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DEFINITIONS:

A. Company / Buyer: Northern States Power Minnesota (NSPM) or Northern States Power Wisconsin (NSPW).

B. Contractor / Seller: Person, firm, or corporation with whom Company has entered into an agreement with to construct the facility.

C. Engineer / Engineer of Record (EOR): Engineer of Record means a professional engineer who is registered in the state where the project is located. The EOR seals drawings, reports, or documents for a project. The seal shall acknowledge that the professional engineer prepared, coordinated, or had subordinates prepare under the direct supervision of the professional engineer the drawings, reports, or documents for the project.

D. Utility: Company of Interconnection (NSPM or NSPW service territory)

E. Quality Assurance Representative (QAR): The Company reserves the right to engage an individual, partnership or corporation, to perform independent testing, inspection, and analysis to verify the Contractor is supplying a product in compliance with all contractual requirements, including this specification. The QAR shall be qualified by training and experience and hold certifications or documentation of their qualifications. The QAR shall be selected by the Company and be fully independent of the contractor.

F. Geotechnical Engineer: A qualified person licensed to perform geotechnical engineering and investigate, employed by the Contractor, at no cost to the Company. The Geotechnical engineer must be a registered professional engineer in the state of where the project is located.

G. Battery Energy Storage System (BESS): BESS means the battery energy storage system and includes the batteries, battery racks, power conversion system, a battery management system, and a site controller with pre-programmed BESS operating modes.

H. Power Conversion System (PCS): PCS means power conversion system and includes the inverter, harmonic filters, step-up transformer, AC and DC fault and overcurrent protection devices, and instruments and devices to interface with the Communications System. Bi-directional inverters are required on BESS inverters to allow for charging from the distribution system.

I. MESA-ESS: MESA-ESS means the Modular Energy System Architecture Energy Storage System Specification Open Standards for Energy Storage.

PROJECT DESCRIPTION

The Distribution system Connected Solar Generation (DCSG) sites or DCSG sites with Battery Energy Storage Systems (BESS) shall connect to the Utility within the Midcontinent Independent System Operator (MISO) Zone 1.

Each DCSG site shall be a minimum of 5 megawatts ac interconnecting; shall use single axis or dual axis trackers; and be designed for a solar generation DC/AC ratio of 1.3 (Array DC MW capacity rating / AC MW capacity rating at the Point of Interconnect (POI) = 1.3). Contractor is to work with Owner to optimize the final DC to AC ratio to achieve the Lowest Cost of Energy (LCOE) for the Project during the design phase of the project.

Each DCSG with BESS site shall be a minimum of 5 megawatts ac (solar ac power + BESS ac power = 5 MW minimum) interconnecting and shall use single axis or dual axis trackers. Contractor to size the PV Array to be the source of power to charge the BESS system and provide the rated power at the point of interconnection. Contractor to review the BESS operational requirements as identified in Table 8-1 (Minimum Battery Operational Requirements) and Table 8-3 (Minimum PCS Functional Specifications). Contractor to provide with its bid the technical details for the design such as: the DC Array rating; DC to AC ratio; type and quantity of inverters; etc. Contractor is to work with Owner to optimize the final DC to AC ratio to achieve the Lowest Cost of Energy (LCOE) for the Project during the design phase of the project.

Each of the DCSG or DCSG with BESS sites are required to have a separate interconnection to the grid. Interconnection requirement information and information on the application process for sites located in the following states is located at:

Michigan: https://mi.my.xcelenergy.com/s/renewable/developers/interconnection
Minnesota: https://mn.my.xcelenergy.com/s/renewable/developers/interconnection
North Dakota: https://nd.my.xcelenergy.com/s/renewable/developers/interconnection
South Dakota: https://sd.my.xcelenergy.com/s/renewable/developers/interconnection
Wisconsin: https://wi.my.xcelenergy.com/s/renewable/developers/interconnection

No individual “unit” of generation shall be smaller than 5MW AC.

Project Requirements to be submitted with bid:

- Site Plan
- Project execution plan
- Major equipment Contractors and corresponding warranties
- Pricing Summary
- Project Milestone Schedule
- Electrical One-Line Diagram
- PVSYST or equal yearly performance summary
- Performance guarantees with degradation

Contractor to provide/perform all land use permitting, construction permitting, right-of-way permitting, land subdivisions (if necessary), interconnection agreement, engineering, labor, procurement of materials and equipment, and supervision required for the complete design and installation of a fully functional, and operational solar photovoltaic (PV) facility or PV with BESS facility that is in full compliance with Company’s requirements, applicable codes, standards, laws and regulations.

The contractor shall enter into a Project Labor Agreement (PLA) with a local union outfit capable of performing quality work on the project. The described facility, as further detailed in Schedule A, shall be designed for a 35-year operating life, unless explicitly stated otherwise, based on normal operation, and the performance of maintenance, repairs, and the replacement of parts according to manufacturers’ recommendations and standard industry practices.

Contractor shall provide all materials, and full system installation of all components, including photovoltaic modules, DC electrical systems including string inverters or central inverters, DC combiner boxes, mounting systems, weather station, data acquisition system (DAS), BESS components and electrical interconnection to the Utility.

Contractor shall commission the components and systems of the site and coordinate interconnection and start-up with the Company of the interconnection. Contractor shall provide comprehensive on-site construction management for the facility when work is conducted.

The facility shall be designed with single axis trackers and arranged to make optimum use of the space. The design of the facilities shall be to maximize the annual MW hours over a 35 year operating life based on measured actual site conditions, and adjusted for evaluated operating, maintenance, and replacement costs.

Installations shall be pile supported design with direct buried electrical cabling below grade. The transition from PVC raceway above grade to direct buried cables shall include PVC conduit extending below grade to a rigid steel conduit sweep where the cable transitions to direct buried.

The facility shall be capable of a 0.9 lead/lag power factor, unless otherwise indicated by the site interconnection agreement. The facility will interconnect with the point of interconnection specified voltage distribution lines as required per the interconnect agreement. The photovoltaic (PV) Solar installation shall be single-axis tracking. The module racking foundations shall be adequate for the wind and snow loading expected for the area. Medium voltage collection lines from each module shall be direct buried as described in Part 4 of this specification.

ENGINEERING

In all cases, installed components shall carry a nationally recognized testing laboratory (NRTL) listing for their intended use and application (e.g. – UL, CSA, ETL) and shall be appropriate for the local climate and exposure. All components shall be installed per manufacturer guidelines and in a manner that upholds the manufacturer's warranty.

A. Transformers shall be liquid filled and meet or exceed current US Department of Energy transformer efficiency standards.

B. Contractor shall consider the existing site conditions (including any wetland, waterway, habitat, endangered/threatened species, flood, cultural) with respect to soil characteristics, site clearing, grubbing, grading and drainage to minimize site disturbance.

C. Contractor shall undertake and review a geotechnical study suitable for the system level design work at the site and shall take all relevant design and construction measures to accommodate the site conditions as defined in the report. Project shall meet all applicable seismic requirements.

D. Contractor shall install power and communications infrastructure within the system to service the Company DAS. Layout of this infrastructure shall be in accordance with DAS system specification and subject to Company review and approval.

E. Contractor shall be responsible for coordinating telecommunications service to the system with telecommunications provider, where such coordination is allowed. Where such coordination is prohibited by the telecommunications provider, Contractor shall assist Company in their coordination efforts with the telecommunications provider. Contractor is responsible for providing Company with remote access to data (and physical access to the extent provided herein) to the revenue grade meter and "DAS" Data Acquisition System, and weather station (as applicable). Contractor may use the performance data solely to validate the system integrity and production performance.

F. Contractor shall provide and comply with all environmental studies, flood studies, cultural resource studies, habitat/species studies, wetlands studies, geotechnical studies, and surveys for the project. Contractor shall verify all designs incorporated all results, conclusions, and recommendations from those reports.

G. Contractor shall furnish all design drawings stamped by a Professional Engineer licensed in the state that the site is located in.

STANDARDS

At a minimum, Contractor shall confirm that the facility is constructed in accordance with the most current, locally adopted version of the following standards, as applicable. In the case where standards have conflicting requirements, Contractor must notify the Company.

All codes and standards required by the local Authority Having Jurisdiction (AHJ). The most current/up-to-date standards shall be followed.

ACI - American Concrete Institute

- ACI 318 – Building Code Requirements for Structural Concrete

AISC - American Institute of Steel Construction

- AISC 325 - Steel Construction Manual
- AISC 341 - Seismic Provisions for Structural Steel Buildings
- AISC 360 - Specification for Structural Steel Buildings

ANSI - American National Standards Institute

- ANSI C37.90 – IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
- ANSI Z21.83 – Solar Photovoltaic Performance Safety

ASCE - American Society of Civil Engineers

- ASCE 7 – Minimum Design Loads for Buildings and Other Structures

ASTM - American Society for Testing and Materials

- ASTM E1799 – Standard Practice for Visual Inspections of Photovoltaic Modules
- ASTM E1802 – Standard Test Methods for Wet Insulation Integrity Testing of Photovoltaic Modules
- ASTM E1830 – Standard Test Methods for Determining Mechanical Integrity of Photovoltaic Modules
- ASTM E2047 – Standard Test Method for Wet Insulation Integrity Testing of Photovoltaic Arrays
- ASTM E2848 – Standard Test Method for Reporting Photovoltaic Non-Concentrator System Performance

IBC - International Building Code

IEC - International Electrotechnical Commission

- IEC 61215 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules

- IEC 61646 – Thin-film Terrestrial Photovoltaic (PV) modules Design Qualification and Type Approval
- IEC 61683 – Photovoltaic Systems Power Conditioners – Procedure for Measuring Efficiency
- IEC 61724-1,2,3 - Photovoltaic System Performance Monitoring – Guidelines for Measurement, Data Exchange and Analysis
- IEC 61727 – Photovoltaic (PV) Systems – Characteristics of the Utility Interface
- IEC 61829 – Crystalline Silicon Photovoltaic (PV) Array – On site Measurement of I-V characteristics
- IEC TS 61836 – Solar Photovoltaic Energy Systems Terms and Symbols
- IEC- TS 62804 - Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation
- IEC-62817 Photovoltaic Systems - Design qualifications of solar trackers.

ICEA - Insulated Cable Engineers Association

IEEE - Institute of Electrical and Electronics Engineers

- IEEE 928 – Recommended Criteria for Terrestrial PV Power Systems
- IEEE 1374 – Guide for Terrestrial PV Power System Safety
- IEEE 1547 – Standards for Interconnecting Distributed Resources with Electric Power Systems

ISA – Instrumentation Society of America

NEC - National Electrical Code

NEMA - National Electrical Manufacturers Association

NESC – National Electrical Safety Code (if required by AHJ, Incentives, or other governing authorities)

NETA - InterNational Electrical Testing Association

NFPA – National Fire Protection Agency

- NFPA 1 – National Fire Code

OSHA – Occupational Safety and Health Act

UL - Underwriters Laboratories

- UL – Underwriter’s Laboratories for all AC equipment when such standards exist
- UL 1703 – Flat Plate Photovoltaic Modules and Panels
- UL – 1741 Inverters, Converters, Controllers and interconnection System Equipment for Use with Distributed Energy Resources
- UL 2703 –Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels
- UL 3703 – Standard for Solar Trackers
- UL 61730 – Photovoltaic (PV) Module Certification

System electrical design shall be NEC compliant to the greatest extent possible and in accordance with all applicable legal requirements.

INTERCONNECTION AGREEMENT

The Contractor shall be responsible for applying for and obtaining the interconnection agreement from the Utility. Contractor will coordinate with the Utility and provide all necessary work, support, and materials for interconnection of the facility on the customer side of the Point of Common Coupling (POCC) as defined in the Project/Company scope in the Interconnection Agreement, and as defined in the electrical drawings and site plan.

A. Contractor shall coordinate DCSG construction and interconnection with the Utility.

B. Contractor shall support and accommodate all necessary work for interconnection of the facility by the Utility.

C. Contractor shall be responsible for all work associated with the interconnection to the Utility on the customer side of the POCC as defined in the Project/Company scope in the Interconnection Agreement, and as defined in the electrical drawings and site plan attached to this specification. If interconnection utilizes existing equipment, Contractor to determine suitable point of interconnection that complies with all Applicable Permits, the Interconnection Agreement and Utility requirements. The DCSG shall include switchgear (if applicable), circuit breakers, disconnect switches, surge arrestors, relay and protective systems, recloser/pad- mounted breaker (as applicable), revenue grade metering, supports, foundations, grounding systems, grounding transformer, step-up transformers, inverters, PV modules, DC collection system, BESS, auxiliary control power, access roads (if applicable), utilities, and other related equipment for a complete and functioning system.

D. Contractor shall provide a one-line diagram with a PE stamp.

GENERAL SITE WORK

All Work performed must be in accordance with the most stringent requirements of this specification, and the applicable AHJ.

Site Preparation:

1. Contractor shall provide a plot plan identifying access, egress, laydown and storage areas, and turn-around ratios required for deliveries.

2. Contractor shall provide lay down area that meets relevant codes and standards.

3. Contractor shall construct (if necessary) & maintain the permanent roadway to the site throughout the entire construction phase. Contractor is solely responsible for the cost of additional changes to site access required by any code/permit/jurisdiction/otherwise.

4. Contractor shall be responsible for traffic control, when applicable, stabilized construction entrances, secure entrance gate. Entrances to site must be maintained and any track-off from site controlled via best management practices.

5. The system, laydown, and storage shall account for the existing site conditions (including any wetland, waterway, habitat, endangered/threatened species, flood, cultural) with respect to soil characteristics, site clearing, grubbing, grading and drainage in order to minimize site disturbance.

6. A preconstruction visual survey documenting the conditions of the Company's property will be performed, documented with appropriate images, and delivered to Company no later than five days prior to construction mobilization.

7. Site Maintenance During Construction:
   A. All temporary access roadways used by Contractor shall be constructed and maintained by Contractor in serviceable condition.
   B. The Contractor shall maintain all SWPPP Best Management Practices during the entire course of the construction period.
   C. Contractor shall be responsible for temporary erosion control requirements above and beyond those developed in the SWPPP that are deemed necessary by site conditions or AHJ. All required stormwater permits shall be procured, maintained, and closed out by the Contractor.
   D. The Contractor shall coordinate all activities with any adjacent property Company's and local authorities to the satisfaction of the Company and local authorizes.
   E. A final post-construction survey documenting the condition of the Company's property after all construction trucking activity for the Project will be delivered to Company within ten (10) days after the last heavy truck has traversed the road.
   F. Contractor shall be responsible for design and implementation of dust suppression and erosion control measures at the DCSG.
   G. Contractor shall supply and be responsible for the delivery and drainage of water necessary for Contractor's performance of the Work, including dust suppression. Consumption costs shall be paid by Contractor.

8. Excavating, Trenching, boring, Filling and Backfilling:
   A. Excavation, trenching, boring and backfill activities shall be completed as recommended in the project geotechnical investigation.
   B. Contractor shall be responsible for performing all operations in connection with underground (or above ground) DC and AC cabling and equipment pads.
   C. Contractor shall be responsible for performing all excavation, grading, backfilling, and compaction for the equipment pads and buildings.
   D. Contractor shall be responsible for the collection and containment of spoils during excavation activities. Spoils not used for backfilling upon completion of construction are to be disposed of by the Contractor in compliance with all applicable laws, regulations, and codes.
   E. Spoils from any source shall not be placed in or near ditches, swales, canals, or impoundments, or any location susceptible to erosion from high water, flooding, or storm water runoff. Spoil piles shall be maintained per Project SWPPP using best management practices.

9. Site Restoration.
   A. All site development areas disturbed during construction, including laydown, parking, temporary roadways, and temporary office trailers shall be restored and stabilized in accordance with the approved grading plan, SWPPP, and/or erosion control plans.
   B. Post Construction Soil Stabilization (as applicable)
      i. A soil stabilization plan shall be reviewed by Company and AHJ prior to implementation by Contractor.
      ii. The soil stabilization plan shall define the areas to be stabilized along with data sheets describing the materials and methods to be used.

C. Materials shall be installed per manufacturer's recommendations.

D. Materials shall be installed suitable to seasonal conditions.

E. Seed all cut / fill slopes and the PV Array area utilizing an approved seed mixture. Seeding shall occur during a time / season when the probability of successful seed germination is maximized; hydro-seeding is acceptable for slopes. Seeding shall conform to landowner and SWPPP requirements. Contractor is responsible for any additional seed applications as necessary to meet the requirements of the SWPP restoration plan.

F. The PV Array area shall be seeded with a low growth seed mix that is native to the state and area of its application. Contractor is to complete the Minnesota Board of Water and Soil Resources (BWSR) Solar Site Pollinator Habitat Assessment Form for Project Planning worksheet and submit for review by Owner with its proposal. When a project is located outside of Minnesota, the Contractor is to also include the solar site pollinator habitat form (where available) for the state where the project is located and submit with its proposal.

G. Contractor shall leave the site in the same or better condition that what was found at the commencement of construction. Areas affected by construction will be cleaned of all construction materials and stabilized in accordance with the SWPPP and/or erosion control plan. Contractor shall repair and replace any affected irrigation systems and leave them fully operational to the satisfaction of the Company's representative. Trees removed for solar arrays will be cut as low as possible with stumps remaining intact.

H. All storm water controls, silt fencing, wattles, track-off pads, and other best management practices shall be removed upon completion of construction activities and once suitable vegetative regrowth has occurred.

I. All site restoration shall be in compliance with the applicable governing bodies, permits, or otherwise applicable to the site prior to final acceptance.

GENERAL AND TEMPORARY CONSTRUCTION FACILITIES

A. Temporary Facilities & Utilities

1. Contractor shall be responsible for establishing and maintaining all restroom, office, and meeting areas for the duration of the construction and commissioning portion of the Project. Contractor shall provide an enclosed heated workspace for the Company's representatives.
2. Contractor shall provide construction power, compressed air, and temporary lighting as required for construction.
3. Contractor shall provide telephone and internet services for site personnel.
4. Contractor shall provide temporary facilities consisting of washing stations and sanitary facilities. Contractor shall also supply potable water for personnel.
5. Contractor shall maintain on-site dumpsters and personnel to maintain a clean and rubbish free work site.
6. Contractor shall provide temporary electrical services for its use during construction and consumption costs shall be paid by Contractor.
7. Contractor shall be responsible for supplying site water source for its use during construction for personal/equipment washing and dust suppression.
8. Contractor shall fix at their expense all damaged pavement, utility lines, concrete, and landscape that is damaged because of construction activities at an equal or better condition than existed prior to operations.

SOLAR EQUIPMENT SPECIFICATIONS – PART 1

1. Solar Equipment Specifications

1.1. Photovoltaic Panels

1.2. Solar PV Field

1.2.1. All equipment specified by Contractor shall be approved by Company.

1.2.2. The area available for the solar PV arrays is limited by a Contractor-provided geotechnical survey, landscape, protected areas, and other site constraints specified in a Contractor-provided ALTA Survey or equivalent.

1.2.3. Design parameters other than those specified in this document shall be defined by Contractor.

1.2.4. PV module row pitch (post-to-post) shall be adequate to allow access for customary maintenance vehicles, such as pick-up truck, equipment, and personnel.

1.2.5. PV array site shall allow enough space for customary maintenance vehicles to drive around the entire perimeter of the array, inside the fence.

1.2.6. PV module tilt angle shall be adequate to allow proper water shedding.

1.2.7. PV module strings – groups of PV modules electrically connected in series – shall be designed in accordance with the inverter manufacturer's maximum DC voltage input specifications and applicable code requirements for maximum operating DC voltage.

1.2.8. PV module arrays – groups of PV arrays electrically connected in parallel – shall be designed in accordance with the inverter manufacturer's maximum DC current and power input specifications and applicable code requirements for maximum operating DC current and power.

1.3. Photovoltaic Modules

1.3.1. PV modules shall be designed to produce electricity for a minimum of 35 years under the environmental conditions of the Site.

1.3.2. The electricity generation capabilities of the modules shall meet or exceed the capabilities defined by the module electrical data sheet of the product.

1.3.3. Annual degradation shall be specified by the manufacturer.

1.3.4. PV modules shall comply with the following parameters to ensure maximum quality and performance.

1.3.4.1. The module manufacturer shall be as agreed upon by Contractor and Company.

1.3.4.2. Manufacturer Experience

a. The manufacturer shall have at least five (5) years of experience manufacturing photovoltaic modules.

1.3.4.3. Manufacturing Capacity

a. The manufacturer shall have a current minimum manufacturing capacity of at least 100 MW per year.

1.3.4.4. Specification Sheet

a. The manufacturer/Contractor shall provide detailed electrical and mechanical specification sheets for the module.

b. The manufacturer shall provide the estimated annual degradation of their module and justify the value provided with historical production data.

c. The maximum allowable annual degradation for modules used on this Facility shall be 0.7 percent per year or less as specified by the panel manufacturer.

d. Minimum snow load capacity shall be 5400 Pa or greater.

e. Minimum wind load capacity of 2400 Pa or greater.

1.3.5. Technology

1.3.5.1. The cell technology for the PV module shall be either monocrystalline or polycrystalline silicon.

1.3.5.2. Thin film PV modules are acceptable if approved by the Company.

1.3.6. Codes and Standards

1.3.6.1. Modules shall either be UL listed or certified by an OSHA-approved testing agency to meet the UL 1703 specification.

1.3.6.2. The certificates of factory/laboratories tests and compliance to the codes and standards referenced by the manufacturer shall be provided to Company.

1.3.6.3. The modules shall be provided with a permanent label indicating, at a minimum, the following information:

a. Make/model

b. Electrical characteristics, including open circuit voltage (Voc); short circuit current (Isc); maximum power point voltage (Vmpp); maximum power point current (Impp); nameplate power (W), and maximum series fuse size

c. Temperature coefficients of Isc, Voc and nameplate power

d. Nominal power conditions (STC, NOCT, etc.)

e. Environmental operating conditions

f. Compliance with applicable standards (UL, IEC, CE, etc.)

g. Warnings of electrical hazard

h. Maximum system voltage

i. Maximum Load Capacity

j. Date and location of manufacture, manufacturing code

k. Serial number

1.4. Module Design and Construction

1.4.1. The modules shall be new and, to maintain the homogeneity of the system, all cells and modules used throughout the Facility shall be supplied by the same manufacturer, be of the same make and model types, and shall have the same nameplate power rating.

1.4.2. The modules shall include factory installed power conductors at least No.12 AWG, rated at 1500 Vdc, with clearly defined polarities, weather-proofed, UV resistant/outdoor rated and with locking-type plug-in connectors of single polarity and with the same environmental and electrical ratings as the power conductors.

1.4.3. All modules of the same type shall have the same connectors.

1.4.4. The modules shall include a grounding lug, grounding hole, or some other tested grounding attachment mechanism (applicable for framed modules only).

1.4.5. Grounding attachment must specifically be approved by the AHJ.

1.4.6. The module framing, where provided, shall be corrosion-resistant, resistant to damage from snow, wind, hail and windblown dust and sand.

1.4.7. PV modules, at minimum, shall be supplied with a 10-year defects warranty and a 35-year performance warranty.

1.4.8. Contractor shall provide 0.1 percent of the modules installed to be kept as spares, or a minimum of two pallets of modules.

1.4.9. Contractor shall provide weather resistant storage on site for all panels in a Company approved Tuff Shed style or equivalent container.

1.5. PV Module Mounting System

1.5.1. The PV Module Mounting Systems for typical single or dual axis tracking arrays shall meet the following specifications:

1.5.1.1. The design specifications for the foundations of the module mounting system ("mounting system") shall be provided by Contractor as part of the mounting system design specifications for either single or dual axis tracking systems.

1.5.1.2. The mounting system foundation shall be designed to withstand the soil chemistry of the Site location, as documented in the project geotechnical investigation, (ground- mounted system) without replacement or compromising its structural integrity for a minimum of 35 years.

1.5.1.3. The foundation shall be designed to comply with all environmental conditions of the Site.

1.5.1.4. The mounting system shall be designed to withstand wind speeds up to the maximums specified by applicable codes, over its specified operating lifetime, without compromising its structural integrity.

1.5.1.5. The mounting system and modules shall have provisions to be continuously bonded and grounded to the ground grid system of the array.

1.5.1.6. The mounting system shall be certified by UL or another approved testing agency to meet the requirements of UL Subject 2703.

1.5.1.7. Single Axis Tracker (SAT) system shall be certified by UL or another approved testing agency to meet the requirements of UL Subject 3703.

1.5.1.8. SAT system provided must satisfy minimum site requirements for mechanical and electrical equipment ground clearances.

1.5.2. In addition to meeting the requirements of the mounting system, Contractor shall:

1.5.2.1. Provide detailed information on the materials and design of the mounting system.

1.5.2.2. Provide a detailed structural analysis of the foundations and demonstrate that the design conforms to the applicable standards and codes and the geotechnical investigation.

1.5.2.3. Demonstrate that the modules will stay attached to the mounting structure under all environmental conditions specified by applicable codes.

1.5.2.4. Ensure that the design of the mounting structure specifies the attachment of the PV modules to mounting structure in accordance with the mounting specifications provided by the PV module manufacturer.

1.5.2.5. Submit all structural designs and calculations for the mounting system to Company for review prior to purchase of any mounting system equipment.

1.5.2.6. Contractor shall prepare a design to mitigate the effects of corrosive soils on the structural support system for the design life, which includes installing concrete around posts, adding a sacrificial layer to the structural steel members, galvanizing, and/or coating the structural steel members with epoxy coating as specified.

1.5.2.7. Provide a detailed description of the method of installation for the mounting system.

1.5.3. Required Manufacturer’s Warranties- Mounting System

1.5.3.1. The module mounting manufacturer shall provide a product warranty of at least 20 years.

1.5.4. Required Spare Parts- Mounting System

1.5.4.1. All necessary hardware for at least two PV module racks shall be provided as spare parts.

1.5.5. Required Manufacturer's Warranties- Single Axis Tracker Mounting System

1.5.5.1. The module mounting manufacturer shall provide a product warranty of at least 10 years on structural components.

1.5.5.2. Tracker drive and control system shall be warranted for a minimum of 5 years, with options for extension.

1.5.6. Required Spare Parts- Single Axis Tracker Mounting System

1.5.6.1. All necessary hardware for at least two PV module racks shall be provided as spare parts.

1.6. Combiner Boxes

1.6.1. Each combiner box shall include a fused connection between all underground DC circuit wiring from PV strings to provide over-current and short-circuit protection.

1.6.2. The ungrounded DC circuit wiring from PV strings (if any) shall be connected to a terminal block and bus bar.

1.6.3. The combiner box output circuit (homerun) shall be provided with a load-break disconnect switch with exterior lockable handle, rated for the voltage and current of the combined PV strings.

1.6.4. The string fuses and fuse holders shall be finger-safe and rated according to the string DC current and voltage, and environmental conditions.

1.6.5. The power terminal blocks shall be rated for use with copper conductors and rated for continuous duty at 1000 or 1500 V DC and 90°C conductor and terminal temperature ratings.

1.6.6. The combiner box shall be equipped with a mechanical ground lug and bus, rated for terminations with copper grounding conductors.

1.6.7. The combiner enclosure shall be outdoor-rated, weatherproof, NEMA 4 or NEMA 4X, and the doors shall be easily interchangeable.

1.6.8. The manufacturer shall supply a fully assembled combiner box and shall provide detailed drawings, specifications sheets, mounting instructions, and maintenance requirements of its product.

1.6.9. Each combiner box shall provide "touch-safe" power circuit terminations and include provisions for bolted terminations of the output power circuit to the inverter.

1.6.10. Surge protective devices, per UL 1449, shall be installed at the line side of the main disconnect switch.

1.6.11. Conduit entries into the combiner box shall be from the side or bottom to prevent water ingress.

1.6.12. Each combiner box shall include a provision for a padlock, including a padlock and key.

1.6.13. All padlocks shall be keyed the same.

1.6.14. The combiner box door shall be interlocked with a load-break disconnect switch in such a manner that the door cannot be opened when the switch is "closed." In addition, the switch shall not be capable of being placed in the "closed" position unless the combiner box door is fully closed.

1.6.15. An external door interlock defeat mechanism shall be provided to allow authorized personnel access to the interior of the combiner box while the switch is in the closed position for periodic inspection, troubleshooting, and electrical field measurements.

1.6.16. The combiner box shall be listed to UL 1741 to 1000 or 1500 V dc, and rated for an operating temperature range of -40°C to +50°C.

1.6.17. Each combiner box shall be suitable for application of permanent labels in the field and shall include electrical warning labels.

1.6.18. All information and warnings required by the National Electrical Code sections 690 and 705 shall be provided on a permanent label attached to each combiner.

1.6.19. Arc Flash PPE requirements shall be provided on a permanent label attached to each combiner box.

1.6.20. As an alternate, A Big Lead Assembly ("BLA") from Shoals Technologies may be utilized in lieu of combiner boxes. In-line fuses for BLA cable systems shall be field serviceable.

1.6.21. Required Manufacturer's Warranties:

1.6.21.1. Combiner boxes shall have a manufacturer's warranty of at least 5 years.

1.6.22. Required Spare Parts:

1.6.22.1. Contractor shall provide at least one spare combiner box for each type installed.

1.6.22.2. Each combiner box shall include four spare fuses of each size and type.

1.7. Recombiner Boxes (if required)

1.7.1. Recombiner boxes shall provide a main DC disconnecting means.

1.7.2. Recombiner boxes shall be connected directly before the inverter input via throat connection.

1.7.3. Recombiner boxes shall also meet the following requirements:

1.7.3.1. Rated for 1000 or 1500 Vdc

1.7.3.2. Up to 24 input circuits with configurations up to 1200 A

1.7.3.3. Overcurrent protection (fuses or breakers)

1.7.3.4. If fuses are used, load break disconnects shall be provided that meet the provisions of NFPA-70-2011 (NEC) 690.16(A) and (B) (fuses: disconnecting means and fuse servicing).

1.7.3.5. 90°C rated terminals

1.7.3.6. Continuous duty rated

1.7.3.7. NEMA 3R or NEMA 4 or NEMA 4X

1.7.3.8. Each recombiner box shall include a provision for a padlock, including a padlock and key.

1.7.3.9. All padlocks shall be keyed the same.

1.7.3.10. Ground bus

1.7.3.11. As an alternate, provide monitoring of PV output circuit currents.

1.7.4. Each recombiner box shall be suitable for application of permanent labels in the field and shall include electrical warning labels.

