seller shall make all applications and/or filings required by Applicable Law for REC accreditation and for the provision of such RECs to Company.
	Commercial Operation Milestone (should match date provided in the "COD" field on the "Applicant Info and Reference tab). *Hybrid proposals: see directions above and provide commencement date for each resource type included in the application.*

8 - Technical Descriptions

NSP 2024 RFP

Who Should Complete this Form: This form is intended for applications proposing new battery energy storage systems, solar PV and/or wind generation assets, including repowers at existing facilities. See the instructions below for further details.

General Directions
Enter equipment specifications in the applicable rows for Battery Energy Storage Systems (BESS), Solar PV, and Wind plants. *Where prompted below, provide a single set of PV modules, modules, or WTG you are considering or planning for your proposed projects. This is required as per Section 5.2 of the RFP; failure to designate a single set for evaluation may result in elimination of your project.* Where this form indicates to list alternatives, you may list alternative makes and models you are considering in addition to the model proposed for evaluation.

Battery Energy Storage

1) Battery (Single Cell Manufacturer & Enclosure Type must be designated for NSP 2024 Evaluation)

Cell Manufacturer		Enter single name for Company to evaluate
Model / Physical Size (L x W x H) (ft)		
Capacity Rating (MWh-DC)		
Enclosure Type		Enter single name for Company to evaluate
Battery Storage Chemistry		
(System) Integrator		
Thermal Management Technology		
Warranty Term (years)		If pro-rated, describe in Notes section
Guaranteed Monthly Availability		

List all alternative cell manufacturers and enclosure types, that may be used, and their associated information (i.e. model, rating, etc).

Describe procurement plan including existing supply agreements, planned solicitations, procurement schedule, etc:

2) Power Conversion System (Single PCS must be designated for NSP 2024 Evaluation)

Manufacturer		Enter single name for Company to evaluate
Model		
Nameplate Ouptut per Container or Main Inverter (MW-AC)		
Warranty Term (years)		If pro-rated, describe in Notes section
Grid Forming		(select from drop-down)

List all alternative Power Converstion Systems that may be used, and their associated information (i.e. model, rating, etc).

Describe procurement plan including existing supply agreements, planned solicitations, procurement schedule, etc:

3) BESS Ratings

Starting Nameplate Capacity (MW-DC)	
Starting Nameplate Capacity (MW-AC)	
Useable/Dispatchable Capacity (MW-AC)	
Storage Duration at Useable Capacity (hours)	
Useable Storage Capacity (MWh-AC)	
Average Annual Capacity Degradation (MWh/yr) *(in addition to warranty curve)*	
Expected Capacity Degradation per Year (%/yr)	

4) Augmentation Planning (Company Ownership Applications only - Self-Build or Build-Transfer)

Container Capacity (MW-DC)	
Container Cost (Current Pricing) ($)	
Area Required for Container (Sq Ft)	

8 - Technical Descriptions

NSP 2024 RFP

5) BESS Unit Dispatchable Range

Minimum Storage Level (SoC_min, MWh)		
Maximum Storage Level (SoC_max, MWh)		
Preferred Resting State of Charge (RSoC, MWh)		
Maximum Real Power Charge Limit (Cmax_p, MW)		
Minimum Real Power Charge Limit (Cmin_p, MW)		
Maximum Real Power Discharge Limit (Dmax_p, MW)		
Minimum Real Power Discharge Limit (Dmin_p, MW)		
Self-Discharge Rate Maximum (MWh/Month)		
Minimum Duration for Full Charge at Cmax_p (SoC_min to SoC max) (minutes)		
Minimum Duration for Full Discharge at Dmax_p (SoC_max to SoC_min)		

6) Dispatch Time Limitations & Ramp Rates

Minimum Run Time Per Charge Period (minutes)		
Minimum Run Time Per Discharge Period (minutes)		
Minimum Down Time Required Between Two Discharge Periods (minutes)		
Minimum Down Time Required Between Two Charge Periods (minutes)		
Maximum Ramp Up Rate (Dmin_p to Dmax_p, MW/sec)		
Maximum Ramp Down Rate (Dmax_p to Dmin_p, MW/sec)		
Ramp Rate Bi-Direction (MW/min)		
Time from notification of dispatch until release for remote AGC over full range of operation (minutes)		
Cmax_p to Cmin_p (MW/sec)		
Cmin_p to Cmax_p (MW/sec)		
Ramp Rate Reduction at High SoC (MWh)		(Min %, Max %, High SoC)
Ramp Rate Reduction at Low SoC (MWh)		(Min %, Max %, High SoC)

7) Cycle Limitations (within manufacturer's warranty)

Maximum Cycles per Day		# of Cycles
Maximum Cycles per Year		# of Cycles
Planned Cycles per Year		# of Cycles
Guaranteed Lifetime Number of Cycles		# of Cycles

8) Throughput Limitations (within manufacturer's warranty)

Maximum Daily Discharge Throughput (MWh)	
Maximum Annual Discharge Throughput (MWh)	
Guaranteed Lifetime Discharge Throughput (MWh)	

9) Other

Maximum Station Use Power (MW)	
Planned Outage (hours/year)	

Solar Photovoltaic

1) PV Modules (Enter single module used for energy production estimate and for rest of NSP Evaluation)

Manufacturer		Enter single name for Company to evaluate
Model		Enter single name for Company to evaluate
Cell Material		
Nominal Rating (W)		
Quantity		
Degradation Rate (%/yr)		

8 - Technical Descriptions

NSP 2024 RFP

Warranty Term (years)		If pro-rated, describe in Notes section

List all alternative modules that may be used, and their associated information (i.e. model, rating, etc)

Describe procurement plan including existing supply agreements, planned solicitations, procurement schedule, etc:

2) Inverters (Enter single inverter used for energy production estimate and for rest of NSP Evaluation)

Type		(select from drop-down)
Grid Forming		(select from drop-down)
Nameplate Output (MW)		
Manufacturer		Enter single name for Company to evaluate
Model		Enter single name for Company to evaluate
Quantity		
Warranty Term (years)		If pro-rated, describe in Notes section

List all alternative modules that may be used, and their associated information (i.e. model, rating, etc)

Describe inverter procurement plan including existing supply agreements, planned solicitations, procurement schedule, etc:

3) Tracking/Mounting/Orientation ((Enter single tracker used for energy production estimate and for rest of NSP Evaluation)

