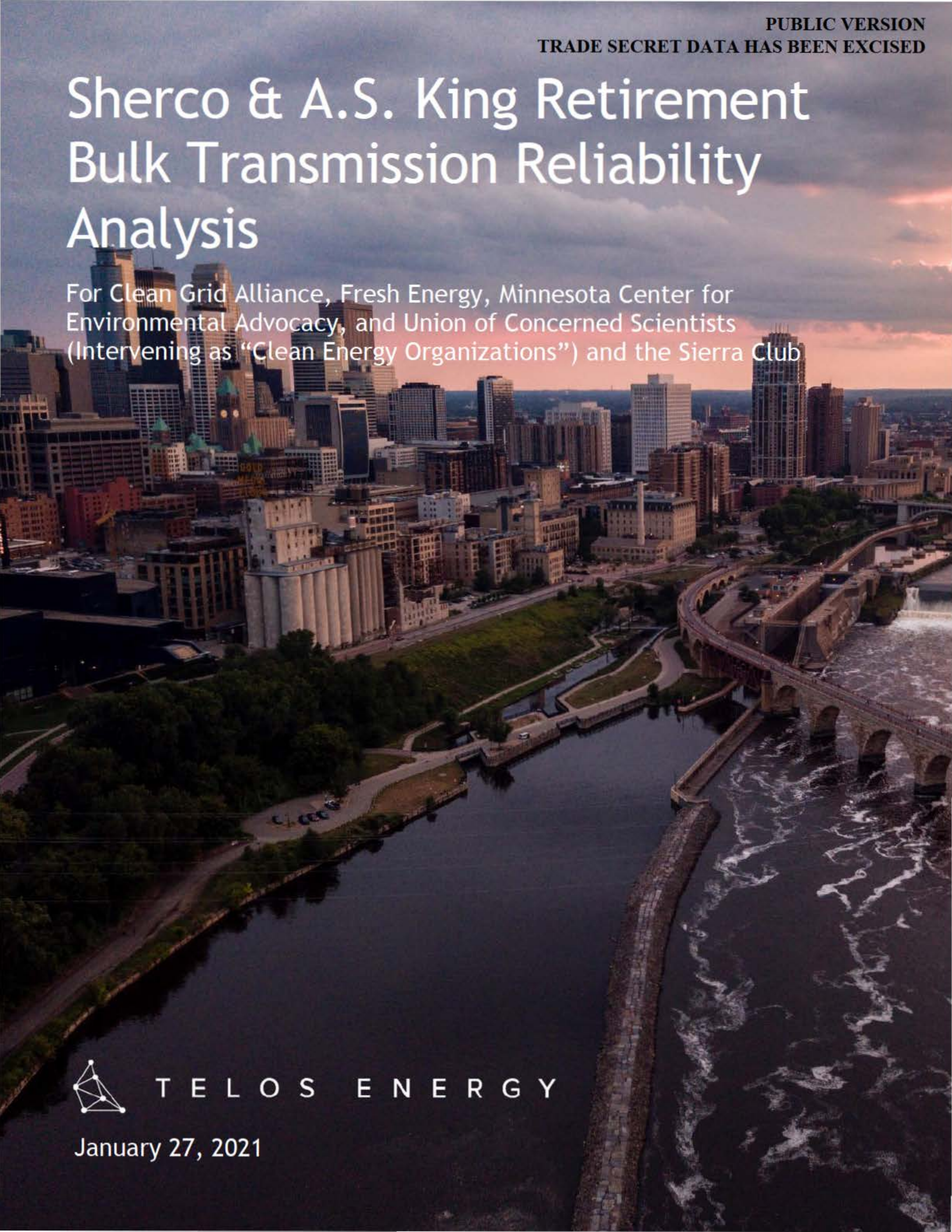
PUBLIC VERSION
TRADE SECRET DATA HAS BEEN EXCISED

Sherco & A.S. King Retirement Bulk Transmission Reliability Analysis

For Clean Grid Alliance, Fresh Energy, Minnesota Center for Environmental Advocacy, and Union of Concerned Scientists (Intervening as "Clean Energy Organizations") and the Sierra Club



TELOS ENERGY

January 27, 2021

Sherco & A.S. King Retirement Bulk Transmission Reliability Analysis

For Clean Grid Alliance, Fresh Energy, Minnesota Center for Environmental Advocacy, and Union of Concerned Scientists (Intervening as "Clean Energy Organizations") and the Sierra Club

Minnesota PUC Docket 19-368

Contact Information

Matthew Richwine
Founding Partner
Telos Energy, Inc.
518-396-6412

Revision History

Revision	Date	Author	Comment
Rev 0	January 27, 2021	M. Richwine	Original Release

Table of Contents

1 Executive Summary

The purpose of this analysis is to assess reliability challenges related to the retirement of Xcel's remaining coal-fired generation in the greater Twin Cities region, and to examine whether Xcel's proposed Sherco combined cycle gas plant would cost-effectively mitigate any such reliability issues. Telos Energy, Inc. (Telos) conducted this analysis by updating and extending three previous Y-2 studies[1],[2],[3] conducted between 2015 and 2018 that focused on the retirement of Xcel Energy's (Xcel) coal units in the region.

In 2015, Xcel first requested that MISO screen for reliability issues associated with their proposal to retire the Sherburne County ("Sherco") units 1 and 2 in the year 2024 ("Sherco 1&2 Only Y-2" or "2015 Y-2").[4] Xcel has subsequently relied in large part on reliability issues identified in the 2015 Y-2 as showing a reliability need for a new combined cycle gas plant at the Sherco site.[5] That study also identified voltage issues at the Monticello nuclear plant resulting from the Sherco 1&2 retirements. At that time, Xcel also requested that Siemens study the replacement of Sherco 1&2 with a 1,500 MW combined cycle power plant ("Siemens Report"). In 2018, Xcel requested that MISO study the reliability impacts of retiring all three of the Sherco coal units as well as the A.S. King coal-fired power plant in 2030 ("Full Retirement Y-2" or "2018 Y-2"). Telos reviewed all three studies, but the 2018 Y-2 is the most relevant given that Xcel has proposed to retire all of its remaining coal units in the current IRP process.

Table 1: Summary of Previous Studies of Xcel Coal Plant Retirements

Study	MISO Y-2	Siemens Replacement Report	NSP Y-2 Study
Short Study Name	"2015 Y-2"	"Siemens Report"	"2018 Y-2"
Year of Report	2015	2016	2018
Unit Retirement Considered	Sherco 1 in 2021; Sherco 2 in 2024	Sherco 1&2 in 2020	Sherco 3, King in 2030; (Sherco 1&2 retired already)
Mitigation Considered	Transmission Upgrades	New 1,500 MW Combined Cycle Plant	New Sherco 786 MW Combined-Cycle Plant

[1] System Support Resource Attachment Y2 Study Final Report, MISO. Xcel Energy, The Sherburne County Generating Plant ("Sherco") Units 1 & 2, August 28, 2015 ("2015 Y-2 Study"), CEO IR 029

[2] Sherco 1 and 2 Replacement Power Study, Siemens PTI Report Number: R067-15, Prepared for Xcel Energy Services, Inc. January 22, 2016 (CEII Redacted) ("2016 Siemens Report"), CEO IR 030

[3] IRP Part 4, Appendix J3 [original]; Attachment Y-2 Study Report, A.S. King Unit 1 and Sherburne County Unit 3 Retirement 5/31/2027, NSP Energy Marketing. November 14, 2018 ("2018 Y-2"), Docket No. E002 / RP19-368

[4] See supra note 1

[5] "Supplement, 2020-2034 Upper Midwest Integrated Resource Plan," Northern States Power Company. Section 3: Supplement Preferred Plan. Docket No. E002/RP-19-36, page 64, June 30, 2020 ("Siting a CC at the existing Sherco site will cost-effectively address grid issues identified by the MISO Attachment Y2 study of the Sherco Unit 1 and 2 retirements".)

Telos conducted an "AC Contingency Analysis" to identify potential violations of the regional transmission system's reliability standards that might result from either the retirement of Sherco 1&2 or the retirement of all of Xcel's remaining coal units. An AC Contingency Analysis is commonly performed by transmission system planners, and follows a methodology that is consistent with the methodology used in Xcel's 2015 and 2018 Y-2 studies, as well as the guidelines specified by the MISO Business Practices Manual[6] for conducting Y-2 studies to analyze generator retirements. The primary input to Telos' analysis was the MISO MTEP19 powerflow database.

Telos' primary focus was on reviewing and refining the 2018 "Full Retirement" Y-2 to assess the bulk transmission reliability impacts of the proposed Sherco Combined-Cycle (Sherco CC) power plant (2 gas turbines and 1 steam turbine) if all of Xcel's remaining coal units are retired. Telos modeled the Sherco CC as having a 786 MW power rating, consistent with Xcel's 2018 Y-2 study.[7] The details of Telos' analysis of the "Full Retirement" scenario, and Telos' findings from that analysis, are presented in Section 5.1. Telos also analyzed the reliability impacts of retiring only Sherco 1&2 using updated inputs from the MTEP19 database. The details of this analysis are presented in Section 5.2.