1.7.5. All information and warnings required by the National Electrical Code sections 690 and 705 shall be provided on a permanent label attached to each combiner.

1.7.6. Required Manufacturer's Warranties

1.7.6.1. Recombiner boxes shall have a manufacturer's warranty of at least 5 years.

1.7.7. Required Spare Parts

1.7.7.1. Each recombiner shall include 4 spare fuses of each size and type.

1.8. Solar PV Inverters / BESS (Battery Energy Storage System) Inverters

1.8.1. Inverters shall meet the following requirements: The inverters shall include the necessary DC circuit breakers/disconnect switches, AC circuit breakers/disconnect switches, local controls, remote SCADA system interface (or web-based interface if Company approved), grid operator control interfaces, and accessories necessary for the inverter to meet all code requirements and function properly as part of a power generation facility.

1.8.1.1. Environmental ratings: -40° to +50°C (-40° to 122°F), Humidity: 15 % - 95%, non- condensing, 6,500 ft elevation. Inverters shall include the inverter manufacturers cold-weather package to allow for reduced temperature operation and protect components from cold weather condensation.

1.8.1.2. >0.99 power factor above 20% rated power.

1.8.1.3. Power factor capability at the point of interconnection shall be at least 0.9 leading/lagging and have the capability to be controlled/tuned.

1.8.1.4. Power factor capability shall be compliant with the interconnection agreement requirements.

1.8.1.5. Inverters shall include flicker mitigation.

1.8.1.6. Central Inverters (if used) shall have a nameplate rating greater than or equal to 1 MWac, unless otherwise approved by Company.

1.8.1.7. Upon preliminary selection of the inverter make and model, Contractor shall provide a user's list for this inverter in operation. Inverter must meet sound level requirements in the field per equipment specifications and permit requirements.

1.8.1.8. Inverter maximum input voltage shall be 1000 or 1500 Vdc, unless otherwise approved by Company.

1.8.1.9. Inverters shall be IEEE 1547 compliant with the exception of anti-islanding and grid disturbance behavior.

1.8.1.10. Output current harmonics shall contain <3% total harmonic distortion (THD) at rated power output, per IEEE 519.

1.8.1.11. Inverter California Energy Commission (CEC)efficiency shall be >97% without medium voltage step-up transformer.

1.8.1.12. Inverters located outdoors shall be enclosed in lockable, NEMA 3R enclosures, at a minimum.

1.8.1.13. The Contractor's design shall include an analysis of the maximum anticipated operating temperature to ensure that the manufacturer's recommended operating temperature is not exceeded.

1.8.1.14. Enclosure shall have a door interlock system to prohibit the door(s) from being opened while energized.

1.8.1.15. Inverters shall incorporate a non-load break, two (2)-pole, lockable disconnect switch for main DC power disconnect for maintenance personnel safety, or other Company approved method.

1.8.1.16. Inverter output shall be protected by an AC output circuit breaker with short and long time adjustable over current protection.

1.8.1.17. Inverters shall be capable of rated output at 50ºC ambient or higher without derating.

1.8.1.18. Inverters shall employ a maximum power point tracking scheme to optimize inverter efficiency over the entire range of PV panel output for the given site design conditions.

1.8.1.19. Inverters shall be equipped with all hardware for data collection and communication to the central SCADA server, including the ability to write to the control registers to reset inverter and modify AC output parameters, including power factor and maximum power.

1.8.1.20. Inverters with Battery Energy Storage System (BESS) charged and discharged from the AC collection system shall be designed for four-quadrant, bi-directional operation (Inverter provides DC current to charge the battery modules from the AC collection system, and delivers AC power from the DC battery modules to supply the utility distribution system).

1.8.1.21. Inverters with BESS charged from the Solar PV DC system shall be designed as a bi-directional DC-DC converter (Inverter charges the batteries from the Solar

PV DC system when PV Power is available. Charged battery power is sent to the PV DC bus where it is converted to AC collection system voltage by the PV inverters)

1.8.1.22. Data collection points shall be integrated into the inverter monitoring and communications package.

1.8.1.23. Inverter Data collection points included shall be (at a minimum):

a. AC Voltage

b. DC Voltage

c. AC Current

d. DC current

e. Real Power (kW)

f. Reactive Power (Kvar)

g. Apparent Power (kVA)

h. Energy (kWh)

i. Alarms

j. Inverter status and faults (including ground fault interrupts)

1.8.2. Required Manufacturer's Warranties

1.8.2.1. The inverter manufacturer shall provide a warranty of at least 5 years, with Company option to extend.

1.8.3. Required Spare Parts

1.8.3.1. If a repair is needed, the manufacturer shall provide the necessary spare parts and assume responsibility for the repair service under the warranty.

1.8.3.2. One (1) spare String Inverter (matching size used at site) is required per 2MW. Pricing to be provided for additional spare String Inverters.

1.8.3.3. Recommended spare parts list with quantities and pricing to be provided for Central Inverters.

1.8.4. Disconnect Switches, 600 VAC

1.8.4.1. Disconnect switches shall meet the following requirements:

a. 600 volts AC

b. Continuous current rating as specified on the drawings (minimum 30 A)

c. Three-pole

d. NEMA 3R enclosure

e. High conductivity copper

f. Visible blades

g. Positive, quick-make, quick-break mechanisms

h. Operating handle whose position is easily recognizable, and which can be locked in the OFF position with multiple padlocks.

i. The ON and OFF positions shall be clearly marked.

j. Door interlock that prevents the door from being opened while the operating handle is in the ON position.

k. All AC service disconnects shall include integrated or compatible adjacent surge protection.

l. Conform to NEMA KS1

m. UL listed.

1.8.5. Manufacturer's standard warranties shall apply.

1.9. Meteorological Monitoring Station

1.9.1. Contractor shall supply and install one stand-alone central meteorological monitoring station (Met Station) at the Site.

1.9.2. The Met Station shall include all instrumentation and sensors necessary to comply with the requirements set forth below and in Attachment 2.

1.9.3. The Met Station shall include a Datalogger that can record data from all required instruments and sensors.

1.9.4. The Met Station Datalogger shall include a backup power system, which may or may not be connected to the SCADA System UPS system, to allow for stand-alone operation for at least fifteen days.

1.9.5. The Met Station Datalogger shall have at least a fifteen-day on-board non-volatile data storage capacity.

1.9.6. The Met Station Datalogger shall be capable of sampling data at a rate of at least once per minute.

1.9.7. Five-minute averages of the one-minute data samples shall be recorded every five minutes.

1.9.8. The access to the data logger shall be password protected and Contractor shall provide the required software, connection cables and instruction manual to connect to the port and access the data.

1.9.9. The meteorological monitoring station shall include a communications port compatible with a standard laptop computer running Windows OS or Company approved operating system to be able to read and download data on site.

1.9.10. Weather Station items shall be as listed:

1.9.10.1. Datalogger with battery backup and Modbus TCP/IP communications

1.9.10.2. Ambient Air Temperature and Relative Humidity

1.9.10.3. Global Horizontal Irradiance Pyranometer

1.9.10.4. Plane of Array Pyranometer (2 minimum)

1.9.10.5. Back of Monitor Temperature Sensors (minimum 2, site size dependent)

1.9.10.6. Precipitation Gauge and Meter

1.9.10.7. Anemometer, Wind Speed and Direction

1.9.10.8. Panel Auxiliaries – Lighting and Receptacle

1.10. GROUNDING SYSTEMS

1.10.1. All grounding systems shall be designed and provided as required by NEC, NESC, IEEE, and local code requirements.

1.10.2. All grounding systems shall comply with the following:

1.10.2.1. Ground loops shall be provided under/around major electrical equipment.

1.10.2.2. The grounding system shall consist of bare copper conductor and copper-clad steel ground rods.

1.10.2.3. The system shall be designed to protect personnel and equipment at the Facility from the hazards that occur during power system faults and lightning strikes.

1.10.2.4. For ground grids below grade, each junction of the grid shall be bonded with either exothermic welds or irreversible compression connections.

1.10.2.5. Major items of equipment such as inverters and transformers shall have integral ground buses connected to the grounding electrode system.

1.10.2.6. Contractor shall route a grounding conductor sized per the NEC parallel to all power conductors operating above 50 volts.

1.10.2.7. The module DC system grounding electrode(s) shall be common with, or bonded to, the AC grounding electrode as indicated in NEC Article 690.4

1.10.2.8. Module grounding shall comply with module manufacturer recommendations for grounding.

1.11. Power Conversion Systems (PCS)

1.11.1. PCS means power conversion system and includes the inverter, harmonic filters, step-up transformer, AC and DC fault and overcurrent protection devices, and instruments and devices to interface with the DAS communications system.

1.11.2. The PCS, in conjunction with the BESS site controller (on sites that include BESS), shall be capable of automatic, unattended operation. The PCS shall include all necessary self-protective and self-diagnostic features to protect itself from damage in the event of component failure or from operating beyond equipment ratings, whether due to internal or external causes.

1.11.3. The PCS internal cooling system design may be the manufacturer's standard, if failure of a single cooling fan does not cause more than 50% derating of the affected PCS's power rating.

1.11.4. PCS shall include Maximum Power Point Tracking ("MPPT") capability.

1.11.5. The PCS transformer shall have the specifications as noted in STEP-UP TRANSFORMER SPECIFICATIONS – PART 7.

1.11.6. The PCS inverter shall have the specifications as noted in section 1.8, Solar PV Inverters / BESS (Battery Energy Storage Systems) Inverters.

1.11.7. PCS Shelter:

1.11.7.1. Shelter shall be rated prefabricated metal or pre-cast concrete enclosures for wind, rain, or UV protection.

1.11.7.2. Shelter may include HVAC equipment or other means as required to maintain inverter operating environment within inverter manufacturer's specifications. HVAC equipment with a minimum SEER rating of 14 shall be utilized.

1.11.7.3. Shelter layout shall include provision for inverter(s) with adequate spacing to accommodate inverter maintenance activities and safe operating distances. Minimum equipment clearances shall be in accordance with the NESC and inverter manufacturer's installation and maintenance requirements.

1.11.7.4. Shelter shall have provisions for equipment removal and replacement.

1.11.7.5. Shelter shall have adequate task lighting to perform all maintenance activities.

1.11.7.6. Shelter shall not be designed or classified for occupancy.

1.11.7.7. Shelter shall be configured to have no roof penetrations of any kind, except for HVAC equipment needs, if any.

1.11.7.8. Shelter manufacturer shall provide detailed engineering design drawings and calculations complying with the requirements of the applicable building code(s) and local and state laws that have jurisdiction where the building will be delivered and erected. Drawings shall be stamped by a Professional Engineer registered in the Project state and are subject to Company review and approval.

1.11.7.9. Shelter shall have air terminal lightning protection in accordance with NFPA 780 standards.

1.11.7.10. Shelter shall have a means of prohibiting access when energized.

1.12. POWER AND CONTROL WIRING

1.12.1.1. Cables shall be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served.

1.12.1.2. The type of cable used shall be determined by individual circuit requirements, temperature, and individual equipment manufacturer's recommendations.

1.12.1.3. Current carrying conductors shall be copper only.

1.12.1.4. All exposed wiring shall be clearly indicated as sunlight or UV resistant.

1.12.1.5. DC Cables – Type I

1.12.1.6. Type I DC cables shall include those used for:

a. Interconnecting PV modules

b. Connecting PV module strings to combiner boxes

c. Type I DC cables shall be sized in accordance with the NEC requirements for "Solar Photovoltaic Systems" (Article 690) and shall be rated according to the maximum system voltage.

1.12.1.7. Copper conductor is required for all cables from module to module or combiner.

1.12.1.8. Conductors shall be sized accordingly taking into account any ambient temperature or ampacity de-rate factors and voltage drop considerations.

1.12.1.9. DC cabling shall be sized to not exceed a maximum voltage drop of 2 percent total from PV to module to inverter at Standard Test Conditions.

1.12.1.10. PV wire is recommended for DC string cables, Company approval required for alternative DC cable types or PV wire harnesses.

1.12.1.11. If the DC system is ungrounded, PV wire is required for all conductors that are not enclosed in raceway.

1.12.1.12. DC cable may be direct buried and shall have a minimum insulation that meets the NEC requirement for "Wet Locations." If the DC system is ungrounded, PV Wire is required for all direct buried DC cable.

1.12.1.13. Schedule 80 PVC conduit shall be used for transitions "entering" and "exiting" the cable trench to meet NEC 300.5(D) requirements.

1.12.1.14. DC conductors installed underground or in concrete slabs in PVC conduit are acceptable.

1.12.1.15. Schedule 80 PVC conduit shall only be used above ground to allow immediate transition to metallic raceway.

1.12.1.16. Schedule 40 PVC shall only be used below ground or in concrete slabs.

1.12.1.17. Cable insulation levels shall be rated according to the maximum system voltage.

1.12.1.18. Insulation and jacket materials on all DC conductors, regardless of location, shall be made from thermoset materials such as XLP.

1.12.1.19. No thermoplastic insulation or jacket materials are permitted for DC conductors.

1.12.1.20. Cable insulation type shall be sunlight resistant, rated for wet locations, and have a temperature rating of 90° C or better.

1.12.1.21. Exposed DC string wiring shall be secured at intervals of approximately 24 inches, on center, maximum.

1.12.2. DC Cables – Type II

1.12.2.1. Type II DC cables shall include those used for:

a. Connecting combiner boxes to recombiner boxes or inverters

b. Connecting recombiner boxes to inverters

1.12.2.2. Conductors shall be sized accordingly taking into account any ambient temperature or ampacity de-rate factors and voltage drop considerations.

1.12.2.3. DC cabling shall be sized to not exceed a maximum voltage drop of 2 percent total from PV module to inverter at Standard Test Conditions.

1.12.2.4. Aluminum conductor may be used for conductors from the combiner to the inverter if the conductor is AWG 1/0 or larger. Otherwise, copper conductor is required.

1.12.2.5. DC cable may be direct buried and shall have a minimum insulation that meets the NEC requirement for "Wet Locations." If the DC system is ungrounded, PV Wire is required for all direct buried DC cable.

1.12.2.6. Schedule 80 PVC conduit shall be used for transitions "entering" and "exiting" the cable trench to meet NEC 300.5(D) requirements.

1.12.2.7. DC conductors installed underground or in concrete slabs in PVC conduit are acceptable.

1.12.2.8. Schedule 80 PVC conduit shall only be used above ground to allow immediate transition to metallic raceway.

1.12.2.9. Schedule 40 PVC shall only be used below ground or in concrete slabs.

1.12.2.10. Cable insulation levels shall be rated according to the maximum system voltage.

1.12.2.11. Insulation and jacket materials on all DC conductors, regardless of location, shall be made from thermoset materials such as XLP.

1.12.2.12. No thermoplastic insulation or jacket materials are permitted for DC conductors.

1.12.2.13. Cable insulation type shall be rated for wet locations and have a temperature rating of 90 °C or higher.

1.12.3. Low Voltage AC Power Cables

1.12.3.1. Low Voltage (LV) AC Power Cables shall include those used for:

a. Connecting inverter output terminals to step-up transformer input terminals

1.12.3.2. Aluminum conductor may be used for conductors for LV AC Power Cable if the conductor is AWG 1/0 or larger. Otherwise, copper conductor is required.

1.12.3.3. All power and control cables shall be UL listed.

1.12.3.4. Cables shall be routed in UL listed wireway, conduit, direct buried PVC conduit, or underground duct banks.

1.12.3.5. A maximum of 1 percent AC voltage drop is acceptable between inverter AC output and step-up transformer LV AC input.

1.12.3.6. A maximum of 3 percent AC voltage drop is acceptable in other AC circuits not associated with solar power production.

1.12.3.7. Less than 600 V AC applications

1.12.3.8. Cable insulation levels shall be rated 600 V.

1.12.3.9. Conductors installed in PVC conduit are acceptable.

1.12.3.10. Low voltage power cables for loads up to 480 volts AC and control cables (i.e., 120 volts ac) shall have copper conductor with 600-volt class insulation.

1.12.3.11. Power cables shall be Type XHHW-2 with concentric-lay, uncoated copper, strand B conductor, rated for normal maximum operating temperature of 90° C in wet and dry applications, cross-linked thermosetting polyethylene insulation, and conforming to ICEA S-95-658 (NEMA WC 70).

1.12.4. Auxiliary Power Cables

1.12.4.1. Auxiliary power cables shall include those used for:

1.12.4.2. Lighting, electrical receptacles, computers, programmable logic controllers (PLCs), and heating/ventilation.

1.12.4.3. Auxiliary power cables for loads up to 480 volts AC and control cables (i.e., 120 volts ac) shall have copper conductor with 600-volt class insulation.

1.12.4.4. All power and control cables shall be UL listed.

1.12.4.5. Cables shall be routed in UL listed wireway, conduit, direct buried PVC conduit, or underground duct banks, as required.

1.12.4.6. A maximum of 3 percent AC voltage drop is acceptable in AC circuits not associated with solar power production.

1.12.4.7. Power cables shall be Type XHHW-2 with concentric-lay, uncoated copper, strand B conductor, rated for normal maximum operating temperature of 90° C in wet and dry applications, cross-linked thermosetting polyethylene insulation, and conforming to ICEA S-95-658 (NEMA WC 70).

1.12.5. Control System Cables

1.12.5.1. Control cables shall include those used for:

a. System control, alarms, contacts, etc. shall be Type THHN/THWN 600 volt rated with stranded, uncoated copper conductor, rated for normal maximum operating temperature of 90° C dry and 75° C wet applications, polyvinyl chloride insulation, jacket thickness of 4 mils minimum, and conforming to ICEA S-95-658 (NEMA WC 70) and UL 8

1.12.6. Analog Instrumentation Cables

1.12.6.1. Analog instrumentation cables shall meet the following requirements:

a. Twisted Shielded Pair type

b. No less than 16 AWG seven-strand

c. Concentric-lay

d. Uncoated copper conductor

e. Rated for normal maximum operating temperature of 90° C dry and 75° C wet applications

f. Polyvinyl chloride insulation not less 15 mils average thickness

g. Twisted pair of 1-1/2 inch to 2-1/2 inch (38.10 mm - 63.5 mm) lay

h. Shield consisting of combination aluminum-polyester tape and seven-strand

i. 20 AWG minimum tinned copper drain wire

j. With shield applied to achieve 100 percent cover over insulated conductors

k. Jacket thickness of 4 mils minimum

l. Conductor color identification with one black conductor and one white conductor

m. Conforming to UL 62 for Type TFN, and UL 1277 for vertical-tray flame test requirements.

1.12.7. Fiber Optic Cables

1.12.7.1. Fiber optic cable shall meet the following requirements:

a. Multi-mode or single mode (per Company's requirement)

b. 6-strand minimum

c. Double armor (corrugated steel tape), double jacket, when direct buried

d. Single armor (corrugated steel tape), single jacket when installed in conduit

e. Black polyethylene inner and outer jacket.

f. Nominal wall thickness of 0.06 inches.

g. Gel filled

h. Overall water swellable barrier tape with 25 percent overlap

i. Tensile load (installation) of 600 lbs.

j. Minimum bending radius 20 times cable diameter Operating temperature -40 °C to 70 °C

1.12.8. Category 5e or Category 6 Cables

1.12.8.1. Category 5e or Category 6 cable shall meet the following requirements:

a. Sunlight, oil, and gas resistant

b. Industrial grade

c. 4 bonded pairs, 22 AWG

d. Solid copper conductor

e. Polyolefin insulation

f. Black PVC jacket, 0.03 inches

g. UL listed Operating temperature of -25° C to 75° C

1.13. TESTING

1.13.1. PV STRING OPEN-CIRCUIT VOLTAGE TESTING

1.13.1.1. Open-circuit voltage (Voc) string testing shall be conducted to assess overall module and string performance.

1.13.1.2. The test shall be conducted and witnessed by at least two qualified technicians using best practices and the following procedure:

1.13.1.3. The test shall be conducted during periods of irradiance greater than 500 W/m2 and between the hours of 10:00am and 2:00pm

1.13.1.4. Inspect string fuses for appropriate use and correct sizing

1.13.1.5. Measure and record the following for every string:

a. String number and combiner box location (or similar relevant string identification)

b. Measurements made every five (5) or fifteen (15) minutes

c. Time of test and weather conditions

d. Module back sheet temperature at a location representative of the strings being tested

e. Plane-of-Array (POA) irradiance measurement for area of strings being tested

f. Open-circuit voltage (Voc) measurement of every string within each combiner box.

g. Measurement shall be made using a voltmeter with the suitable voltage rating and accuracy of at least 0.5%

h. Each measured string Voc shall be within 5% from the expected Voc (Voc-expected) and within 5% of adjacent strings under identical temperature and irradiance conditions.

1.13.1.6. The expected Voc shall be calculated using the following equation:

Voc−expected=r]·Voc−ref·[1+{J·(Tmod−Tmod−ref)] where:

Voc−expected = expected open-circuit voltage of the string Voc−ref = module open-circuit voltage at reference conditions r] = number of modules in series in tested string

{J = module open-circuit temperature coefficient (°C-1)

Tmod = measured module backsheet temperature (°C)

Tmod−ref = back of module temperature at reference conditions

1.13.2. Comparisons between all measured and expected Voc shall be analyzed in a spreadsheet which shall include the following PASS/FAIL tests for each string:

1.13.2.1. String Voc-measured is within 5% of Voc-expected

1.13.2.2. String Voc-measured is within 5% of the Voc-measured of adjacent strings

1.13.2.3. Strings that fail either test shall be investigated for module defects, loose connections, disconnected modules, or other possible defects tested)

1.13.2.4. Ambient temperature

1.13.2.5. Wind speed

1.13.2.6. Weather conditions

1.13.2.7. Correct polarity shall be verified

1.13.3. Using an IV Curve Tracer, perform the curve trace using the manufacturer's instructions.

1.13.4. The Curve Tracer shall be configured to record at least 10 current-voltage data points and record the following values:

a. Maximum power (Pmax)

b. Voltage at maximum power (Vmp)

c. Current at maximum power (Imp)

d. Open circuit voltage (Voc)

e. Short circuit current (Isc)

f. Fill Factor (FF)

1.13.5. Short-circuit current test: Each measured string short-circuit current shall be greater than the expected short-circuit current (Isc-expected) derived using the following equation:

Isc−expected=K·Isc−ref·(GGref)

where:

Isc−expected = expected short-circuit current of the string

Isc−ref = short-circuit current at Standard Test Conditions (STC) as shown on module datasheet

K = 0.95 (uncertainty and soiling factor)

G = measured irradiance (W/m2)

Gref = 1000 W/m2

1.13.6. LOW VOLTAGE INSULATION RESISTANCE TESTING

1.13.6.1. All low voltage (LV) direct current (DC) and alternating current (AC) cables shall be tested for insulation resistance in accordance with the NETA-ATS.

1.13.6.2. Measured insulation resistance values shall be adjusted to a 20°C reference to determine acceptance with NETA-ATS, Tables 100.1 and 100.1

1.13.6.3. All insulation resistance acceptance criteria shall be proposed by Contractor for approval by Company.

1.13.6.4. Any test results that fail to be in accordance with the NETA-ATS, or do not meet the accepted criteria, shall be documented as a deficiency on the test report.

1.13.6.5. Corrective action shall follow the identification of a failed test, followed by re-testing.

1.13.7. LOW VOLTAGE CABLE TESTING

1.13.7.1. Low voltage cables shall include only those designed to operate at or below 1500 V.

1.13.7.2. All low voltage cables shall be inspected and tested in accordance with NETA-ATS, Section 7.3.

1.13.7.3. Test Values shall be in accordance with NETA-ATS, Section 7.3.2.

a. Note: NETA-ATS, states that Section 7.3.2 is for low-voltage cables up to a 600 Volt Maximum.

b. This Section shall also be used for cables with voltages up to 1000 Volts

1.13.7.4. Test voltages applied in the field shall not exceed the maximum test voltage of NETA- ATS, Table 100.1

1.13.7.5. Verify uniform resistance for all parallel conductors

1.13.8. POLARITY VERIFICATION

1.13.8.1. All circuits shall be verified to have the correct polarity according to the design drawings.

1.13.9. THERMOGRAPHIC IMAGING

1.13.9.1. Thermographic Imaging of PV Arrays with an unmanned aerial vehicle (drone) may be used as an option to confirm that the panels are operational when in service under irradiance.

1.13.10. INVERTER COMMISSIONING

1.13.10.1. Inverters shall be commissioned by the inverter manufacturer, or an authorized representative of the manufacturer, using the manufacturer's specified procedures.

1.13.10.2. Commissioning reports shall be in a format provided by the manufacturer.

1.13.10.3. At a minimum, inverter commissioning shall meet the following requirements:

a. Inverters shall be fully operational after commissioning completion

b. All shipping and packing materials shall be removed from inverter cabinets

c. Fuses and air filters shall be checked, verified as correct and in place

d. Torque wrench marks shall be recorded

e. Software updates and data acquisition (DAS) communication shall be tested and functional

f. Noise Level Study shall indicate inverter meets the manufacturer's specifications.

1.13.11. METEOROLOGICAL MONITORING STATION TESTING

1.13.11.1. All meteorological monitoring station equipment shall be commissioned, calibrated and tested using the manufacturer's specified procedures with accuracy being compared to the manufacturer's specifications.

1.13.11.2. Current calibration certificates for each installed instrument shall be provided to Company.

1.13.11.3. Test reports shall be in a manufacturer provided format if available.

1.13.11.4. The following instrumentation, if it is part of the metrology equipment specified by Company, shall be tested, at a minimum:

1.13.11.5. Solar irradiance measurement device, as applicable, e.g.:

a. Global horizontal irradiance (GHI)

b. Plane of array (POA) irradiance

c. RaZON solar monitor system, as applicable

1.13.11.6. Anemometer (wind speed), as applicable

1.13.11.7. Module temperature, as applicable

1.13.11.8. Ambient temperature, as applicable

1.13.11.9. Precipitation gauge, as applicable

1.13.11.10. Data-logger and communications equipment, as applicable

1.14. Data Acquisition System - (Data Logger Monitoring System)

1.14.1. An overall data acquisition site monitoring system shall be provided separately or shall be integrated into the Weather Station referenced in Specification Section 1.9. The manufacturer of the system shall be included in the Preferred PV Solar Equipment Contractors List or approved by the Company. Each inverter will be equipped with a condition-based monitoring system. The inverter monitoring system shall connect to the site data logger. Power metering data shall be provided to the data logger to provide revenue grade accuracy metering data and provide alerts for discrepancies with inverter readings. The data logger shall provide wireless communication to allow for secure remote access of the information via the internet, or Company approved equivalent method.

1.14.2. Hardware

1.14.2.1. The data collection / signal processing unit shall be installed in a serviceable location in the inverter and connected.

1.14.2.2. All cables shall be oil and grease resistant, cold weather flexible, and routed in trays, conduit or raceways that provide protection to the cable.

1.14.3. Data logger and Software shall meet the following requirements:

1.14.3.1. Ability to communicate with other devices via Modbus TCP, OPC, PI, or similar protocols

1.14.3.2. Capable of quickly running the provided analysis software

1.14.3.3. Capable of storing 1 year of data

1.14.3.4. Unrestricted access without user count-based licensing

1.14.3.5. Analysis software shall be preinstalled and meet the following requirements:

a. Unrestricted access without individual user licensing

b. High level display to view all status on 1 page

c. Record data at least once per day

d. Local alarm function with remote notification

e. Access to all raw data

1.14.4. Minimum Features

1.14.4.1. Solar operation and control from a secure, web-based monitoring system.

1.14.4.2. Main control server with 1-year minimum data storage

1.14.4.3. Secure remote access server

1.14.4.4. Backup power supply

1.14.4.5. All applicable software licenses

1.14.4.6. Automatic backup software

1.14.4.7. Software to modify screens

1.14.4.8. System monitoring screen(s) including the display of all alarms and statuses along with a one line overview of breaker position and MWs, volts, amps, and VARs at all metered locations

1.14.4.9. Remote Alarm Notification

1.14.4.10. Power curtailment at the substation level

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

1.14.4.12. Power ramp rate control

1.14.4.13. System VAR

1.14.4.14. System voltage

1.14.5. Products

1.14.5.1. The solar and associated equipment provided by the manufacturer shall be new and shipped directly from the factory to the project site and shall comply with all Occupational Safety and Health Administration (OSHA) regulations

1.14.6. Execution

1.14.6.1. The solar panels shall be assembled and commissioned in strict compliance with the solar panel manufactures requirements and procedures.

1.14.6.2. All panels and associated array components shall be cleaned internally and externally and free of surface coating scratches, chips, etc. and the subject scratches, chips, etc. repaired prior to being lifted into place. All damage shall be repaired in strict compliance with manufacturer requirements.

1.14.7. Testing and Inspection

1.14.7.1. All facility components will be commissioned and tested in strict compliance with manufactures requirements and procedures

1.14.8. Submittals

1.14.8.1. Contractor shall use a Company-approved Project Management tool/suite such as ProCore for the life of the project. This management suite shall be used for all submittals, reviews, comments, RFI's, document storage, punch-lists, etc.

1.14.8.2. All Contractor commissioning and testing procedures, checklists, inspection reports, punch lists and other records related to solar facility assembly, inspection, commissioning, and testing shall be submitted to Company

1.14.8.3. Contractor and Subcontractor(s) commissioning and testing procedures, checklists, inspection reports, punch lists and other records related to solar panel assembly, inspection, commissioning, and testing shall be submitted to Company

CIVIL TECHNICAL SPECIFICATIONS – PART 2

2. Civil Technical Specifications

Work under this specification applies to the construction of the roadways, foundations, and drainage.

2.1. Road and Foundation Grading Specifications

2.1.1. All grading shall conform to county grading ordinances, storm water permit requirements, and other Applicable Laws and Applicable Standards pertaining thereof.

2.1.2. The Contractor shall perform the grading work, including the exercise of sufficient supervisory control during construction, to ensure compliance with all plans, specifications, and codes. Subject to soil conditions, the Contractor shall install geotextile membrane as required by the geotechnical Engineer of Record on the compacted subgrade prior to placement of road material. The road base coarse material thickness shall be based on recommendations provided in the geotechnical investigation report and adjusted to accommodate construction traffic and to meet all other requirements as specified in this agreement if geotextile membrane is not used.