Fixed or Tracking		(select from drop-down)
Azimuth (degree)		Does not applty to 2-Axis Tracking
Elevation (degree)		Does not applty to 2-Axis Tracking
Mounting Orientation		(select from drop-down)
Manufacturer		Enter single name for Company to evaluate
Model		Enter single name for Company to evaluate
Quantity		
Warranty Term (years)		If pro-rated, describe in Notes section

4) Facility Level Information

DC:AC Ratio (@ POI)	
DC:AC Ratio (@ Inverter)	
Ground Coverage Ratio (%)	
Estimated Land Area (acres) - Solar PV	

Wind

1) Wind Turbines (In first Manufacturer and Model below, designate the WTG used for energy production estimate and for rest of NSP Evaluation)

Manufacturer		Enter single name for Company to evaluate
Model		Enter single name for Company to evaluate
Nameplate Ouptut (MW)		
Number of Turbines		
Hub Height (meters)		
Rotor Diameter (meters)		
Manufacturer 2		Only if multiple turbine types/sizes will be installed

8 - Technical Descriptions

NSP 2024 RFP

Model 2		Only if multiple turbine types/sizes will be installed
Nameplate Ouptut 2 (MW)		Only if multiple turbine types/sizes will be installed
Number of Turbines 2		Only if multiple turbine types/sizes will be installed
Rotor Diameter 2 (meters)		Only if multiple turbine types/sizes will be installed
Hub Height 2 (meters)		Only if multiple turbine types/sizes will be installed
Manufacturer 3		Only if multiple turbine types/sizes will be installed
Model 3		Only if multiple turbine types/sizes will be installed
Nameplate Ouptut 3 (MW)		Only if multiple turbine types/sizes will be installed
Number of Turbines 3		Only if multiple turbine types/sizes will be installed
Rotor Diameter 3 (meters)		Only if multiple turbine types/sizes will be installed
Hub Height 3 (meters)		Only if multiple turbine types/sizes will be installed
Warranty Term (years)		
Turbines Meet the Cold-Weather Package Requirement *Allows turbines to reliably operate down to -30 deg C (-22F)*		(select from drop-down)

2) Facility Level Information

Annual Plant Availability (%)		
Estimated Land Area (acres)		
ADLS Required		(select from drop-down)
Avian Detection System Likely Required		(select from drop-down)
Turbine Layout Included (map with lat/long to 3 decimal places)		(select from drop-down)

3) Annual Energy Production

Average Free Wind Speed (m/s)		
Gross Plant Production (MWh/yr)		
Net Plant Production (MWh/yr)		
Net Capacity Factor (%)		

4) Project Specific Energy Losses

Blockage (%)		
Wake Effect (Internal/External) (%)		
Availability (%)		
Electrical (%)		
Turbine Performance (%)		
Environmental (%)		
Curtailments/Operational Strategies (%)		
Total Loss (%)		

Notes

**Standard Test Conditions: 25 °C, 1 kW/m^2, AM 1.5.*

9 - Capacity Accreditation

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all bid types. See the instructions below for further details. Form is long, please see additional items below 1).

1) Wind and Solar - New Resources

For the purposes of capacity accreditation, provide a profile of hourly expected energy production for a typical year (AC MWh).

Expected Hourly Production for Typical Year (AC MWh)

	Hour																							
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
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9 - Capacity Accreditation

NSP 2024 RFP

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9 - Capacity Accreditation

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2) Wind and Solar Accreditation - Existing Resources

Provide 3 years of hourly energy production data (or if in operation for less than 3 years, all hourly energy production since COD) of hourly energy production data. Provide the file name(s) below. *If the application proposes adding a new resource onto an existing wind or solar asset, provide the existing wind or solar asset's historical hourly generation.*

Name of Applicable file name(s) of historical hourly energy production.

3) Estimated Annual Curtailment (% of Gross Annual Generation):

4) Storage Accreditation - All Storage Proposals

Confirm that the following statement on capacity accreditation has been read:

"Capacity accreditation for battery energy storage systems (BESS) will be reflective of utilization to meet capacity needs (i.e., resource adequacy) for each MISO season".

Bidder is aware of how the Company will assume BESS utilization for purposes of capacity accreditation.

9 - Capacity Accreditation

NSP 2024 RFP

10 - Solar Energy Production Estimate

NSP 2024 RFP

Who Should Complete this Form: This form is intended for any bids that propose a new solar PV resource, including repowers, *or that have an existing solar resource as part of the proposal*. See the instructions below for further details.

Bids proposing a newly constructed solar asset should provide a solar pre-construction energy production estimate from PVSyst that has been completed by an independent 3rd party and submitted as part of the application. Bids that incorporate an existing solar asset already in commercial operation should submit an energy production estimate energy production estimate from PVSyst that has been completed by an independent 3rd party and submitted as part of the application

1) Solar Pre-Construction Energy Production Report

Pre-Construction Energy Production Estimate Completed by 3rd Party?		(select from drop-down)
Pre-Construction Energy Estimate Report Submittted with application?		(select from drop-down)
Energy Production Estimate Provider / Author		
Uncertainty (P50, P90, etc)		

2) PVsyst Model Inputs

a) Plant Capacities

DC Capacity [kWdc]	0
AC Capacity - Inverter [kWac]	0
AC Capacity - POD [kWac]	
DC AC Ratio @ Inverter	#DIV/0!
DC AC Ratio @ POD	#DIV/0!

b) Solar Resource

Onsite Data Collected and Included in model?		Include dates of data collection and MET station provider
Data Source		Explain why data set was chosen
GHI (kWh/m2/year)		
DHI (kWh/m2/year)		

a) Equipment Information

PV Module Manufacturer		
PV Module Model Number		
PV Module Nominal Power [W]		
PAN File Provider		Include PAN file as attachment
Quantity Modules per String		
Total Quantity of Strings		
Total Number of Modules		
Inverter Manufacturer		
Inverter Model Number		

10 - Solar Energy Production Estimate

NSP 2024 RFP

Inverter Nominal Capacity [kWAC]		
Inverter OND File Provider		Include OND file as attachment
Total Number of Inverters		
Number of Trackers		

b) Equipment Orientation

Field Type	
Tracker Spacking [m]	
Collector Width [m]	
Axis Height Above Ground [m]	
GCR	-
Tracker Phi min/max [deg]	
Azimuth [deg]	

c) Bifacial Parameters (if applicable)