Telos' Report finds that, in the case of the retirement of all of Xcel's remaining coal units, the addition of the Sherco CC plant did not materially decrease the number or severity of bulk system reliability violations. While Telos' analysis identified the need for several transmission reinforcements prior to 2029 – as did the 2018 Y-2 analysis – Telos found that the addition of the Sherco CC did not solve or reduce any significant reliability issues or violations.

MISO's Attachment Y evaluation criteria[8] quantitatively define which transmission system violations are considered "valid" and which are not. Valid violations, according to the MISO process, are those in which the presence of the generator considered for retirement has a significant impact on the violation magnitude. On the other hand, violations that are roughly the same magnitude regardless of the presence of the generator considered for retirement are not considered valid. Telos' analysis of the "Full Retirement" scenario identified a total of 63 elements of the grid showing voltage or thermal violations occurring when all of Xcel's remaining coal units are retired, similar to Xcel's findings in its 2018 Y-2 study. Our analysis also found, however, that none the identified violations would be resolved by the addition of the Sherco CC plant, and are therefore considered not valid by the MISO Attachment Y criteria.

Similarly, our analysis of the Sherco 1&2 Only scenario identified 6 moderate thermal or voltage violations, and found that typical mitigation measures such as operational adjustments or, in some cases, line upgrades, would be expected to resolve the violations. Importantly, for both scenarios, our analysis found that voltage issues that the MISO 2015 Y-2 study had identified at the Monticello plant

[6] Generator Retirement and Suspension Studies and System Support Resources (SSR), Section 6.2. *MISO Business Practices Manual, Transmission Planning Manual No. 020*. Revision 22, May 1, 2020
[7] Note that in the Xcel IRP Supplement, Xcel states that the Sherco CC could have a rating of up to 835MW. "Supplement, 2020-2034 Upper Midwest Integrated Resource Plan," Northern States Power Company. Docket No. E002/RP-19-368, Page 6. June 30, 2020.
[8] Generator Retirement and Suspension Studies and System Support Resources (SSR), Section 6.2. *MISO Business Practices Manual, Transmission Planning Manual No. 020*. Revision 22, May 1, 2020

are no longer present, with the exception of one small (0.53%) change-in-voltage violation at the 13.8kV Monticello bus that could be mitigated through operational adjustments.

Our analysis concludes that there are no major obstacles or grid reliability concerns associated with retirement of Xcel's remaining coal units, although several more minor transmission system mitigations and upgrades will likely be required. We further conclude that a new combined cycle power plant at the Sherco site would not mitigate or materially reduce any of the identified reliability issues with the "Full Retirement" of all Xcel coal units.

2 Introduction

The purpose of Telos' analysis is to provide a screening of reliability challenges and potential mitigations related to two future scenarios that include the retirement of Xcel's coal-fired generation in the greater Twin Cities region. This analysis updates and extends two previous Y-2 studies conducted in 2015 and 2018 that focused on the retirement of Xcel's coal-fired units in the region.

2.1 Full Retirement Scenario: When Sherco and King plants are retired, would the addition of the Sherco CC provide reliability system benefits?

The main scenario Telos studied examines the impact of the proposed Sherco Combined-Cycle (Sherco CC) plant to the regional grid in the year 2029 under a future in which Xcel retires all of its remaining coal units (Sherco 1-3 and A.S. King plants) in the greater Twin Cities region ("Full Retirement Scenario"). Xcel proposed the Sherco CC plant in its 2018 Y-2 study as a 786 MW plant comprised of two gas turbines and one steam turbine.

Telos' analysis builds upon Xcel's 2018 Y-2 study by evaluating the bulk transmission system reliability impact with and without the Sherco CC in service. Telos' analytical methodology follows the MISO Y-2 study process, and compares two cases – one with the Sherco CC plant and one without the Sherco CC – to assess the reliability impacts of the Sherco CC. Telos' analysis also updates the 2018 Y-2 study by including new solar photovoltaic (PV) plants. Xcel detailed a "preferred plan" for future renewable generation expansion in its IRP Supplement document, which includes 2500 MW of new solar PV plants installed by 2029.[9] As such, our analysis compares two cases:

1) A "reference case" that includes:
    a. All Xcel coal units off-line
    b. Solar additions as proposed in Xcel's preferred plan, and
    c. The proposed Sherco CC; and
2) A "change case" that includes:
    a. All Xcel coal units off-line
    b. Solar additions as proposed in Xcel's preferred plan, but
    c. Does not include the proposed Sherco CC

[9] "Supplement, 2020-2034 Upper Midwest Integrated Resource Plan," Northern States Power Company. Section 3: Supplement Preferred Plan. Docket No. E002/RP-19-368. June 30, 2020.

In addition, Telos updated the underlying grid model from the previous Y-2 studies for purposes of this analysis. These updates include:

- Upgrading from MISO's MTEP17 powerflow database, which the 2018 Y-2 study[10] used, to the MTEP19 database. The MTEP19 database contains updates to planned generation and transmission projects, which affect the results of the study.
- The addition of 2,500 MW of new Solar PV projects based on the Xcel IRP Supplement. In our analysis, we represented this 2,500 MW of new solar generation as five 500 MW projects, each producing 250 MW of power in each case. The 50% power production assigned to the new PV projects is consistent with both MISO's dispatch of other solar PV for summer and shoulder cases as well as with the approach cited by the MISO Planning Subcommittee[11] in June 2020.
- Xcel's 2018 Y-2 study examined reliability issues based on a 2030 model year (i.e., it looked at reliability issues that might arise in the year 2030). However, the MTEP17 powerflow database is only a 10-year database that looks out to 2027, so Xcel took the MTEP17 2027 inputs and scaled load to represent 2030. However, Xcel did not commensurately scale up generation and transmission projects. As a result, Xcel's modeling inputs included increased load without increased generation and transmission. In contrast, Telos' analysis uses 2029 as the future study year, which is a year included in the MTEP19 database, and so the 2029 load, generation and transmission information is taken directly from MTEP19 without alteration.

As stated above, the purpose of the Full Retirement scenario is to provide a direct comparison of system reliability with and without the Sherco CC Plant, proposed at 786 MW and located at the existing Sherco site. Telos applied the Attachment Y study methods described by the MISO Business Practices Manual on Transmission Planning[12] as well as MISO's MTEP19 database for its analysis.

2.2 Sherco 1 & 2 Only Scenario: What system reliability issues arise when only Sherco Units 1 and 2 are retired in 2024?

Telos also analyzed a scenario in which only Sherco units 1 and 2 retired in year 2024. This scenario was included for completeness as an update to the 2015 Y-2 analysis and Siemens Report[13] that examined the retirements of only Sherco 1 and 2. However, we note that the Full Retirement scenario that considers retirement for all Xcel coal units is the more relevant analysis for purposes of examining the reliability needs for the Sherco CC as part of Xcel's current resource plan. Telos once again updated the underlying modeling database from the previous Y-2 studies for this analysis. These updates include:

---

[10] IRP Part 4, Appendix J3; Attachment Y-2 Study Report, A.S. King Unit 1 and Sherburne County Unit 3 Retirement 5/31/2027, NSP Energy Marketing. November 14, 2018.
[11] "Wind / Solar Generation Dispatch Assumptions In The Reliability Planning Models," MISO Planning Subcommittee, June 23, 2020.
https://cdn.misoenergy.org/20200623%20PSC%20Item%2004c%20Wind%20Solar%20Gen%20Dispatch%20Assumptions453933.pdf Retrieved September 23, 2020.
[12] MISO Business Practices Manual, Transmission Planning Manual No. 020. Revision 22, May 1, 2020.
[13] System Support Resource Attachment Y2 Study Final Report, MISO. Xcel Energy, The Sherburne County Generating Plant ("Sherco") Units 1 & 2, August 28, 2015, and
Sherco 1 and 2 Replacement Power Study, Siemens PTI Report Number: R067-15, Prepared for Xcel Energy Services, Inc. January 22, 2016 (CEII Redacted)

- The 2015 Y-2 study and Siemens Report were based off the MISO MTEP14 and MTEP15 powerflow databases. Telos used the MISO MTEP19 powerflow database, which contains updates to planned generation and transmission projects.
- Importantly, the MTEP19 database reflects an expanded voltage tolerance at the Monticello Nuclear Plant. Monticello's voltage tolerance (that is, the variation in voltage that can occur at the Monticello plant buses without causing concerning violations) was updated in the Monticello Nuclear Power Interface Requirements[14] (NPIR) document released in May 2019, with the agreement of both Xcel, the generator owner, and Great River Energy (GRE), the transmission operator. This official change to the voltage tolerance requirements at Monticello is important because the previous Y-2 studies identified dozens of voltage violations at the Monticello plant based on the old, more restricted Monticello NPIR voltage tolerances. The changes with the Monticello violations are discussed in more detail in Section 5.2.

3 Analysis Methodology

The analysis performed herein is consistent with the analysis performed in Xcel's 2015 and 2018 Y-2 studies, as well as the Siemens Report.[15] [16] [17] First, all examined the impact to the same set of Transmission System Operators (TSOs): Xcel, Great River Energy (GRE), Minnesota Power (MP), American Transmission Company (ATC), Dairyland Power Cooperative (DPC), Southern Minnesota Municipal Power Agency (SMMPA), Ottertail Power (OTP). Our analysis also examines summer peak and shoulder cases for the study years considered, as did the 2016 (Siemens) and 2018 Y-2 studies.