2.1.3. Structural fill shall be defined as any fill area receiving permanent loading from an external source, i.e., equipment foundation. Structural fill shall be compacted to a minimum of 95% of the maximum dry density per ASTM 1555. Fill materials designated as structural fill shall be placed in lifts not exceeding design requirements or a maximum of 12 inches in loose depth.

2.1.4. Prior to placing structural fill, the existing ground shall be cleared of brush, roots/organic matter, debris, and standing water. All unsuitable material shall be placed in non-structural fill areas. Clean granular soil is suitable for fill imported material and shall be approved by the Engineer prior to use. Proof roll testing may be requested by the Company to verify competent subgrade prior to commencing placement of structural fill. The means and methods used for proof roll shall be developed by the Contractor and agreed upon by the Company. Subgrade determined to be unsuitable for placement of material will require compaction. Subsequent failing tests following compaction may require over-excavation and backfill using structural fill complying to the requirements outlined in section 2.1.3.

2.1.5. Structural fill shall be clean granular soil, free of deleterious material including expansive and organic material, rocks greater than 3 inches in diameter, loam, debris, ice, and frozen soil, and shall be approved by the engineer prior to transport. Structural fill shall be placed on compacted native soil. Depth of the structural fill and compaction requirements shall be according to drawings and specifications.

2.1.6. Any structural fill required to be imported from off-site must be from a clean certified pit. Otherwise, Contractor must conform to Company's requirements which include sampling and testing of: Asbestos, DRO, GRO, ORO, VOCs, SVOCs, and RCRA-8 metals and be approved by Company prior to bringing on site.

2.1.7. Compaction tests shall be taken as required by design requirements. In the event of failed tests, the Contractor shall not place additional fill until acceptable test results are obtained.

2.1.8. Positive drainage is required to drain water away from all footing or load bearing structures. Drainage shall be directed to natural drainage ways and shall be graded according to the drawings and specifications.

2.1.9. Access and Maintenance Road locations shown on maps may be altered to avoid sensitive vegetation. "AS BUILT" drawings conforming to Company drawing standards will be provided upon completion to reflect road and equipment foundation pad modifications made during construction.

2.1.10. Access roads shall be restricted from use by the general public. Signs at all entrances shall indicate "NO TRESPASSING, AUTHORIZED PERSONNEL ONLY. DANGER – HIGH VOLTAGE". Sign size, content, location, etc. shall be approved by Company prior to installation. The integrity of the sign shall be designed to withstand all seasonal and earthly elements including but not limited to sun, wind, snow, ice, rain, acidic soils, etc.

2.1.11. All work will be constructed, tested, and inspected in compliance with the Project Quality Assurance Plan.

2.1.12. Access and maintenance roads shall be designed and constructed such that all uses during construction produce a maximum rut depth of 3 inches. Roadways shall also be maintained by the Contractor in acceptable condition for a standard 2-wheel drive ½ ton class truck to safely navigate the entire road to perform site inspections.

2.1.13. Contractor will meet or exceed all recommendations in the geotechnical report.

2.1.14. Roads damaged during construction will be repaired to like new condition.

2.1.15. Road design will consider water runoff patterns that will exist after construction is complete

2.1.16. Site Maintenance Roads may be compacted native soil provided the soil is suitable per the geotechnical report.

2.2. Definition Key

2.2.1. Site Access Road" is defined as a road used to access the solar farm from a state or county road or an existing access road.

2.2.2. "Site Maintenance Road" is defined as a road around the outside of the solar farm or between solar arrays used to maintain the solar panels, arrays, inverters, etc. Site mainten

2.3. Submittals

2.3.1. Contractor shall use a Company-approved Project Management tool/suite such as ProCore for the life of the project. This management suite shall be used for all submittals, reviews, comments, RFI's, document storage, punch-lists, etc.

2.3.2. Contractor will submit to the Company all QA/QC plan records, all testing and inspection results, compaction test results for road base material, including location, dry density, and moisture content.

2.3.3. Contractor will submit to the Company grain size analysis test results for road base material, including location and moisture content.

2.3.4. Contractor will submit to the Company copies of all completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents, and Testing and Inspection requirements included in this document.

2.4. Products

2.4.1. Road base and cap material: Shall be as specified in the design documents. At a minimum, road base material shall consist of class 5Q aggregate meeting the Minnesota Department of Transportation specification or Company-approved equal and have a minimum of three (3) fractured faces.

2.4.2. Geotextile Membrane: Shall meet the requirements of the design documents. The Engineer of Record shall follow the manufacturer's recommendations for aggregate base thickness to be used during construction.

2.4.3. Culvert: Those located in State or County road right of ways shall be PVC or corrugated metal pipe and shall meet the requirements as directed by the State Department of Transportation and/or the County Engineer in which the project is located. Culverts on project property shall be PVC or corrugated metal pipe and shall meet the required specifications of the construction drawings.

2.5. Execution

2.5.1. Where new access and maintenance roads are planned for agricultural areas, all topsoil shall be stripped through the root zone.

2.5.2. The entire access road subgrade shall be proof rolled prior to placement of the aggregate base to identify unsuitable areas of subgrade. The method to scarify, dry and recompact subgrade will not be allowed unless the material is proven not to contain organic material and/or material unable to remain compacted during or after a rain event.

2.5.3. All trees, stumps, brush, and debris within the grading areas shown in the design document shall be removed. Tree branches overhanging the drive zone of the access road shall be trimmed back to the edge of the access road.

2.5.4. Permanent Culverts: Shall be installed per the manufacturer's recommendations. The area where culverts are to be installed shall be cleared and grubbed. Organic materials shall be removed and replaced with recommended bed material. Provide a minimum cover over culverts of 12 inches.

2.5.5. Compaction of the sub grade for roads, crane pads and foundations shall be the more stringent of the design documents or 95% of Modified Proctor (ASTM D1557).

2.5.6. Compaction of the road base and top course shall be as required by the design documents or to a minimum of 95% of Modified Proctor (ASTM D1557).

2.5.7. Aggregate material shall be placed in layers not exceeding 6 inches in loose depth.

2.6. Testing and Inspection

2.6.1. All testing and inspections shall be performed as required by the design documents but at a minimum as indicated and described in this section.

2.6.2. All testing and inspection records shall be sent to the Engineer of Record for review. A copy of all testing and inspection records and any recommendations made by the engineer shall be sent to the Company. Review of testing and inspection records does not alleviate the Contractor from the responsibility of correcting defective areas or work.

2.6.3. Soils used for fill material shall be tested for grain size analysis and classification (ASTM D6913 and D2487), Atterberg Limits (ASTM D4318), moisture content (ASTM D2216), modified proctor tests (ASTM D1557), and aggregate durability (ASTM D3744).

2.6.4. Compacted Subgrade: Access roads, switchgear pads, and all areas to receive concrete shall be proof rolled the full length in the presence of a geotechnical engineer or qualified and approved representative with a loaded tandem axle dump truck having a minimum gross weight of 25 tons. Subgrade shall be corrected if rutting greater than 1.5 inches and/or “pumping” of the subgrade occurs.

SITE FENCING SPECIFICATIONS – PART 3

3. Fencing Specifications

3.1. Site Fencing – For Facilities Not Located Within Existing Plant Security Fences

3.1.1. The chain link fence is covered by the following standard and is considered a protective barrier for unattended facilities, a security barrier for the public and the first line of defense as a wildlife deterrent.

3.1.2. Fencing details including but not limited to type, wire gage, height and post size and spacing shall meet Company's minimum specifications. Entrance gates shall be two 8 feet wide gates that latch and lock at the center. The gates shall be designed to withstand wind loads of 60 mph in operation.

3.1.3. The fence height is 7 foot high: 6 ft. fabric plus a minimum of 1 ft. vertical height of barbed wire, mounted at a 45-degree angle, pointing outward from the Facility.

3.1.4. Contractor shall provide and install the fence to the configuration and details as shown on the permit set of plans.

3.1.5. Contractor shall provide fencing for construction equipment, laydown, and storage as necessary and according to applicable AHJ requirements.

3.1.6. The site fencing shall be grounded.

3.2. Security

3.2.1. 2" diamond chain link fence to deny good toe hold and make climbing over the fence more difficult for the public.

3.2.2. 45° outrigger with three stands of barbed wire to make climbing over the fence more difficult for the public and to legally declare the facility fences as security barriers.

3.2.3. 8-foot fence height is the security requirement.

3.2.4. Two six-foot swing gates will be installed at the access road. A personnel gate shall be located near the access road.

3.3. Fencing Material and Application

3.3.1. The height of a standard fence including the barbed wire shall be 8 feet above the rough grade.

3.3.2. The fence fabric is a 2" diamond mesh chain link style, galvanized or aluminum and coated as follows:

3.3.2.1. Galvanized Maximum of 2-inch mesh Number 11 AWG (American Wire Gauge), galvanized after weaving, Class I Conforming to ASTM A392, "Zinc Coated Steel Chain Link Fence Fabric"

3.3.2.2. Aluminum Coated Maximum of 2-inch mesh Number 11 AWG (American Wire Gauge) Class II, Conforming to ASTM A491 "Aluminum-Coated Steel Chain Link Fence Fabric".

3.3.2.3. Barbed wire top guards, consisting of 3 or 4 strands of barbed wire, shall be mounted on outriggers directed outward at a 45-degree angle. The barbed wire should be equally spaced about 6" inches apart. Outriggers should be at least 18" or 24" long to insure 1' 0" vertical height over the top rail of the fence. Wire material to be either galvanized or aluminum coated as follows:

a. Galvanized 12 1/2 gauge with 14-gauge 4 barb, 5-inch spacing, conforming to ASTM A121, Class 3 "Zinc Coated Steel Barb Wire."

b. Aluminum Coated 12 1/2 gauge with 14-gauge 4 barb, 5-inch spacing, conforming to ASTM A585, Class 2 "Aluminum Coated Steel Barb Wire."

3.4. Fence Framework

3.4.1. Fence posts, top rail, and braces shall be compliant with ASTM F1043 or ASTM F1083.

3.4.2. Intermediate line posts shall be a minimum of 2 1/2" galvanized Schedule 40 pipe (2 7/8" O.D.)

3.4.3. 5.79 lbs. per foot of sufficient length to be driven into the ground a minimum of 4 feet deep.

3.4.4. Corner and terminal posts shall be a minimum of 2 1/2" galvanized Schedule 40 pipe (2 7/8" O.D.) standard pipe, 5.79 lbs. per foot. Posts shall be of sufficient length to be set in concrete at a minimum of 5 feet deep.

3.4.5. Gate posts shall be galvanized standard weight pipe of the following size for single swing gates or one leaf of the double gate. Posts shall be of sufficient length to be set in concrete at a minimum of 5 feet of depth.

Up to 6' wide	2 7/8" O.D	5.79 lbs. per foot.
Over 6'to 13'	4" O.D.	9.11 lbs. per foot.
Over 13' to 18'	6 5/8" O.D.	18.97 lbs. per foot

3.4.6. Top rail and braces shall be 1 5/8" O.D. 2.27 lbs. per foot. All pipes shall be galvanized to conform to ASTM A120 covering "Black and Hot Dipped Zinc-Coated (galvanized) Welded and Seamless Steel Pipe for Ordinary Uses."

3.4.7. Gates shall be galvanized 1.90-inch O.D. pipe, 2.72 lbs. per foot, complete with hinges, stops, rests, and latching devices of a type to accommodate a padlock.

3.4.8. Fittings and latches shall be of appropriate specifications for their functions.

3.4.9. All pipes shall be galvanized to conform to ASTM A120 covering "Black and Hot Dipped Zinc- Coated (galvanized) Welded and Seamless Steel Pipe for Ordinary Uses."

3.4.10. Latch for double gate shall allow opening one half of the gate without disturbing anchorage of the second half.

3.4.11. Hardware fittings and braces shall comply with applicable industry standards for complete and proper installation of the fence standard. Galvanizing shall conform to ASTM A153 "Zinc Coating Hot Dip Iron and Steel Hardware."

3.4.12. Each shipment of fence shall be inspected by the Contractor and the Company to confirm that the galvanizing meets the specifications under which it was purchased.

3.5. Installation of Chain Link Fencing

3.5.1. Installation shall be made in a professional manner by skilled persons experienced in the erection of this type of fence. The fence shall be erected on lines and to grades as provided in the design documents. Fence shall follow the ground line unless otherwise specified. Line posts shall be spaced not more than 10 feet apart and shall be driven into the ground, 4 feet minimum, without concrete. All gate, corner and terminal posts shall be set in concrete foundations to a minimum depth of 60 inches. The diameter of the foundation is to be a minimum of 9 inches, except for gate posts, on which the minimum diameter shall be three times the outside diameter of the post. The foundation shall be 3000 P.S.I. concrete or greater.

3.5.2. All foundations shall extend to the finished grade and shall slope away from the post to assure proper drainage. The top shall be the same diameter as the remainder of the foundation and shall be neat in appearance. The fabric and the barbed wire shall be stretched to proper tension between the terminal posts and securely fastened to the framework members as covered in the material specifications. The bottom of the fabric shall be held uniformly to the existing grade elevation.

ELECTRICAL SYSTEM SPECIFICATIONS – PART 4

4. Electrical System Technical Specifications

4.1. DESIGN REQUIREMENTS

4.1.1. All construction work and the completed electrical system shall be in accordance with and conform to applicable provisions of Schedule A.

4.1.2. All equipment shall be new materials, free of defects, and appropriately listed and NEMA rated. Where applicable, utility-grade equipment shall be used. All new equipment shall have identification tags installed.

4.1.3. Array must be sized to operate within the current, voltage and power limits approved and warranted by the inverter manufacturer. The temperature-adjusted voltage must remain within the inverter limits at historical record low temperature for the location in which it is installed.

4.1.4. Wires must be sized to keep the total voltage drop below 2 percent on the DC conductors from the array to the inverter including existing wire whips on the PC modules, and 2 percent on the AC conductors from the inverter to the point of interconnection. Total drop not to exceed 4 percent.

4.1.5. Electrical design shall include the design of equipment grounding and lightning and ensure adequate protection for the entire PV DCSG site.

4.1.6. Design and specify all communications hardware and software required for system protection and remote monitoring and control.

4.1.7. The electrical system shall be designed to minimize power losses from nameplate generation at the PV panel or battery module through the inverter, and switchgear to the substation or distribution line breaker.

4.1.8. The latest adopted edition of the National Electric Code (NFPA 70, NEC), and National Electric Safety Code (NESC), ANSI C2 1997 shall be followed except where the Utility electric company standards and/or local regulations are more stringent, in which case the most stringent requirement shall govern. Intermediate grounds-4 per mile will not be provided.

4.1.9. All work will be constructed, tested, and inspected in compliance with the Project Quality Assurance requirements.

4.2. AC System

4.2.1. AC Cabling - Cabling for AC systems should be designed to provide a safe and cost-effective means of transmitting power from the inverters to the transformers and beyond. Cables shall be rated for the correct voltage and have conductors sized, considering the operating currents and short-circuit currents. Design shall consider as follows:

4.2.1.1. Cable must be rated for the maximum expected voltage

4.2.1.2. Conductor shall be able to pass the operating and short circuit safely.

4.2.1.3. Cabling sized to avoid voltage drop

4.2.1.4. Insulation should be adequate for the environment of installation

4.2.1.5. Earthing and bonding

4.2.1.6. Installation methods and mechanical protection of the cable

4.2.2. Step-up Transformers

4.2.2.1. Transformer shall be sized based on the output power from the PV arrays with sufficient capacity.

4.2.2.2. Transformer efficiency standards set forth in the Department of Energy "Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Final Rule"

4.2.2.3. Transformers shall be supplied with a no-load tap changer with high voltage taps capable of operating @ +/- 2, 2.5% above and below nominal voltage at full rating.

4.2.2.4. Transformers shall be mineral oil insulating liquid.

4.2.2.5. Enclosure finish shall be a powder coat designed for a 35-year service life.

4.2.2.6. Accessories to include liquid level and pressure/vacuum gauges, dial-type thermometer with SPDT alarm contacts, pressure relief valve, and a drain valve with sampler.

4.2.3. Switchgear – Switchgear and protection systems shall be included to provide disconnection isolation, earthing and protection. On the output side of the inverters, provision of a switch disconnector shall be provided to isolate the PV array.

4.2.3.1. Switchgear shall be located outdoors, Enclosure shall be NEMA 4 and lockable. Switchgear shall include thermostat supervised anti-condensation heaters.

4.2.3.2. Switchgear shall include an auxiliary compartment containing all instrument transformers associated with the protective relays and 120/240V control power transformer (CPT).

4.2.3.3. Communication hardware shall be included

4.2.3.4. Relay current transformers shall be C400 accuracy class

4.2.3.5. Medium voltage protective device and relaying shall be provided

4.2.3.6. The main circuit breaker shall be capable of being both mechanically and electrically operated. Contractor shall furnish an external on/off (close/open) switch located away from the breaker to minimize arc flash exposure.

4.2.4. Grounding and Surge Protection – Grounding should be provided to protect against electric shock, fire hazard and lightning. The grounding of a solar PV system shall include array frames, inverters, lightning, and surge protection. Design guidelines should be considered:

4.2.4.1. Ground rods should be placed close to junction boxes

4.2.4.2. A continuous earth path is to be maintained throughout the PV array

4.2.4.3. Cable runs should be kept as short as possible

4.2.4.4. Surge suppression devices can be installed at the inverter end of the DC cable and at the array junction box

4.2.4.5. Inverter models may include internal surge arrestors

4.3. DC System

4.3.1. DC components shall be rated to allow for thermal and voltage limits. DC system comprises the following constituents:

4.3.1.1. Array of PV modules

4.3.1.2. DC cabling (module, string, and main cable)

4.3.1.3. DC connectors (plugs and sockets)

4.3.1.4. Junction boxes/combiner boxes

4.3.1.5. Disconnect/switches

4.3.1.6. Protection devices

4.3.1.7. Earthing

4.3.2. PV Array Design – Multiple PV modules shall be installed in sufficient quantity to form a complete PV solar array generating system to generate the projected mega-watts, alternating current (MWac). Design of the arrays should optimize efficiency and should consider the following:

4.3.2.1. Minimize ohmic losses

4.3.2.2. Inverter voltage limits

4.3.2.3. Minimize string voltage drops

4.3.2.4. Maximum number of strings shall not lead to yield loss

4.3.3. Combiner Boxes – Combiner boxes are needed at the point where the individual strings forming an array are marshalled and connected in parallel before leaving for the inverter through the main DC cable. Junctions should be made with screw terminals and must be of high quality to ensure lower losses and prevent overheating.

4.3.4. Fuses/Miniature Circuit Breakers – String fuses or miniature circuit breakers are required for over-current protection. They must be rated for DC operation.

4.3.5. DC Switching – DC switches provide a manual means of electrically isolating entire PV arrays, which is required during installation and maintenance. DC switches must be:

4.3.5.1. Double pole to isolate both the positive and negative PV array cables

4.3.5.2. Rated for DC operation

4.3.5.3. Capable of breaking under full load

4.3.5.4. Rated for system voltage maximum current

4.3.5.5. Equipped with safety signs.

4.3.6. DC Cabling – The selection and sizing of DC cables shall be designed for solar PV installations,

4.3.6.1. Module and string cables – single conductor, double insulated cables are preferable for module connections. Using such cables helps protect against short circuits.

4.3.6.2. Cables shall be resistant to ultraviolet (UV) radiation and weather if laid outdoors without protection.

4.3.6.3. Cables should be rated to the highest temperature they may experience. Appropriate de-rating factors for temperature, installation method and cable configuration should also be applied

4.3.6.4. Main DC cable – the overall voltage drop between the PV array and the inverter should be minimized and reduce losses. A benchmark voltage drop of less than 2 percent (at STC) shall be used.

4.3.7. Cable management

4.3.7.1. Over-ground cables such as module cables and string cables need to be properly routed and secured to the mounting structure, either using dedicated cable trays or cable ties. Cables should be protected from direct sunshine, standing water and abrasion by the sharp edges of support structures. They should be kept as short as possible.

4.3.7.2. Plug cable connectors to be touch-proof

4.3.7.3. The laying of DC cables in trenches must comply with the NEC and consider the specific ground heat transfer characteristics and site environmental conditions.

4.3.7.4. Cables shall be listed and identified as PV wire per NEC

4.4. Communication System:

4.4.1. The plant monitoring system will require a communications medium with remote access. Contractor shall provide a cellular or DSL link for remote monitoring.

4.4.2. Contractor shall procure and install all materials and equipment necessary to complete the communication (data collection) cable installation. This includes, but is not limited to fiber optic cable, conduit, pull boxes, terminations, connectors, and panels

4.4.3. Communication tests shall be performed to demonstrate its ability to meet the requirements of its intended use. Fiber loops will also be tested, and loop functional check sheets shall be provided for each communication circuit.

4.4.4. Documentation shall include test results and materials provided

4.5. Meteorological Stations

A meteorological station shall be provided to measure meteorological data to evaluate facility performance. Station shall have capability of recording and storing environmental conditions without AC power per Section 1.9 of the Schedule A.

4.6. Supervisory Control and Data Acquisition (SCADA)

4.6.1. Contractor shall provide engineering workstation providing local control.

4.6.2. SCADA system as required by the interconnection agreement shall be composed of integral operator human-machine interface (HMI), input/output (I/O) and remote telemetry units (RTU) hardware, firmware, and software, internal control/communications devices designed to industry standards shall provide for remote monitoring, alarm management, control, and historical trending of the monitored equipment.

4.6.3. Contractor shall coordinate with Company on the SCADA system design and its communication and control components to align with Company cyber security standards and ATTACHMENT 13 – EPRI Security Architecture for the Distributed Energy Resources Integration Network.

4.6.4. Communication shall be transmitted via ANSI compliant optic or wireless communications infrastructure for client interface. In the selection of network communication components and design of the network architecture, Contractor shall

4.6.5. Points to be monitored by the SCADA system shall include, at a minimum:

a. Meteorological stations

- Reference cell temperature
- Reference cell Irradiance
- Ambient Air Temperature
- Wind Speed
- Wind Direction
- Global Horizontal Irradiation
- Rain
- Module Temperature

b. Inverters

- AC Voltage
- DC Voltage
- AC Current
- DC Current
- kW
- kWh

c. Metering – System shall monitor and store data from the DCSG site meter on an interval from between five (5) to twenty (20) seconds.

d. Tracker remote monitoring and control.

e. Plant switchgear

4.7. Underground Power Distribution Installation

4.7.1. High voltage cables shall be pulled to the distribution line and tied off to the termination structure with a Kellems grip, or equivalent.

4.7.2. Contractor shall use a minimum cable insulation rated for 133% of distribution voltage.

4.7.3. Contractor shall obtain all necessary permits for road bores or trench crossings.

4.8. Underground Power Distribution Feeder Grounding

4.8.1. An analysis of the maximum transient overvoltage along the feeder collection circuits under a fault shall be performed to determine the appropriate ratings and placement of arrestors and the placement of grounding transformers (if required). The analysis shall be provided to Company for review. Grounding transformers shall be sized to limit the collection feeder voltage rise during a fault on the feeder to less than 1.39 pu voltage as per IEEE C62.92.1-2000.

4.8.2. Arrestors shall be placed on each feeder at the substation, and along the collection circuit at the end of each string, and as needed between to limit the voltage rise during fault conditions, or other events that can cause transient overvoltage.

4.9. Conduit and Wire

4.9.1. Contractor shall keep phasing and color-coding of phases consistent throughout the Project.

4.9.1.1. The minimum bending radius of primary cable is twelve (12) times the overall diameter of the cable. The minimum bending radius of secondary and service cable is eight (8) times the overall diameter of the cable. In all cases the minimum radius specified is measured to the surface of the cable on the inside of the bend. No cable bend shall be made within six (6) inches of a terminal base.

4.9.1.2. A pull rope shall be installed in all empty conduits All exposed ends of conduit shall be plugged during construction to prevent the entrance of foreign matter and moisture into the conduit. Burrs or sharp projections, which might damage the cable, shall be removed. Riser shield or conduit shall extend at least eighteen (18) inches below grade at all riser poles or as shown on the drawings. If full round conduit is used as a riser shield, an end bell shall be installed on the lower end to prevent damage to the cable.

4.9.1.3. Each cable in a switch, sectionalizing cabinet, transformer, etc. shall be identified by circuit number, phase, and location of the opposite end with permanent plastic or corrosion resistant metal tags. Close to each cable termination, Contractor shall also mark the cable termination phase designation on the cabinet.

4.9.1.4. At each medium voltage junction box or inverter foundation, a minimum of 10 ft of slack cable shall be coiled in the junction box vault, transformer vault or buried as close as possible if a vault is not used.

4.10. Direct Burial Installation of Cables

4.10.1. The bottom of the trench receiving conduit or direct-buried cable should be smooth, undisturbed, well-tamped earth without exposed rocks. When excavation is in rock or rocky soils, the conduit or cable should be laid on a protective layer of well-tamped backfill. Backfill should be compacted to 90% modified proctor per ASTM D1557.

4.10.2. All cables shall be buried a minimum depth of 3 ft to the top of cable/conduit, or as specified by the design engineer, local code requirement, whichever is greater. Communication cable shall be buried at the same depth as the power cable, except in the case when the manufacturer requires that ground cable be buried above power cable. In that case the communication cable shall be buried at the same level as the ground cable.

4.10.3. A minimum bend radius of twelve (12) times the outside diameter of the cable shall be followed.

4.10.4. Cable separation distance shall be maintained at all times as specified by the product documentation and engineered drawings.

4.10.5. Sufficient slack shall be left at all risers, transformer pads, pedestals, and terminal points so that movement of cable after backfilling will not cause damaging strain on the cable or terminals.

4.10.6. All debris shall be removed from the fill before placing it back in the trench. Cable trenches shall be mechanically compacted six (6) feet minimum from all riser poles, pads, pedestals, and terminal points. All disturbed area shall be restored as to not cause ground settling greater than 1" below the undisturbed elevation.

4.11. Medium Voltage Splices/Terminations/Connections

4.11.1. Splices

4.11.1.1. Cable splices shall be of the pre-molded rubber, cold shrink type, of the correct voltage rating and shall be installed in accordance with the splice manufacturer's instructions. Splices that depend solely on tape for a moisture barrier shall not be used.

4.11.1.2. Electrical works design shall minimize the number of splices required.

4.11.1.3. No bends shall be permitted within twenty-four (24) inches of the end of a splice.

4.11.1.4. The cable or circuit numbers and the exact location of all splices shall be noted on the As-Built Drawings and Documentation shall include GPS locations of each splice.

4.11.1.5. Splicing in ducts is not allowed.

4.11.1.6. The location of each splice shall be marked with single or stacked locating marker balls depending upon the depth of cable burial.

4.11.1.7. A marker ball detection device compatible with the marking balls installed shall be provided.

4.11.2. Primary Cable Terminations and Stress Cones: Prefabricated stress cones or terminations shall be installed in accordance with the manufacturer's instructions at all primary cable terminals. They shall be suitable for the size and type of cable that they are used with and for the environment in which they will operate. Any indication of misfit, such as a loose or exceptionally tight fit, shall be called to the attention of the Company. The outer conductive surface of the termination shall be bonded to the system neutral. A heat- shrink or cold-shrink sleeve shall be installed to seal between the body if the termination and the cable jacket.

4.11.3. Special Precautions for Cable Splices and Terminations: A portable covering or shelter shall be used when splices or terminations are being prepared and when prefabricated terminations are being switched. Since cleanliness is essential in the preparation and installation of primary cable fittings, care shall be exercised to prevent the transfer of conducting particles from the hands to insulating surfaces. Mating surfaces shall be wiped with a solvent such as denatured alcohol to remove any possible accumulation of dirt, moisture, or other conducting materials. A silicone grease or similar lubricant shall be applied afterwards in accordance with the manufacturer's recommendations. Whenever prefabricated cable devices are opened, the un-energized mating surfaces shall be lubricated with silicone grease before the fittings are reconnected.

4.11.4. Secondary and Service Connections:

4.11.4.1. A suitable inhibiting compound shall be used with all secondary and service connections.

4.11.4.2. All secondary cable connections located below grade or in secondary pedestals shall be made with pre-insulated secondary connector blocks. Diving bells with open terminals, insulating boots or moisture barriers that depend solely on tape are not acceptable.

4.11.4.3. If the secondary phase terminals are threaded studs, the connection shall be made with a pre-insulated secondary transformer connection block. If the transformer secondary phase terminals are insulated cable leads, connection shall be made with a pre-insulated secondary connector block or with a secondary prefabricated splice when the transformer leads continue directly to the service.

4.11.4.4. Transformer secondary spades shall be taped or otherwise insulated. Boots used for insulation shall be taped so that they cannot be readily slipped off.

4.11.4.5. The secondary connections and insulation shall have accommodations for all future and existing service as shown on the plans and specifications

4.12. Pedestals

4.12.1. Where required, pedestals stakes shall be driven vertically into the bottom of the trench before cables are placed and shall be located as shown on the drawings. Pedestal posts and supporting stakes shall be in place before the cable is installed. All pedestals should be approximately at the same height above finish grade.

4.13. Equipment Pads

4.13.1. The site for the pad shall be adjacent to but not over the trench. The site shall be cleared of all debris and excavated to the specified depth. Native soil shall be compacted to 95% modified proctor, per ASTM D1555 Structural fill, as defined in this specification, shall be added per plans, and compacted to 95% proctor. The pad shall be installed level at the specified elevation.

4.14. Transformers

4.14.1. Transformers shall be handled carefully to avoid damage to the finish and shall be positioned in accordance with the plans and specifications. Only qualified and experienced personnel shall be allowed to make connections and cable terminations.

4.15. Grounding

4.15.1. All neutral conductors, ground electrodes, and ground-able parts of equipment shall be interconnected. All interconnections shall be made as shown on the design documents. Ground rods shall be installed at all equipment locations as shown in the design documents. All underground ground connections shall be exothermically welded or a listed irreversible crimp. Clamps shall not be used to make underground ground connections.