Bifaciality Factor	
Rear Shading Factor	
Rear Mismatch Loss	
Module Transparency	

d) Albedo & Soiling Losses

	Albedo	Soiling	
Total Year Average			Explain source for albedo values
January			
February			
March			
April			
May			
June			
July			Explain source for soiling loss values
August			
September			
October			
November			
December			

e) Electrical Losses

DC Circuit Loss Fraction [% at STC]	
AC Wire Loss Inverter to Trans. Loss Fraction [% at STC]	
Medium Voltage Line - Voltage [kV]	
Medium Voltage Line - Loss Fraction [% at STC]	
MV Transformer - No Load Loss [% at STC]	
MV Transformer - Resistive Loss [% at STC]	

10 - Solar Energy Production Estimate

NSP 2024 RFP

HV Transformer - No Load Loss [% at STC]	
HV Transformer - Risistive Loss [% at STC]	
HV Line - Loss Fraction [% at STC]	

e) Thermal Parameters

Thermal Loss Factor (Uc) [W/m^2K]	
Wind Loss Factor (Uv)	

e) IAM - Module Quality - LID - Mismatch - Horizon

IAM Losses	
Module Quality/Efficiency Loss	
LID Loss	
Module Mismatch Loss	
Strings Voltage Mismatch Loss	

e) Auxiliary Losses

Auxiliaries during day operation	
Continuous Auxiliary Loss (Fans, etc) [kW]	
…From Inverter output power threshold [kW]	
Proportional to the Inverter Output Power [W/kW]	
…From Inverter output power threshold [kW]	
AC Circuit Loss Fraction	
Night Auxiliaries Losses	
Night Auxiliaries Consuption [kW]	

3) Solar Energy Loss Tree

Effective Irradiation	**Percent Loss (%)**
Global Incident In Collector Plane	
Global Incident Below Threshold	
Far Shadings / Horizon	
Near Shadings: Irradiance Loss	
IAM Factor on Global	
Soiling Loss Factor	
Ground Reflection on Front Side	
Bifacial System Irradiation and Loss Factors	
Global incident on ground (kWh/m2)	
Ground reflection loss (albedo)	
View Factor for rear side	
Sky diffuse on the rear side	
Beam effective on the rear side	
Shadings loss on rear side	
Global Irradiance on rear side (%) - PVsyst	

10 - Solar Energy Production Estimate

NSP 2024 RFP

PV Conversion and DC Losses	
PV Loss Due to Irradiance Level	
PV Loss Due to Temperature	
Shadings: Electrical Loss acc. to strings	
Module Quality Loss, Modules and Strings	
LID - Light Induced Degradation	
Mismatch Loss, Modules and Strings	
Mismatch for Back Irradiance	
DC Ohmic Wiring Loss	
Inverter and AC Losses	
Inverter Loss During Operation (Efficiency)	
Inverter Loss Over Nominal Inverter Power	
Inverter Loss Due to Max Input Current	
Inverter Loss Over Nominal Inverter Voltage	
Inverter Loss Due to Power Threshold	
Inverter Loss Due to Voltage Threshold	
Night Consumption	
Auxiliaries (fans, other)	
AC Ohmic Loss	
External Transformer Loss - MV	
External Transformer Loss - HV	
Post-Processed Losses	
DC System Performance Loss	
Tracking System Performance	
Tracker Wind Stow	
Sub-hourly Clipping Error	
AC System Availability Loss (PPA applications only)	
POI Limitation	
Additional Loss	
Additional Loss	
Additional Loss	
Additional Loss	
Additional Loss	
First Year Net Energy (MWh) With Availability, With Night losses [MWh]	

Ownership applications - Do NOT include in the loss estimate

10 - Solar Energy Production Estimate

NSP 2024 RFP

	PPA Applications - With Availability Loss, No Night Losses	Ownership Applications (BTs and Self-Builds) - No Availability & Night Losses
Net Energy [MWh/yr]		
Performance Ratio [%]		
AC Capacity Factor - POI (%)		

10 - Wind Resource and MET Tower Summary

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all bid types containing a wind generation asset, *including existing wind projects currently in operation*. See the instructions below for further details.

Instructions

Confirm whether Energy Production Estimates have been completed by a 3rd party and submitted as part of the bid package. The report(s) should address the following items: Validated data and/or description of validation criteria and monthly wind speeds, description of remote sensing data used if applicable, description of adjustments made to the data; why; how (i.e. Wake, DFW, TI, etc.), MCP methods, long-term wind speeds at each mast, and chosen reference station and correlations. If modeled datasets are used, provide the time series used in the assessment, assumed wind rose, frequency distribution used in energy capture, and modeling/energy capture software used.

Complete a separate row for each past and present MET tower within the project boundary or outside the boudary that were used for the development of the submitted project. An example row is included.

1) Wind Resource

New Projects only: Pre-Construction Energy Production Report Completed _____ (select from drop-down)
New Projects only: Pre-Construction Energy Production Report Submitted _____ (select from drop-down)
Existing Projects only: Energy Production Report Completed by 3rd Party? _____

Turbine Site Suitability Study Completed? _____ (select from drop-down)
(Expected) Date of Completion of Turbine Site Suitability Study _____
Is the following documentation available for pre-construction met towers (original construction)?
Met tower data sheet including location, sensor types and elevations, _____ (select from drop-down)
Photos from installation of the MET towers _____ (select from drop-down)
Calibration certificates _____ (select from drop-down)

2) Met Tower Summary

Monitoring Station Name/ID	Tech	Type	Top Height (m)	Lat	Long	Reference Station	Hub Height (m)	Projected Wind speed at Hub Height (m/s)	Install Date	Decom Date

3) Notes

10 - Wind Turbine Power and Thrust Curves

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all bids containing a wind generation asset within the proposal, *including existing wind projects currently in operation.* See the instructions below for further details.

The proposal should include all pertinent technical information for the project including detailed turbine information and facility information.

Proposed Turbine Level Information. If multiple Turbine models are proposed, Turbine Level Information, Project Level Information, and the Power and Thrust Curve data should be provided for all Turbine Models. Use the tab copy feature to create additional tabs as needed for the additional turbine models.

1)

	Turbine Power Curves (kW per Turbine)		Turbine Thrust Curves (kN per Turbine)	
Wind Speed (m/s)	Air Density 1 (kg/m3)	Air Density 2 (kg/m3)	Air Density 1 (kg/m3)	Air Density 2 (kg/m3)
0				
0.5				
1				
1.5				
2				
2.5				
3				
3.5				
4				
4.5				
5				
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11 - Interconnection Details - New MISO POIs

NSP 2024 RFP

Who Should Complete this Form: This form is required for all bids that propose a new point of transmission interconnection with MISO. Please see the form called "Interconnection Reuse" for other types of transmission interconnection involving existing points of interconnection with MISO.