Second, Telos' analysis considered NERC planning contingencies consistent with NERC TPL-001-4. These include the base case (P0) as well as P1, P2, P4, P5, and P7 contingency categories. This is consistent with the 2015 and 2016 Y-2 studies. Both of those studies noted that the transmission system operators had not provided P3 and P6 contingencies, just as P3 and P6 contingencies were not available for Telos' analysis.[18]

---

[14] Nuclear Plant Operating Agreement (NPIR) for Monticello Nuclear Generating Plant, dated May 1, 2019, between Northern States Power Company and Great River Energy.

[15] System Support Resource Attachment Y2 Study Final Report, MISO. Xcel Energy, The Sherburne County Generating Plant ("Sherco") Units 1 & 2, August 28, 2015

[16] Sherco 1 and 2 Replacement Power Study, Siemens PTI Report Number: R067-15, Prepared for Xcel Energy Services, Inc. January 22, 2016 (CEII Redacted)

[17] IRP Part 4, Appendix J3; Attachment Y-2 Study Report, A.S. King Unit 1 and Sherburne County Unit 3 Retirement 5/31/2027, NSP Energy Marketing. November 14, 2018.

[18] Note that the 2018 Y-2 study acquired P3 and P6 contingency datasets from the other TSOs. Telos' analysis considered all of the contingency datasets that were available from the MISO MTEP database in order to provide as complete an analysis as possible. Further, while the P3 and P6 contingencies from the 2018 Y-2 study were redacted for Critical Energy Infrastructure Information (CEII) purposes, the overloaded elements listed (buses and transmission lines) also showed up in the results of Telos' analysis, indicating that overloaded elements of the transmission system are revealed through evaluating contingency categories other than P3 and P6. The consistency between our analysis and the 2018 Y-2 study indicate that it is highly unlikely that P3 or P6 contingencies result in any transmission violations that are substantial enough as to require mitigation from a large new thermal plant, like the Sherco CC.

One important difference between the previous Y-2 studies and Telos' analysis is that the voltage violation criteria applied for the Monticello Nuclear Plant, as specified in its Nuclear Power Interface Requirements (NPIR) document,[19] were updated in May 2019, after the previous Y-2 studies were performed. In the updated NPIR document, the acceptable voltage tolerance for the 115kV bus increased on the low-voltage side. Telos used the updated NPIR criteria for Monticello in its analysis.

Third, Telos used the same definitions for violations for thermal and voltage issues as MISO used in its Y-2 studies. For each thermal and voltage violation identified in our evaluation, there is a validation threshold defined in the MISO Business Practice Manual[20] for determining whether a violation caused by a generator retirement is considered "valid." The Attachment Y reliability evaluation criteria are as follows:

Thermal:

- Normal (P0): The difference in MW flow on a transmission element (i.e., on a line or transformer) between the pre-retirement case and the post-retirement case must be greater than 5% of the retired generator rating
- Contingency (P1-P7): The difference in MW flow on a transmission element between the pre-retirement case and the post-retirement case must be greater than 3% of the retired generator rating

Voltage:

- Contingency (P1-P7): The difference in voltage at each bus (substation) between the pre-retirement case and post-retirement case must be greater than 1%.

The details of the violation criteria for each transmission system operator (TSO), nuclear power plant, and a brief background description of voltage and thermal violations are contained in the Section 12.

Telos performed its analysis using Siemens PTI's PSSE power system simulation software package. This is the same software tool that was used to perform the previous Y-2 studies and it is the same software tool that MISO uses extensively in its transmission planning studies.

4 Scenario Preparation

For both scenarios, Telos prepared the pre-retirement and post-retirement scenarios in a manner consistent with the MISO Business Practices Manual No. 20 for Transmission Planning, which establishes the methodology for Attachment Y-2 analysis. This process is described further in this section.

---

[19] A Nuclear Power Interface Requirements (NPIR) document is a formal document required by the North American Electric Reliability Council's (NERC) reliability standard NUC-001 to ensure coordination between nuclear plant generator operators and transmission entities. The reliability standard was established in 2013 and requires both parties to create and abide by a set a mutually agreed requirements like voltage limits, operating scenarios, configurations, etc.

[20] MISO Business Practices Manual, Transmission Planning Manual No. 020. Revision 22. Section 6.2.5. May 1, 2020.

Full Retirement Scenario

To prepare the cases representing the Full Retirement scenario, which assesses the reliability impacts of the proposed Sherco CC, Telos used the MTEP19 "2029 summer" and "shoulder (40% wind)[21]" cases as a starting point. Telos then removed all three Sherco coal units from service, as well as the A.S. King unit. Then, utility-scale solar PV resources were added to the case based on Xcel's Preferred Plan Resource Additions[22], as shown in Figure 1.

Figure 3-2: Supplement Preferred Plan Resource Additions

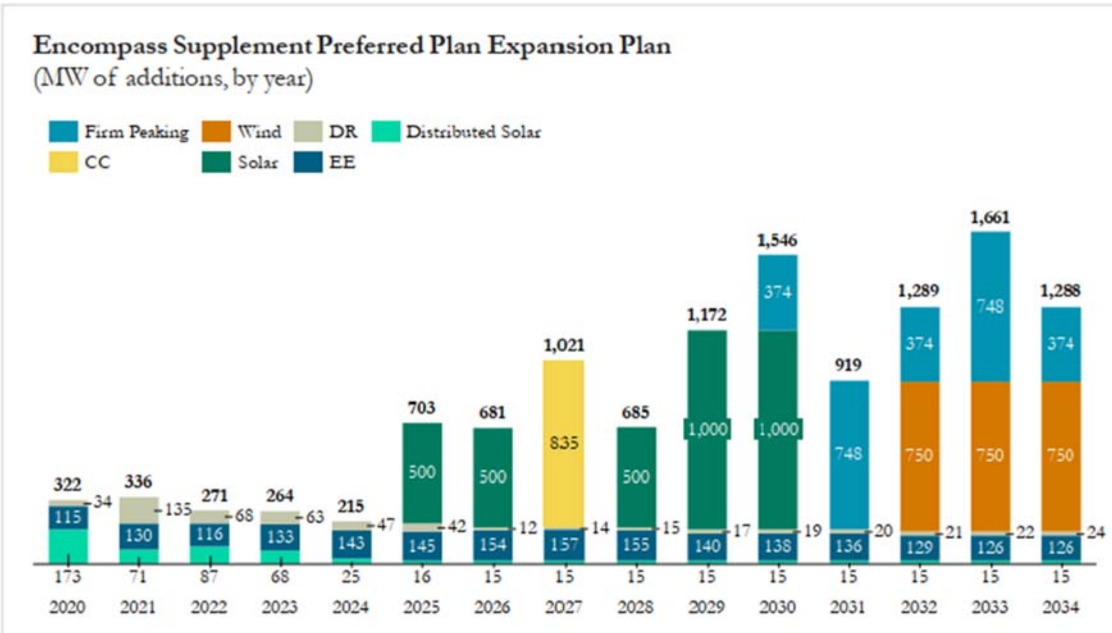


Figure 1: Xcel's Preferred Plan for Resource Additions

To capture the solar PV project additions from the Xcel IRP Supplement preferred expansion plan, each solar plant was modeled in an industry-standard fashion: as an aggregate generator with a lumped step-up transformer and a 0.95PF reactive capability range. Each solar plant was modeled as regulating voltage at its low-voltage bus. The interconnection locations were selected on the 345kV transmission system at locations not directly within the metropolitan area which are assumed to be land-constrained, but at locations that are less populated. Each of the new solar PV plants were dispatched at 50% of their rated capacity. The 50% power production assumption for solar PV plants in 2029 is derived from MISO

[21] The "shoulder 40% wind" case is one of two shoulder cases developed by MISO as part of the MTEP19 database. The other shoulder case is "shoulder 90% wind." The percentage of wind indicates the output of all wind resources in the powerflow case. The 40% wind case was selected for Telos' analysis to be conservative regarding the availability of variable resources for an analysis of thermal generation retirements. In this report, "shoulder case" refers to the 40% wind shoulder case.

[22] "Supplement, 2020-2034 Upper Midwest Integrated Resource Plan," Northern States Power Company. Section 3: Supplement Preferred Plan. Docket No. E002/RP-19-368. Page 62. June 30, 2020.

practice,[23] and is consistent with the dispatch of all of the other solar PV plants in the summer and shoulder cases from the MISO MTEP19 database. Telos modeled generic solar PV plants as presented in Table 2, below.

Table 2: Solar PV Resource Additions for the Primary 2029 Scenario

Generic PV Plant Name	Rating	Interconnection Bus	2029SUM Case Dispatch	2029SH40 Case Dispatch
PV1	500 MW	Sherco 345kV	50 %	50 %
PV2	500 MW	Chisago 345kV	50 %	50 %
PV3	500 MW	Scott County 345kV	50 %	50 %
PV4	500 MW	Benton 345kV	50 %	50 %
PV5	500 MW	Alexandria 345kV	50 %	50 %

To assess the reliability impact of adding the Sherco CC plant to the transmission system, for each of the two 2029 cases (summer peak and shoulder), Telos evaluated them: 1) with the Sherco CC in service; and 2) with the Sherco CC not in service. Telos then compared the resulting violations from the contingency analysis for each case. If the analysis shows that the same violations that appeared without the Sherco CC persist with the Sherco CC in-service, then one can conclude that the Sherco CC did not mitigate those violations. On the other hand, if the analysis shows that the number of violations decrease when the Sherco CC is put in-service, then one can conclude that the Sherco CC is an effective mitigation for the specific violations that were resolved by the addition of the Sherco CC.