4.16. Equipment Enclosures

4.16.1. Excavations for sleeve-type sectionalizing cabinet pads and other below grade enclosures shall be made to disturb the surrounding earth as little as practical. Enclosures shall be installed with side walls plumb and without any panel distortion. When installation is complete, the cover of the enclosure shall not be lower than and not more than two (2) inches higher than specified grade. Soil in the immediate vicinity shall be tamped and sloped away from the enclosure. The excess soil shall be spread evenly over the surface of the ground to the design requirements.

4.17. Security System

4.17.1. Security cameras shall be provided and located such that the entry area is monitored, and the entire site area is visible.

4.17.2. Security cameras shall be able to be monitored remotely at Utility’s operations center.

4.17.3. Security camera locations to be approved by Company.

4.18. Warning Signs

4.18.1. Each equipment enclosure shall display a “Caution” sign placed so that it is visible to anyone attempting entry to the enclosure. Also, the equipment inside the enclosure shall display a “Danger” sign so that it is visible when the enclosure is open. Cable markers which indicate the presence of underground electrical facilities shall be installed at all road crossing locations.

4.19. Cleanup, Disposal and Restoration

4.19.1. All excess excavated material debris, such as boulders, broken concrete, trees, shrubs, roots, lumber, and any other items resulting from the construction operation, shall be removed and the site restored to its original appearance.

4.19.2. All areas in which trenching takes place shall be restored to the original condition. This includes gravel, concrete, and asphalt surfaces.

4.19.3. Construction areas shall be de-compacted to a workable condition for farming to the extent practicable and vegetation cover re-established where disturbed by the work.

4.20. Underground Power Distribution Testing

4.20.1. Power Cable Acceptance Testing

4.20.1.1. Installations of power cable including terminations are to be acceptance tested using per NETA Acceptance Testing Standards and at a minimum to include the following tests:

a. Continuity: After installation of the cable and prior to the high potential test specified below, a simple continuity test shall be conducted on the system. This can be accomplished by grounding the conductor at the source and checking for continuity from the end of each tap with an ohmmeter.

b. Cable jacket integrity testing shall be performed. Defects or damage to cable jackets shall be repaired using a cable OEM approved method, or the damaged cable section shall be replaced.

c. High Potential: After successful continuity and cable jacket integrity tests of the distribution voltage collection system, high potential very low frequency (VLF) tests on each length of cable, with terminations in place but disconnected from the system.

4.20.1.2. If more than three failures of any particular component occur within six months of commercial operation, then partial discharge testing shall be performed on all similar components

4.20.1.3. Other Test and Inspections: All other tests and inspections described in the Project Quality Assurance Plan

4.20.1.4. After completion of a test and before handling the cable, the conductor shall be grounded to permit any charge to drain to earth.

4.20.2. Ground Loop Testing

4.20.2.1. Measure ground loop resistance to remote earth using the three-point method and verify the measured results conform to the requirements of the Inverter Contractor and the design documents.

4.20.3. Pad – Mount Transformer Testing

4.20.3.1. The following transformer checks and tests shall be completed on all units:

a. Inspection of satisfactory mechanical installation including proper torque on bolts, labeling and grounding.

b. Insulation resistance test between windings and from each winding to ground. Calculate Polarization Index

c. Field test of transformer turns ratio (TTR) test on all taps

d. Winding resistance test.

e. Insulation power factor test.

f. Manufacturer's routine and design tests specified for Class I power transformers identified in IEEE C57.12.00.

g. Oil analysis for visual inspection, gas, liquid screen, and Karl Fischer moisture at minimum prior to energization and at least 30 days following energization respectively.

4.21. Submittals

Contractor shall submit to the Company copies of all completed forms and documentation of all tests, studies, and inspections. Contractor shall use a Company-approved Project Management tool/suite such as ProCore for the life of the project. This management suite shall be used for all submittals, reviews, comments, RFI's, document storage, punch-lists, etc. noted below. Submittals required in the sections that refer to this section shall conform to the requirements of the definitive project agreement and to the following additional requirements:

4.21.1.1. Project Schedule

4.21.1.2. Interface Matrix

4.21.1.3. Construction Plan

4.21.1.4. Design Drawings shall include but not limited to:

a. Site plan showing infrastructure layouts, PV array locations.

b. Overall single line diagrams

c. Schematics Diagram

d. Wiring Diagram

e. Medium voltage and low voltage switch gear oneline diagrams

f. Riser diagrams showing connection to utility AC disconnects and main electrical switchboard

g. Indicate conduits, power and communication wires, and combiners, disconnects, inverters, meter, etc.

h. Provide PV system(s) power production calculations and total system(s) rating.

i. Complete point to point PV System interconnection diagram identifying all DC and AC components.

j. Combiner box schedule

k. Bill of materials.

l. Cable Schedule

m. Mounting frame and module layout

n. Inverter locations and foundation/housing

4.21.1.5. Control Systems

4.21.1.6. Protection Systems

4.21.1.7. Auxiliary power requirements

4.21.1.8. System Performance Reports: System study shall use software modeling program such as PVsyst for the sizing, simulation, and data analysis of complete PV systems. Output reports shall provide yearly energy production, performance, and energy gains and losses. See Attachment 2.

4.21.1.9. Medium voltage ampacity report: The purpose of the cable ampacity study is to determine if the calculated cable ampacity is greater than the load on any given cable in the collection system.

4.21.1.10. Low voltage ampacity report: The purpose of the low voltage cable ampacity study is to determine a safe operating ampacity the system can maintain.

4.21.1.11. Insulation coordination study: The purpose of the insulation coordination study is to ensure the insulation coordination requirements have been met per IEEE Std. C62.22 - 2009.

4.21.1.12. Effective grounding report: The purpose of the effectively grounded system study is to determine if the collection system is effectively grounded as defined by IEEE Standard C62.92.1 – 2000.

4.21.1.13. Ground grid analysis report: The purpose of the ground grid analysis study is to calculate the touch and step potential and certify that the proposed ground grid will meet or exceed IEEE Std. 80 safety requirements and the inverter manufactures touch potential requirements.

4.21.1.14. Fault current report: The purpose of the fault current analysis and coordination study is to determine the maximum fault current on each section of cable or conductor in the collection system and determine the maximum amount of time the conductor can withstand the fault before the cable is damaged.

4.21.1.15. Power factor report: The purpose of the power factor study is to calculate the power factor over a range of plant outputs to ensure the power factor of the solar farm meets utility's required power factor range while staying within the power factor limitations of the installation.

4.21.1.16. Energy loss report: The purpose of the energy loss evaluation is to calculate the annual energy loss as a percentage of solar farm production to the distribution voltage bus at the solar farm substation/switching station.

4.21.1.17. Arc flash report: The purpose of the arc flash hazard assessment is to calculate the arc flash incident energy at various points of the solar farm and switchyard under all operating configurations to ensure the worst possible set of results is captured at each location. Applicable standards include IEEE 1584 NFPA 70E.

4.21.1.18. Harmonics report: The purpose of this report is to confirm the solar farm will meet interconnection harmonic requirements under all configurations of the solar farm and interconnection substation

4.21.1.19. Oil sample analysis report for each padmount transformer

4.21.1.20. Manufacturer's Catalog Data: Submittals for each manufactured item shall include current manufacturer's descriptive literature of cataloged products, equipment drawings, diagrams, performance and characteristic curves, and catalog cuts. Handwritten and typed modifications and other notations not part of the manufacturer's preprinted data will result in the rejection of the submittal. Should manufacturer's data require supplemental information for clarification, the supplemental information shall be submitted as specified for certificates of compliance

4.21.1.21. Bill of Materials: for major equipment

4.21.1.22. Instructions: Where installation procedures or part of the installation procedures are required to be in accordance with manufacturer's instructions, submit printed copies of those instructions prior to installation. Installation of the item shall not proceed until manufacturer's instructions are received. Failure to submit manufacturer's instructions shall be cause for rejection of the equipment or material

4.21.1.23. Operation and Maintenance Manuals: Comply with the requirements of the technical sections

4.21.1.24. Operation and Maintenance Manuals for Electrical Works: Submit operation and maintenance manuals for electrical works that provide basic data relating to the design, operation, and maintenance of the electrical system. This shall include:

a. Single line diagram of the "as-built" electrical works

b. Schematic diagrams of electrical control system

c. Manufacturers' operating and maintenance manuals on active electrical equipment, as applicable

4.21.1.25. Operating Instructions: Submit text of proposed operating instructions for each system.

4.21.1.26. Manufacturer product warranty information.

4.22. Products

4.22.1. General

4.22.1.1. All materials equipment and workmanship shall conform to the applicable chapters of the National Electrical Code (NEC), the National Electrical Safety

Code (NESC), and the terms and conditions of the Transmission Provider's and other Authorities having lawful jurisdiction pertaining to the work required.

4.22.1.2. All products shall be capable of compliance with all OSHA lockout requirements

4.22.1.3. Underground cable shall be as required by final design. Provide all rubber termination and splice materials

4.22.1.4. Padmounted transformer(s) as described in the padmount transformer technical specification which is a part of the document

4.22.1.5. Junction box medium voltage terminations shall utilize "T" type connectors that will allow for the easy relocation of surge arrestors

4.22.1.6. Pedestals for padmount transformers shall be fiberglass, pre- cast, or poured concrete

4.22.1.7. Junction boxes shall be pad mounted within the confines of the power substation.

4.22.1.8. Junction boxes, such as DC combiner boxes, located within the solar array may be pad mounted or mounted to deep foundation post(s)

4.22.2. Condition of Products

4.22.2.1. Except as otherwise indicated, provide new electrical products free of defects and harmful deterioration at the time of installation. Provide each product complete with trim, accessories, finish, guards, safety devices and similar components specified or recognized as integral parts of the product or required by governing regulations. Unless otherwise indicated by the plans or specifications or approved in writing, the materials and equipment furnished under these specifications shall be the standard products of manufacturers regularly engaged in the production of such equipment, and shall be the manufacturers' standard design

4.22.3. Uniformity

4.22.3.1. Where multiple units of a product are required for the electrical work, provide identical products by the same manufacturer without variations.

4.23. Execution

4.23.1. Coordination of Electrical Works

4.23.1.1. It is recognized that the electrical drawings are diagrammatic in showing certain physical relationships that must be established within the Electrical Works and in its interface with other work, including utilities and mechanical work, and that such establishment is the exclusive responsibility of the Contractor

4.23.1.2. Arrange all electrical work in a neat, well organized manner. Indoor conduit and similar services shall be installed running parallel with the primary lines of the building construction and with a minimum of 7 feet of overhead clearance where possible

4.23.1.3. Arrange all electrical work with adequate access for operation and maintenance

4.23.1.4. Electrical connections shall be tightened to torque specifications stated by the equipment manufacturer

4.23.2. Quality Control Testing

4.23.2.1. Upon completing installation of all systems and equipment, but prior to electrical substantial completion, the Contractor shall conduct an operational test of all equipment, controls, and devices installed or modified by the Contractor

4.23.2.2. Contractor shall notify Company in writing a minimum of three (3) days in advance of any test. This operational testing is in addition to testing required in separate sections of this specification. Where possible, combination of this testing and other testing required should be accomplished to minimize travel requirements

4.23.3. Labeling

4.23.3.1. Install permanent labels on all electrical panels, cabinets, disconnects, motor starters, major equipment, or components. Weatherproof labels shall be either laminated black phenolic plastic with white engraved letters or engraved (or embossed) stainless steel nameplates. Lettering for panels and equipment shall be a minimum of 1/2 in. high. Labels shall be permanently installed by gluing or screwing to equipment covers. Labels shall show panel or load name and the circuit it is fed from.

FOUNDATION TECHNICAL SPECIFICATIONS – PART 5

5. Foundation Technical Specifications

5.1. Excavation, Backfill and Compaction

5.1.1. General

5.1.1.1. Ensure foundation site is graded in accordance with the design documents.

5.1.1.2. All work will be constructed, tested, and inspected in compliance with the Project Quality Assurance Plan and as indicated in the design documents

5.1.2. Submittals

5.1.2.1. Grain size analysis, natural moisture content and modified proctor maximum dry density test data for common fill soil materials

5.1.2.2. Compaction test results indicating location of test, dry density, and moisture content of placed fill

5.1.2.3. Copies of all completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents, and Testing and Inspection requirements included in this document.

5.1.3. Products

5.1.3.1. Lean Concrete: as required by the design documents

5.1.3.2. Common Fill: Lean clay free of organic matter or deleterious material

5.1.4. Execution

5.1.4.1. Excavate soils to the limits according to the design documents

5.1.4.2. Prior to placing a protective lean concrete surface, a qualified technician shall inspect and approve the subgrade conditions and record the soil type encountered, groundwater conditions, or other subsurface conditions. Check that observations taken are consistent with the observations contained in the reference geotechnical documents

5.1.4.3. To protect the subgrade, place a lean concrete surface, and fill to the lines and levels indicated on the drawing. It is recommended that the surface be placed as level as possible to facilitate placement of the reinforcing steel and embedment ring

5.1.4.4. Backfill and Compaction. Place and compact common fill materials to the limits, depth and in-situ density indicated on the drawings, place fill in maximum loose lifts according to the recommendations from a structural/geotechnical engineer to achieve the specified density. The in-situ density includes the dry density and natural moisture content of the soil

5.1.4.5. Grade the site in accordance with drawings to prevent water from ponding over the foundation while maintaining the maximum depth of fill specified on the design documents

5.1.4.6. Restore the site in accordance with the definitive project agreement

5.1.5. Testing and Inspection

5.1.5.1. Obtain samples of common fill materials and perform grain size analysis, moisture content, Atterberg limits on fines content and proctor tests

5.1.5.2. For placed and compacted fills, provide one test per lift indicating test location, dry density, moisture content and % modified proctor maximum dry density

5.1.5.3. All other tests and inspections described in the Project Quality Assurance Plan and as indicated in the design documents

5.2. Cast in Place Concrete and Steel Reinforcing

5.2.1. General

5.2.1.1. Concrete work shall be in general compliance with all applicable codes and specifications including the following:

a. ACI 318 latest edition, Building Code Requirements for Structural Concrete and Commentary

b. ACI 301, Standard Specifications for Structural Concrete

c. ACI 305, Hot Weather Concreting

d. ACI 306, Cold Weather Concreting

5.2.1.2. All work will be constructed, tested, and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents

5.2.2. Submittals

5.2.2.1. Final mix design meeting the concrete specifications. Concrete specifications shall be certified by a professional engineer

5.2.2.2. Product data for admixtures, aggregate gradation, and hardness tests, cement, and fly ash mill reports, as well as specifications for all other additives in the concrete mix. Transportation, placement, and curing of concrete shall be according to the latest ACI standards of practice/recommendations.

5.2.2.3. Mill reports for the reinforcing steel confirming the grade and strength of the reinforcing steel used on the Project is as specified in the design documents

5.2.2.4. Quality control field tests of air content, temperature, and slump

5.2.2.5. Concrete cylinder strength test results for three (3), seven (7) and twenty-eight (28) day cures.

5.2.2.6. All completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents and, Testing and Inspection requirements included in this document.

5.2.3. Products

5.2.3.1. As specified by design documents.

5.2.4. Execution

5.2.4.1. Place reinforcement and concrete in accordance with the final design dimensional tolerances

5.2.4.2. Reinforcement shall be clean and free of rust, mud, debris, and foreign material

5.2.4.3. Provide necessary chairs and standees to support rebar and prevent movement or deflection of the mats during placement of concrete

5.2.4.4. Prevent formwork from moving during placement of concrete

5.2.4.5. Place concrete in accordance with ACI 31Place successive lifts of concrete as quickly as possible to insure proper consolidation of concrete between successive lifts

5.2.4.6. Foundation reinforcement and concrete shall be placed over a lean concrete working surface clear of debris, ponding of water, standing mud, and organic material

5.2.4.7. Consolidate concrete in accordance with ACI 318 preventing the formation of joints, voids, or honeycombing

5.2.4.8. Drop height of concrete being placed shall not exceed a height that may cause separation of ingredients or water to pond on the surface of the newly placed concrete

5.2.4.9. Finish top of concrete footings, equipment pads, and pedestal

5.2.4.10. Cure concrete in accordance with ACI 318 a curing membrane is used, apply curing membrane as soon as bleeding has stopped, and free water has disappeared from the surface

5.2.5. Testing and Inspection

5.2.5.1. Either 4-inch or 6-inch diameter cast cylinders as defined in ACI 318 will be acceptable for laboratory strength testing.

5.2.5.2. Cast cylinders for laboratory strength testing at 7 and 28 days or as required in design documents and the minimum required by ACI 318.

5.2.5.3. Casting and testing of cylinders in-excess of ACI minimums will be the sole cost of the contractor.

5.2.5.4. Perform a minimum of one air test per concrete truck

5.2.5.5. Perform a minimum of one slump test per cylinder test

5.2.5.6. Perform all other tests and inspections described in the Project Quality Assurance Plan and as indicated in the design documents

5.2.5.7. Assurance Plan and as indicated in the design documents

5.2.5.8. All concrete, reinforcement, anchor bolts, embed plates, formwork, etc. shall be inspected per the current International Building Code (IBC), Chapter 17, "Special Inspections."

5.3. Anchor Bolts and Embedment Plates

5.3.1. General

5.3.1.1. Products, execution, and testing are specified to provide durable anchor bolts

5.3.1.2. All work will be constructed, tested, and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents

5.3.2. Submittals

5.3.2.1. Product data for anchors and hardware

5.3.2.2. Mill certificates for anchors indicating the yield strength

5.3.2.3. Mill certificates for the embedment ring indicating the material meets the minimum strength requirements

5.3.2.4. Tension test data for anchor bolts that are tested indicating bolt location and tension value

5.3.2.5. Copies of all completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents and Testing and Inspection reports.

5.3.3. Products

5.3.3.1. As required by design documents

5.3.4. Execution

5.3.4.1. The final engineered dimensional tolerances shall be adhered to for all installations

5.3.4.2. Use a template ring to set anchor bolt plumbness and position. Ensure the template ring is set in accordance with the specified construction tolerances

5.3.4.3. Place and level the embedment ring in accordance with the specified tolerances. Ensure the embedment ring is properly anchored to prevent movement

5.3.4.4. After placement of concrete and at the final elevation, seal the space between the anchor bolt and the anchor bolt sleeve to prevent water from entering the sleeve annulus prior to setting of equipment and grouting of baseplate

5.3.4.5. After setting of the equipment and grouting the baseplate anchor bolts shall be tensioned according to the specified tensioning procedure to a force as specified in the final design. The tensioning device for the anchor bolts should be calibrated in accordance with the approved procedure described in the Project Quality Assurance Plan on a regular basis to ensure required tensions are maintained

5.3.5. Testing and Inspection

5.3.5.1. After all bolts have been tensioned or torqued; a minimum of 10% shall be tested to verify that the final design tension has been achieved by use of an approved testing procedure

5.3.5.2. All work will be constructed, tested, and inspected as described in the Project Quality Assurance Plan and as indicated in the Design Documents

5.4. Grout

5.4.1. General

5.4.1.1. The grout selected must cure to the required strength as specified in the design documents

5.4.1.2. All work will be constructed, tested, and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents

5.4.2. Submittals

5.4.2.1. Manufacturers’ product data for grout

5.4.2.2. Grout cube strength test results

5.4.2.3. All completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents and Testing and Inspection reports.

5.4.3. Product

5.4.3.1. Non-Shrink Grout: Prepackaged grout conforming to design documents

5.4.4. Execution

5.4.4.1. Mix, place, and cure grout in accordance with manufacturer’s instructions

5.4.5. Testing and Inspection

5.4.5.1. Cast grout cubes and perform laboratory strength testing at 3 and 28 days or in accordance with design documents

5.4.5.2. All other tests and inspections described in the Project Quality Assurance Plan and as indicated in the design documents

5.5. Miscellaneous Concrete Embeds

5.5.1. General

5.5.1.1. All work will be constructed, tested, and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents

5.5.2. Submittals

5.5.2.1. Documentation stating that electrical conduit and grounding grid have been installed in accordance with the manufacturer requirements

5.5.2.2. All completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan and design documents

5.5.3. Product

5.5.3.1. Electrical Conduit: In accordance with manufacturer requirements

5.5.3.2. Grounding Grid: In accordance with manufacturer requirements

5.5.4. Execution

5.5.4.1. Verify the location of miscellaneous concrete embedment's and ensure they are properly secured to prevent movement during concrete placement

5.6. Miscellaneous Submittal Requirements

5.6.1. Documentation from the Structural Engineer of Record confirming that they have reviewed the testing and inspection records and that the work was performed in conformance and compliance with the design documents. The review does not relieve the Contractor of the work due to errors contained in those documents.

5.6.2. Submit copies of testing and inspection records

INFRASTRUCTURE TECHNICAL SPECIFICATIONS – PART 6

6. Infrastructure Facilities Layout

Not used

STEP-UP TRANSFORMER SPECIFICATIONS – PART 7

7. Technical Specification Solar Generator Step-up Transformer, Three-Phase Padmount Loop Feed

Note: Engineer of Record (EOR) shall review this specification to identify and report inconsistencies within the specification and areas where the specification may not be compatible with the overall solar farm design

7.1. Codes and Standards

7.1.1. All transformers shall conform to the applicable standards of ANSI, ASTM, IEEE, NEC, NEMA, and NFPA. All materials and devices shall be in accordance with the applicable requirements of the Federal "Occupational Safety and Health Administration" Standards

7.1.2. In case of conflict between the requirements of the various parts of these documents, the requirements of the different parts shall govern in the following sequence: Mandatory governmental regulations, codes and standards, this Specification and the referenced industry codes and mid standards

7.2. Enclosure Construction

7.2.1. The exterior color of the transformer shall be powder coated Munsell Green or as required by the AHJ.

7.2.2. The transformer doors shall be equipped to latch in the open position.

7.2.3. Each door shall open 180°

7.2.4. Heavy 18" stainless steel door rods

7.2.5. All compartment door latching bolts shall be self-aligning, captive, penta-head and be in accordance with Figure 1 of IEEE C57.12.28

7.2.6. The penta-head cylinder and hasp shall have ½ inch (minimum) holes for padlocking

7.2.7. The transformer connection compartment shall be arranged so that the high-voltage section shall be separated from the low voltage section by a vertical steel barrier

7.2.8. An automatic pressure-relief valve shall be installed in the low voltage compartment

7.2.9. A pressure vacuum gauge shall be in the low voltage compartment

7.2.10. A liquid level gauge shall be in the low voltage compartment

7.2.11. A dial type thermometer with maximum temperature indicator shall be installed in the low voltage compartment

7.2.12. A drain valve and sampler shall be installed such that it is enclosed in and accessible by opening an external lock box. The lock box and hasp shall have ½ inch (minimum) holes for padlocking

7.2.13. The transformer nameplate shall be located on the inside of the low voltage cabinet door and shall contain data listed in Table 7 of IEEE Standard C57.12.00 - 2010, under Nameplate.

The serial number of the transformer shall also be indicated on the low voltage tank wall. The nameplate shall also include the volume of insulating fluid in gallons and the statement "INSULATING FLUID IS NON-PCB CONTAMINATED." Taps shall be listed in actual voltage rather than percent of nominal. All protective devices, such as fuses and isolation links shall be identified on the nameplate schematic

7.2.14. All bushings, terminals, and switches shall be identified on the tank wall in yellow stencil or decal

7.2.15. To preclude exposing internal parts designed to be under oil, the transformer shall be capable of operation without derating when placed on a flat surface up to five degrees out of level in any direction

7.2.16. The termination cabinets shall be a minimum of 36 inches deep

7.2.17. A clear barrier on top and front of low voltage circuit breaker

7.2.18. Dielectric fluid shall be PCB free mineral oil

7.2.19. There shall be a minimum of 2 grounding pads in the high voltage compartment and low voltage compartment. Bronze, vice type (Fargo GC 208 or approved equivalent) grounding lugs shall be installed in each ground pad and shall accommodate a 1/0 conductor

7.2.20. The high voltage bushing pattern shall be, at a minimum, as shown in IEEE C57.12.26 figures 2 and 3.

7.2.21. The low voltage bushing pattern shall be, at a minimum, as shown in IEEE C57.12.26 figures 3 and 4a.

7.2.22. Core ground shall be accessible through a hand hole

7.3. Service Conditions

7.3.1. Class I power transformer

7.3.2. The padmount transformers will be used as Photovoltaic solar inverter step-up transformers.

7.3.3. Multiple transformers may be connected in parallel to the same distribution voltage collector circuit and/or branch of the collector circuit

7.3.4. Design elevation = 1,000 meters a.s.l

7.3.5. Design ambient temperature max = +40 degrees C

7.3.6. Ambient temperature min = -40 degrees C

7.3.7. The transformer will be connected to the inverter, and other transformers, in such a way that the transformer(s) may be subject to abnormally high voltages associated with an inverter load rejection and other transient conditions. Therefore, the transformer shall be designed to withstand the voltage stress associated with 1.4 times the rated voltage applied to the transformer terminals for 5 seconds

7.3.8. The transformer will be designed to withstand voltage excursions associated with substation breaker closing.

Feed configuration	Loop feed
kVA	10% at 25 C greater than the maximum generation level allowed by the inverters.
Phases	3
Frequency	60 Hz
Maximum average temperature rise above ambient	65 ° C at rated kVA for the combination of connections and taps that gives the highest average temperature rise
Maximum (hottest spot) temperature rise above ambient	80 ° C at rated kVA for the combination of connections and taps that gives the highest average temperature rise
High voltage	Per One-line or per Engineer of Record
Low voltage	XXX grounded Y [Engineer of Record to specify]
Winding Electrostatic shield	Yes, drain to core ground
High voltage taps	Two full capacity taps above nominal rated voltage in 2.5% steps. Two full capacity taps below nominal rated voltage in 2.5% steps.
High voltage BIL	xx kV (per site requirements, EOR to specify). If on 34.5 KV system, 200 kV
HV Switch	Under oil – Disconnect, Load Break
Low voltage BIL	xx kV (per site requirements, EOR to specify)
*** Neutral BIL, grounded Y**	xx kV
*** Neutral BIL, impedance grounded Y**	xx kV
Low voltage bushing	Per Engineer of Record
Target impedance	As specified by the Engineer of Record
Losses:	
**** No load losses @ 20 ° C**	**
**** Load losses @ 85 ° C**	**
High voltage bushings	Six XXX amp dead break or load break bushing [Engineer of Record to specify]
Low voltage bushings	Engineer of Record to specify
Low voltage bushings supports	Engineer of Record to specify
Infrared viewing windows with metal cover	Optional – Provide pricing for MV, LV compartment viewing windows
Oil sampling valve	Required; Provide option pricing for located in external padlockable compartment.
*	Engineer of Record is to specify grounded Y or Impedance grounded Y neutral BIL requirements
**	Minimized assuming $4000/KW no load loss evaluation factor & $2000/KW load loss evaluation factor.

7.4. Auxiliary Equipment and Accessories

7.4.1. Internal expulsion cartridge fuse x3

7.4.2. Parallel oil-immersed partial range current limiting fuse x6

7.4.3. Hook-stick operable, two position, amp rating per EOR, under oil, loop feed switches. Switch positions shall be labeled “open” and “closed.” Switch position labels shall be readable from 2 feet away.

7.4.4. Hook-stick operable tap change switch located at an accessible location which does not require reaching behind cables. The tap change switch shall snap into each voltage setting. The switch shall be visible indicating from 2 feet. Provisions, such as a spring loading locking pin or set screw shall be made to assure that accidental operation of the tap changer will not occur

7.4.5. Low voltage surge arrestor: Ferraz-Shawmut surge arrestor or Company approved equal. The low voltage surge arrestor shall be mounted in an easily viewable and accessible location and shall not be mounted behind cables

7.4.6. Low voltage power breaker. ABB SACE Emax, or equivalent, as specified by the Engineer of Record

7.5. Documentation

7.5.1. Factory recommended spare parts list

7.5.2. Shop drawings

7.5.3. Operations and maintenance manual(s)

7.5.4. Certified factory test reports

7.6. Shipment and Storage

7.6.1. Transformer shall be shipped in a manner that they are protected from damage, and with provisions for safely moving them onto and off the shipping vehicle to perform inspection and test listed in NETA Acceptance Testing Standard.

7.7. Transformer Spill Containment

7.7.1. Spill containment for transformers shall be based on the number of gallons (liters) of oil/fluid in the transformer.

7.7.2. Design shall comply with requirements for environmental, civil, structural, and fire protection systems.

7.7.3. Containment shall be sized to retain any fluid that may be accidentally spilled from the transformer plus a 25-year storm event rainfall depth, plus any applicable fire suppression water.

7.7.4. Containment may be combined to include multiple transformers or transformer areas; such that the containment meets requirements for the maximum containment needed for a single event.

7.8. Transformer Fire Walls

7.8.1 Refer to NFPA 850 for location and configuration of firewalls.

7.8.2 A minimum 2-hour fire barrier of appropriate height shall be provided between any transformer of sufficient oil volume and any building in accordance with applicable Codes or insurance requirements.

7.8.3 Adequate physical separation distance may be provided in lieu of fire barriers.

BATTERY ENERGY STORAGE SYSTEMS (BESS) – PART 8

8. Technical Specification for Battery Energy Storage System (BESS) that is co-located with a Distribution Connected Solar Generation (DCSG) facility.

8.1 General Provisions

8.1.1 This portion of the specification is for solar generation facilities that include a Battery Energy Storage System (BESS) that is co-located with the Distribution Connected Solar Generation (DCSG) facility.

8.1.2 The BESS, including all components, shall have a minimum design life of 15 years based upon the Project Site Conditions and be compliant with NFPA 855 (Standard for the Installation of Stationary Battery Energy Storage Systems).

8.1.3 Battery cell / module design shall be of proven technology and shall have been installed in similar applications for a minimum of two (2) years. It is expected that 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 battery rack modifications are not required. The BESS supporting infrastructure shall be designed and constructed to withstand a 100-year, 24-hour storm event. Final constructed grade shall be at least twelve (12) inches above such flood depth, as determined in the Contractor-provided hydrology study.

8.1.4 The BESS shall be designed and constructed to a high level of reliability using a non-occupiable containerized solution, with ease of maintenance designed into the system.

8.1.5 Contractor shall design and construct the BESS in accordance with the Interconnection Requirements of the interconnecting utility.