1) Project Information

Project Name	
Project MW (AC) for interconnection request	
Project Description	
What is the projects's proposed Commercial Operating Date	

2) Generator Interconnection Request Information

MISO Project Number(s)	
Definitive Planning Stage ("DPP") Cycle	
Amount of Energy Resource Interconnection Service requested (MW)	
Amount of Network Resource Interconnection Service requested (MW)	

3) Generator Interconnection Study or Agreement Information

Interconnection Study: MISO Study Status and expected completion date	
Interconnection Agreement: GIA Execution Date	
Interconnection Agreement: Is the GIA Execution Date actual or expected?	
Generator feeder transmission line status (routing, permitting, etc.)	
Submit copies of all existing/completed System Impact Studies, Restudies, or Facility Studies and provide the file names here.	
Provide copies of Facility Construction Agreements or Multi-Party Facilities Construction Agreement(s)	

4) Project Transmission Information

Location of Point of Interconnection (including substation name)	
Interconnection voltage (kV)	
Location of Point of Delivery, if different than Point of Interconnection (POI)	
Transmission Owner at Point of Interconnection	

5) Project Congestion/Curtailment Information

Provide any analysis performed regarding projected congestion at the project POD	
Provide any analysis performed regarding projected curtailment at the project POD	

11 - Interconnection Details - Existing MISO POIs

NSP 2024 RFP

Who Should Complete this Form: This form is intended for two main types of bids: 1) bids that plan to continue operation at an existing MISO POI without modification; and 2) bids that propose to reuse an interconnection with MISO for Repowering existing Generating Facilities, Replacing an existing Generating Facility or adding Surplus Interconnection Service to an existing Generating Facilty. Bids proposing surplus interconnections or generator replacement should please see MISO BPM 015 - Generation Interconnection for additional information about interconnection reuse. MN Energy Connection bids should complete a different version of Form 11: MN Energy Connection Form 11

1) Project Information - all projects

Project Name		
Project Type *(i.e. Repower - Replacement or modification of existing generation facility with same generation types, Replacement of existing facility, but with modified fuel type, Surplus (new resource added to existing generation facility), or continued operation at an existing MISO POI without modification)*		(select from drop-down)
Project MW (AC)		
Project Description		
What is the projects's proposed Commercial Operating Date		

2) Existing Generation - all project types

Existing Generating Facility Name		
Existing Generating Facilty Gross and Net MW Capability		
Existing Generating Facilty Fuel Type		
Is the Existing Generating Facility operating under a MISO Generator Interconnection Agreement (GIA) or as Grandfathered Unit?		(select from drop-down)
If the Existing Generating Facility has a MISO GIA, provide the CPNode(s) for the Facility, MISO Project Number and a copy of the MISO GIA (provide file name & CP Node names here)		
If Existing Generating Facility is operating as a Grandfathered Facility provide the CPNode(s) for the Facility and a copy of the GIA if any (provide file name here).		
Amount of Energy Resource Interconnection Service granted (MW) to Existing Generator		
Amount of Network Resource Interconnection Service granted (MW) to Existing Generator		
Point of Interconnection Including voltage		
Transmission Owner at Point of Interconnection		
Does the Bidder also own the Existing Generating Facility?		(select from drop-down)
Owner of Existing Generating Facility if not Bidder		
Note: If applicant is not the owner of the Existing Generating Facilty, applicant to provide executed agreements with Existing Generating Facilty Owner allowing or consenting to proposed reuse of the facility.		
Are there any other offtakers at the POI that are not already included in one of the answers above?		(select from drop-down)
If there are other offtaker in the immediately prior question, please list and describe the additional offtakers here.		

3) Generator Interconnection Request Information for Reuse of Interconnection (Surplus, Repower, and Replacement projects only)

MISO Project Number(s) for Reuse Project Request	
Amount of Energy Resource Interconnection Service requested (MW)	
Amount of Network Resource Interconnection Service requested (MW)	
Fuel Type Requested	
Point of Interconnection Including substation name and voltage	
Location of Point of Delivery, if different than Point of Interconnection (POI)	
Transmission Owner at Point of Interconnection	

4) Generator Interconnection Study or Agreement Information - all project types

Interconnection Study: MISO Study Request Date	
Interconnection Study: MISO Study Status (ongoing or expected completion date)	
Interconnection Agreement: GIA Execution Date (please designate whether it is actual or expected)	
Does reuse project require new transmission line to reach Point of Interconnection? If so provide transmission line status (routing, permitting, etc.)	
Provide copies of all existing/completed Interconnection Studies and Facility Studies	

5) Project Congestion/Curtailment Information - all project types

Provide any analysis performed regarding projected congestion at the project POD	
Provide any analysis performed regarding projected curtailment at the project POD	

6) Notes to Delivery Option - Include detailed plans for route, design, regulatory approval, and permitting information for the transmission facilities delivery option in your response to 5).

11 - Interconnection Details - MN Energy Connection (Sherco POI Reuse)

NSP 2024 RFP

Who Should Complete this Form: This form is intended for bids proposing to reuse Sherco interconnection capacity, including both Traditional Option and MN Energy Connection Contingent Bids that propose interconnection with the MN Energy Connection.

Proposals are not required to request MISO generator interconnection service to participate in this option of the RFP.

1) Project Information

Project Name	
Project MW (AC) for interconnection request	
Project Description	
What is the projects's proposed Commercial Operating Date	
Project Type - Traditional or Contingent (As Designated on Form 3; do not modify)	o

2) Project Route, Substation, & Transmission Information

Appendix E route proposed for Interconnection (Please indicate: "Blue Route", "Purple Route", "Green Route" or "Route Connector" or "Route Segment" as labeled in Appendix E).	
Is this project proposing interconnection at one of the three "Known Substations" (Sherco, Sherco West, Garvin) identified in Table 2 of the RFP Document?	(select from
If bid proposes interconnection at one of the three "Known Substations", confirm the name of intended substation for interconnection.	
Generator feeder transmission line length (collector substation to POI)	
Generator feeder transmission line design details (kV)	
Generator feeder transmission line status (routing, permitting, etc.)	
Summary of interconnection upgrades associated with delivering energy from the project to the POI including the gen-tie line.	

3) Point of Contact for Transmission Information

Contact Name	
Contact Phone Number	
Contact e-mail	

4) Collector Substation Design Information

Main Power Transformer Quantity	
Main Power Transformer Manufacturer/Model	
Capacitor Bank Quantity/Rating	

5)	Traditional Option Only: Associated Interconnection Costs (From Form 6-D1-PricingOwn T1. Bidder: Do Not Modify)	$0

6) Route Details - Include detailed plans for route, design, regulatory approval, and permitting information for the transmission facilities delivery option in your response to 5).