Sherco 1&2 Retirement Only Scenario

In our assessment of the retirement of just the Sherco 1 and 2 units, we used the MTEP19 database's 2024 "summer" and "shoulder" cases as a starting point. Telos then removed the Sherco 1 and 2 units from service. Telos then increased other generation in the region and brought other thermal generating units online only when necessary to restore the power balance between generation and load in MISO. Telos selected the units brought online, beginning with combined-cycle plants, which are considered to be the next lowest-cost units. Available plants were brought on in the Xcel territory first, then proceeding to bring online other plants from nearby owners. The additional dispatch and commitment are generally aligned with an economic merit order, though it is acknowledged that further economic optimization is possible.[24] The resulting case established the post-retirement case without Sherco Units 1 and 2. From the post-retirement case, the pre-retirement case was created by placing the units back in-service and backing down or decommitting other generation in the region until the power balance is restored. The thermal and voltage violations resulting from the Sherco Units 1 & 2 retirements were analyzed.

[23] MISO Planning Subcommittee meeting on Wind and Solar Dispatch Assumptions held in June 2020. https://cdn.misoenergy.org/20200623%20PSC%20Item%2004c%20Wind%20Solar%20Gen%20Dispatch%20Assumptions453933.pdf

[24] The additional step of economically optimizing the order of dispatching additional generation would not be expected to materially change the reliability findings from this analysis.

Additional Telos Study Methodology Information

In all scenarios and all cases, Telos did not adjust renewable (wind, solar, or hydro) production between the pre-retirement and post-retirement cases so that the MISO renewable output assumptions remain intact. Only thermal generation is adjusted, with resource dispatch priority based generally on economic merit.

Consistent with the MISO Y-2 methodology, in the summer cases for both the partial and full retirement scenarios, Telos modified the area interchanges to allow increased imports from TSOs adjacent to Xcel, or decreased exports to areas adjacent to Xcel. Existing thermal generation was turned on and/or increased in adjacent areas so that additional power could flow to the loads in the Xcel territory. In the shoulder cases for both the partial and full retirement scenarios, no changes were made to area interchanges because these cases had sufficient generation within the Xcel area to replace the power from the retired units.

5 Telos' Results

In this section, we present the results of our analysis for both the Full Retirement and Sherco 1&2 Only scenarios, which are further sub-divided into summer and shoulder cases. We also summarize the voltage and thermal violations found for each case and for each overloaded element of the transmission system.

The Contingency Label for all cases is redacted for distribution of this document, as it is considered Critical Energy Infrastructure Information (CEII).

5.1 Full Retirement Scenario

The Full Retirement Scenario examines the impact of the proposed Sherco CC plant to the regional grid in the year 2029 under a future in which Xcel retires all of its remaining coal units as described in Section 2.1.

Table 3: Description of Sherco & King Unit Retirement ("Full Retirement") Scenario

Scenario	Year Studied	Model	Case 1	Case 2	Change in Generation Resources from MTEP19
All Sherco & King retired	2029	MTEP19	2029 Summer Peak	2029 Shoulder (40% Wind)	Added 2,500 MW of Solar PV; Evaluation with and without Sherco CC

5.1.1 "Summer" Case

Voltage Violations

The model did not identify any valid voltage violations that were resolved by the addition of the Sherco CC. While the model identified 24 buses as having voltage violations in the summer case without the Sherco CC, each violation was also found to be present with the Sherco CC in service. The difference between the voltage violations without the Sherco CC and the violations with the Sherco CC was so small (less than 1%) as to be considered insignificant and deemed not valid according to the MISO Attachment Y reliability evaluation criteria.[25] For completeness, the list of buses with violations is shown in Table 8 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in voltage (%).

Thermal Violations

The model did not identify any valid thermal violations that were resolved with the addition of the Sherco CC. While 12 transmission elements (lines or transformers) were identified as having thermal violations in the summer case without the Sherco CC, the difference in power flow for each thermal violation between the case without the Sherco CC and the case with the Sherco CC was so small (less than 3% of retired generation[26]) as to be considered insignificant and deemed not valid according to the MISO Attachment Y reliability evaluation criteria. For completeness, the list of buses with violations is shown in Table 9 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in power flow as a percent of the Sherco CC MW rating.

5.1.2 "Shoulder" Case

Voltage Violations

The model did not identify any valid voltage violations that were resolved with the addition of the Sherco CC. While the model identified 25 buses as having voltage violations in the shoulder case without the Sherco CC, each violation was also found to be present with the Sherco CC in service. The difference in voltage for each voltage violation between the case without the Sherco CC and the case with the Sherco CC was so small (less than 1%) as to be considered insignificant and deemed not valid according to the MISO Attachment Y reliability evaluation criteria. For completeness, the list of buses with violations is shown in Table 10 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in voltage (%).

Thermal Violations

The model did not identify any valid thermal violations that were resolved with the addition of the Sherco CC. While the model identified 2 transmission elements (one line and one transformer) as having thermal violations in the shoulder case without the Sherco CC, the difference in power flow of each thermal violation between the case without the Sherco CC and the case with the Sherco CC was so small (less than 3% or retired generation[27]) as to be considered insignificant and deemed not valid according to the MISO Attachment Y reliability evaluation criteria. For completeness, the list of buses with violations is shown in Table 11 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in power flow as a percent of the Sherco CC MW rating.

---

[25] MISO Business Practices Manual, Transmission Planning Manual No. 020. Revision 22. Section 6.2.5. May 1, 2020.
[26] For purposes of this analysis, the Sherco CC is considered the "retired unit," and therefore, a 3% change would be 23.58MW.
[27] For purposes of this analysis, the Sherco CC is considered the "retired unit," and therefore, a 3% change would be 23.58MW.

5.1.3 Full Retirement Scenario Conclusion

While Telos' analysis identified several thermal and voltage violations in need of mitigation by 2029 (like operational adjustments, shunt compensation, and/or line reconductoring or rebuild), our analysis of the Full Retirement scenario finds that the addition of the proposed Sherco CC does not reduce the number of valid thermal or voltage violations. The Sherco CC does not materially mitigate any valid thermal or voltage violations that could be expected to arise as a result of the retirement of all Sherco coal units and the King coal unit in the 2029 scenario studied.

5.2 Sherco 1 & 2 Only Scenario

This scenario analyzed the retirement of Sherco Units 1 and 2 in the year 2024. This scenario was included for completeness as an update to the 2015 Y-2 analyses that examined the retirements of just Sherco 1 and 2.[28] [29] The Full Retirement scenario in section 5.1 above is the more relevant analysis for Xcel's current resource plan, but review of the prior Y-2 studies is also useful for reasons discussed in greater detail herein.

The previous Sherco 1 and 2 Y-2 studies identified dozens of voltage violations at the Monticello Nuclear Plant. Those studies found that when Sherco 1 & 2 were retired in 2024, the voltages at the Monticello 115kV bus fell just outside the limits set by the NPIR document that was in place at the time of the studies in 2016. Our analysis updates the previous Y-2 studies not only by updating the generation and transmission projects in the region using the MTEP 19 database, but also by incorporating updates to the Monticello NPIR in its 2019 revision, which expanded the voltage tolerance, as discussed in Section 2.2 above. With these two updates, our analysis finds few violations, none of which change the findings from the more complete Full Retirement 2029 scenario.

Table 4: Description of Sherco 1&2 Unit Retirement "Sherco 1&2 Only" Scenario

Scenario	Year	Model	Case 1	Case 2	Change in Generation Resources from MTEP19
Sherco 1&2 Retired	2024	MTEP19	2024 Summer Peak	2024 Shoulder (40% Wind)	None

5.2.1 "Summer Case"

Our analysis did not identify any voltage violations or thermal violations that are valid under the MISO reliability evaluation criteria.

5.2.2 "Shoulder" Case

This case identified more violations than did the summer case, which is to be expected given lower levels of load and therefore fewer generation assets online. However, the violations are mostly very small and likely resolvable with small operational adjustments.

[28] System Support Resource Attachment Y2 Study Final Report, MISO. Xcel Energy, The Sherburne County Generating Plant ("Sherco") Units 1 & 2, August 28, 2015.

[29] Sherco 1 and 2 Replacement Power Study, Siemens PTI Report Number: R067-15, Prepared for Xcel Energy Services, Inc. January 22, 2016 (CEII Redacted).

Voltage Violations

Four voltage violations were identified in Appendix B, Table 12; however, all are relatively small in severity, and it is expected that these violations could be mitigated through operational adjustments (like generation dispatch) or, in the worst case, may require some reinforcements, such as switched shunt capacitors. It is noted that the cost of utility-scale shunt capacitors of a size likely to manage the violation is on the order of a few million dollars, which is a small fraction ~1% of the cost of a combined-cycle plant.

Thermal Violations

Our analysis identified two valid thermal violations, listed in Appendix B, Table 13.