8.1.6 Contractor shall receive explicit approval from Company or Company's representative(s) of the design of the BESS supporting infrastructure prior to construction. Company shall have unlimited access to such designs throughout the design process, and construction of all such facilities shall be completed by one of Company's approved subcontractors, as more particularly detailed in Attachment 9 (*Approved Suppliers and Contractors*).

8.1.7 Basis of the Contractors BESS portion of the bid:

(1) Contractor shall provide a turnkey installation including development of the site, permitting, the complete supply of all required equipment and the complete installation and commissioning of all equipment.

8.1.8 Requirements for BESS civil and structural works:

(1) All civil and structural works including, but not limited to, grading, structures, foundations, assemblies, and components for the BESS shall be designed and constructed in accordance with the applicable specifications in this specification.

8.1.9 Requirements for BESS operating criteria:

(1) Contractor shall design the BESS operation to assume the duty cycle and other minimum operational requirements noted in Table 8-1.

(2) Convenience power: 120V_{AC}.

(3) Instrumentation voltage: 24 V_{DC} and/or 48 V_{DC} and/or 125 V_{DC}.

(4) Minimum battery operational requirements are listed in Table 8-1.

Table 8-1 – Minimum Battery Operational Requirements

Description	Requirements
Intended Applications	Firm Capacity / Resource Adequacy
Applications / Use Cases	Primary application is supply capacity and resource adequacy Secondary application is energy time shift (C rate = __) Additional use cases include Automatic Voltage Regulation and Autonomous Frequency Regulation. (C rate = __) The battery will be operated at Charge/Discharge rates ranging from 2 hours to 4 hours by varying the power flow through the inverters. Maximum C rate is 0.5. (C rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. The C rate is calculated as the inverse of battery discharge rate in hours. (*i.e. a battery that discharges in 2 hours would have a C rate of ½ = 0.5.)*
Beginning of Life Power	Contractor to advise with bid (MW)
Beginning of Life Energy	Contractor to advise with bid (MWhr useable depth of discharge @ ___C rate)
Minimum End of Life Energy	Contractor to provide expected degradation curves based on specified Duty Cycle with proposal.
Duty Cycle	Contractor to provide the following: (1) Maximum number of cycles of full depth of charge/discharge per year = _____. (2) Maximum number of cycles per day within +/- 15 percent range depth of discharge (of 50% nominal) = _____.
Charging Method	Constant current / constant voltage
Discharging Method	Constant current
Inverter Nominal Voltage Range	____ V_{DC} nominal (Contractor to Advise with Bid)

Description	Requirements
Battery Maximum Continuous Discharge to Inverter	____ A nominal (Contractor to Advise with Bid)

8.1.10 Requirements for battery modules:

(1) Battery modules shall be provided with a permanent label.

(2) Battery cells shall be UL1642 (Lithium-Ion Batteries), and UL-9540A (Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems), and UL 2591 (Component certification for lithium-ion battery cell separators) listed.

(3) Module-to-module terminations shall utilize supplier provided quick disconnects or allow for NEMA standard connections. Any cables and connectors provided by manufacturer shall be sized in accordance with the NEC and UL listed where applicable.

(4) Positive and negative string-level post connections shall accept stranded copper conductor, NEMA standard connections, or supplier provided quick disconnects. Connections shall be sized to accept conductor rated per NEC requirements. Any cables and connectors provided by manufacturer shall be sized in accordance with the NEC and UL listed where applicable.

(5) Battery module enclosure shall be designed to be easily inserted and removed from the supplier provided battery rack. This may include non-tooled locking mechanisms, handles or lifting points, and/or track sliding.

(6) Battery modules utilizing an open rack design shall provide fans directing air flow over the battery module such that a hot/cold aisle arrangement can be designed.

(7) Battery cells shall incorporate safety features such as burst disks, replaceable fuses, and positive temperature coefficient switches.

(8) All battery modules shall be physically mounted in a battery rack system.

(a) Battery rack system shall be designed to withstand the Project Site conditions noted in Attachment 3 (*Site and Ambient Conditions*).

(b) Battery rack system manufacturer shall have ISO 9001 manufacturing capability.

(c) Steel framing shall be hot-dipped galvanized after fabrication in accordance with ASTM A123/A123M for fabricated products and ASTM A153/153M for hardware. Any subsequent process that causes damage or otherwise removes the galvanized coating shall be repaired in accordance with ASTM A780/A780M.

(d) Cold formed sheet steel shall be in accordance with the requirements of one of the following standards ASTM A1008 / A1008M, ASTM A1003/A1003M, ASTM A653/A653M or ASTM A792 with a coating thickness of G90.

(e) The dimensions and design of the battery rack systems shall be compatible with the battery modules selected for the Project.

(f) Metal battery racks shall be bonded or provide provisions for bonding of all components.

(g) The battery rack system shall have provisions to be grounded to the grounding loop of the Project Site. If a grounding bond incorporates two dissimilar metals such as tin-plated copper to steel, the joint shall be accomplished with the inclusion of a Belleville washer to prevent loosening or shall be otherwise installed according to manufacturer directions.

(h) All outdoor grounding connectors within 18 inches of finished grade shall be UL listed for direct burial. All grounding hardware shall utilize stainless steel, bronze, or copper hardware and be compatible for its application and environment. All grounding hardware shall be submitted to Company for review and approval during design phase.

(i) Battery rack systems shall be factory pre-assembled into vertical sections. Rack dimensions shall be manufacturer's standard, designed for installation into a building or environmental enclosure arranged in back-to-back rows. Racks shall include all bracing required for the site seismic conditions and to ensure racks cannot tip during module installation. Racks shall be suitable for installation directly onto a finished concrete floor or electrical enclosure floor. Racks shall be anchored using drilled concrete anchors and leveling shims as required. Rack design shall include provisions to protect personnel from inadvertent contact with exposed energized parts, such as ventilated doors or insulated covers over live parts.

(j) Each rack section (or pair of sections for long duration systems) shall include a load-break disconnecting means to allow isolation of the rack's modules from the DC bus by the BMS.

(9) All battery modules shall be interchangeable in both size and output voltage rating to allow any module to be inserted in place of any other module at the Project site. This shall include interchangeable replacements as needed through the design life of the BESS.

(10) Battery modules shall be provided in a containerized system, that includes, but is not limited to the battery modules, battery racks, module interconnections, DC disconnects, battery thermal management system / HVAC, etc.

8.1.11 Requirements for containerized BESS:

(1) Containers shall be shipped fully assembled to the extent practical, except for loading of the battery modules in the field.

(2) Battery thermal management / air conditioning units may be removed for shipment if required.

(3) All materials shall be non-flammable.

(4) Occupancy Class

(a) Containerized systems shall be classified as equipment enclosures rather than occupiable buildings.

(b) The layout of equipment in containerized systems shall be such that personnel cannot occupy the enclosure.

(c) Access to battery modules and other equipment shall be via doors arranged along the length of the container such that personnel have adequate working space and are not required to enter the container to perform maintenance.

(5) Windows

(a) Viewing windows that allow the main DC disconnect position to be viewed or thermal / infrared viewing windows for monitoring the temperature of connections or components are allowed.

(6) Doors

(a) Doors are not required for personnel ingress/egress.

(b) Doors for equipment access should be provided along the long sides of the container. Doors arranged in “French Door” fashion are preferred.

(c) Door opening width shall be as required to provide access to battery racks for module installation and removal.

(d) Doors shall be lockable and keyed alike. Door lock hardware shall be tamper resistant. Locks shall incorporate security features such as hardened alloys for drill or grinder resistance, shackle guards to provide protection against bolt cutters being used to remove them, cover / hood over the lock, etc.

(e) Exterior hardware shall be stainless steel.

(f) It is preferred that breakers or disconnects be able to be operated without opening doors. Breakers and disconnects shall be padlockable in the disconnect position.

(g) Doors with ventilation openings shall include additional security features on the rear of the door ventilation area such as bars to block forced entrance through the ventilation area on the door.

(7) Fire Detection and Suppression

(a) Containerized BESS systems shall comply with all applicable fire and building codes including NFPA 855 (Standard for the Installation of Stationary Energy Storage Systems).

(b) Fire detection schemes incorporating early off-gas detection and interlock to shut down affected BESS equipment prior to fire or smoke detection are encouraged.

(c) BESS system shall be designed and constructed to be compliant with the most recent version of the NERC "Lesson Learned: Battery Energy Storage System Cascading Thermal Runaway" dated March 29, 2021 (ATTACHMENT 12). This requirement includes, but is not limited to:

1. Work with and select a BESS supplier to minimize or eliminate battery cell-to-cell and module-to-module heat transfer to stop battery thermal runaway.

2. Implement fire detection and suppression system designs that will fully manage a thermal runaway.

3. Include monitoring and reporting of flammable gas concentrations with ventilation systems to mitigate the flammable gas concentrations.

4. A registered fire protection engineering firm shall perform a hazard mitigation analysis that includes a review of the BESS UL 9540a test data. Fire protection engineering firm shall also produce a Pre-incident guide (NFPA 1620) that outlines the hazards and response tactics that should be employed during an incident.

5. Prior to placing the BESS in service, a familiarization tour shall be conducted with local fire services along with any specialized units, such as hazmat, who may respond during an incident. This tour should include supplying them with the NFPA 1620 Pre-incident guide developed for the system.

(8) Container shall include a thermal management system to maintain the battery modules and any other instruments or components with the manufacturers specifications. HVAC equipment with a minimum SEER rating of 16 shall be utilized.

(9) Container shall have provisions for equipment removal and replacement.

(10) Container shall have adequate task lighting to perform all maintenance activities.

(11) Container shall be configured to have no roof penetrations of any kind, except for HVAC equipment needs, if any.

(12) Container manufacturer shall provide detailed engineering design drawings and calculations complying with the requirements of the applicable building code(s) and local and state laws that have jurisdiction where the building will be delivered and erected. Drawings shall be stamped by a Professional Engineer registered in the Project state and are subject to Company review and approval.

(13) Container shall have air terminal lightning protection in accordance with NFPA 780 standards.

(14) Container shall have a means of prohibiting access when energized.

(15) Company shall have the option to conduct a factory visit for inspection of the manufacturing/assembly process and inspection of at least one containerized battery

module system. This shall take place before the shipment of the first unit to the Project Site. Company shall pay all its own costs associated with this visit.

8.1.12 Requirements for battery management system:

(1) The BMS shall be the battery OEM's standard product, providing the following functions, at a minimum:

(a) Measurement of battery operating parameters

(b) Measurement of battery cell voltages

(c) Measurement of battery cell temperatures

(d) Measurement of battery string current

(e) Measurement of battery string voltage

(f) Calculation of battery string State of Charge (SOC)

(g) Calculation of battery string State of Health (SOH).

(h) Cell Balancing

(i) Battery Protection from the following:

1. Cell under voltage
2. Cell over temperature
3. Cell under temperature
4. Cell over current

(j) Pre-charge protection

(2) At a minimum, the BMS shall monitor the data points listed in

(3)

(4)

(5)

(6) Table **8-2**. The BMS shall monitor all data points required and store data a minimum of 24 hours of pre- and post- event (or as required by the battery OEM) for root cause / post- mortem analysis and warranty claim disposition. Data points shall also be transmitted to the site controller / Historian for long term data storage and retrieval.

(7) Rack BMS to System BMS communication protocol shall be manufacturer standard.

(8) System BMS to site controller communication protocol shall be coordinated with the site Communication System / SCADA.

Table 8-2 – Minimum BMS Functional Specifications

Description	Points to be Monitored. *Sample interval: 1 second*
System Level	Fault Status
	Alarm Status
	System Current
	System Voltage
Each Rack or String	Rack Voltage
	Rack Current
	Rack SOC
	Rack SOH
	Rack Fault Status
	Rack Alarm Status
	Maximum Cell Voltage Value
	Maximum Cell Voltage Position
	Minimum Cell Voltage Value
	Minimum Cell Voltage Position
	Maximum Cell Temperature Value
	Maximum Cell Temperature Position
	Minimum Cell Temperature Value
	Minimum Cell Temperature Position
	Rack DC Switch Status

8.1.13 Requirements for Power Conversion Systems (PCS):

(1) See Section 1.11

(2) The PCS shall meet the requirements of Table 8-3:

Table 8-3 – Minimum PCS Functional Specifications

Description	Requirements
Intended use	Firm Capacity / Resource Adequacy
Applications / Use Cases	Primary application is supply capacity and resource adequacy Secondary application is energy time shift (C rate = __) Additional use cases include Automatic Voltage Regulation and Autonomous Frequency Regulation. (C rate = __) The battery will be operated at Charge/Discharge rates ranging from 2 hours to 4 hours by varying the power flow through the inverters. Maximum C rate is 0.5.
Reactive Capability	Inverters shall be capable of operation between 0.9 lagging to 0.9 leading power factor with active power de-rating
Charging Method	Constant current / constant voltage
Discharging Method	Constant current

8.1.14 Requirements for BESS site controller:

(1) General

(a) The BESS system supplied under these specifications will be used by the Company to operate under various operating modes. The site controller shall coordinate with the PCS and BMS to perform the functions specified in this section.

(b) The site controller shall interface with the Company's SCADA system including the remote dispatch system. Contractor shall coordinate with Company as required.

(c) The site controller shall aggregate the operation of the individual PCS such that the BESS may be remotely operated as if a single asset. The site controller / SCADA shall include a data historian function able to store a minimum of 1 month of required BESS operating data locally. The site controller / SCADA shall include a local HMI station and shall be in the Project Substation control building.

(d) The site controller hardware and application software shall be of proven technology and shall have been installed in similar applications for a minimum of two (2) years.

(2) Functions and operating modes

(a) At a minimum, the BESS site controller shall provide the following BESS functions and operating mode capabilities that may be enabled.

(b) Functions and operating mode capabilities are per the Modular Energy System Architecture Energy Storage System Specification Open Standards for Energy Storage ("MESA-ESS"), Table 11 – ESS functions and modes

1. Interactive functions.

   a. Monitoring function – the BESS site controller provides nameplate, configuration, status, measurements, and other requested data.

   b. Disconnect/connect function - disconnect or connect the BESS from the grid at its electrical connection point ("ECP").

   c. Cease to energize and return to service – cease any current flow at the ECP or point of common coupling ("PCC") or allow current flow at the ECP or PCC

2. Emergency Modes.

   a. Low/high voltage ride-through mode – The BESS rides through temporary fluctuations in voltage.

   b. Low/high Frequency Ride-Through Mode – The BESS rides through temporary fluctuations in frequency.

   c. Frequency-Watt Emergency Mode – The BESS responds to large frequency excursions during H/LFRT events at a referenced ECP by changing its charging or discharging rate.

   d. Dynamic Reactive Current Support Mode – The BESS reacts against rapid voltage changes (spikes and sags) to provide dynamic system stabilization.

   e. Dynamic Volt-Watt Mode – The BESS system dynamically absorbs or produces additional watts.

3. Active Power Modes.

   a. Active Power Limit Mode - Limits the discharging and / or charging level of the BESS based on the referenced ECP.

   b. Charge / Discharge Mode – Set the BESS to charge or discharge at the Referenced ECP.

   c. Coordinated Charge / Discharge Management Mode – The BESS determines when and how fast to charge or discharge so long as it meets its target state of charge level obligation by the specified time.

   d. Peak Power Limiting Mode – The ESS limits the load at the Referenced ECP after it exceeds a threshold target power level.

e. Load Following Mode – The BESS counteracts the load by a percentage at the Referenced ECP, after it starts to exceed threshold target power level.

f. Generation Following Mode – The charging and / or discharging of the BESS counteracts generation power at the referenced ECP.

g. Automatic Generation Control (AGC) Mode – The BESS responds to raise and lower power level requests to provide frequency regulation support.

h. Active Power Smoothing Mode - The BESS produces or absorbs Active Power in order to smooth the changes in the power level at the Referenced ECP.

i. Volt-Watt Mode – The BESS responds to changes in the voltage at the Referenced ECP by changing its charging or discharging rate.

j. Frequency-Watt Mode – The BESS responds to changes in frequency at the referenced ECP by changing its charging or discharging rate based on frequency deviations from nominal as a means for countering those frequency deviations.

4. Reactive Power Modes

a. Constant VARs Mode – The BESS VAR's are set to a fixed value.

b. Fixed Power Factor Mode – The BESS power factor is set to a fixed value.

c. Volt-VAR Control Mode – The BESS responds to changes in voltage at the Referenced ECP by supplying or absorbing VARS in order to maintain the desired voltage level.

d. Watt-Var Mode – The BESS responds to changes in power at the referenced ECP by changing its power factor.

e. Power Factor Correction Mode – The BESS supplies or absorbs VARS to hold the power factor at the Referenced ECP.

5. Additional Capabilities

a. Pricing Signal Mode – The BESS uses the pricing signal for determining other actions

b. Scheduling of Power Settings and Modes – The BESS follows the schedule which consists of a time offset (specified as a number of seconds) from the start of the schedule and is associated with:

i. A Power system setting.

ii. The enabling/disabling of an operational mode.

iii. A price signal.

c. Historical Information – Detailed measurement and performance data which may be valuable to record in an operational historian.

d. Provide Black Start Capability – Ability to start without grid power and the ability to add significant load in segmented groups.

(3) Functions to be implemented in coordination with Company include the Functions and Modes listed below [TBD – Remove functions and modes not implemented].

(a) Interactive Functions:

1. Monitoring
2. Disconnect/Connect
3. Cease to Energize and Return to Service

(b) Emergency Modes:.

1. Low/High Voltage Ride-Through Mode
2. Low/High Frequency Ride-Through Mode
3. Frequency-Watt Emergency Mode
4. Dynamic Reactive Current Support Mode
5. Dynamic Volt-Watt Mode

(c) Active Power Mode:

1. Active Power Limit Mode
2. Charge / Discharge Mode
3. Coordinated Charge / Discharge Management Mode
4. Peak Power Limiting Mode
5. Load Following Mode
6. Generation Following Mode
7. Automatic Generation Control (AGC) Mode
8. Active Power Smoothing Mode
9. Volt-Watt Mode
10. Frequency-Watt Mode

(d) Reactive Power Modes:

1. Constant VARs Mode
2. Fixed Power Factor Mode
3. Volt-VAR Control Mode
4. Watt-Var Mode
5. Power Factor Correction Mode

(e) Additional Capabilities

1. Pricing Signal Mode
2. Scheduling of Power Settings and Modes: a power system setting, the enabling/disabling of an operational mode, and a price signal.
3. Historical Information

8.1.15 Requirements for grounding:

(1) Grounding shall be designed and provided as required by the NEC, NESC, IEEE 80 and local code requirements. Ground grids or ground loops shall be provided under/around major electrical equipment (step-up transformers, medium voltage switchgear, inverters, fence, etc.).

(2) All equipment ground conductors shall be copper. Grounding electrodes may be copper or copper clad steel. Cable may be bare if exposed or protected by a conduit sleeve and green insulated if in a raceway along with the circuit conductors.

(3) Ground connections shall be exothermic or mechanical and acceptable for copper conductor termination. All exposed grounding connections within 18 inches of grade shall be listed for direct burial. All exposed grounding connections more than 18 inches above grade shall use materials compatible for the exposed application.

(4) A grounding electrode system consisting of a ring shall be installed at each power conversion system and shall consist of bare copper or copper-clad steel buried below grade, sized, and located according to the Project Substation grounding study. Four (4) ¾-inch by 10-foot minimum copper clad steel ground rods shall be placed equidistant along the ring. Below grade connections shall be exothermic. Ground grid connections to equipment shall be bolted to facilitate separation of grounds for continuity testing and ground mat testing. Ground electrode cable size shall be such to not allow ground loop resistance to exceed requirements per the NESC.

(5) Equipment grounding conductors shall be routed with the phase conductors.

(6) Module mounting structure and combiner boxes shall be grounded per NEC requirements.

(7) Transformers and inverters/PCS units shall be bonded to the ground ring.

(8) One (1) ground test well shall be furnished at each PCS. A flush cover shall expose one ground rod and cable with mechanical cable to rod connectors to allow disconnection for testing purposes.

(9) Grounding connections shall be tested in accordance with the NETA ATS standards.

8.1.16 Requirements for labeling and identification:

(1) Labels for equipment shall be provided. Contractor shall coordinate with Utility on labelling of equipment.

8.2 Submittals

8.2.1 Contractor shall provide a grounding study for the BESS. Such study may be included as part of the Project Substation grounding study.

8.2.2 Contractor shall provide a BESS integration plan for the coordination, integration, and implementation of the BESS into the protection and controls of the Project Substation.

8.2.3 Contractor shall provide data sheets for the modules from the manufacturer for Company approval, including nominal module power and energy ratings at specific environmental conditions, power and energy rating tolerance, temperature coefficients, and voltage, current, and environmental ratings. Contractor to provide performance curves for the items listed below. Data should be provided under multiple variables such as ambient temperatures, C-rates, elevation, cycles / state of health, and battery age.

(1) Energy capacity / degradation

(2) Round-trip efficiency

(3) Charge / discharge rates

(4) Cycle life / energy throughput

(5) Heat loads

(6) Operating voltage

(7) Operating current

(8) Self-discharge

(9) Available short circuit current and duration

8.2.4 Contractor shall provide a minimum 5-year warranty plan for the BESS, including the assumptions for degradation and operation over the warranty period.

8.2.5 Contractor shall provide a complete recommended spare parts list for the BESS. Such list shall include recommended quantities, part / model numbers, and nominal pricing.

8.2.6 Contractor shall submit all manufacturer's product sheets (material cut sheets), warranties, and operations and maintenance manuals (as applicable) for all permanently installed equipment and materials. This shall include, but is not limited to, HVAC, breakers, cabling, PCS, transformers, battery units, racking system, and fire protection system.

8.3 Battery Energy Storage System

8.3.1 Contractor shall design, furnish, construct, and install the BESS in conformance with the minimum requirements set forth herein.

(1) Contractor shall furnish all labor, equipment, and materials that are necessary for a complete, fully functional, and safe BESS system, including, but not limited to, battery modules, PCS, DC cabling, transformers, etc.

8.3.2 Contractor shall furnish and install fencing and gates at the BESS.

(1) The BESS perimeter shall be fenced. The fence shall be tied into the grounding grid, as applicable.

(2) At least one (1) vehicle gate and one (1) pedestrian gate shall be installed at the BESS. If co-located with the Project Substation, the gates for the Project Substation may be utilized for access to the BESS.

(3) All fencing and gates shall comply with the minimum specifications in SITE FENCING SPECIFICATIONS – PART 3.

8.3.3 Contractor shall offload, inspect, and install the BESS in accordance with the BESS specifications.

8.3.4 Contractor shall integrate the BESS systems and controls into the Project Substation protection and control schemes and shall actively coordinate with the BESS supplier and Company with respect to such work.

8.3.5 The BESS shall be located within the solar PV Array footprint.

8.3.6 The BESS shall be coupled to the AC collection system or DC side of the PV Array and shall allow charging/discharging from the grid.

8.4 Testing and Quality Control

8.4.1 Contractor shall coordinate with BESS manufacturer to develop a test plan for the functional testing and capacity testing of the BESS system.

8.4.2 Contractor shall submit the test plan to the Utility for review and approval.

8.4.3 Contractor shall provide reports and outputs of functional tests performed during integration of the BESS.

8.4.4 Copies of testing reports (including a summary of testing procedures and acceptance criteria) shall be submitted to Company within 10 days of completing such test.

ATTACHMENT 1 - DELIVERABLES (Documentation After Award)

DRAWINGS AND SPECIFICATIONS

Drawing List							
Sheet	Title	Equip. Spec Review	30% Design Review	Equipment Drawing Review	60% Design Review	90% Design Review	As-Builts
-	Coversheet		X			X	
S100	Structural General Notes				X		X
S101	Racking details		X			X	
S102	Racking assembly details		X			X	
S103	Racking Configuration		X			X	X
S300	Existing site topos		X				X
S301	Final site grades				X		X
S302	Fence plan				X		
S3202	Fencing details				X		X
E100	Legend & Specifications		X			X	X
E101	Site Plan - Electrical	X	X			X	X
E102	Partial Site Plan - Electrical		X			X	
E103	Partial Site Plan - Electrical		X			X	
E300	One Line Diagram	X	X			X	X
E301	Array Circuit Schematic		X			X	X
E302	Cable schedule				X	X	X
E303	Communication Wiring				X	X	X
E400	Interconnect Detail		X			X	X
E401	Trench detail		X			X	
E402	Grounding plan		X			X	X
E403	Grounding details		X			X	
O100	Engineer studies and calculations		X			X	
O200	Startup & commissioning plan				X		X
O300	Performance Test procedure					X	X
O400	QA/QC plan		X			X	

O500	Inspection test plan		X			X	
O600	O&M Manual					X	X
O700	Construction Schedule		X		X	X	
O800	Engineered Equipment Specs	X					
O900	Manufacturer's Drawings, Data sheets and Manuals			X		X	X
P100	Permits		X			X	

Drawings Furnished by Company to Contractor

1. Company will furnish copies of drawings and specifications reasonably necessary for the execution of the work. Such drawings are the property of the Company and shall be returned upon completion of the work.

2. Contractor shall field verify all lines, elevations and dimensions shown on drawings furnished by Company before ordering any material or doing any work. Contractor shall be responsible for the accuracy of all dimensions shown on Company drawings.

3. The Contractor shall notify Company if any errors or discrepancies are discovered in any of the Company drawings.

Drawings Furnished by Contractor to Company

1. All drawings shall be placed on the Utility provided drawing border and drawing numbers shall be provide by Utility to the Contractor. Contractor shall coordinate with Utility to comply with the Utility drawing standards.

2. Contractor shall prepare and furnish necessary fabrication and erection drawings for installation by others.

3. The Contractor shall submit electronic copies of all data and drawings compatible with Microstation or AutoCAD required to perform the work. All drawings shall be transmitted electronically to the Company. The drawings required and their descriptions are as follows:

   A. All physical outlines as required showing the overall size and space requirements (including that required for dismantling and maintenance) and the inter-relationship of the various components. All angles shall be indicated.

   B. Cross sections and details as required satisfying the Company that all components conform to these requirements including design and physical arrangement.

   C. All information required by the Company for the design and location of all connecting Company furnished structural, mechanical, or electrical items, such as steel supports, anchor bolts, piping, etc.

   D. Weight of the equipment and distribution of the static, live, wind, and other loads.

E. Equipment assembly drawings.

F. Erection drawings of Contractor's furnished equipment.

G. Details of special features.

4. The Project location and Company's purchase order number shall be shown on all drawings, including sub-Contractor drawings.

5. When of necessity, non-reproducible material is furnished; three (3) copies shall be transmitted to the Company.

6. Drawings will be examined promptly for general arrangement, general dimensions and suitability and returned with or without comments or suggestions. The Company has the right to make minor changes and changes required for compliance with these specifications at no change in the Purchase Order price.

SUCH REVIEW WILL NOT RELIEVE THE CONTRACTOR OF RESPONSIBILITY FOR THE ACCURACY OR CORRECTNESS OF ITS WORK OR FOR THE PROPER CONSTRUCTION AND SUCCESSFUL PERFORMANCE OF THE EQUIPMENT IN ACCORDANCE WITH THE CONDITIONS SPECIFIED IN THE CONTRACT.

7. After the first drawing submittal, all drawing changes shall be clearly marked or circled by the Contractor and identified with a complete description in the revision block of the drawing. "General Revision, Per Customer's Marked Print" is not a complete description and is not acceptable.

8. If the Company's comments or suggested changes are all incorporated into the drawings, then the Contractor may release the drawings for construction. No fabrication or construction shall be performed until the Company has returned all drawings related to that work with approval. If the Company's comments or suggested changes are all incorporated into the drawings, then the Contractor may release the drawings for construction. No fabrication or construction shall be performed until the Company has returned all drawings related to that work with approval.

9. If the Contractor, or a sub-Contractor, changes a drawing which has been released for construction, and the change causes the Company extra expense due to changes in foundation, piping, wiring, etc., the Contractor shall reimburse the Company for the additional expense caused by the change.

10. The Company requires permission from the Contractor to reproduce its drawings and other data as required for any purpose deemed necessary by the Company. Execution of the Purchase Order by the Contractor grants such permission. The Company recognizes the sensitive nature of the information contained in these drawings and will protect its confidentiality to the extent practical while still allowing maintenance, operation, and modification of the Equipment.

OPERATION AND MAINTENANCE MANUALS

The Contractor shall furnish four (4) hard copy and one electronic set (PDF) of Company approved installation, operation, and maintenance instructions and final design approval. The manuals shall include but are not limited to the following:

A. A description of the equipment or engineered system, including major components.

B. Operating theory and enough information to assist the operators and maintenance personnel to properly care for the equipment.

C. Operating instructions, which includes, but is not limited to, proper start-up and shutdown instructions, upset and emergency instructions, operating adjustments, general operating, and maintenance procedures, trouble-shooting guides, and personnel safety instructions, including warnings for maintenance.

D. Recommended spare parts list.

ATTACHMENT 2 – PERFORMANCE GUARANTEES

1.0 Functional Tests

The equipment shall be tested for performance prior to commercial operation. This process shall verify the installed system is performing per the design based on the current weather variables.

Prior to the Performance Test, the Contractor shall perform functional tests. As part of the commissioning process of the newly constructed solar array, the Contractor shall perform a functional test on each of the circuits to verify that they are all operating as expected and designed.

The Contractor shall start up and commission each of the inverters and ensure they are running under their MPPT (Maximum Power Point Tracking) range for optimal performance. The Contractor shall inspect the entire array and measure the operating current of each individual string and the respective irradiance level in the plane of the array at the time current testing is completed. Based upon the design of the system, the Contractor shall calculate the expected current level based upon the recorded/observed conditions and compare that to the actual current level to verify that each string is performing as designed.

The Contractor shall complete a PVSyst report based upon the final design of the system and 30-year historical weather data for the area that shall provide an expected monthly production estimate for each of the 12 months of the year.

2.0 Performance Tests

This portion of the Performance Test shall be conducted after the Contractor completes the functional tests and is required for commercial operation. The Performance Test shall follow the guidelines in ASTM E2824 and shall be three days in duration. The Contractor shall meet a minimum of 98% of the performance guarantee prior to commercial operation.