11 - Interconnection Details (Interconnection to NSP Distribution System)

2024 NSP RFP

1) Interconnection Application Progress

Date of Interconnection Application Submittal	
Date of signed Interconnection Application or issued Interconnection Approval Memo	
Application/Case #:	
Please submit copies of all interconnection study results received to date as part of this Interconnection Process. Itemize here what is attached.	

12 - Project Financing, Credit Worthiness, and Legal Claims

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all applications. See the instructions below for more details.

1) Project Financing

Confirm the Applicant's type of organization (Corporation, Partnership, etc)	
Describe the financial and legal organizational structure including any subsidiaries. In addition please enclose an ownership structure showing the legal name and the percentage of ownership of each owner.	
Describe the financing or funding plan, equity participants and any project financing guarantees, including but not limited to any form agreement(s) utilized in similar past transactions. Include any financing requirements and an indicative financing structure (construction and permanent). Describe how current financial markets are likely to impact ability to access the debt and tax equity markets.	
Disclose any threshold requirements that must be met prior to having access to the various components of the financing or funding plan described above.	
Do you foresee any issues in obtaining and maintaining a security fund per the requirements described in the applicable NSP Model Term Sheet (Build-Transfer applications) or NSP Model Power Purchase Agreement?	
Please identify the guarantor	
Provide the current credit rating of the guarantor.	
Is the guarantor on credit watch?	

2) Credit Worthiness

Provide three of your most recent audited annual reviews with financial statements in either a standalone pdf format and/or website link including any relevant supplemental financial information. If you are unable to provide these, what can you provide to demonstrate credit worthiness?	
Describe any credit issues (e.g. bankruptcy, events of default, etc.) for any participant who will have a more than a 20% share of the equity position in the project.	

3) Legal Claims

Disclose any past, current, or anticipated future litigation related to projects owned, developed, or managed by the applicant or any of its affiliates or predecessors in the United States.	

13 - Siting Environmental - PPA Bids

NSP 2024 RFP

1) Project Description

Overview of Project	
Project Site Map and Geospatial Data: Illustrate physical location of project as related to other area features, including roads, county boundaries, State or Federal Owned properties and transmission facilities.	
Legal Description: Describe project location by Section(s), Township(s) and Range(s).	
Timeline: Provide an overall project acquisition plan, permitting plan and schedule for the project.	

2) Land Control and Permits

Site Control: Provide a summary of the status of acquired lease and easement agreements, targeted parcels for each generation asset and include on a corresponding map with the acquired agreements.	
Provide a discussion of additional agreement types other than Land Lease and wind Easements and Provide on map (Example: Setback or Neighbor Agreements, Utility Crossing Consent Agreements	
Provide a map showing proposed substation, O&M building, and transmission line.	
Provide a copy of any easement templates	
State Site Permits: Provide an overview of any State Site permit requirements and the status of acquiring those permits.	
Federal Site Permits: Provide an overview of any Federal Site permit requirements and the status of acquiring those permits.	
Local Zoning/Permits/Agreements: Provide an overview of any local zoning permit requirements, including CUPs, development agreements. road use agreements, drainage agreements, and the status of acquiring those permits.	
Timeline: Provide an overall project acquisition plan, permitting plan and schedule for the project.	
Siting Issues: Disclose any siting issues with landowners or permitting agencies and how those are being mitigated.	

3) Environmental Studies

Local Government Interactions: Provide a summary of local government interaction and project support.	
Site Environmental Studies: Project a general summary of environmental studies.	
Other Environmental Issues and Risks: Provide a summary of any environmental permitting risks including state historic and tribal cultural resources.	
Provide a summary of and documentation for any known or past environmental concerns related to the Facility, including but not limited to any avian or bat concerns, e.g. eagle take permit, whooping crane sighting etc. and how the issue was resolved.	

4) Legal Claims

Disclose any past, current, or anticipated future litigation related to projects owned, managed, or developed by the bidder or any of its affiliates in the United States.	

5) Pollinator Habitat

Describe the quantity and location of pollinator habitat that the bidder is planning on establishing along with requirements for maintaining the habitat.	
Describe how you plan on evaluating the effectiveness of the pollinator habitat created.	

13 - Siting Environmental - Build-Transfer and Self-Builds Bids

NSP 2024 RFP

Please complete each item below. If an item is not applicable to the specific bid, please write "N/A".

1) Project Description

Overview of Project	
Project Site Map and Geospatial Data: Illustrate physical location of project as related to other area features, including roads, county boundaries, State or Federal Owned properties and transmission facilities	
Legal Description: Describe project location by Section(s), Township(s) and Range(s)	
Timeline: Provide an overall project acquisition plan, permitting plan and schedule for the project.	

2) Site Control

Overall Land Lease and Easement Acquisition Document Completeness: Provide an overview of the lease, easement, and acquisition process for solar arrays & battery energy storage systems (BESS), access roads, collector lines. Include status of agreements (signed, in process, declined), timeline to complete and any potential issues and include on a corresponding map.	
Documents: Provide copies of all signed agreements, provide copies of any draft agreements, and any easement templates	
Existing Property Easements/Programs: Describe any parcels that have state or federal agency conservation easements, including the USFWS, state DNR, Dept. of Agriculture Conservation Programs	
Other Agreements: Provide a discussion of additional agreement types other than Land Lease and provide on map. (Example: Setback or Neighbor Agreements)	
Records Related to Land Owner Meetings: Provide landowner diaries	
Itemized Costs of Long-term Land Leases For the Site: Provide overview of the long term payment commitments to landowners	
Please confirm whether an O&M building is included in the proposal	
Land Ownership Agreements for O&M Building and Substation: Provide land ownership or option agreements for O&M building, substation, laydown yard, and batch plant.	
Non Participant Land Owner Risks: Provide overview of any known non-participants opposed to the project.	
Land Title/Tax Risks: Provide an overview of any impacts to landowner tax payments that may fall to owner. Describe any potential title issues identified.	
Collector Lines and Substation: Provide copies of all signed agreements, provide copies of any draft agreements	
Generation Tie Line: Provide copies of all signed agreements, provide copies of any draft agreements	
Project Transmission Line Easement: Complete list of Transmission Easement Agreements signed and targeted. Include copies of signed Transmission Easement Agreements and Transmission Easement compensation schedules	
Underground Utility Crossing Risks: Please provide all consent agreements for all foreign utility crossings	

3) Local Permitting

Local Zoning/Permits: Provide an overview of any local zoning permit requirements (including CUPs), timeline to acquire, and the status of acquiring those permits.	
Local Government Interactions: Provide an overview of local government interactions, describe any local support and include all correspondence from county and townships as well as project notes	
Roadway Improvement Agreements: Provide a summary of any discussions with the local governments regarding road use and commitments to repair after construction. Include any draft or final documents. Provide a copy of all road crossing agreements.	