The most significant thermal violation is the Iron Range – Forbes 230 kV 34-mile line. Thermal violations of this line appeared in Xcel's previous Y-2 Studies, which recommended reconductoring the line to increase the rating by 12% at a cost of [**TRADE SECRET BEGINS… …TRADE SECRET ENDS**],[30] which serves as a cost estimate for mitigating this overload.

The Osseo-Hennepin 115kV line has a small overload of less than 2%. It is expected that slight adjustments to dispatch of generation can mitigate this violation.

The remaining violations do not meet the MISO Attachment Y reliability evaluation criteria because the change in load of the lines does not exceed 3% of the generation being retired (Sherco coal units 1 & 2).[31]

5.2.3 Sherco 1 & 2 Only Scenario Conclusion

While the previous Y-2 studies analyzing the Sherco 1 and 2 retirements showed dozens of voltage violations at the Monticello Nuclear Plant, those are no longer present due to updates to Monticello's NPIR thresholds, other than one minor violation. Otherwise, Telos' analysis found few violations, all of which could likely be mitigated through low-cost operational adjustments (like generation dispatch, transformer tap settings) or, in the worst case, may require some reinforcements, such as adding shunt capacitors, or potentially reconductoring for one line[32] Notably, none of the identified violations are significantly mitigated by the addition of the proposed Sherco CC because the Sherco CC does not mitigate the violations that are still found in the more complete Full Retirement 2029 Scenario.

For example, as shown in Appendix A, the Shea's Lake voltage violations and the Iron Range – Forbes thermal violation also appear in the Full Retirement Scenario for the Summer Case, both with and without the Sherco CC present. Therefore, these results clearly indicate that the voltage and thermal violations identified in both the Sherco 1 & 2 Scenario as well as in the Full Retirement Scenario are not effectively mitigated with the proposed Sherco CC plant. These violations would be more effectively

---

[30] IRP Part 4, Appendix J3; Attachment Y-2 Study Report, A.S. King Unit 1 and Sherburne County Unit 3 Retirement 5/31/2027, NSP Energy Marketing. November 14, 2018.

[31] Given that 1,460 MW of generation is retired, a 3% change is 43.8 MW.

[32] For context, all of these mitigation approaches would cost significantly less than a new combined cycle gas plant. The most expensive potential mitigation identified – a 230kV line reconductoring – is estimated to cost 2% of the cost of a new combined-cycle plant.

mitigated through routine transmission reinforcements (shunt compensation, reconductoring) applied directly at the location of the violations.

6 Overall Conclusions and Findings

The resulting voltage and thermal violations are summarized for each scenario and for each case in the following tables.

Full Retirement Scenario: All Xcel Coal Retired in 2029

This scenario analyzed system reliability with all of Xcel's coal units retired, with and without the proposed Sherco CC, in order to isolate the reliability impacts the Sherco CC would be expected to provide.

The model identified a total of 63 elements of the power system with thermal or voltage violations in the summer and shoulder cases. All of these violations were present both with and without the Sherco CC unit in-service. This indicates that the Sherco CC would not eliminate these violations. Other approaches like a combination of operational adjustments to grid power flows, shunt compensation, and/or line reconductoring are better suited to addressing each violation directly at the location that it occurs.

Table 5: Pre-Existing Violations Found Upon the Retirement of all Xcel Coal Units

	Summer	Shoulder
Thermal violations	12	2
Voltage violations	24	25

While the severity of the violation differed in cases with and without the Sherco CC in service, the differences in severity were so slight that none are considered valid under the MISO Attachment Y reliability evaluation criteria.

Table 6: Violations Resolved by the Sherco CC Plant with all Xcel Coal-Fired Plants Retired

	Summer	Shoulder
Thermal violations	0	0
Voltage violations	0	0

Therefore, Telos' analysis finds that the addition of the proposed Sherco CC offers a negligible reliability benefit to the bulk transmission system in a scenario that considers the retirement of all Xcel's coal generation (2941 MW in total) and the addition of solar PV generation (2500 MW in total) in the Greater Twin Cities region using the MISO MTEP19 database and MISO's Y-2 study methodology.

Sherco 1 & 2 Scenario: Sherco 1 & 2 Retirement in 2024

The vast majority of violations cited in the previous 2015 and 2016 Y-2 studies analyzing the Sherco 1 & 2 retirements involved the Monticello Nuclear Plant. The updates to the voltage tolerance at the Monticello 115kV bus in combination with updates from the MTEP19 database show that the voltage violations at Monticello cited in the previous Y-2 studies no longer exist, except for one small (0.53%) change-in-voltage violation at the 13.8kV Monticello bus. However, that violation is considered very minor because the bus voltage remains within the upper and lower limits set by the NPIR, and it is expected that the change-in-voltage could be mitigated through operational adjustments such as switching transformer taps or shunt compensation devices nearby.

The model identified a small number of violations, including several violations previously identified in prior Y-2 studies. The number of violations is summarized in Table 7. Furthermore, none these violations change the findings from the more complete Full Retirement 2029 scenario.

Table 7: Violations Resulting from Retirement of Sherco Units 1 and 2

	2024 Summer	2024 Shoulder
Thermal violations	0	2
Voltage violations	0	4

7 References

1. System Support Resource Attachment Y2 Study Final Report, MISO. Xcel Energy, The Sherburne County Generating Plant ("Sherco") Units 1 & 2, August 28, 2015.
2. Sherco 1 and 2 Replacement Power Study, Siemens PTI Report Number: R067-15, Prepared for Xcel Energy Services, Inc. January 22, 2016 (CEII Redacted)
3. IRP Part 4, Appendix J3; Attachment Y-2 Study Report, A.S. King Unit 1 and Sherburne County Unit 3 Retirement 5/31/2027, NSP Energy Marketing. November 14, 2018
4. MISO Business Practices Manual, Transmission Planning Manual No. 020. Revision 22, May 1, 2020.
5. Nuclear Plant Operating Agreement (NPIR) for Monticello Nuclear Generating Plant, dated May 1, 2019, between Northern States Power Company and Great River Energy.
6. "Supplement, 2020-2034 Upper Midwest Integrated Resource Plan," Northern States Power Company. Docket No. E002/RP-19-368. June 30, 2020.
7. "Wind / Solar Generation Dispatch Assumptions In The Reliability Planning Models," MISO Planning Subcommittee, June 23, 2020. https://cdn.misoenergy.org/20200623%20PSC%20Item%2004c%20Wind%20Solar%20Gen%20Dispatch%20Assumptions453933.pdf Retrieved September 23, 2020.
8. NERC Reliability Standards for the Bulk Electric Systems of North America, updated January 9, 2019.

8 Appendix A: 2029 Full Retirement Scenario Detailed Results

This appendix contains the detailed results of the analysis for the 2029 scenario. The following tables show the thermal and voltage violations that have been identified in the analysis but that are not considered valid according to the MISO Attachment Y evaluation criteria (Section 6.2 of MISO BPM-020-r22) because the change in voltage or the change in power flow between the pre-retirement case and the post-retirement case does not exceed the thresholds set by MISO; 1% change for voltage violations and 3% change (of retired generation) for thermal violations. MISO states that violations that meet this criteria are valid for justifying a unit as a system support resource (SSR) and those violations that do not meet this criteria are not valid for justifying a unit as an SSR.

Overloaded elements are transmission system buses (substations) in the case of voltage violations and transmission lines or transformers in the case of thermal violations. For each of the overloaded element identified in a row of the table, at least one contingency was found to cause the overload and the highest value of the overload is reported in the table. It is further noted that for some overloaded elements in the following tables, the overload may become slightly worse with the addition of the Sherco CC. While counterintuitive, this is a real characteristic that can result from certain changes to the grid due to the highly complex and non-linear nature of most electric transmission networks.

8.1 2029 Summer Case, Voltage Violations

Voltage violations have been identified for twenty-four buses in the 2029 summer case. However, no new voltage violations occur in the absence of the Sherco CC; all of the voltage violations found without the Sherco CC in-service were also present with the Sherco CC in-service. Moreover, the change in voltage violations that occur with the Sherco CC in-service do not meet the Attachment Y reliability evaluation criteria (1% change in voltage)[33]. As such, the change in magnitude in voltage violations with the addition of the Sherco CC is too minimal to be considered valid. Table 8 lists each voltage violation with and without the Sherco CC in service.

Table 8: 2029 Summer Voltage Violations

Bus	Contingency	Violation without Sherco CC (%)	Voltage without Sherco CC (pu)	Voltage with Sherco CC (pu)	Change in Voltage (%)	Violation Status (SSR criteria)
603158 RIV FLS7 115.00	[redacted]	7.98	0.8406	0.8402	0.04	Not Valid (< 1% change in voltage)
617725 GRE-TRIPPLK7115.00	[redacted]	6.94	0.8488	0.8506	0.18	Not Valid (< 1% change in voltage)
615421 GRE-BIRCHLK7115.00	[redacted]	5.21	0.846	0.8479	0.19	Not Valid (< 1% change in voltage)
615517 GRE-4CORNRS7115.00	[redacted]	3.96	0.8599	0.8604	0.05	Not Valid (< 1% change in voltage)
601072 SHEAS LK3 345.00	[redacted]	3.74	0.881	0.8826	0.16	Not Valid (< 1% change in voltage)
603218 SHEAS LK 7 115.00	[redacted]	3.74	0.8811	0.8826	0.15	Not Valid (< 1% change in voltage)

[33] MISO Business Practices Manual, Transmission Planning Manual No. 020. Revision 22. Section 6.2.5. May 1, 2020.