The Performance Test boundary for the solar array shall be Contractor supplied weather station and the production power meter or other meter shown on the one-line in interconnection agreement in Attachment 8. Calibration certificates shall be provided for all test instruments. The test tolerance shall be +/- 5% based on the accuracy of the instruments provided.

The Performance Test data shall be taken in one (1) minute intervals and averaged over 15-minute intervals for calculating the CSG output. The minimum number of data points over the three-day test period shall be 50 (12 hours of data collection). The minimum plane of array (POA) solar irradiance shall be 500 W/m^2 during data collection. Data shall generally be taken between 10:00 AM to 2:00 PM.

The weather data and MWhr AC (megawatt hour, alternating current) output data shall be recorded during the test with the Company approved DAS software. The measured total MWhr output during the test shall be the actual AC output of the solar array.

The weather data recorded during the test shall be entered into the as-built PVSYST model. The PVSYST model shall be used to calculate the expected MWhr AC output over the duration of the test.

The performance guarantee shall be met if the actual measured MWhr AC output plus test tolerance is greater than or equal to the expected MWhr AC output calculated by the PVSYST model. If the actual measured MWhr out is less than the expected MWhr output, the Contractor shall repair or replace components as required and retest the solar facility to meet this portion of the performance guarantee.

The Performance Test may be suspended and restarted due to transient weather conditions as mutually agreed to by the Company and Contractor. The data collected during the test suspension shall be excluded from the performance calculations.

The Contractor shall submit a preliminary Performance Test procedure for review 90 days prior to the Performance Test. The final test procedure shall be issued 30 days prior to the Performance Test.

[Contractor to supply PVsyst performance model for the facility]

ATTACHMENT 3 - SITE AND AMBIENT CONDITIONS AND REFERENCE MATERIALS

1. SUMMARY
   1.1. This Schedule outlines the site conditions used as the basis of equipment design for the site.
2. LOCATION
   2.1. (*Contractor / EOR to provide*)
3. AMBIENT DESIGN CRITERIA
   3.1. Meteorology
      3.1.1. Local Instrumentation data is used for design wet-bulb temperature, dry-bulb temperature, wind, and other design criteria.
         a. Temperature and Humidity:
            - Maximum Summer Extreme Temperature: (*Contractor / EOR to provide*)
            - Minimum Winter Extreme Temperature: (*Contractor / EOR to provide*)
            - Summer Design Dry Bulb Temperature up to: (*Contractor / EOR to provide*)
            - Summer Design Wet Bulb Temperature: (*Contractor / EOR to provide*)
            - Winter Design Dry Bulb Temperature Down to (*Contractor / EOR to provide*)
            - Yearly Average Relative Humidity: (*Contractor / EOR to provide*)
         b. Indoor Temperatures
            - Summer Design Temperature (Ventilated Areas)
            - Winter Design Temperature (Heated Areas)
            - Winter Design Temperature (Freeze Protection) 4
         c. Precipitation and Snow:
            - Annual precipitation averages (*Contractor / EOR to provide*).
            - Annual snowfall averages *(Contractor / EOR to provide)*
      3.1.2. Elevation/Barometric Pressure: (*Contractor / EOR to provide*)
      3.1.3. Wind Speed
            - Structures shall be designed for wind loads in accordance with the currently adopted local building codes, IBC, and ASCE 7.
            - The minimum exposure classification shall be (*Contractor / EOR to provide*).
            - Pressure coefficients shall be determined in accordance with ASCE 7
            - Wind tunnel design Procedures shall be completed according to ASCE 7, Chapter 31.
   3.2. Seismic Design
      3.2.1. Seismic design shall be in accordance with the current local building codes and the IBC. The soil shall be classified as (*Contractor / EOR to provide*).

ATTACHMENT 4 - QA/QC (Including Inspection Test Plans)

See Schedule O – Company and Contractor QA/QC documents for additional requirements.

The Contractor shall have primary responsibility for Quality Control and Assurance for all activities in support of the work covered herein. These requirements are mandatory and shall be imposed on all subcontractors furnishing materials or services. Submittal requirements are contained herein. Submittal schedules are as follows:

NT	E
Operations Manuals	Upon Contract Award and after final design is approved
Shop Quality Control Manual (Non- Controlled)	60 Days Prior To Start of Fabrication
Materials List	60 Days Prior To Start of Fabrication
Design Data	60 Days Prior To Start of Fabrication
Fabrication Schedule	30 Days Prior To Start of Fabrication
Controlled list of fabrication drawing numbers	30 Days Prior To Start of Fabrication
Cleaning, Painting & Shipping Procedures	30 Days Prior To Start of Fabrication
Contractor’s Quality Certification	Upon Shipment
Required drawings	Upon Shipment

1. The Contractor shall submit a detailed fabrication and manufacturing sequence that includes all the Contractor's inspection or hold points. References are to be included to all called for submittals required at the specific point within the work sequence. The furnishing of such information is to be used in the Company's determination of any necessary "witness points". The Company reserves the right to have a representative perform QA surveillance of any activity in the Contractor’s shop.

2. The Company shall be provided free access at all times where the work or testing is being performed. The Contractor shall provide the Company with reasonable facilities for inspection, witnessing of tests, and examination of records, including subcontractor's facilities if required. The Contractor shall provide a minimum of five (5) working days' notice prior to those tests identified for QA surveillance above. Work shall not proceed beyond established "inspection points” without an authorized waiver from the Company to proceed.

3. All procedures shall include a procedure identification and revision number or date, and be transmitted via a letter containing the following:

   A. Purchase Order.

   B. Procedure identification number.

   C. Statement that the procedure is in accordance with the applicable revision of these specifications and all referenced codes and standards.

4. Contractor shall submit a controlled list of fabrication drawing numbers including revision numbers. This list will be utilized when any QA surveillance is made by the Company's representative to assure that the correct drawing revision is being used for fabrication.

5. The Contractor shall not begin fabrication until a work release is obtained from the Company.

6. The Company will issue a work release upon completion of the following:
   A. Approval of all relevant fabrication procedures.
   B. Receipt of all required documents.

7. The Contractor will make data or information, which affects the quality of product, available for review by the Company. Nonconformance with these specifications shall be documented and submitted to the Company for disposition promptly.

8. Contractor shall inform Company of all subcontractors for Company approval prior to work being commenced.

9. The Contractor shall provide a statement of certification, signed by the Contractor's QA inspector. The statement shall be sufficient to specifically identify the purchased material or equipment, such as purchase order number, supplements and item number where applicable. The statement shall indicate that all contractual requirements have been met and include a list of all non-conformities. The quality records documentation package shall contain all required documentation results, test data, non-conformities, certifications and a "Release for Shipment Form". The documents shall be sequentially numbered for easy identification and indexing and each package shall contain an index sheet identifying the contents of the package. All documents shall be of a quality suitable for microfilming. The documentation package, including radiographs, shall be reviewed and accepted by the Company's representative prior to release for shipment. The certification transmittal letter and documentation package shall be forwarded to the Project Engineer.

10. Prior to shipment, the Contractor shall have the "Traveler for Fabrication" signed off to indicate that all designated hold points have been satisfied by either witnessing by the Company or appropriately waived by the Company. To assure that all Company concerns are completely satisfied, the Contractor shall obtain a formal written release for shipment prior to shipping any equipment. This document shall be included with shipment and all document packages.

11. The following procedures shall be submitted to the Company for review and approval:
    A. Shop Quality Control Procedure. This procedure shall include the Contractor's method of documentation of materials, control of design drawings and specifications, control of various production steps and tests, materials identification, welder identification, and welding electrode handling and distribution.
    B. All applicable welding procedures, welding procedure qualification tests records and welder and operator qualification records must be on file for Company's review in the Contractor shop.
    C. All applicable nondestructive testing procedures, including the written practice.
    D. All applicable welding procedures.

12. Upon completion of the project, the Contractor shall submit three certified copies of:
    A. Material certifications.
    B. The test results from nondestructive and destructive tests.

13. The Contractor shall have a quality organization in which individuals performing quality functions have defined responsibility, authority, and freedom from production pressures, to effectively identify, pursue, and resolve quality related problems. The organization shall be arranged so that the individual or group assigned the responsibility for checking, reviewing, inspecting, or otherwise verifying that an activity has been correctly performed is independent of the individual or group directly responsible for performing the specific activity. The personnel performing these functions shall be fully qualified, knowledgeable and properly trained on the specific function they are responsible to perform.

14. Methods shall be established for assuring control of the issuance, revision and distribution of documents affecting the quality including changes thereto. These documents shall include but not be limited to, drawings, instructions, procedures, purchase orders and contracts.

15. Measures shall be established and documented to assure identification and control of materials, parts and components including partially fabricated subassemblies, to assure that only correct and acceptable items are used in the fabrication and assembly. The measures shall include provisions for relating the item to any stage of production activity or completion.

16. Documented measures shall be established to assure that gauges, instruments, and other measuring and testing devices affecting acceptance testing are controlled. To assure accuracy and control, these devices shall be calibrated and adjusted at the required frequency prior to use. The devices shall be of the proper type, range and accuracy for the intended application. Calibration shall be certified to standards recognized by the National Institute of Standards and Technology or other sources acceptable to the Company.

17. The method for control of purchased material and services shall be described and shall indicate how subcontractors are selected, qualified and controlled. This description must include provisions to ensure applicable quality requirements are included in the procurement documents.

18. The method describing how welding, nondestructive examination, heat treating and other special procedures which are of a complex and specialized nature, and therefore require more precise detailing than ordinary work instructions must be controlled and documented. Controls must include considerations for process, personnel and equipment qualification and control. The procedure for the control of the quality program shall include the acceptance criteria to be used.

19. All nonconforming items shall be documented and the disposition of such non- conformances, except “scrap”, shall receive approval from the Company prior to their implementation. Non- conformances are generally defined as, but not limited to, items resulting in un-engineered welds, items requiring a repair to base materials, items requiring rework such that the item must be reinserted into the manufacturing process at a point previously completed, and items requiring rework such that additional steps must be added to the manufacturing process. It is not intended to include welds that are rejected by in process inspection and immediately repaired, provided none of the above stated definitions apply. Measures shall be established and documented to control these discrepant items and prevent their inadvertent use on work covered herein. These measures shall provide a means of identifying, documenting, segregating, dispositioning and notifying all concerned parties of conditions and required actions.

20. Documentation and records shall be prepared and maintained which shall furnish evidence that the activities affecting quality have been performed, monitored, inspected, tested and analyzed as required.

21. See Schedule N – Company QS/QC Requirements and Contractors QA/QC Manual for additional requirements.

ATTACHMENT 5 - STARTUP, TESTING, AND COMMISSIONING

See Schedule C – Startup, Commissioning and Turnover for additional requirements.

The Contractor shall be responsible for startup, testing, and commissioning of the solar facility or Solar facility with BESS.

The electrical equipment and its installation shall be tested according to the current International Electrical Testing Association (NETA) Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

Contractor shall submit a startup, testing, and commissioning plan for review and approval by Company. Documentation of testing performed shall be submitted for review and approval by Company.

ATTACHMENT 6 - PACKAGING, SHIPPING, AND STORAGE

PART 1 - GENERAL

1.01 SUMMARY:

A. This Section includes administrative and procedural requirements for Contractor's shipment, transportation, delivery, unloading, handling, and storage. It also includes the requirements governing Contractor's selection of products for use in the Project.

1.02 PREPARATION FOR SHIPMENT:

A. Contractor shall prepare all equipment and material in this Agreement (or subcontract) for shipment in a manner to facilitate unloading and handling, and to protect against damage, deterioration, or unnecessary exposure to the elements in transit and storage. Contractor shall adequately prepare Contract Parts for shipment to allow for proper storage. For this purpose, Contractor shall adequately wrap, pack, crate, load, enclose and brace all parts and equipment in a good and workmanlike manner.
   1. Provisions for protection shall include the following:
      a. Crates or other suitable packaging materials.
      b. Covers and other means to prevent corrosion, moisture damage, mechanical injury, and accumulation of dirt in panels, electrical equipment, and tracker materials.
      c. Suitable rust-preventive compound on exposed machined surfaces and unpainted steel.
      d. Grease packing or oil lubrication in all bearings and similar items.
   2. Quality and cleanliness shall be maintained during shipment and prolonged outdoor storage.
   3. The interior and exterior of all equipment, components, and all parts and equipment shall be cleaned of all metal chips, weld spatter, slag, oil, grease, dirt, scale, and any other foreign material.
   4. Shipping saddles, bracing, supports, and rigging connections shall be provided by Contractor to prevent damage during shipment, lifting, or unloading.
   5. Lifting points shall be clearly marked and easily usable. All lifting plans shall be approved by Contractor and reviewed by Company.

B. Contractor shall deliver products to the Site in an undamaged condition in the manufacturer's original sealed container or other packaging system, complete with labels and instructions for handling, storing, unpacking, protecting, and installing.

C. Contractor shall furnish Company information on care of equipment during long and short-term storage (if applicable).

D. Contractor shall ensure that separate, loose, and spare parts are completely boxed. Pieces of equipment and spare parts shall have a securely attached tag with item number and service, and marked with Company's order number, item number, and weight, both inside and outside of each individual package or container.

E. Complete packing lists and bills of material shall be included with each shipment. Each piece of every item need not be marked separately, provided that all pieces of each item are packed or bundled together, and the packages or bundles are properly tagged or marked.

1.03 SHIPMENT:

A. Contractor shall furnish and deliver materials Delivery Duty Paid (DDP) at the on-site designated location.
   1. Contractor shall schedule delivery to minimize long-term storage at the Site and to prevent overcrowding of construction spaces.
   2. Coordinate delivery with installation time to assure minimum holding time for items that are flammable, hazardous, easily damaged, or sensitive to deterioration, theft, and other losses.
   3. If Company agrees in writing (in its sole reasonable discretion) to accept delivery of Goods before Contractor has mobilized at the Site, then Company will be responsible for

unloading all parts and equipment, provided however, that Contractor shall at all times retain care, custody, and control of and bear risk of loss for the Goods.

4. Once Contractor has mobilized at the Site, then Contractor shall receive and unload Goods shipped under this Agreement in accordance with this Section 1.03.
5. Allow ample time to avoid delay of the Work.
6. Notify Company of all shipping plans.
7. Notify Company upon receiving items at the Site.
8. Contractor is responsible for unloading all parts and equipment while on site.

B. Contractor shall make no shipments in advance of a Company specified shipping date without the prior written approval of Company. Contractor must notify Company in writing (the "Shipment Notice"), at least twenty one (21) calendar days in advance of shipping and again the day prior to delivery, of its intent to deliver any items to the Site. Company shall be entitled to delay any shipment for up to fifteen (15) calendar days after Contractor's stated intended delivery date, without cost, provided Company notifies Contractor of its intent to delay delivery within seven (7) calendar days of receipt of a Shipment Notice. Any and all shipments with a point of origin outside the United States must have proof of U.S. Customs clearance. A statement that customs clearance has been obtained must be included in Shipment Notice and confirming proof-of-clearance documentation provided at time of delivery.

C. Delivery Site Delivery Hours. If the Shipment Notice has been received, the Contractor is not on site and Company has agreed to unload such delivery, Company will receive such items at Company-designated delivery point at the Site at the applicable Site's posted times for acceptance of deliveries. Items delivered without proper advance notice, or deliveries attempted at times outside the above hours, may be refused and any demurrage or delay costs will be to Contractor's account. Alternatively, Company may accept delivery and back charge Contractor the labor and equipment costs incurred by Company in unloading, storing and later moving the delivered items to their intended location and all other costs, expenses and damages arising from such delivery.

D. Delivery Shipment Documentation. The Shipment Notice shall include a complete packing list (a "Packing List"). The Packing List must contain a "Master Parts and Pieces List" identifying all components, parts, pieces, sub-assemblies, and tools to be delivered. The Packing List must also indicate the name of the entity originating the shipment, the geographic point of origin (city and state if U.S. origin, city and country if foreign origin), carrier name and date of shipment. Such detailed description of the items to be delivered shall identify each item on the list by an individual piece number and include the weights of each individual item if in excess of 100 pounds. In addition, each individual item on the Master Parts and Pieces List shall be cross-referenced to the Packing List provided by Contractor for each shipment. Where the items being shipped are identified on any installation Drawing(s) supplied by Contractor to Company, a copy of the installation Drawing(s) with the items being shipped highlighted on the installation Drawing(s) shall also be provided with the Packing List. Where the items being shipped are identified on a parts list or the Master Parts and Pieces List supplied by Contractor to Company, a copy of the parts list or the Master Parts and Pieces List with the items being shipped highlighted on the list shall also be provided with the Packing List.

E. All parts and equipment Labeling. All parts and equipment shall be labeled with the manufacturer's name, Contract Part number, and Contract Part serial number. All parts and equipment and other parts and items delivered to the Site shall be labeled in a fashion that ties each piece to the Packing List. Such labels shall be affixed to the pieces or the packaging (for parts and items supplied with All parts and equipment that are not typically identified by individual serial number) in a fashion that makes removal or destruction of the labels in the normal course of shipping, storage, staging and construction reasonably unlikely.

F. Delivery Costs in Price. All costs associated with the delivery of All parts and equipment and any other items to the Site in accordance with the terms of this Agreement, including freight and transportation insurance, are included in the Agreement Price. Contractor shall be responsible for transportation insurance, which such coverage shall be for the full replacement value of the shipment. If applicable, Contractor shall insure All parts and equipment for marine loss.

G. Damage to Shipment; Delivery Refusal. If there is any apparent physical damage to such shipment Company will notify Contractor within five (5) Business Days after receipt of any shipment delivered to a Site (a "Damage Notice"), and Company may refuse to accept delivery of any such item. If such Damage Notice is not given to Contractor within such five (5)-day period, any such shipment will be deemed accepted by Company, and title shall pass to Company in accordance with Article 24. Upon receipt of a Damage Notice, Contractor shall provide field service Personnel to inspect such shipment no later than five (5) Business Days of the receipt of the Damage Notice. If any portion of the All parts and equipment (including design and/or engineering) is determined by Company to be improper or defective, Contractor shall, immediately upon being notified by Company, proceed to remove, dispose of, and replace, or re-deliver as the case may be, such All parts and equipment at its own cost. No inspection by Company shall be construed as constituting or implying either a waiver or acceptance, nor shall it affect any of Company's rights or remedies under this Agreement.

1.04 UNLOADING, STORAGE, AND HANDLING:

A. In accordance with paragraph 1.03 above, unload, store, and handle products according to the manufacturer's recommendations, using means and methods that will prevent damage, deterioration, and loss, including theft. Company shall provide and support the Contractor with the required laydown area as well as the necessary indoor/outdoor storage facilities onsite
   1. Inspect products upon delivery to ensure compliance with the Contract Documents and to ensure that products are undamaged and properly protected. Inspect shipment to assure:
      a. Product complies with requirements of Contract Documents and reviewed Submittals.
      b. Quantities are correct.
      c. Containers and packages are intact, and labels are legible.
      d. Products are properly protected and undamaged.
   2. Store products at the Site in a manner that will facilitate inspection and measurement of quantity or counting of units. Mark deliveries of component parts of Equipment to identify the Equipment, to permit easy accumulation of parts, and to facilitate inspection and measurement of quantity or counting of units.
   3. Store heavy Materials away from the Project structure in a manner that will not endanger the supporting construction.
   4. Protect motors, electrical Equipment, plumbing fixtures, and machinery of all kinds against corrosion, moisture deteriorations, mechanical injury, and accumulation of dirt or other foreign matter.
   5. Protect exposed machined surfaces and unpainted iron and steel as necessary with suitable rust-preventive compounds.
   6. Protect bearings and similar items with grease packing or oil lubrication.

B. Handling:
   1. Provide equipment and personnel necessary to unload and handle products, by methods to prevent damage or soiling to products, or packaging.
   2. Handle by methods to prevent bending or overstressing. Where lifting points are designated, lift components only at those points.
   3. Provide additional protection to surrounding surfaces as necessary to prevent damage.
   4. If Company agrees in writing (in its sole reasonable discretion) to accept delivery of Goods before Contractor has mobilized at the Site, then Company will be responsible for unloading all parts and equipment, provided however, that Contractor shall at all times retain care, custody, and control of and bear risk of loss for the Goods.
   5. Once Contractor has mobilized at the Site, then Contractor shall receive and unload Goods shipped under this Agreement.

C. Maintenance of Storage:
   1. Inspect stored products on a scheduled basis.

2. Verify that storage facilities comply with manufacturer's product storage requirements, including environmental conditions continually maintained.
3. Verify that surfaces of products exposed to elements are not adversely affected; that any weathering of finishes is acceptable under requirements of Contract Documents.
4. For mechanical and electrical Equipment in long-term storage, provide manufacturer's service instructions to accompany each item, with notice of enclosed instructions on exterior of package. Service Equipment on a regularly scheduled basis.

D. Protection After Installation: Provide substantial coverings as necessary to protect installed products from damage from subsequent construction operations. Remove coverings when no longer needed or as specified.

PART 2 - PRODUCTS

2.01 PRODUCT SELECTION:

A. General Product Requirements: Provide products that comply with the Contract Documents, that are undamaged and, unless otherwise specified or indicated, new at the time of installation.
1. Provide products complete with accessories, trim, finish, safety guards, and other devices and details needed for a complete installation and the intended use and effect.
2. Where available, provide standard products of types that have been produced and used successfully in similar situations on other projects.
3. Continued Availability: Where, because of the nature of its application, Company is likely to need replacement parts or additional amounts of a product at a later date, either for maintenance and repair or replacement, provide standard products for which the manufacturer has published assurances that the products and its parts are likely to be available to Company at a later date.
4. Conform to applicable Specifications, codes, standards, and regulatory agencies.
5. Comply with size, make, type, and quality specified, or as specifically approved in writing by Company.
6. Manufactured and Fabricated Products:
   a. Design, fabricate, and assemble in accordance with the best engineering and shop practices.
   b. Manufacture like parts of duplicate units to standard sizes and gages, to be interchangeable.
   c. Equipment and Materials shall be suitable for service conditions intended.
   d. Equipment capacities, sizes, and dimensions indicated or specified shall be adhered to unless variations are specifically approved in writing by Company.
   e. Provide labels and nameplates where required by regulatory agencies or to state identification and essential operating data.
7. Do not use products for any purpose other than that for which designed.
8. To the fullest extent possible, provide products of the same kind from a single source.

PART 3 - EXECUTION

3.01 INSTALLATION OF PRODUCTS:

A. Comply with manufacturer's instructions and recommendations for installation of products in the applications indicated, with the exception of manufacturer's procedures and specifications that are deemed confidential to the manufacturer. Anchor each product securely in place except as required for proper movement and performance, and accurately located and aligned with other Work.
1. Obtain and distribute copies of manufacturer's printed instructions and recommendations if not a part of Submittals, containers, or packaging to parties involved in the installation, including a copy to Company.
2. Maintain one complete set of instructions at the Site during installation and until completion.

3. Handle, install, connect, clean, condition, and adjust products in accordance with such instructions and in conformance with specified requirements. Should job conditions or specified requirements conflict with manufacturer's instructions, consult with Company for further instructions.

B. Clean exposed surfaces and protect as necessary to ensure freedom from damage and deterioration at time of Substantial Completion.

3.02 <u>HANDLING EXISTING EQUIPMENT OR MATERIALS:</u>

A. Products to be Reused:

1. For Equipment and Materials specifically indicated or specified to be reused in the Work, use special care in removal, handling, storage, and reinstallation to assure proper function in the completed Work. Arrange for transportation, storage, and handling of products which require off-Site storage, restoration, or renovation and pay all costs for such Work. Contractor may at its option, furnish and install new items in lieu of those specified to be reused. Applicable to All parts and equipment only. For non-all parts and equipment, all costs shall be likewise deferred to the Company.

B. Products Not to be Reused:

1. Equipment and Materials designated to be removed but not reused or delivered to Company, shall become the property of the Contractor and shall be removed from the Site, as mutually agreed upon by the Company and the Contractor.

ATTACHMENT 7 – SITE PLAN

[Contractor shall provide site plan for specific site or sites chosen for the project.]

ATTACHMENT 8 – INTERCONNECTION AGREEMENT WITH ONE LINE DIAGRAM

[Contractor shall provide interconnection agreements and one line diagram for the specific site or sites chosen for the project.]

ATTACHMENT 9 – APPROVED SUPPLIERS AND CONTRACTORS

1. Electrical engineering:
   1.1. Ulteig
   1.2. Burns and McDonnell
   1.3. HDR Engineering
   1.4. Power Engineers
   1.5. Westwood (Solar PV Array)
   1.6. Company approved alternate

2. Electrical commissioning and testing:
   2.1. CE Power
   2.2. High Voltage Service
   2.3. L&S Electric
   2.4. EPS
   2.5. Company approved alternate

3. Civil and Geotechnical engineering:
   3.1. Westwood
   3.2. Barr
   3.3. RRC
   3.4. Company approved alternate

4. Medium voltage pad-mounted transformer suppliers:
   4.1. GE Prolec
   4.2. ABB
   4.3. Ermco
   4.4. Eaton-Cooper
   4.5. Company approved alternate

5. Medium-voltage pad mounted Box Pad suppliers
   5.1. Nordic
   5.2. Highline
   5.3. Oldcastle
   5.4. Concast, Inc.

6. Medium-voltage pad mounted Grounding Transformer suppliers
   6.1. GE Prolec
   6.2. ABB

7. PV Racking Vendors- Single Axis Tracker Mounting System
   7.1. FTC
   7.2. NEXTracker
   7.3. Array Technologies, Inc. (ATI)
   7.4. Gamechange Solar
   7.5. Company-approved alternate

8. DC Combiner Boxes
   8.1. Sunlink

8.2. SolarBOS
8.3. Shoals
8.4. Amphenol
8.5. Bentek Solar
8.6. Company-approved alternate

9. Recombiner Boxes
   9.1. Sunlink
   9.2. SolarBOS
   9.3. Shoals
   9.4. Amphenol
   9.5. Bentek Solar
   9.6. Company-approved alternate

10. Central Inverters
    10.1. TMEIC
    10.2. FIRMER (ABB)
    10.3. Sungrow
    10.4. General Electric
    10.5. SMA
    10.6. Power Electronics
    10.7. Ingeteam
    10.8. Gamesa
    10.9. Company-approved alternate

11. String Inverters
    11.1. ABB
    11.2. SMA
    11.3. Sungrow
    11.4. SolarEdge
    11.5. Chint
    11.6. Company-approved alternate

12. Approved Auxiliary Relay Suppliers
    12.1. Allen-Bradley
    12.2. Cutler-Hammer
    12.3. GE
    12.4. Potter-Brumfield

13. Approved Protective Relay Suppliers
    13.1. Schweitzer Engineering Laboratories, Inc. (SEL)
    13.2. Electroswitch

14. Approved Relay Panel Suppliers
    14.1. SEL
    14.2. Electrical Power Products (EP2)
    14.3. Systems Control
    14.4. Western Controls
    14.5. Keystone

15. Approved Station Battery Suppliers

15.1. C&D
15.2. GNB
15.3. Exide
15.4. BAE
15.5. Varta

16. Approved Station Battery Charger Suppliers
    16.1. Exide
    16.2. Ametek

17. Approved Terminal Block Suppliers
    17.1. Allen-Bradley
    17.2. Cutler-Hammer
    17.3. GE

18. Approved Panelboard Suppliers
    18.1. Cutler-Hammer
    18.2. GE
    18.3. Square-D

19. Approved Cable Tray Suppliers
    19.1. B-Line
    19.2. PW Industries
    19.3. T&B

20. Approved Medium Voltage Cable Underground Splice Suppliers
    20.1. 3M

21. Approved Medium Voltage Termination Suppliers
    21.1. Tyco
    21.2. 3M
    21.3. Richards
    21.4. Cooper

22. Approved Medium Voltage Elbow Arrestor Suppliers
    22.1. Cooper
    22.2. Hubbell Power Systems
    22.3. Richards

23. Approved PT Suppliers
    23.1. ABB
    23.2. Kuhlman
    23.3. GE/ITE

24. Approved 34.5 KV PT Suppliers
    24.1. ABB type VOG-20BR

25. Approved Junction Box Suppliers
    25.1. Nordic
    25.2. Highline

26. Approved Low-voltage(<1500 V) Cable Suppliers
    26.1. American Wire Group

26.2. Anixter
26.3. BICC/Cablec
26.4. General Cable
26.5. Houston Wire and Cable
26.6. Okonite
26.7. Southwire

27. Approved Medium-voltage Cable suppliers
    27.1. General Cable
    27.2. Prysmian
    27.3. Synergy
    27.4. Southwire
    27.5. WTEC

28. Approved Fiber Optic Cable Suppliers
    28.1. Commscope
    28.2. Furukawa
    28.3. Brugg

29. Approved Current and Voltage Test Switches
    29.1. ABB flexitest switch

30. Approved Low-voltage power breakers
    30.1. ABB SACE EMAX
    30.2. Company approved alternate

31. Approved Solar and BESS DAS (Data Acquisition System) and Plant Controller
    31.1. Also Energy
    31.2. Ulteig/NLS Engineering
    31.3. Company-approved alternate

32. PV Array Modules
    32.1. PV Array Module manufacturers must be rated CCC++ or higher in the most recent PV-tech research "PV ModuleTech Bankability Ratings Pyramid". Top 50 most bankable module suppliers in the PV industry today - PV Tech (pv-tech.org)

ATTACHMENT 10 – PROJECT MILESTONE SCHEDULE

[Contractor shall provide a project schedule with milestones for each solar facility or solar with BESS facility]

ATTACHMENT 11 – GEOTECHNICAL INVESTIGATION REPORT

[Contractor shall provide a Geotech report for each solar facility or solar with BESS facility]

ATTACHMENT 12 - NORTH AMERICAN ELECTRIC RELIABILITY COUNCIL (NERC) - LESSON LEARNED: BATTERY ENERGY STORAGE SYSTEM CASCADING THERMAL RUNAWAY

ATTACHMENT 12 - NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION (NERC) - LESSON LEARNED: BATTERY ENERGY STORAGE SYSTEM CASCADING THERMAL RUNAWAY

Lesson Learned

Battery Energy Storage System Cascading Thermal Runaway

Primary Interest Groups

Generator Operators (GOPs)
Generator Owners (GOs)
Transmission Operators (TOPs)
Transmission Planners (TPs)
Resource Planning (RP)

Problem Statement

A fire started in a Battery Energy Storage System (BESS), resulting remote alarm triggering at approximately 16:55 PST. The utility, the maintenance provider, and fire fighters responded to the site. At approximately 20:04 PST, an explosion occurred that injured several firefighters and significantly damaged the BESS. A comprehensive investigation of the event was performed that identified the cause of the fire as being a cascading thermal runaway event that was initiated by an internal cell failure within one battery cell in the BESS.