4) State Permits, Overall Permit Requirements

State Site Permits: Provide an overview of any State Site permit requirements and the status of acquiring those permits	
Overall State Permit Document Completeness: Please provide Site Permit application including supporting studies, surveys, and data.	
Permitting Analysis: Provide an analysis of all permits required for the project, including, but not limited to any state permits, local permits, take permits, wetland permits, stream crossing permits, storm water permits. Include timeline to acquire permits and expected cost.	

5) Environmental studies, agency consultation and permit analysis

Site Environmental Studies: Provide a general summary of environmental studies related to project.	
Potential Project Risks: Provide a summary of any environmental permitting risks, possible impact to project and expected mitigation steps, if any.	
Site Assessments: Provide any Phase I ESAs for the project that were completed within the last two years.	
History and Background: Provide any past environmental issues related to the project site	
Tribal Cultural Resources: Please provide copies of assessments or analysis of potential impacts to tribal cultural resources in the area and any communications with local Native American Tribe(s) regarding the project.	
Cultural Resource Studies: Please provide copies of state historic preservation consultation and literature survey reports for the project.	
Raptor Studies: Please provide copies of raptor nest surveys, or raptor nest survey plans, if completed.	

T&E and State Projected Species: Please provide copies of T&E and T&E Critical Habitat surveys completed. Provide a summary of any T&E species that may require additional follow-up work or mitigation	
Agency Consultation: Provide status of discussions with permitting agencies including those listed in this section.	
USFWS Consultation: Provides copies of all USFWS correspondence to date	
State DNR Consultation: Provides copies of all State DNR correspondence to date	
Department of Agriculture: Provide amount of impacted Prime Farm Land and any correspondence with either federal or state Departments of Agriculture.	
Army Corps of Engineers: Please provide any 404 jurisdictional determination obtained by the project, if needed.	
Wetlands: Provide an overview of potential wetland impacts and any completed wetland delineation reports	
Noise Model: Please provide any noise modeling report developed for the project if required by federal, state, or local permitting agencies. If not requried, provide justification.	
Communications Studies: Please provide any microwave beam path and local broadcast interference assessments or studies conducted for the project, if applicable.	
Vegetation Plan: Please provide any vegetation and vegetation management plans for the site.	
Solar Glare/Glint Studies: Please provide any solar glare/glint studies developed for the project.	
Aeronautical Studies: Provide any information concerning aeronautical assessments or studies (including FAA Study numbers, if available) that have been conducted or initiated for the project.	
Other Environmental Issues and Risks: Provide a summary and documentation regarding any other potential environmental concerns or risks.	
Provide documentation on any known or past environmental issues related to the project and how the issue was resolved.	

6) Geospatial Data

Provide the following information in ESRI GIS Shape files. This list may include information previously identified.

Project Boundaries	
Planned Site Layout, including anticipated placement of major equipment and other project facilities, including transmission layouts and POD.	
Solar Array Coordinate Information	
Access roads	
Site substation and feeder lines	
For projects with construction of Gen-tie facilities: Gen-tie	
Site layout design optimization potential	
Unique Site features and Setback risks - Identify acquired easements, expired easements	
Lease & Easement polygons	
Collector and transmission line locations	
Environmental data	

7) Legal Claims

Disclose any past, current, or anticipated future litigation related to projects developed, owned or managed by the bidder or any of its affiliates in the United States.	

8) Decommissioning

Describe what infrastructure will be abandoned and/or removed during site decommissioning at the end of life. Ensure you describe how the decommissionign plan meets the requirements of any applicable agreement or permit conditions.	
Describe the final depth below grade for the top of any abandoned foundations and any abandoned underground cabling and how they meet the requirements of any applicable agreement or permit conditions.	
Describe the following: - How the physical components will be removed, transported off-site and disposed of. - Plans for recycling or scrap of removed components. - Assumed cost of decommissioning. Including solar array dismantling costs, foundation removal, access road removal, site restoration, transportation, disposal fees and estimated scrap value.	

9) Pollinator Habitat

Describe the quantity and location of pollinator habitat that the bidder is planning on establishing along with requirements for maintaining the habitat.	
Describe how you plan on evaluating the effectiveness of the pollinator habitat created.	

14 - Warranties, One-Line Diagram, Safety

NSP 2024 RFP

Who Should Complete this Form: This form is intended for new generation resources, either being newly constructed at new point of interconnection or replacing or substantially modifying other generation previously existing in a given location (i.e., repowers). See the instructions below for more details.

1) Identify each major equipment Contractor and attach all corresponding warranties with the bid. List the file names of each attachments.

2) **BT BESS Bids: Battery Energy Storage System (BESS) Degradation:** For BT Bids containing a BESS component, provide references, including file name and location in the application materials, of any attached correction or degradation curves.

3) **PPA BESS Bids: Confirmation of Augmentation Assumption:** For PPA bids containing a BESS component, confirm either of the following in the space below: 1) the proposed PPA pricing assumes augmentation; or 2) The proposed PPA pricing assumes no augmentation.

4) **PPA BESS Bids: Battery Energy Storage System (BESS) Degradation:** For PPA bids with BESS components and NO augmentation assumed in the proposed pricing, provide references, including file name and location in the bid materials of attached correction, battery cell warranty, or cell degradation curves. PPA bids assuming augmentation may leave this blank.

5) **BT and PPA BESS Bids: Independent Estimate of BESS Degradation Assumptions.** For all BT BESS bids and for PPA bids with BESS components and NO augmentation assumed in the proposed pricing, provide the contact information, file name of attached resume, and describe the experience of the external, unaffiliated consultant shall also be provided.

6) **PV Array Degradation:** For applications containing a solar PV resource, provide references, including file name and location in the bid materials, of any attached correction or degradation curves.