Bus	Contingency	Violation without Sherco CC (%)	Voltage without Sherco CC (pu)	Voltage with Sherco CC (pu)	Change in Voltage (%)	Violation Status (SSR criteria)
603121 LOON LK7 115.00	[redacted]	1.93	0.9004	0.9007	0.03	Not Valid (< 1% change in voltage)
620358 BUFFALO3 345.00	[redacted]	1.26	1.0621	1.0626	0.05	Not Valid (< 1% change in voltage)
620242 CLBKPIP7 115.00	[redacted]	1.11	0.936	0.9389	0.29	Not Valid (< 1% change in voltage)
620240 MN PIPE7 115.00	[redacted]	1.06	0.9365	0.9394	0.29	Not Valid (< 1% change in voltage)
620241 CLEARBR7 115.00	[redacted]	1.04	0.9367	0.9396	0.29	Not Valid (< 1% change in voltage)
620244 ITASCA 7 115.00	[redacted]	0.91	0.9372	0.9409	0.37	Not Valid (< 1% change in voltage)
620381 UNDERWD4 230.00	[redacted]	0.75	1.057	1.0575	0.05	Not Valid (< 1% change in voltage)
620369 JAMESTN3 345.00	[redacted]	0.56	1.0551	1.0556	0.05	Not Valid (< 1% change in voltage)
620252 PLUMMER7 115.00	[redacted]	0.21	0.9457	0.9479	0.22	Not Valid (< 1% change in voltage)
620251 PLUMTAP7 115.00	[redacted]	0.2	0.9458	0.948	0.22	Not Valid (< 1% change in voltage)
620253 PLUMPIP7 115.00	[redacted]	0.2	0.9458	0.948	0.22	Not Valid (< 1% change in voltage)
620416 TWIN BRKS 3 345.00	[redacted]	0.2	1.0512	1.052	0.08	Not Valid (< 1% change in voltage)
620361 MAPLE R3 345.00	[redacted]	0.18	0.9461	0.9482	0.21	Not Valid (< 1% change in voltage)
613140 MILACA 4 230.00	[redacted]	0.16	0.8981	0.8984	0.03	Not Valid (< 1% change in voltage)
605087 FRANKLN8 69.000	[redacted]	0.09	1.0475	1.0509	0.34	Not Valid (< 1% change in voltage)
605492 WBYRON 8 69.000	[redacted]	0.02	1.0419	1.0502	0.83	Not Valid (< 1% change in voltage)
603134 BUFFRID7 115.00	[redacted]	0.01	1.0497	1.0501	0.04	Not Valid (< 1% change in voltage)
620282 NWOOD 7 115.00	[redacted]	0.01	0.9462	0.9499	0.37	Not Valid (< 1% change in voltage)

8.2 2029 Summer Case, Thermal Violations

For completeness, the list of buses with violations is shown in Table 9 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in power flow (% of the Sherco CC).

Table 9: 2029 Summer Thermal Violations

Element	Contingency	Violation (% of Rated)	Flow without Sherco CC (MW)	Flow with Sherco CC (MW)	Change in Flow (% of Sherco CC)	Violation Status (SSR criteria)
608622 IRONRNG4 230.00 608624 FORBES 4 230.00 1	[redacted]	135.2	550.3	541.7	1.1%	Not valid (< 3% change in flow)
699157 COL 345 345.00 699166 COL 3014-S 138.00 1	[redacted]	127.4	318.5	318.5	0.0%	Not valid (< 3% change in flow)
605344 EAUCLAI8 69.000 605382 ELKMOUN8 69.000 1	[redacted]	124.8	47.4	44.8	0.3%	Not valid (< 3% change in flow)
605381 RUSK 8 69.000 605424 RUSK EM8 69.000 1	[redacted]	111.8	44.3	41.7	0.3%	Not valid (< 3% change in flow)
605382 ELKMOUN8 69.000 605424 RUSK EM8 69.000 1	[redacted]	111.8	44.3	41.7	0.3%	Not valid (< 3% change in flow)
608724 HIBBING7 115.00 608731 14L TAP7 115.00 1	[redacted]	106.1	115.6	115.6	0.0%	Not valid (< 3% change in flow)
602013 ROSEAU 4 230.00 667046 RICHER 4 230.00 1	[redacted]	105.1	241.7	241.5	0.0%	Not valid (< 3% change in flow)
619425 GRE-W UNION869.000 605110 SAUKCMU8 69.000 1	[redacted]	104.1	39.6	39.1	0.1%	Not valid (< 3% change in flow)
603067 CHEMOLT7 115.00 603069 COTTAGE7 115.00 1	[redacted]	103.5	247.4	236.8	1.3%	Not valid (< 3% change in flow)
605181 REDWING8 69.000 615479 GRE-SPRNGCK869.000 2	[redacted]	102.6	86.9	91.7	-0.6%	Not valid (< 3% change in flow)
605085 GIBBON 8 69.000 605128 CAIRO R8 69.000 1	[redacted]	101.9	18.0	17.6	0.1%	Not valid (< 3% change in flow)
602013 ROSEAU 4 230.00 657757 MORANVI4 230.00 1	[redacted]	100.8	231.8	230.2	0.2%	Not valid (< 3% change in flow)

8.3 2029 Shoulder Case, Voltage Violations

For completeness, the list of buses with violations is shown in Table 10 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in voltage (%).

Table 10: 2029 Shoulder Voltage Violations

Bus	Contingency	Violation without Sherco CC (%)	Voltage without Sherco CC (pu)	Voltage with Sherco CC (pu)	Change in Voltage (%)	Violation Status (SSR criteria)
603158 RIV FLS7 115.00	[redacted]	4.68	0.8761	0.8732	0.29	Not Valid (< 1% change in voltage)
698230 HUSTISFD 138.00	[redacted]	4.2	0.858	0.858	0	Not Valid (< 1% change in voltage)
699227 HUBBARD_138 138.00	[redacted]	4.14	0.8588	0.8586	0.02	Not Valid (< 1% change in voltage)
620381 UNDERWD4 230.00	[redacted]	1.62	1.0659	1.0662	0.03	Not Valid (< 1% change in voltage)
620242 CLBKPIP7 115.00	[redacted]	1.46	0.9343	0.9354	0.11	Not Valid (< 1% change in voltage)
620240 MN PIPE7 115.00	[redacted]	1.42	0.9347	0.9358	0.11	Not Valid (< 1% change in voltage)
620241 CLEARBR7 115.00	[redacted]	1.4	0.9343	0.936	0.17	Not Valid (< 1% change in voltage)
617725 GRE-TRIPPLK7115.00	[redacted]	1.38	0.9069	0.9062	0.07	Not Valid (< 1% change in voltage)
620358 BUFFALO3 345.00	[redacted]	1.11	1.0609	1.0611	0.02	Not Valid (< 1% change in voltage)
601028 EAU CL 3 345.00	[redacted]	1.04	1.05	1.0604	1.04	Not Valid (< 1% change in voltage)
601028 EAU CL 3 345.00	[redacted]	1.04	1.0508	1.0604	0.96	Not Valid (< 1% change in voltage)
601028 EAU CL 3 345.00	[redacted]	1.03	1.0508	1.0603	0.95	Not Valid (< 1% change in voltage)
613140 MILACA 4 230.00	[redacted]	0.91	0.8916	0.8909	0.07	Not Valid (< 1% change in voltage)
603159 CRYSTAL7 115.00	[redacted]	0.89	1.0603	1.0589	0.14	Not Valid (< 1% change in voltage)

Bus	Contingency	Violation without Sherco CC (%)	Voltage without Sherco CC (pu)	Voltage with Sherco CC (pu)	Change in Voltage (%)	Violation Status (SSR criteria)
620290 HARVEY 4 230.00	[redacted]	0.82	1.0579	1.0582	0.03	Not Valid (< 1% change in voltage)
615517 GRE-4CORNRS7115.00	[redacted]	0.77	0.8927	0.8923	0.04	Not Valid (< 1% change in voltage)
605019 BAYFRT88 88.000	[redacted]	0.74	1.0584	1.0574	0.1	Not Valid (< 1% change in voltage)
693969 MKN INTCOV_S87.000	[redacted]	0.73	0.8927	0.8927	0	Not Valid (< 1% change in voltage)
605108 DGLAS C8 69.000	[redacted]	0.66	1.0556	1.0566	0.1	Not Valid (< 1% change in voltage)
602019 GINGLES5 161.00	[redacted]	0.58	1.0558	1.0558	0	Not Valid (< 1% change in voltage)
620369 JAMESTN3 345.00	[redacted]	0.4	1.0539	1.054	0.01	Not Valid (< 1% change in voltage)
620381 UNDERWD4 230.00	[redacted]	0.35	1.0534	1.0535	0.01	Not Valid (< 1% change in voltage)
620244 ITASCA 7 115.00	[redacted]	0.33	0.9451	0.9467	0.16	Not Valid (< 1% change in voltage)
620416 TWIN BRKS 3 345.00	[redacted]	0.18	1.0516	1.0518	0.02	Not Valid (< 1% change in voltage)
615421 GRE-BIRCHLK7115.00	[redacted]	0.03	0.8987	0.8997	0.1	Not Valid (< 1% change in voltage)

8.4 2029 Shoulder Case, Thermal Violations

For completeness, the list of buses with violations is shown in Table 11 of Appendix A, where the negligible impact of the Sherco CC on each violation is quantified in terms of change in power flow (% of the Sherco CC).