Details

On the day of the event, the 2 MW/2 MWh BESS was performing a solar smoothing function (this entails charging during the daytime; absorbing solar energy produced from rooftop solar on the circuit) and discharging through evening load peak.

At approximately 16:54 PST, a battery cell in the BESS experienced a sudden drop in voltage during a charging cycle. Moments after, the voltage dropped and a battery cell went into thermal runaway. This event generated off-gassing and smoke that activated the smoke detection system, leading to the discharge of the fire suppression system. The initial cell's thermal runaway cascaded into neighboring cells and subsequently into the batteries contained within neighboring modules.

Figure 1 shows the general layout of the BESS. Figure 2 shows how a single cell failure propagated through one Module and consumed the whole rack, releasing a large plume of explosive gases. This could have occurred without a flame, explaining why the gases were not burned as they were emitted.

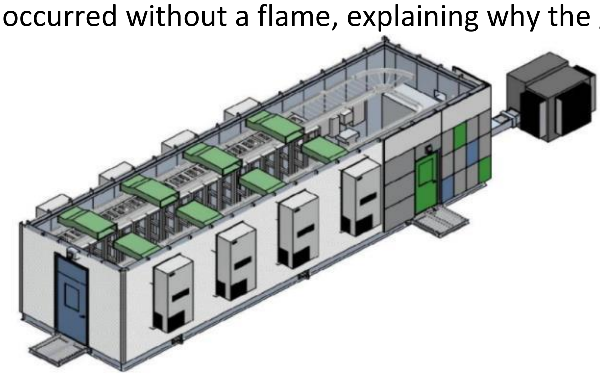

Figure 2: General layout of the BESS (Image credit: APS)

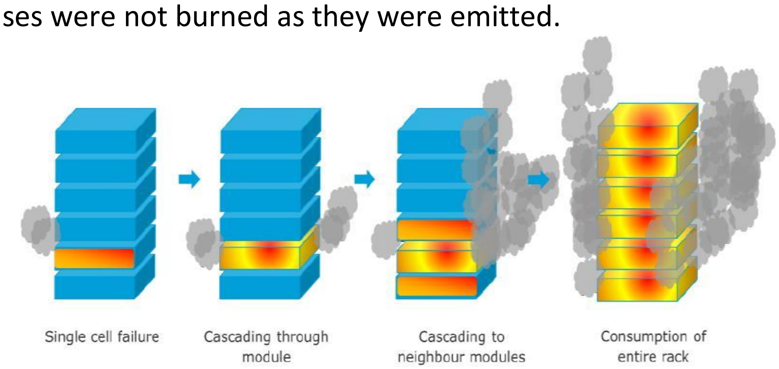

Figure 1: A single cell failure propagated through one Module (Image credit: APS).

A "clean agent" fire suppression system was built into the BESS and functioned as designed. However, the high temperatures generated by the thermal runaway and battery fire negated the agent's ability to suppress the fire.

Figure 3: BESS Exterior after event (image credit: APS)

Approximately three hours after initiation of the event, emergency responders opened the BESS side container door and approximately two minutes later, an explosion occurred.

An extensive investigation of this event was led by the involved entity that included emergency responders, vendor partners, forensic experts, and nationally recognized research institutions. The investigation uncovered the following five main contributing factors:

Figure 4: All modules in Rack 15 were severely damaged by thermal runaway while leaving nearby racks mostly intact (image credit: APS)

- Internal failure in a battery cell initiated thermal runaway
- Lack of thermal barriers between cells led to cascading thermal runaway
- The fire suppression system was incapable of stopping thermal runaway
- Flammable off-gases concentrated without a means to ventilate
- Emergency response plan did not have an extinguishing, ventilation, and entry procedure

Corrective Actions

The primary hazard during a BESS incident is flammable gas in an enclosed space. Planning, training and design modifications will reduce this risk. The following are actions the entity took:

- Improve training, emergency response planning, and procedures for first responders, operations, and maintenance personnel that account for the risks and hazards of cascading thermal runaway, including flammable gases and how to enter systems after a failure.
- Work with suppliers, industry experts, and standards bodies to improve battery safety and limit potential risk in the following areas:
  - Minimize or eliminate cell-to-cell and module-to-module heat transfer to stop thermal runaway.
  - Implement fire detection and suppression system designs that will fully manage a thermal runaway.
  - Implement design changes incorporating monitoring and remote reporting of flammable gas concentrations and implement ventilation systems to mitigate.

Lesson Learned

NERC Lessons Learned normally provide anonymity for the entities involved in the source events. However, in this case, the entity wished to be known in order to expedite the dissemination of information by providing access to their complete investigation report that contains much more detail and photos and can be found at: www.aps.com/mcmicken

The potential for and impact of the contributing factors to this event were not well known at the time this BESS was commissioned, so these risks were not addressed in the design of that system even though it was constructed according to the standards at the time. Energy storage is a vital (but maturing) technology and entities need to consider these findings and the risk of similar events in their own storage implementations. Standards and regulations have developed slower than the technology and still need some improvement. As a result of this event, the NFPA 855 standard is making progress and now addresses several of these learnings.

Until NFPA 855 has been finalized, entities owning BESS should consider:

- The key to managing risk associated with the installation of a BESS focuses on a hazard mitigation analysis. This will identify gaps along with the appropriate control measures like design modifications, suppression, and training.
- The fire services should not be seeing a BESS for the first time when 911 is called. Consideration should be given to developing a pre-incident guide which will serve as the mutual platform for future training of utility personnel and the fire services.
- Conduct training, familiarization tours and exercises with your local fire department. The approach laid out in previous NERC Lesson Learned 20190202 "Substation Fires: Working with First Responders" can be used as a template.

NERC contacted an industry substation fire expert who had additional suggestions:

- A registered fire protection engineering firm should perform a hazard mitigation analysis that includes a review of the UL 9540a test data.
- As a best practice, consider following NFPA 68 guidelines for the installation of deflagration venting on future BESS installations.
- Discontinue use of clean agents as a method of suppression.
- Install a fire alarm control panel in a remote location in the facility to allow fire department to monitor conditions without being in harm's way.
- The panel should have also flammable gas monitoring capabilities along with a purge control feature.
- Install a class 1 /division 1 purge system.
- The design of the BESS container should consider garage type doors that would facilitate suppression operations without having to enter the container
- A fire protection engineering firm should also produce a Pre-incident guide (NFPA 1620) that outlines the hazards and response tactics that should be employed during an incident.
- Training should be provided. This will guide both the utility and fire services as to the appropriate actions when responding to low frequency high hazards events, such as BESS emergencies.
- Prior to placing a BESS in service, a familiarization tour should be conducted with local fire services along with any specialized units, such as hazmat, who may respond during an incident.
- Consider conducting an annual exercise with the members of the first response community to validate the plan or identify gaps.

NERC's goal with publishing lessons learned is to provide industry with technical and understandable information that assists them with maintaining the reliability of the BPS. NERC is asking entities who have taken action on this lesson learned to respond to the short survey provided in the link below.

Click here for: Lesson Learned Comment Form

For more Information please contact:

NERC – Lessons Learned (via email)

Lesson Learned #:	20210301
Date Published:	March 29, 2021
Category:	Transmission Facilities

ATTACHMENT 13 – EPRI SECURITY ARCHITECTURE FOR THE DISTRIBUTED ENERGY RESOURCES INTEGRATION NETWORK

EPRI ELECTRIC POWER RESEARCH INSTITUTE

EPRI SECURITY ARCHITECTURE FOR THE DISTRIBUTED ENERGY RESOURCES INTEGRATION NETWORK

RISK-BASED APPROACH FOR NETWORK DESIGN

EXECUTIVE SUMMARY

As distributed energy resources (DERs) expand rapidly as a major source of electricity generation and interconnect with the grid, the ability to securely monitor and control the operations of the resources in a large geographical area becomes increasingly important to maintain safety, reliability, and resiliency of the nation's grid. Remote monitoring and control of distributed generation require local devices and sensors to communicate operational status and receive commands from the remote systems, via public or private communication networks. In the meantime, the cyber-threats against the nation's grid is increasing as more and more devices become intelligent and connected. Without adequate cybersecurity protection, energy generation and interconnected systems are innately exposed to cyber threats.

This paper provides a practical set of cybersecurity requirements pertaining to the network components supporting distributed energy resources (DER) communications. The requirements specified herein aim to reduce the cybersecurity risk to the distribution grid to which various DER are connected. The requirements discussed herein do not make any assumption to the communication protocols, particular functional standards, or certain ownership/business models in terms of their effectiveness in cybersecurity. Rather, it aims to provide a holistic view of the interconnected systems, including DER, and it suggests how they can be protected from cyberattacks.

The scope of this report is limited to network security concerns. The goal is to provide guidelines for designing and implementing network infrastructure in a way that will minimize the likelihood, duration, or impact of a successful cyberattack.

It is important to note that network security architecture addresses only a portion of the cybersecurity risks associated with DER integration. To protect DER and the connected grid adequately, a more comprehensive cybersecurity standard must be developed and implemented.

The standard must consider various facets of cyber security including:

- Communications and protocol security
- Cryptographic key management
- End-point security for DER devices
- Personnel, physical, and environmental security
- Ongoing security operations—vulnerability and patch management, security monitoring, and incident response

TERMINOLOGY

In this report, *DER, distributed energy resource*, and *resource* are used interchangeably. The following terms that appear in the report might be used to convey slightly different meanings from their general usage:

- ***DER supporting system, supporting system, or system.*** A system, application, or device used to support the operation of DER or grid services in relation to DER.
- ***DER managing system or managing system.*** A supporting system specifically used to manage DER. The essential functions of a DER managing system include data acquisition and control.
- ***External network.*** A telecommunication network that extends external to the local area network (LAN)—that is, a wide area network (WAN), Internet area network (IAN or cloud), or the Internet.
- ***Security zone.*** One or more subnets or broadcast domains where a device in a zone can communicate with other devices within the zone freely, but access to and from devices outside the zone is controlled.

NETWORK SECURITY REQUIREMENTS

The general network security requirements described in this section are drawn from various cybersecurity standards available to the industry [1–6].

R1. Resource Criticality Levels

R-1.1 Each distributed energy resource or supporting system participating in DER communications must be categorized into one of three distinct criticality levels—high impact, medium impact, or low impact.

R-1.2 The criticality level of a resource must be determined based on the impact of any misuse of that resource to grid reliability, public safety, finances, and privacy. The high-impact criticality level should be assigned to a resource determined to have high impact; medium-impact to a resource with medium impact; and low-impact to a resource with low impact.

R-1.3 If a group of resources can be operated simultaneously through the same managing system, each resource in the group must be assigned the criticality level corresponding to the aggregate risk posed by the simultaneous (mis)operation of all resources in the group.

R-1.4 A managing system that can issue a write/control command to one or more resources must be assigned the criticality level that corresponds to the aggregate risk of simultaneous (mis)operation of all resources that can be controlled by the managing system.

R-1.5 If a resource can be categorized into two or more different criticality levels, it must be categorized into the highest possible level.

R2. Network Segmentation

R-2.1 Resources with different criticality levels must be located in different security zones. A security zone with high-impact resources is a high-impact zone. A security zone with medium-impact resources is a medium-impact zone, and a security zone with low-impact resources is a low-impact zone.

R-2.2 Each security zone must have one or more security gateways (see the glossary) with access controls.

R-2.3 Communications between two different security zones must be routed through the security gateways with access controls.

R-2.4 Communications between systems or resources in the high-impact zone and a system/resource in the low-impact zone must be routed through a demilitarized zone (DMZ; see the glossary).

R-2.5 Communications to and from an external network must be routed through a DMZ.

R3. Boundary Protection

R-3.1 Access controls in security gateways should be configured to deny a connection request from a lower security zone to a higher security zone by default.

R-3.2 Security gateways at the boundary of high-impact zones must be monitored on a 24/7 basis in order to detect security events that can negatively impact the operation of systems or resources in the security zone.

R-3.3 Security gateways interfacing with external networks must be monitored on a 24/7 basis in order to detect security events that can negatively impact the operation of resources located in the internal network.

R4. Communication Partitioning

R-4.1 DER communications to and from high-impact resources must be physically or logically partitioned from other types of communications.

R-4.2 Communications required for the administration of network infrastructure must be physically or logically partitioned from other types of communications.

R5. Network Service Protection

R-5.1 Network access control: network infrastructure supporting DER communications must allow only authorized resources or systems to join the network.

R-5.2 Administrative access control: an application, device, or tool used for the administration of network infrastructure must have one or more strong access control mechanisms in place to prevent unauthorized physical or logical access.

R-5.3 Secure name/address resolution service: systems providing name/address resolution to high-impact-level resources must have a technical mechanism to prevent forging or manipulating of DNS data.

R-5.4 Denial-of-service protection: high-impact resources must be protected from a denial-of-service attack or distributed denial-of-service attack through both technical controls and an emergency response service agreement.

R6. Communication Integrity

R-6.1 All DER communications must be protected with a mechanism to verify the authenticity of each resource or system participating in the communication.

R-6.2 All DER communications must be protected with a mechanism to verify the integrity of messages between the resources or systems participating in the communication.

R-6.3 DER communications to and from a high-impact resource must be protected with a mechanism to detect illegitimate alteration of messages between resources connected to the network.

R-6.4 Network infrastructure supporting DER communications must support the communications integrity requirements specified in R6.1–R6.3.

R7. Communication Confidentiality

R-7.1 End-to-end protection of confidentiality means that the data payload is encrypted using a cryptographic mechanism with sufficient security strength at the data source and is not decrypted until it reaches its final destination.

R-7.2 DER communications to and from high-impact resources must be protected end-to-end using a unique cryptographic key for each end-point.

R-7.3 DER communication traversing an external network must be protected end-to-end using a unique cryptographic key for each end-point.

R-7.4 DER communication between two systems or resources with different owners must be protected end-to-end using a unique cryptographic key for each end-point.

R-7.5 Network infrastructure supporting DER communications must support the communication confidentiality requirements specified in R7.1–R7.4.

IMPLEMENTATION GUIDE

This section elaborates on the requirements in the previous section by demonstrating their use in a reference architecture that represents a DER aggregation network implementation.

Note: *To focus the discussion on the security architecture and related requirements, this report uses a simplified criticality categorization based purely on the nameplate real-power rating of the DER, where less than 10 kW is considered low impact, 10 kW or more but less than 100 kW is considered medium impact, and more than 100 kW is considered high impact (see Table 1). In real-life applications, the criticality rating must be assessed based on a thorough impact analysis of the resources with multiple evaluation criteria.*

Table 1 – Example criticality rating criteria (Must be developed by DER managing entity.)

Criticality Rating	Real-Power Nameplate Rating
Low-impact	< 10 kW
Medium-impact	10–99 kW
High-impact	> 100 kW

RISK-BASED NETWORK DESIGN (R1–R4)

A basic DER aggregation network, illustrated in Figure 1, consists of multiple independent DERs, each with its own nameplate rating and local control system, monitored and controlled by a centralized control system. Independently, each DER might have a different criticality; however, when they can all be controlled simultaneously by the same managing system (or headend), criticality must be evaluated at the aggregate group level (R1.3), and the same criticality is then assigned to each component in the group.

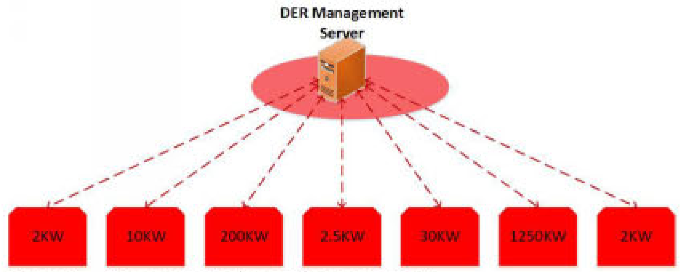

Figure 1 – Nonsegmented central management

In this architecture, some DERs on their own might be low-impact (that is, 2 kW or 2.5 kW), some might be medium-impact (10 kW or 30 kW), and some might be high-impact (200 kW and 1250 kW). However, their aggregate is 1496.5 kW, and they can all be controlled by the same managing system, which places the entire network and each of its component resources squarely in the high-impact criticality categorization. By changing the network topology, the design can be adjusted to reduce the risk posed by various elements and allow the use of appropriate security controls for elements with different risk profiles, as shown in Figure 2.

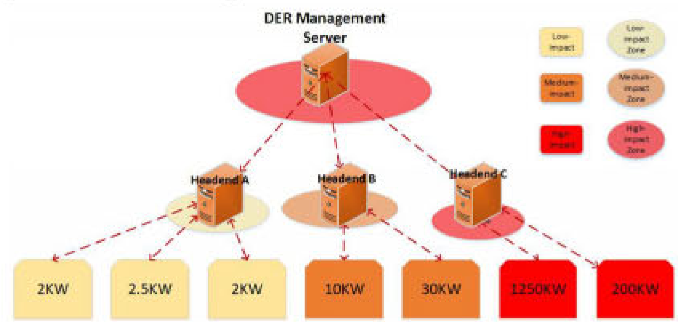

Figure 2 – Segmented central management

R1. Resource Criticality Level

The first step in implementing the proposed architecture in accordance with the preceding requirements is to divide the components into zones based on risk. Resources are grouped such that all the resources in the group share the same criticality classification and the aggregate criticality of each group is the same as the criticality of the resources in it.

A level of indirection needs to be introduced into the control path in order to truly separate the groups of resources and avoid assigning the same criticality to all of them. This can be accomplished by using a separate headend for each group, as shown in Figure 2. Each headend then has the aggregate criticality of the group it controls. All headends typically connect to a centralized control system, which is assigned the criticality of the aggregate of all groups it can control. In the sample architecture shown in Figure 2, the managing system controls three groups of DERs—low-impact, medium-impact, and high-impact.

There can be instances where a distributed energy resource can be included in multiple groups if it can be controlled by different headends. In that case, the distributed energy resource should be assigned the criticality of the highest rated group in which it is included. Note that this will raise the criticality of any other group in which the resource is included, so this situation should be avoided if possible.

R2. Network Segmentation

R-2.1 *Resources with different criticality levels must be located in different security zones. A security zone with high-impact resources is called a high-impact zone. A security zone with medium-impact resources is a medium-impact zone, and a zone with low-impact resources is a low-impact zone.*

Once resources have been divided into groups of various criticality levels, they need to be located in separate security zones so that each zone contains only systems of the same criticality. This allows the same security controls to be applied uniformly to all systems in the zone and creates logical interfaces between zones where network traffic can be inspected and controlled.

A zone is typically defined as one or more subnets or broadcast domains where a device in the zone can communicate with other devices within the zone freely, but access to/from devices outside the zone is controlled. When defining a zone, it is necessary to identify each device that should be part of the zone (that is, each device that is part of the same criticality group), identify each communications network to which it is connected, and then identify all other devices on that same network—for example, all devices connected to the same subnet or virtual local area network (VLAN) on an Ethernet switch or all devices connected to the same service set identifier (SSID) or wireless local access network (WLAN) on an 802.11 wireless access point.

Note that in some cases, a particular subnet, VLAN, or so on might be connected to other networks without any type of access control between them. For example, a layer 3 switch may freely route traffic between different VLANs/subnets defined on it if it has an Internet protocol (IP) addresses on each defined VLAN/subnet. In some cases, this might be allowed if all the VLANs/subnets are supposed to be within that zone. In some cases, some of the VLANs/subnets belong to a different zone, and access control will need to be imposed in some manner. Note that in the latter example, the underlying network device (such as a switch or wireless access point) could contain multiple zones of different criticality and must be assigned the criticality of the most critical zone on the device; this has implications for the location of the management interface, as covered in the following.

There are typically multiple options for how the segmentation is done—through separate hardware, VLANs, virtual routing and forwarding (VRF), virtual switches in a hypervisor, and so on. The tradeoff is typically between cost, flexibility, and probability of compromise—that is, a virtual switch in a hypervisor provides a low-cost, flexible solution, arguably with a higher probability of compromise due to the complexity and larger attack surface of the hypervisor; separate physical switches are a relatively expensive, inflexible solution (each new zone requires a new switch), but with a minimal probability of compromise due to the physical separation. There is no right or wrong approach, but the implementer must weigh the pros and cons of each solution for their particular design and risk level.

As shown in the architecture illustrated in Figure 3, the central management systems will typically consist of multiple zones containing headends of various criticality levels and a zone containing the core managing system, which will have the highest criticality of all the zones. Field device networks might be simple and contain only a single zone (such as a 1-kW residential solar installation with a single smart inverter), or they might be a replica of the central managing system with multiple zones of different criticalities, as shown in Figure 4. An example is a university campus with a variety of DER, battery storage, demand response capability, and a campuswide control network.

R-2.6 *Each security zone must have one or more security gateways with access controls.*

R-2.7 *Communications between two different security zones must be routed through the security gateways with access controls.*

New systems should be designed with this type of zoning built in—that is, each zone should contain only devices with the same level of criticality. Existing systems might require some redesign—some devices might need to be moved to different zones. Note that systems or devices that are not part of the DER control ecosystem but that may communicate with the managing system for the purposes of supplying it with data or collecting data from the managing system should be located in separate zones (that is, not in the distributed energy resource management [DERMS] zone) because they also have a different level of criticality.

In practice, this means that each device in the zone can be connected only to the network(s) in the zone. A device cannot be multihomed such that one connection on the device is inside one zone and another is in another zone, unless that device is acting as a security gateway—that is, unless it has some mechanism for controlling what traffic is allowed to move between zones.

When a zone is mapped or designed (all the networks and devices in the zone are identified), all connections to other zones must also be identified, and an appropriate security gateway must be installed at each such connection point. In some cases, some connection points might be eliminated or consolidated to reduce the number of gateways that need to be installed. The gateway(s) should then be sized to handle the expected amount of traffic without creating a large delay or congestion.

A security gateway is typically implemented as a firewall; however, it could also take the form of a router, layer 3 switch, cellular modem, radio, and so on—essentially, any device with the ability to control incoming and outgoing traffic based on some predefined ruleset. In some cases, this could also be a virtual firewall integrated into a virtualized environment.

In the reference architecture depicted in Figure 4, firewall 1 controls access between the managing system in the high-impact zone and headend in the medium-impact zone and another high-impact zone. Firewall 2 controls access between the DMZs and the communications network to the DERs. Note that the actual

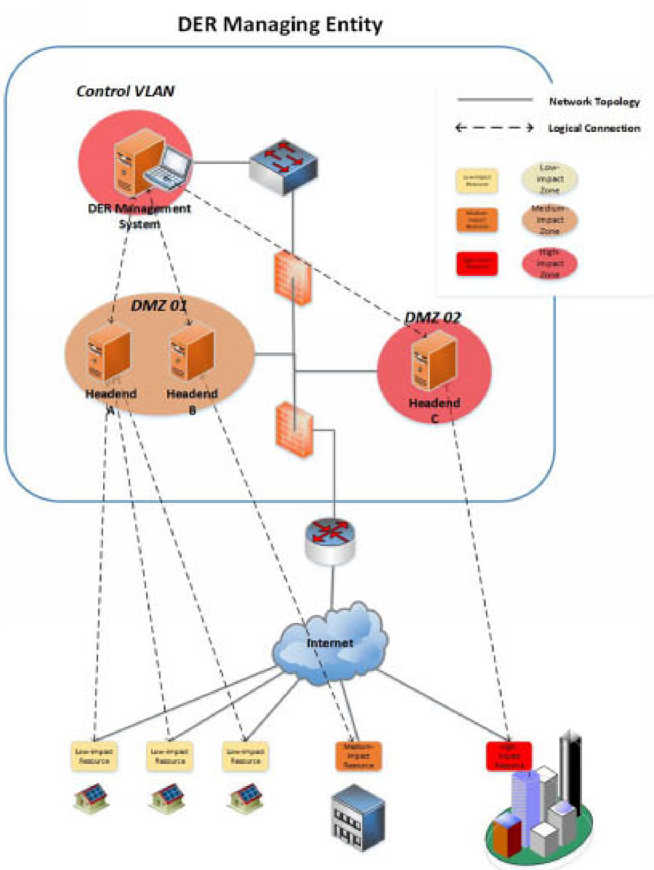

Figure 3 – R2, Network Segmentation

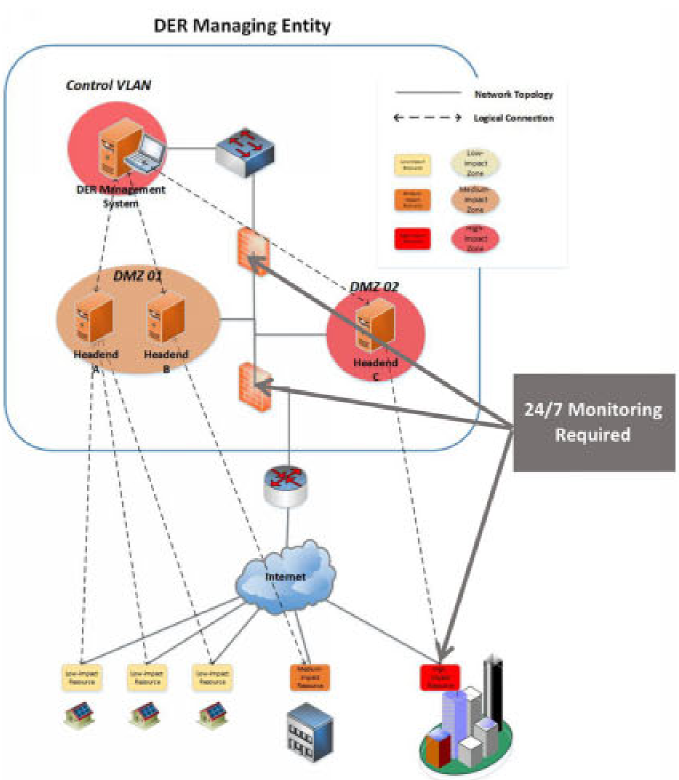

Figure 4 – Boundary protection

implementation of the two firewalls could vary significantly (such as two physical firewalls, a single firewall with multiple connections, virtual firewalls inside a physical firewall, or virtual firewalls inside a virtualization cluster) without impacting the end result—that all traffic between zones must go through a security gateway that determines whether the traffic is allowed based on some predefined ruleset.

R-2.8 *Communications between a system/resource in the high-impact zone and a system/resources in the low-impact zone must be routed through a DMZ.*

R-2.9 *Communications to/from an external network must be routed through a DMZ.*

Where devices with a high-impact rating need to communicate with devices with a low-impact rating (for example, the managing system in Figure 3 communicating with low-impact residential DER) or communications need to traverse an external communications network (for example, the Internet in Figure 3), a level of indirection and additional filtering needs to be incorporated in the design in the form of a DMZ (DMZ01 and DMZ02 in Figure 3). The DMZ is a separate network zone where traffic entering and exiting the DMZ is controlled by the relevant security gateways, but an additional level of control/traffic filtering is exerted by the devices inside the DMZ. Whereas security gateways often perform only rudimentary control/filtering at layers 3 and 4 (such as source/destination IP, layer 4 protocol and destination port), the DMZ systems perform filtering based on a deep packet inspection at layers 5–7 and might perform some conversion (for example, from proprietary, vendor-specific protocols to industry standards such as DNP3) to provide an additional level of security and reduce the likelihood of compromise of the more critical systems.

DMZ filtering can be performed by an application proxy server or communications server and will typically be specific to the systems and protocols used. In the reference design, headends A–C perform the duties of the DMZ filtering systems.

R3. Boundary Protection

R-3.4 *Access controls in security gateways should be configured to deny a connection request from a lower-security zone to a higher-security zone by default.*

Communications should always be initiated in a higher criticality zone—for example, a device in a high-criticality zone should initiate communications to devices in a medium-criticality zone, never the other way around. To make sure that this is the case, any security gateways between zones of different criticality should always have a rule that blocks connections initiated by devices in the lower criticality zone. In some devices, this is implicit based on a built-in hierarchy of zones, but it is best practice to explicitly create a "deny any any" rule to make sure that this is the case. Note that responses to traffic originating in the higher security zone are typically automatically allowed by so-called *stateful firewalls*—that is, the firewall maintains a table of connections that were initiated in the higher security zone and automatically allows related traffic in the opposite direction. It should therefore not be necessary to implement rules allowing connections to be initiated from the lower criticality zone into the higher criticality zone, unless there is a specific technical need for this (such as an unsolicited DNP3 event reporting over User Data Protocol [UDP]).

In Figure 4, traffic should be blocked from the Internet to the DMZs and from the DMZs to the managing system. It should be allowed in the opposite direction only. Typically, there is no need for traffic between the various DMZs, but should it be required, traffic should be blocked from DMZ01 to DMZ02 and allowed to initiate only in the opposite direction.

R-3.5 *Security gateways at the boundary of high-impact zones must be monitored on a 24/7 basis to detect security events negatively impacting the operation of systems or resources in the security zone.*

R-3.6 *Security gateways interfacing with external networks must be monitored on a 24/7 basis to detect security events negatively impacting the operation of resources located in the internal network.*

Security gateways at the boundary of a high-impact zone or those interfacing to an external communications network need to be monitored 24/7 to detect security events that could negatively impact the systems inside the high-impact zone or the internal network. Typically, this means sending the logs from the gateways to a log aggregator or security information and event manager (SIEM) where they can be inspected, analyzed, and alerted/acted on by automated rules or manual inspection. The level of reporting will vary based on the type of gateway used—for example, a simple firewall might detect and report on attacks at only layers 2–4, whereas a firewall with integrated intrusion detection system (IDS) or intrusion prevention system (IPS) might detect and report a much larger range of events. Typically, the monitoring should be done by a 24/7 security operations center, and, if feasible, the logging should be done out of band or be separated from the distributed energy resource's monitoring/control traffic. A management network as described in the following could be an appropriate location for security gateway monitoring traffic, although it might be necessary to implement some type of quality-of-service capability to ensure that the monitoring traffic does not create a denial of service (DoS) for the management traffic.