7) **Attach a one-line diagram for the proposed facility with the proposal. Provide the name of the included attachment and any additional notes below.**

8) **BESS Fire Safety, Part 1: For bids with Storage Components Only.**

For PPA Bids: Please confirm whether the BESS fire safety and fire suppressions systems comply with NFPA 855: Standard for the Installation of Stationary Energy Storage Systems

BT and Self-Build Bids: Please see the applicable Technical Specifications in Exhibit C regarding BESS fire detection and fire suppression systems. Address any exceptions regarding this in Form 16 - Tech Specs Excepts (Exceptions to Exhibit C of the Technical Specifications). Skip this question below.

9) **BESS Fire Safety, Part 2: For bids with Storage Components Only.**

For PPA Bids: Please describe the BESS design features to address cascading thermal runaways below. For further reference, please see Appendix H: NERC Lesson Learned, BESS Cascading Thermal Runaway.

BT and Self-Build Bids: Please see the addendum to the Technical Specifications in Exhibit C labeled "NERC Lesson Learned, BESS Cascading Thermal Runway". Address any exceptions regarding this in Form 16 - Tech Specs Excepts (Exceptions to Exhibit C of the Technical Specifications). Skip this question below.

9) **BESS Fire Safety, Part 3: For bids with Storage Components Only.**

For PPA Bids: Please describe the plan for coordinating with local and emergency authorities prior to placing the BESS in service, as per the recommendations on page 1 of Appendix H: NERC Lessons Learned: BESS Cascading Thermal Runaway.

BT and Self-Build Bids: Please see the Technical Specifications in Exhibit C. Address any exceptions regarding coordination plans in Form 16 - Tech Specs Excepts (Exceptions to Exhibit C of the Technical Specifications). Skip this question below.

10) Security (For PPA Bids Only)

a) Is your equipment subject to Executive Order 13920 barring the installation of bulk system electric equipment from a foreign adversary? If not, do you or any of your vendors source any equipment, materials, or components from the US Department of Commerce's Entity List (restrictions)?

b) Identify any cyber security events that have affected the ability of your existing facilities to perform within the terms of contracts within the last 2 years. Describe the initiatives your company has taken to combat the risk of cyber security events.

c) Describe the physical security features (fencing, signage, security cameras, etc) that you typically include at generation facilities you own and operate.

d) Do you have a control center that allows for remote access to your facilities? How is this remote access protected? Do any other parties have remote access or the ability to obtain remote access?

11) Security (For Self-Build & Build-Transfer Bids Only)

a) Confirm your bid includes all specified physical security features (fencing, signage, security cameras, etc). Are there any other features you would propose to enhance the site physical security beyond what is specified?

b) Confirm your bid contains all specified cyber/data security features. Are there any other cyber/data security features you would propose to enhance the site's security beyond what is specified?

15 - Solar, Wind, Storage Projects Not Placed into Service

NSP 2024 RFP

This Form applies to all bid types.

1) Please report on wind, solar, and storage projects contracted within the last five years that have not been placed into service, or are expected to not be placed into service, consistent with the originally executed contract terms.

Total Number of Projects	Total Size of Projects (MW)	Please describe the circumstances resulting in the project(s) identified not being in-serviced consistent with the originally executed contract terms, or not being expected to be in-serviced consistent with the originally executed contract terms.	Please describe actions your company took to mitigate or remedy the circumstances described.

2) Please provide any additional comments or information regarding projects listed in the response to 1)

16 - Exceptions to Technical Specifications (Build-Transfer)

NSP 2024 RFP

Who Should Complete this Form: This form is intended for all build-transfer (BT) bids.

If the space below is insufficient, please enclose additional documentation to proposal, titled "Exceptions or Proposed Alternatives to Technical Specifications".

Specific Section of Technical Specification where Exception is Taken	Exception Description	Reason for Exception	Is it Possible to Meet Specification, but would require a change in the price from what is currently proposed? (Y/N)

17 - Existing Asset/Repower Information

NSP 2024 RFP

Who Should Complete this Form: This form is intended for bids that contain an existing generation project or utilize an existing MISO point of interconnection other than the MN Energy Connection. Examples include proposed PPA extensions for existing assets, proposed repowers at existing MISO POIs, and the addition of newly constructed storage at a wind farm currently in operation (i.e., information about the existing). See the instructions below for further details.

1) Equipment Status

Generating/Storage Equipment (describe below)	(select from drop-down)
Padmount Transformers (if applicable)	(select from drop-down)
Access Roads	(select from drop-down)
Collection System Cable	(select from drop-down)
Grounding Transformers	(select from drop-down)
Collection Substation	(select from drop-down)
Gen-tie Line	(select from drop-down)
Photos Included of all Existing Equipment to be Re-Used	(select from drop-down)

2) PPA Extensions Only:

If bidder has an existing PPA with NSPM, please state the name of the existing PPA.

Does the proposed PPA Extension extend the life of the existing wind assets beyond 25 years? If so, attach any engineering studies or technical analysis that support the ability of the resource to operate beyond expected design life?

3) Notes

18 - Bidder Checklists (NOIR Not Included)

NSP 2024 RFP

Directions: This is an optional checklist for use in submitting applicable RFP Bidder Forms and other RFP bid requirements. If column is white for your planned bid type, that item is required for your bid type as part of RFP submission if your project meets the additional requirements listed on the Form. If it is black, it is not required for your bid type as part of RFP submission.

Item		Build-Transfer	Self-Build	Power Purchase Agreement
Section 1 Executive Summary (for all bids)				
	Relevant Bidder Experience (separate document from Standard Bidder Form)			
Section 2 Standard Bidder Forms for all Bids (plus all required attachments, if mentioned in Form)				
	1 - Confidentiality			
	2 - Bid Certification - BT,SB Bid			
	2 - Bid Certification - PPA Bid			
	3 - Applicant Info & References			
	4 - GenTech&BOP			
	5 - GenAnnual			
	6-D1-PricingOwn_T1			
	6-Alt-D1-PricingOwn_T1 (only required if submitting Alternate			
	6-D1-PricingOwn_T2			
	6-Alt-D1-PricingOwn_T2 (only required if submitting Alternate			
	6-D1-PricingOwn_T3			
	6-Alt-D1-PricingOwn_T3 (only required if submitting Alternate			
	6-D1-PricingOwn_T4			
	6-Alt-D1-PricingOwn_T4 (only required if submitting Alternate			
	6-D2-Expenses			
	6-Renew Storage PPA Pricing			
	7-Construction			
	8-TechDesc			
	9-Capacity Accreditation			
	10-PVSyst Inputs			
	10-WResource			
	10-Wpower Curve			
	11-Interconnect - New MISO POIs			
	11-Inter. - Existing MISO POIs			
	11-Interconnection - MNEC			
	11-Interconnect - Dx Option			
	12-Creditworthiness			
	13-Siting Environ PPA			
	13-Siting Environ BT,SB			
	14-Warranties, 1Line, Safety			
	15-Projects History			
	16-BT,SB Tech Specs Excepts			
	17-Repower			
Section 3 Term Sheet Exceptions, BT Bids only				
	BT Bids: Proposed Exceptions to BOT Term Sheets (optional)			

BWSR

Habitat Friendly Solar Site Assessment Form for Project Planning

For Solar Companies, Local Governments and Other Partners to Meet Habitat Friendly Solar Standards

Updated 12-22-23

Note: The use of state developed solar seed mixes over 70% of the plantable area of a site will result in automatically meeting the standard.