Table 11: 2029 Shoulder Thermal Violations

Element	Contingency	Violation without Sherco CC (% of rated)	Flow without Sherco CC (MW)	Flow with Sherco CC (MW)	Change in Flow (% of Sherco CC)	Violation Status (SSR criteria)
605085 GIBBON 8 69.000 605128 CAIRO R8 69.000 1	[redacted]	106.8	18.9	19.0	0.0%	Not valid (< 3% change in flow)
615600 GRE-COAL CR4230.00 615002 GRE-COAL 42G22.000 1	[redacted]	100.4	361.4	361.4	0.0%	Not valid (< 3% change in flow)

9 Appendix B: 2024 Sherco 1 & 2 Only Scenario Detailed Results

This appendix contains the detailed results of the analysis for the 2024 scenario where only Sherco 1 & 2 were evaluated for retirement. The following tables show the thermal and voltage violations that have been identified in the analysis.

Overloaded elements are transmission system buses (substations) in the case of voltage violations and transmission lines or transformers in the case of thermal violations. For each of the overloaded element identified in a row of the table, at least one contingency was found to cause the overload and the highest value of the overload is reported in the table. It is further noted that for some overloaded elements in the following tables, the overload may become slightly worse with the addition of the Sherco CC. While counterintuitive, this is a real characteristic that can result from certain changes to the grid due to the highly complex and non-linear nature of most electric transmission networks.

The summer case was also evaluated in the 2024 Sherco 1 & 2 retirement scenario, but the summer case did not identify any valid thermal or voltage violations, which is the reason that there are no tables of violations for the summer case.

9.1 2024 Shoulder Case, Voltage Violations

The list of voltage violations identified in the 2024 shoulder case is shown in Table 12.

Table 12: 2024 Shoulder Voltage Violations

Bus	Contingency	Violation (%)	Voltage with Sherco 1&2	Voltage without Sherco 1&2	Change in voltage (%)	Violation Status (SSR criteria)
603218 SHEAS LK 7 115.00[34]	[redacted]	2.46	1.007	0.895	11.2	Valid Under-Voltage Violation
601072 SHEAS LK3 345.00	[redacted]	2.46	1.007	0.895	11.2	Valid Under-Voltage Violation
608705 BABBITT7 115.00	[redacted]	3.8	1.116	1.138	2.2	Valid Over-Voltage Violation
605715 MONTI TR10T913.800	[redacted]	0.59	1.028	0.997	3.1	Valid Delta-Voltage Violation (delta V > 2.5%)

9.2 2024 Shoulder Case, Thermal Violations

The list of thermal violations identified in the 2024 shoulder case is shown in Table 13.

Table 13: 2024 Shoulder Thermal Violations

Element	Contingency	Violation without Sherco 1&2 (% of Rated)	Flow with Sherco 1&2 (MW)	Flow without Sherco 1&2 (MW)	Change in Flow (% of Sherco 1&2)	Violation Status (SSR criteria)
608622 IRONRNG4 230.00 608624 FORBES 4 230.00 1	[redacted]	118.9	286.0	483.7	13.5%	Valid Violation
603094 OSSEO 7 115.00 616302 GRE-HENEPIN7115.00 1	[redacted]	101.7	132.6	250.8	8.1%	Valid Violation

[34] In previous Y-2 studies, there were thermal violations also identified in the Shea's Lake region, and Xcel noted upgrades could be expensive. However, those upgrades and commentary were for thermal mitigations, which are in contrast to voltage mitigations that are relatively less expensive, as they do not involve line reconductoring or re-builds.

10 Appendix C: Technical Review of Resource Attributes

Xcel Energy submitted a supplement to the Integrated Resource Plan (IRP) on June 30, 2020 that details modeling and assumptions behind the analysis. Telos Energy has been asked to review and provide comments specifically on Attachment A, Section VI: Resource Attributes.[35] This appendix summarizes the review and commentary on the Resource Attributes Section.

The table shown in Figure VI-1: "Resource Attributes Mapped to Resource Types" is misleading, outdated, or incorrect in several boxes, which are marked in blue in Figure 2 and elaborated below.

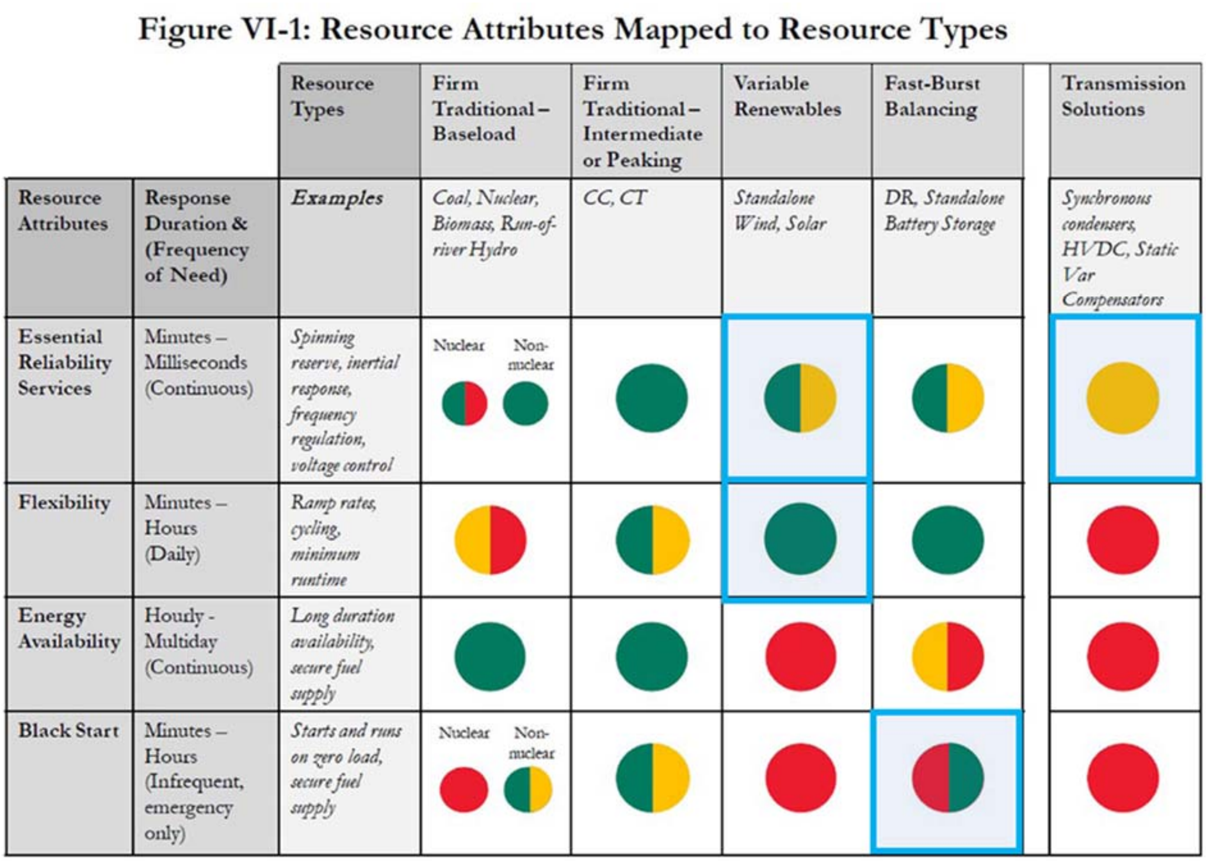


Figure VI-1: Resource Attributes Mapped to Resource Types

		Resource Types	Firm Traditional – Baseload	Firm Traditional – Intermediate or Peaking	Variable Renewables	Fast-Burst Balancing	Transmission Solutions
Resource Attributes	Response Duration & (Frequency of Need)	*Examples*	*Coal, Nuclear, Biomass, Run-of-river Hydro*	*CC, CT*	*Standalone Wind, Solar*	*DR, Standalone Battery Storage*	*Synchronous condensers, HVDC, Static Var Compensators*
Essential Reliability Services	Minutes – Milliseconds (Continuous)	*Spinning reserve, inertial response, frequency regulation, voltage control*	Nuclear Non-nuclear				
Flexibility	Minutes – Hours (Daily)	*Ramp rates, cycling, minimum runtime*					
Energy Availability	Hourly - Multiday (Continuous)	*Long duration availability, secure fuel supply*					
Black Start	Minutes – Hours (Infrequent, emergency only)	*Starts and runs on zero load, secure fuel supply*	Nuclear Non-nuclear				

Figure 2: Summary Table of Resource Attributes Modified by Telos Energy

General Note: The "Essential Reliability Services" row mixes several different types of services, which cut across the capabilities of various technologies. It is more accurate and informative to break out the individual services and associate those with technology capability. It is also important to differentiate between technical capability and current industry practice, which are not always aligned.