In Figure 4, firewalls 1 and 2 as well as the security gateway at the Level H DER resource need to be monitored on a 24/7 basis.

R4. Communications Partitioning

R-4.3 *DER communications to/from must be physically or logically partitioned from other types of communication.*

Communications from high-impact or medium-impact resources must be physically or logically separated from other types of communications (such as low-impact resources, corporate IT traffic, and so on). Essentially, this type of traffic needs to be on physically separate networks (separate switches, wireless access points, and so on); where this is not feasible, it must be separated from the other traffic using technologies such as VLANs, VRFs, and virtual private networks (VPNs) such that it is not possible for the lower-security/lower-priority devices to communicate with or interfere with the higher-security/higher-priority devices. Typical implementations include the following:

- Dedicated network equipment (such as switches) for larger installations where this can be justified.
- Shared network equipment with dedicated VLANs or VRFs for traffic with different levels of criticality where dedicated equipment cannot be justified (such as smaller installations where none of the networks requires the port density or bandwidth provided by a typical managed switch). Traffic between levels is routed through a security gateway through either a single trunk port that carries multiple VLANs or dedicated "uplink" ports for each criticality level.
- VPNs where higher-criticality traffic must cross a lower-criticality/security zone to get to its destination—for example, traffic from a high-criticality managing system to a high-criticality distributed energy resource travelling across the Internet.

In the reference architecture in Figure 5, a dedicated switch is used to segregate high-impact zones (such as control VLAN) from other zones, a shared switch uses VLANs to segregate the corporate VLAN from the DB VLAN, and VPN should be used to segregate DER traffic across the Internet from all other Internet traffic.

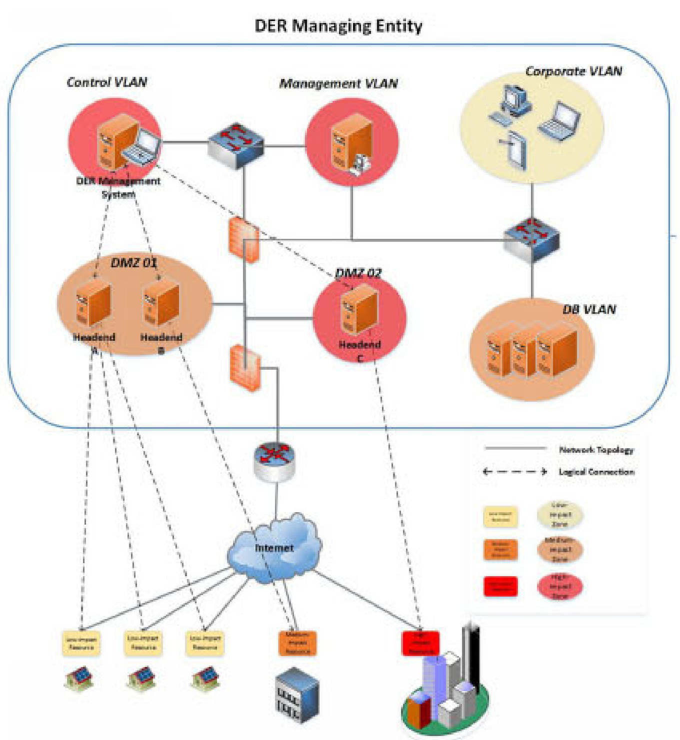

Figure 5 – Communication partitioning

R-4.4 Communications required for the administration of network infrastructure must be physically or logically partitioned from other types of communication.

Similarly, administration traffic (such as configuration [SSH, HTTPS, SNMP], logging [syslog, SNMP traps], AAA (RADIUS, TACACS+, Kerberos, LDAP]) must be segregated from all other types of traffic. Many devices will have a dedicated physical port that is used for management; where that is the case, this port should be connected to a separate network used purely to manage the network equipment. In some cases, such a dedicated port is not available (such as a wireless access point or microwave radio); however, the management traffic can be isolated to a separate VLAN. In such cases, the management VLAN should be configured and routed to a management network at the next piece of equipment capable of doing so (an upstream switch, for example). Note that administration ports/networks of equipment with different levels of criticality and/or equipment connected to external communications networks should not be directly connected to the same management network; this can break segmentation if a misconfiguration occurs. Multiple management networks can be created for different criticality levels and connected through a security gateway to ensure that traffic is still controlled and monitored appropriately.

The reference architecture in Figure 5 shows a management VLAN for several switches and firewalls. Although all the management is likely to be done from one management console, ideally, the management traffic for the low-impact and high-impact switch passes through a security gateway before it reaches the high-impact management console. Similarly, if the internet router were managed from the same console, any management traffic to/from that router should pass through a security gateway.

RISK-BASED NETWORK SERVICE PROTECTION (R1, R5)

R-5.1 Network access control—network infrastructure supporting DER communications must allow only authorized resources to join the network.

The underlying network infrastructure should be configured to allow only authorized resources to join/connect to the network—that is, a new device attempting to connect to the network needs to identify itself and be authenticated before it is allowed to communicate on the network.

At minimum, on a wired Ethernet network, this should consist of disabling unused Ethernet ports and using media access control (MAC) address-based port locking. Similarly, on an 802.11-based wireless network, this should include at least a WPA2 password and MAC address filtering. If it is supported by the devices being connected, 802.1X authentication using EAP-TLS with a unique certificate for each device should be used on either type of network. Additional "host checks," such as malware prevention updates or patch level, may be done by a network access control (NAC) system prior to allowing the device on the network (subject, of course, to device capability). At a physical level, it might be possible to simply prevent (or at least deter) connection to wired networks by locking cabinets, implementing port locks for both used and unused ports, and so on.

Other types of (wireless) networks will have varying types and levels of device authentication that should be enabled to prevent rogue devices from being connected.

Depending on the complexity of the NAC being used, this could require the configuration of specific devices that act as the NAC server(s). These devices should be a) redundant to minimize outages and b) treated as network management systems and located on the network management network, away from non-administrative traffic. Where possible, the NAC solution should also report connection attempts to a centralized log server or SIEM (on a management network) for correlation, alerting, and response.

R-5.2 Administrative access control—an application, device, or tool used for the administration of network infrastructure must have one or more strong access control mechanisms in place to prevent unauthorized physical or logical access.

Any device used to administer the network infrastructure (that is, a network management console) must use two or more authentication mechanisms to prevent unauthorized access. Typically, this would include more than just a password, which can be intercepted or stolen during usage or storage, and would include something that the user physically possesses (a token with one-time password, phone with the appropriate application, or so on) or, less commonly, the user's biometrics. Multiple factors should be used to access the management console, regardless of whether it is being accessed locally (physically) or over the network (logically).

Each type of authentication method typically requires a separate authentication server, which should be redundant and treated with the same level of criticality as the network management systems or higher—that is, the authentication servers could reside in the same management network, or they could be moved to an even more secure authentication network to minimize the likelihood of compromise.

R-5.3 Secure name/address resolution service—systems providing name/address resolution to high-impact-level resources must have a technical mechanism to prevent forging or manipulating of DNS data.

Attackers can use poorly secured name resolution services (that is, domain name system [DNS]) or address resolution services (such as address resolution protocol [ARP]) to redirect traffic to compromised or malicious hosts. Securing these services reduces the likelihood of compromise by ensuring that users (systems) relying on them do not access such malicious hosts by accident.

Where possible, DNS servers should be configured to use DNS security extensions (DNSSECs) to cryptographically sign records and prevent DNS spoofing or cache poisoning. For internal domains, this will generally require the creation and out-of-band distribution of trust anchors because the zone will probably not be signed by the "parent." Note that the private keys used to sign zones (and so on) should be stored offline to minimize the likelihood of compromise. DNS servers should reside in high-criticality or management zones, and access should be controlled by the appropriate security gateways. DNS servers should be configured to serve only the zones for which they are authoritative and never act as recursive resolvers for other zones; that functionality should be delegated to separate caching resolvers.

At the address resolution level, there are no security features built into existing mechanisms (that is, ARP, NDP). Instead, the solution will need to rely on ARP/NDP spoofing protection built into the network equipment being used and might need to be combined with NAC to some extent. For instance, network equipment or NAC might be able to detect ARP/NDP advertisements for IPs that are already associated with other ports or devices, and/or they might block gratuitous ARP/NDP advertisements altogether. Equipment should at the very least be configured to detect such spoofing attempts and report on it to a centralized log server or SIEM and, where possible (and safe), block such attempts and report on them as well. Because this functionality is highly dependent on the equipment being used, implementors will need to review the features available in their equipment and configure it accordingly.

Other networking technologies might offer more robust address resolution protocols that prevent or minimize the likelihood of spoofing. These should be deployed where possible.

R-5.5 Denial-of-service protection—high-impact resources must be protected from denial-of-service attack or distributed denial-of-service attack through both technical controls and emergency response service agreement.

There are no perfect solutions for preventing or mitigating DoS or distributed denial-of- service (DDoS) attacks; however, some level of protection should be provided for high-impact resources. It is difficult to attack something that you cannot get to, so the first option should be to not make high-impact systems accessible to the general public by avoiding public internet and relying on private networks—utility-owned fiber, third-party MPLS, private APNs, and so on. Where this is not possible, the resource should rely on a combination of camouflage, communications redundancy, router/firewall features designed to minimize the damage caused by a DoS/DDoS attack, third-party DoS/DDoS mitigation services, and manual intervention, as follows:

- **Camouflage.** The resource should not be advertised through DNS to anyone other than systems with a legitimate need to know where it is and should not respond to any network traffic other than preconfigured headend IP addresses.
- **Communications redundancy.** The resource should use redundant communications through different providers (with completely different IP addresses) to minimize the likelihood of a simultaneous attack against both connections.
- **Router/firewall features.** Routers and firewalls connecting the resource to the source of the attack should have features for throttling the attack, blackholing attack traffic, and so forth. These can be used to mitigate some attacks to some extent, although without communications redundancy, they might also impact regular communications due to high resource usage on the mitigating device.
- **Third-party DoS/DDoS mitigation services.** These services can be obtained from the communications provider or an independent third party and consist of scrubbing and diversion of bad traffic using much more powerful systems in the provider's network and by passing only the "good traffic" onto the target system.
- **Manual intervention.** Manual response to a DoS/DDoS attack should be the last resort, and the details will be highly dependent on the type and source of the attack and the available resources. It might, for example, include specific ACLs to block traffic, tuning network equipment to limit connection attempts, disconnecting an affected network link (assuming that communications redundancy is in place), and so on. Manual response might also be coordinated with upstream providers and other third parties.

RISK-BASED DATA INTEGRITY PROTECTION (R1, R6)

Data integrity protection must include three key components—a mechanism for authenticating each participant in the conversation (R6.1), a mechanism to verify the integrity of the communications (R6.2), and a mechanism to detect illegitimate or unauthorized alterations of the communications to/from high-impact resources (R6.3). All these components require a cryptographic mechanism.

R-6.1 All DER communication must be protected with a mechanism to verify the authenticity of each resource or system participating in the communication.

This requires handshake or authentication that positively identifies both sides. This should be based on proven, peer-reviewed protocols and algorithms using unique credentials (such as certificates) for each device. Typically, this handshake also yields a key or keys that can be used to sign messages to ensure their authenticity.

R-6.2 All DER communications must be protected with a mechanism to verify the integrity of messages between the resources or systems participating in the communication.

R-6.3 DER communications to/from high-impact resources must be protected with a mechanism to detect illegitimate alteration of messages between resources connected to the network.

R-6.2 and R-6.3 require cryptographic hash or checksum to allow recipients to calculate the hash themselves and verify that it matches the hash sent with the message. The hash must use a proven, peer-reviewed algorithm that has the five properties of an ideal cryptographic hash (deterministic, fast, pre-image, second pre-image, and collision-resistant). The hash is typically signed using a key determined during the initial authentication handshake or a subsequent rekeying activity.

The implementation of the preceding can be accomplished through well-known, well-supported protocols, such as TLS, DTLS, IPsec, and SSH. The parties should agree on protocol versions, cipher suites, key length and rotation, and so on, that support the desired level of security, taking into account industry guidance such as that provided by the National Institute of Standards and Technology (NIST). A public key infrastructure (PKI) will need to be implemented to support this level of security. The PKI components should be treated as H criticality management devices and protected as such. DNSSEC and DNS-Based Authentication of Named Entities (DANE) can be useful in eliminating the need for a PKI hierarchy based on certificate authority (CA).

All cryptography provides some level of overhead and might have some minimum timing requirements. The network infrastructure design must take this into consideration (R6.4)—that is, the network must have sufficient bandwidth, speed, reliability, and so on to allow the cryptography to be used without impacting the timely and reliable delivery of the actual control and monitoring data. Some modelling and field testing might need to be performed to ensure that this is the case, particularly under adverse conditions, such as a large rate of data updates or interference. Any such modelling and testing should account for a realistic amount of growth in the number of devices on the network, the amount/frequency of the data being transmitted, and so on.

In the reference architecture in Figure 6, communications between the managing system and the headends in the DMZs as well as communication between the high-impact DMZ and the high-impact DER (over the Internet) all require message alteration detection and integrity controls.

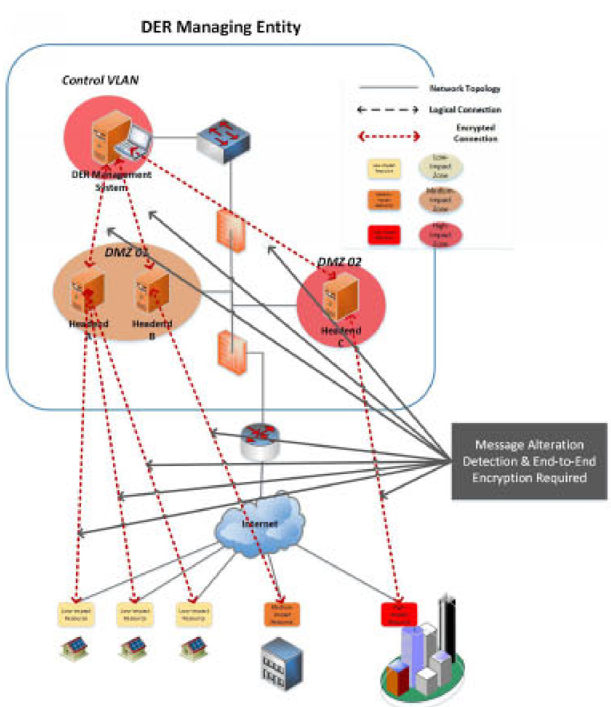

Figure 6 – Communication integrity and communication confidentiality

RISK-BASED DATA CONFIDENTIALITY PROTECTION (R1, R7)

Some DER data might be confidential and should not be exposed to unauthorized parties for various reasons, including because the data might provide key details that could be used to compromise individual DERs or the grid in general. To prevent such unauthorized exposure, DER communications should be encrypted at a minimum when the communications involve an H-level resource or traverse an external network (such as the Internet), or when the resource on each end has a different owner. Encryption needs to be end to end; that is, only the two end-points can read the contents of the message, and the message is illegible to all other devices along the communications path.

Similar to integrity, confidentiality requires cryptography—in this case, to encode the contents of a message in a way that only a device with the correct key can decode and read the message. In general, DERs should use proven, peer-reviewed cryptographic protocols and algorithms (and, where possible, well-known and well-reviewed implementations) to avoid unknown weaknesses in design or implementation. Protocols such as TLS, DTLS, SSH, and IPsec are obvious candidates for such end-to-end encryption. The implementation should use certificate-based PKI for both end-points such that every end-point has its own keypair and associated certificate to make revocation simpler. The same considerations outlined in the integrity section for selecting secure protocol versions, ciphers, key lengths, and so on apply here. Where DNSSEC is available, DANE can be an alternative to traditional CA-based PKI—that is, certificates are signed by the zone owner and stored in DNS, eliminating the need for a CA-based signing hierarchy.

The security considerations for the PKI infrastructure outlined in the integrity section apply here as well, as do the performance considerations for the underlying network. Encryption adds more overhead than integrity checking and must be considered when designing the communications system.

Note that end-to-end encryption creates a level of blindness for IDSs along the communication path. There are some ways to enable the inspection of encrypted traffic, but all such mechanisms degrade the security to a certain degree by exposing private keys to intermediary devices. Careful considerations must be given in weighing the pros and cons of this approach.

REFERENCE ARCHITECTURE

The requirements R1–R7 are applicable for all levels of network architecture, including local networks. Figure 7 shows the overall reference architecture with two local networks.

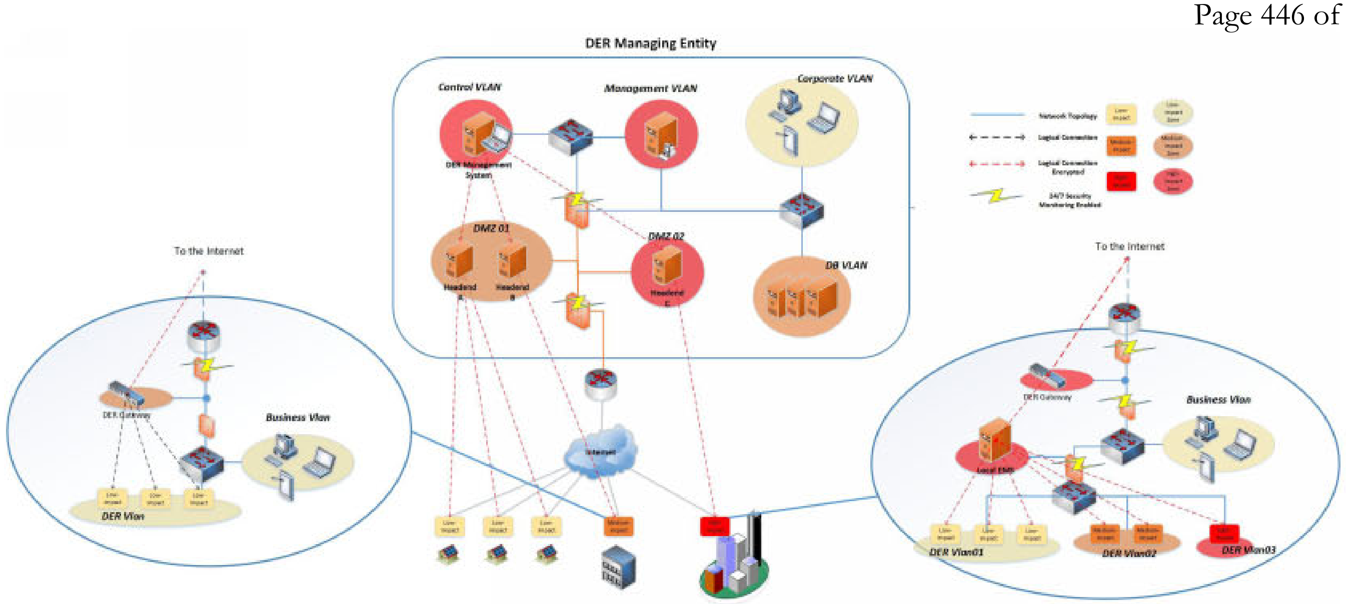

Figure 7 – Risk-based security architecture: local networks

COMPLIANCE CHECKLIST

To aid implementation and assessment, this section provides checklists for each requirement described in this report.

R1. RESOURCE CRITICALITY LEVEL

- Have all resources been identified and categorized correctly?
- Have all headends been identified and associated with all resources that they can operate simultaneously?
- Have all resources that can be operated by each headend been categorized based on the aggregate impact of the entire group?
- Have all resources that can issue write/control commands to other resources been identified? Have all such resources been categorized based on the aggregate impact of the resources that they can control?
- Have all possible categorizations for each resource been identified? Has each resource been categorized with the highest possible level?

R2. NETWORK SEGMENTATION

1. Identify the networks to which each resource is connected.
2. For each network identified in Step 1:
   a. Identify all other devices on the network.
   b. Identify all connections from the devices on each network to other networks.
3. Identify all security zones, and determine which networks belong to each zone.
4. Validate that all devices in a given security zone have the same criticality level.
5. Validate that all devices that connect to networks in two or more security zones are security gateways.
6. Review the configuration of each interzone security gateway, and validate that it has access controls that allow only required communications between zones.
7. Review the configuration of each interzone security gateway, and validate that if it connects an H, M, or L zone and an external network, there are no rules that would allow direct communications between the two—that is, all communications between the two pass through a third DMZ zone.
8. Validate that communications passing through each DMZ are filtered at open system interconnection (OSI) layers 5–7.

R3. BOUNDARY PROTECTION

1. Review the access controls in each interzone security gateway, and ensure that they are configured to deny communications from a lower security zone to a higher security zone by default.
2. Review each security gateway that connects directly to a high-security zone, and ensure that a mechanism exists for monitoring/reviewing all security events on a 24/7 basis, either directly on the security gateway or through an aggregator. Ensure that personnel are assigned to monitor/review the events on a 24/7 basis and have access to the relevant mechanism.
3. Review each security gateway that connects directly to an external network and carries data to/from a high security zone, and ensure that a mechanism exists for monitoring/reviewing all security events on a 24/7 basis, either directly on the security gateway or through an aggregator. Ensure that personnel are assigned to monitor/review the events on a 24/7 basis and have access to the relevant mechanism.

R4. COMMUNICATIONS PARTITIONING

1. Identify all network devices (switches, routers, wireless access point, and so on) connected to each medium or high resource.
2. Validate that each identified network device has only resources with the same categorization connected to it.
3. If a network device has resources with different categorizations connected to it, review the configuration of the network device and validate that the device has been logically partitioned such that resources connected to it can communicate only with other resources with the same categorization without passing through a security gateway (for example, the network device has been configured for multiple VLANs, VRFs, and so on that cannot communicate with each other directly).
4. Identify all security gateways connected to each high and medium security zone.
5. Enumerate communications to high and medium security zones.
6. Trace the communications paths from end to end, and validate that there are no other communications on the same physical media or that the other communications are logically partitioned (VLANs, VRFs, VPNs, and so on).
7. Identify each management/administration interface on each network device—such as a switch, router, firewall, or wireless access point.
    a. If the management-administration interface is physical, validate that it is on a separate physical network from non-administration traffic.
    b. If the management-administration interface is not physical, validate that it is logically partitioned from non-administration traffic—for example, by VLANing, access control rules, and so on.

R5. NETWORK SERVICE PROTECTION

1. Identify each network that is part of a DER zone, and identify all network devices on each such network to which a device can connect.
    a. For each identified network and network device, validate that a method exists for ensuring that only authorized devices can connect to/join the network—such as MAC address locking/filtering, WPA2 shared secret, 802.1X with EAP-TLS, or an NAC device or software.
2. Identify all devices and applications used to manage the network infrastructure. For each device or application:
    a. Review the user authentication mechanism.
    b. Validate that the user mechanism requires two or more factors to authenticate (that is, something you know [password], something you have [token, certificate], or something you are [biometrics]).
3. Determine whether DNS is being used. If it is, validate that DNSSEC is enabled and configured for all zones containing resources with high criticality.
4. Identify all network devices that are connected to resources with high criticality.
    a. For each such device, validate that it is configured to detect and prevent ARP cache poisoning (or its equivalent if a protocol other than ARP is used).
    b. Determine whether any mechanism/devices are in place to monitor for and respond to or alert on ARP cache poisoning (or its equivalent if a protocol other than ARP is used).
5. For each high-criticality zone:
    a. Validate that there is a mechanism for detecting DoS/DDoS attacks within the zone and isolating the source.
    b. Validate that each security gateway connected to the zone has DoS/DDoS mitigation measures (such as rate limiting) enabled.
    c. Validate that other DoS/DDoS mitigation mechanisms exist on upstream networks (particularly external networks) and with upstream providers.
    d. Validate that redundant paths through different providers exist, where feasible.
    e. Validate that incident response/business continuity plans include processes for dealing with DoS/DDoS attacks.

R6. COMMUNICATION INTEGRITY

1. Identify all communication paths/streams from each distributed energy resource. For each identified communication path/stream:
    a. Validate that a mechanism exists for each participant in the communication to authenticate the other participants.
    b. Validate that each participant can verify the integrity of messages from other participants.
    c. If one of the participants is categorized as a high, validate that each participant can detect illegitimate/unauthorized changes to message from other participants.
2. Validate that all network infrastructure that messages in item 1 traverse has sufficient capacity, appropriate latency, and so on to allow consistent use of the mechanisms in items 1a–1c, including under adverse conditions.

R7. COMMUNICATIONS CONFIDENTIALITY

1. Identify all communication paths/streams from each distributed energy resource. For each identified communication path/stream, if one of the participants is categorized as high, the path includes an external network, or the participants have different

owners, ensure that the messages are encrypted by one participant and can be decrypted only by the other participants and each participant uses a unique key.

2. Validate that all network infrastructure components that messages in item 1 traverse has sufficient capacity, appropriate latency, and so on to allow the consistent use of the mechanisms in item 1, including under adverse conditions.

GLOSSARY

802.11. Set of media access control and physical layer protocols for implementing wireless local area networks.

802.1X. Standard for port-based network access control; provides an authentication mechanism to devices wishing to attach to a wired or wireless local area network.

Access Control List (ACL). A set of permissions attached to some object; in the context of this report, a list of permissions defining what types of communications are allowed through a security gateway.

Address Resolution Protocol (ARP). A protocol used to determine the link layer address associated with an IP address under IPv4.

Authentication, Authorization, Accounting (AAA). Refers to family of protocols that mediate network access.

Certificate Authority (CA). An entity that signs certificates used to authenticate devices or users.

Datagram Transport Layer Security (DTLS). A protocol used to secure communication using User Datagram Protocol (UDP) as its transport protocol.

Demilitarized Zone (DMZ). Any intermediary network between networks with highly disparate security provisions (such as a DERMS and the Internet). Typically, traffic into and out of the DMZ is highly controlled, and systems within the DMZ perform additional filtering or transformation of the traffic before passing it onto the ultimate recipient.

Denial of Service/Distributed Denial of Service (DoS/DDoS). An attack that exhausts a computing resource (such as the CPU, memory, disk space, or network bandwidth) in order to temporarily or indefinitely disrupt service.

Distributed Energy Resources (DER). Resources connected to a distribution network that provide real power and, optionally, ancillary services.

Distributed Energy Resource Management System (DERMS). A set of software and hardware used to manage one or more DER.

Distributed Network Protocol, Version 3 (DNP3). A protocol commonly used in the electric industry to communicate between SCADA/DERMS headend systems and field equipment.

DNS-Based Authentication of Named Entities (DANE). A protocol used to bind digital certificates to domain names using DNSSEC without the need for a certificate authority.

DNS Security Extensions (DNSSEC). Suite of specifications for securing information provided by the DNS.

Domain Name System (DNS). System and protocol used to translate human-readable domain names to IP addresses and vice versa.

Extensible Authentication Protocol—Transport Layer Security (EAP-TLS). Part of an authentication framework used to authenticate devices in wired or wireless networks using transport layer security to authenticate the device attempting to connect.

Hypertext Transport Protocol Secure (HTTPS). A secure extension of the hypertext transport protocol used to deliver Web pages and Web applications; in the context of this report, used for Web-based management/administration interfaces to network devices.

Internet Protocol (IP). A protocol used to deliver data on most modern networks; versions 4 (IPv4) and 6 (IPv6) are in use today.

Internet Protocol Security (IPsec). An extension of the Internet protocol used to provide security features, such as integrity and confidentiality.

Intrusion Detection/Prevention System (IDS/IPS). Software or hardware used to detect (and prevent) attempts to gain unauthorized access to a system or network.

Kerberos. A protocol used to authenticate users, services, or devices.

Lightweight Directory Access Protocol (LDAP). A protocol used to access directory information services; typically used to authenticate and/or obtain authorization information about a user, service, or system.

Media Access Control (MAC) layer address. The address of a device at the media access layer (Ethernet, for example); typically programmed into the device in the factory.

Neighbor Discovery Protocol (NDP). A protocol used under IPv6 for various purposes, including resolution of IPv6 addresses to link layer addresses, such as an Ethernet MAC addresses.

Network Access Control (NAC). Software or device used to control which devices are allowed to connect to/join a network and under what circumstances.

Open System Interconnection (OSI) model. A conceptual model for network communications using a set of seven layers, with various functions at each layer.

Public Key Infrastructure (PKI). A set of roles, policies, procedures, and systems for managing digital certificates and the associated private keys used for authenticating systems, users, services, and so on.

Quality of Service. A set of features and protocols used to prioritize traffic and enforce/guarantee the performance of network-based services.

Remote Authentication Dial-In User Service (RADIUS). A protocol used to provide authentication, authorization, and accounting services for users who connect to a particular device.

Secure Shell (SSH). A network protocol used to administer systems in a secure manner.

security gateway. A device, such as a firewall, that applies controls to network traffic between devices and networks.

Security Information and Event Management (SIEM). Software or systems used for monitoring and real-time analysis of security events created by systems and applications.

Security Operations Center (SOC). A facility where security-related events from one or more enterprise information systems are monitored, analyzed, assessed, and dispositioned.

Service Set Identifier (SSID). An identifier used to announce the presence of an 802.11-based network.

Simple Network Monitoring Protocol (SNMP). A network protocol used to monitor and administer network devices.

syslog. A network protocol used to deliver log messages to a central server for storage and analysis.

Terminal Access Controller Access—Control System Plus (TACACS+). Protocol used to provide authentication, authorization, and accounting services for users who connect to a particular device.

Transport Layer Security (TLS). A network protocol used to secure communications that use the Transport Control Protocol (TCP) as their transport layer protocol.

Virtual Local Area Network (VLAN). A logical partition of a physical network at the data link layer; typically works by applying tags to network frames, with the tags used by network devices to isolate devices in different partitions.

Virtual Private Network (VPN). A protocol and related software used to encapsulate (and encrypt) network traffic in a manner that allows the extension of secure networks across a less secure intervening network.

Virtual Routing and Forwarding (VRF). Technology that allows multiple instances of a routing table to coexist in the same router, effectively creating separate routing domains in the same network infrastructure.

Wi-Fi Protected Access, Version 2 (WPA2). A set of security protocols used to authenticate devices on an 802.11 WLAN and secure the traffic between them and the access point.

Wireless Local Area Network (WLAN). Wireless computer network; in the context of this report, a virtual wireless network with a separate SSID on a wireless access point with multiple such WLANs.

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