1) PLANNED PERCENT OF PLANTABLE AREAS WITHIN PROJCT FOOTPRINT DOMINATED BY NATIVE SPECIES COVER (forbs, grasses, sedges, rushes, ferns). PROJECTS MUST HAVE A GOAL OF AT LEAST 70% COVER OF NATIVE VEGETATION TO MEET HABITAT FRIENDLY SOLAR STANDARDS

- ☐ 70-84% — +15 points
- ☐ 85% and above — +20 points — Total Points ☐

2) PERCENT OF PROPOSED SITE VEGETATION COVER TO BE DOMINATED BY FORBS (not grasses, sedges and rushes)

- ☐ 10-19% — +5 points
- ☐ 20-29% — +10 points
- ☐ 30-39% — +15 points
- ☐ 40 and above — +15 points — Total Points ☐

Note: Projects may have "array" mixes and diverse border mixes; forb dominance should be averaged across the entire site. The dominance should be calculated from total numbers of forb seeds vs. grass seeds based on seeds per square foot (from all seed mixes to be planted).

3) PLANNED COVER DIVERSITY (# of species in seed mixes; numbers from upland and moist soil mixes can be combined

- ☐ 10-19 species — +5 points
- ☐ 20-25 species — +10 points
- ☐ 26-39 species — +15 points
- ☐ 40 and above — +20 — Total Points ☐

4) PLANNED SEASONS WITH AT LEAST THREE BLOOMING SPECIES (check all that apply)

- ☐ Spring (April-May) — +4 points
- ☐ Summer (June-August) — +3 points
- ☐ Fall (September-October) — +3 points — Total Points ☐

See BWSR pollinator toolbox about bloom season

5) SITE PLANNING

- ☐ Detailed establishment and management plan (see notes) — +20 points
- ☐ Seed Mixes are composed of at least 40 seeds per square foot — +5 points
- ☐ All seed genetic origin is within 200 miles of site (see notes) — +5 points
- ☐ At least .5% milkweed cover within each seed mix — +5 points
- ☐ Plant species with more than 3 flower colors in mixes (see notes) — +5 points — Total Points ☐

6) INSECTICIDE RISK

- ☐ Planned on-site insecticide use (excluding buildings/electrical boxes, etc.) — -30 points
- ☐ Communication with local chemical applicators/neighbors about need to prevent drift from adjacent areas. — +10 points — Total Points ☐

GRAND TOTAL ☐

Gold Standard 85+ points
Meets Standard 70 points

Project Name:
Project County:
Project Size:
Evaluation Date:

See notes related to the questions on the back side of this form

Notes:
Estimates of percent "cover" should be based on "absolute cover" (the percent of the ground surface that is covered by a vertical projection of foliage as viewed from above).

All project plans must include detailed vegetation establishment and management specifications to ensure the success of projects (see sample specifications on *BWSR's Habitat Friendly Solar Webpage*).
Seed mixes provided for projects need to show seeds per square foot for each species in the mix.

Question 1 - *Native plant species provide benefits to a wide range of pollinators and other wildlife species. The Minnesota DNR List should be used to determine if a species is native. Native species include wildflowers, graminoids (grasses, sedges rushes), shrubs and trees. The percent areal cover of native vs. non-native species should be estimated based on the seeds per square foot of all species to be used across all seed mixes. As non-native fescues tend to have a high seeding rate, but also small seeds with a lower germination success the number of fescue seeds per square foot in mixes can be decreased by half when calculating native species dominance of mixes. This should result in a more accurate representation of native dominance.*

Question 2 - *There is a focus on native forbs on this assessment form to maximize benefits to the approximately 500 species of native bees in Minnesota, honeybees and other pollinators. Forbs are (flowering plants that are not woody or graminoids such as grasses and sedges) and can include introduced clovers and other non-native species beneficial to pollinators. No noxious weeds or invasive plants can be included in the total.*

Question 3 - *Plant diversity adds to wildlife benefits, as well as the resiliency of projects. For this question, planned native and non-native species from all seed mixes can be combined for the total.*

Question 4 - *Having blooming species throughout the season helps support pollinator species. See BWSR's Pollinator Toolbox for a listing of bloom seasons for species.*

Question 5 - *To meet requirements for a long-term management plan projects must provide information about:*
-Timing of yearly inspections,
-A detailed native vegetation establishment plan with detailed instructions for contractors.
-A detailed maintenance schedule for the first three years of the project (establishment period) listing timing of establishment mowing/ trimming, spot herbicide application, prescribed grazing or other management actions.
-Proposed maintenance schedule for year four and beyond.
-List of weed species that may become problematic at the site and how they will be managed if needed.

All mixes being used for the project must include at least 40 seeds per square foot to receive points for the first category. Using seed with a genetic origin within 200 miles helps ensure that species will be adapted to site conditions and decrease the risk of introducing invasive species in seed mixes. Please refer to pages 7-8 of BWSR's Native Vegetation Establishment and Enhancement Guidlines for more information about appropriate seed sources. To obtain points for including milkweed in projects mixes must contain at least .5% milkweed seed based on seeds per square foot, or a combination of seed and containerized plugs could be used with a plan to cover .5% of the ground surface with milkweed. Flower colors can include blue, pink, purple, yellow, white, orange, red, green and brown. The Minnesota Wildflowers website allows for searching species based on flower color Minnesota Wildflowers Categorized by Color.

Question 6 - *It is important that seeds treated with insecticides are not used at project sites and that insecticides are not being sprayed at the site. To meet requirements for communication/registration with local landowners/applicators about the need to prevent drift from adjacent areas, information provided can be in the form of email communication or copies of letters. Communication must be provided to all landowners adjacent to the property including municipalities.*

Send completed forms, project plans, seed mixes (showing seeds per square foot for each species) and any communications with pesticide applicators to BWSR at Dan.Shaw@state.mn.us as well as any local government staff involved in reviewing the project.