[35] "Supplement, 2020-2034 Upper Midwest Integrated Resource Plan," Northern States Power Company. Docket No. E002/RP-19-368. June 30, 2020.

Essential Reliability Services from Variable Renewables: Today's wind and solar plants have excellent capability to provide all of the Essential Reliability Services (spinning reserve, frequency regulation, and voltage control) with the exception of "inertial response," which is a service that is only provided by "Traditional" generators today.

The Supplement states that "…their inverters can provide fast voltage/reactive control capabilities over a wide range of active power conditions, although not at the same level as synchronous resources." This statement is outdated and incorrect. The performance of wind and solar plants in providing spinning reserve, frequency regulation, and voltage control exceeds the performance of traditional generators in terms of speed and accuracy.[36] Therefore, it is more appropriate that this box be split green/yellow.

The Supplement also notes that wind and solar resources are typically not operated with headroom, and as such, they cannot provide primary frequency response in the "up" direction. This is correct - just as gas turbines or coal plants that are operated with no headroom also cannot provide frequency response to increase power. But it is important to differentiate these operational and economic decisions from technology capability when considering the needs for long-term grid planning.

Further, the Supplement states that "Battery energy storage can provide extremely fast reactive power and voltage control services, but it is duration-limited;" It is true that batteries can provide extremely fast reactive power and voltage control services, but for these services in which there is no exchange of active power (only reactive power and some small losses), batteries are not duration-limited. They simply act like STATCOMs, which are transmission assets that have been used for decades without any duration limits.

Essential Reliability Services from Transmission Solutions: The all-green box mixes and over-states the capabilities of the listed technologies (synchronous condensers, HVDC, SVCs). HVDC and SVCs are not capable of providing inertia response, only synchronous condensers on this list are capable of providing inertia. However, synchronous condensers are not able to provide spinning reserve; HVDC is the only capable technology on this list for providing spinning reserve. Therefore, the all-green box is misleading and is better coded as yellow as no single resource can provide all of the listed essential reliability services.

It should be noted that the capability of HVDC and FACTS (Flexible AC Transmission Systems) devices are closely related to that of wind and solar technologies, which makes sense because the underlying technologies -- power electronics -- are common to both resources. Therefore, wind and solar plants are able to simultaneously provide the same Essential Reliability Services of FACTS and HVDC while also providing energy to the system.

Flexibility from Variable Renewables: The yellow box indicates partial capability of wind and solar to provide flexibility (ramp rates, cycling, minimum runtime). However, wind and solar have very fast

[36] California Independent System Operator, "Avangrid Renewables Tule Wind Farm, Demonstration of Capability to Provide Essential Grid Services," 2020.

bidirectional ramping capability, with the ability to change from zero to rated output and vice versa in a matter of seconds, a feat that requires most traditional resources several minutes to execute, when it is even possible. Further, wind and solar resources have no cycling or minimum runtime requirements, which increases their flexibility.[37] It is acknowledged that wind and solar must have "fuel" availability to perform as flexible resources, but this requirement is better captured separately in the "Energy Availability" row. Therefore, this box should be coded solid green.

Black-Start from Batteries: Battery storage has been demonstrated to provide black-start capability in 2017, where a battery was used to start Imperial Irrigation District's (IID) El Centro Natural Gas Plant in California.[38] This proves that the capability of the technology - though not wide-spread today - is commercially available and currently in practice.

As Xcel correctly points out, the batteries must have sufficient charge to execute their black-start duties. But this is an operational decision, not a technology capability issue. The Supplement also noted that black-start resources may need to be able to energize the grid for periods of up to 24 hours. This number sounds like a tall order for most batteries, which typically have 4- 8-hour ratings. However, it is not expected that a black-start resource would be providing all of its power capability for the full duration of an extended-start 24-hour period. Rather, much of the time in an extended black-start scenario would be spent at a partial discharge rate by energizing some lines, control systems, and plant auxiliaries and not large amounts of load. Therefore, it is not appropriate to discuss "hours" of battery storage, but rather peak power rating (MW) and energy capacity (MWh). For instance, a 30MW 4-hour battery could discharge for 24-hours at up to 5 MW.

Further, it should be noted that black-start is an extremely rare function in the US power grid, which has never been called on in MISO as any outages have been restored from other still-operating parts of the grid. While it is critically important to have the capability to perform black-start, it is important to also consider the broader context, given that black-start has never been called on and yet the other three rows (Essential Reliability Services, Flexibility, and Energy Availability) are called on continuously throughout every day.

---

[37] California Independent System Operator, "Avangrid Renewables Tule Wind Farm, Demonstration of Capability to Provide Essential Grid Services," 2020.

[38] Peter Maloney, "California muni IID completes first US demonstration of black start battery capability." Utility Dive. May 19, 2017. Accessed on August 17, 2020. https://www.utilitydive.com/news/california-muni-iid-completes-first-us-demonstration-of-black-start-battery/443099/

11 Appendix D: Commentary on Power Deliverability and System Regulation

Xcel's original 2019 Resource Plan filing referred to two specific advantages for having a thermal power plant at the Sherco location, namely Power Deliverability and System Regulation[39]. This appendix intends to provide a brief background and context for these two characteristics of generator plants.

Power Deliverability

As part of this analysis, Telos reviewed the Siemens study[40] referenced in Appendix L of the Xcel 2019 Resource Plan that stated that "the Siemens study confirmed that the system operates well with significant injection at the Sherco site and the replacing retiring units at a different location would require transmission system upgrades… and increased energy losses." The Siemens study evaluated the Sherco location and three other locations for the siting of 1500 MW of combined-cycle generation, and found that siting 1500 MW of generation at the Sherco location resulted in fewer transmission violations than siting 1500 MW of generation at the three other locations selected by Xcel, two of which were more distant from the load center than Sherco. Therefore, the Siemens study concluded that the Sherco site is good for "generator deliverability."

MISO defines "Generator Deliverability" as "the ability of groups of generators in an area to operate at their maximum capability without being limited by transmission constraints, i.e., without being bottled-up." [41] The deliverability of a generator is not a function of the generating resource, but rather, the transmission network between the generator and the load center. Because the Sherco plant interconnects to the high-voltage transmission network at 345kV, which has very high capability for power transmission, and is located a relatively short distance from the Twin Cities load center, the Sherco location is advantageous for power generation. This deliverability advantage applies to any type of power generation located at the Sherco site, regardless of the underlying resource. Therefore, this is a general siting aspect that is advantageous to the Sherco site relative to more remote sites; however, it is not a specific reliability attribute of a generator.

Furthermore, the results of the Telos study imply that distributing generation over multiple different sites that interconnect with the grid at different locations makes it less likely to hit a transmission constraint, as compared with injecting a lot of power at a single location. For instance, the solar PV generation in Xcel's Preferred Plan calls for 2500 MW of new PV generation, but the new solar power is anticipated to be spread over at least five different grid interconnection locations. The approach of spreading out the generation tends to reduce the stress on the transmission network.

[39] 2020-2034 Upper Midwest Resource Plan, Appendix L – Xcel Energy Resources: Sherco CC. Xcel Energy. Docket No. E002/RP-19-368.
[40] Sherco 1 and 2 Replacement Power Study, Siemens PTI Report Number: R067-15, Prepared for Xcel Energy Services, Inc. January 22, 2016 (CEII Redacted) ("2016 Siemens Report"), CEO IR 030
[41] Generator Retirement and Suspension Studies and System Support Resources (SSR), Section 4.5.2. *MISO Business Practices Manual, Transmission Planning Manual No. 020*. Revision 22, May 1, 2020

System Regulation

Xcel, in Appendix L of the 2019 Resource Plan, also pointed to the Siemens study as addressing "the heavy reliance of the system on Sherco Units 1 and 2 for system regulation." System regulation refers to the ability of a generator to adjust its power output up or down in order to achieve some objective of the system operator, like balancing load and generation and managing system frequency. However, the Siemens study focused primarily on steady-state (constant power) operation and transient stability (faster dynamics, < 10 seconds). The Siemens study did not evaluate the performance of the Sherco units for system regulation, which typically occurs in the timeframe of 10s of seconds to minutes and involves the governor dynamics. Therefore, the Siemens study does not support Xcel's statement that the system has a heavy reliance on Sherco 1 & 2 for system regulation. The following paragraphs provide more context on system regulation services and how different generation resources can play a role in providing these important reliability services.

System operators like MISO calculate and send real-time dispatch signals, often referred to as automatic generation control (AGC) signals to each online generator in order to achieve a two-fold objective. The first objective is to regulate system frequency and the second objective is to manage interchanges or flows of power among different areas or zones of the grid, thereby balancing generation and load in areas across the grid.

In MISO, the purpose of regulation is primarily for managing flows on transmission lines by balancing generation and load within areas of the grid and less about managing the grid frequency. This is for two reasons: (1) MISO is part of a much larger grid called the Eastern Interconnect, which spans from Nova Scotia to Arkansas and Florida to Saskatchewan, and is comprised of thousands of generators that are supporting grid frequency across the entire grid, and (2) the fast-acting response of resources to sudden changes in generation or load is considered a separate service known as "primary frequency response" (PFR). PFR, or its faster cousin, fast-frequency response (FFR), are autonomous services that are procured or mandated separately from regulation services and are also able to be provided by a host of conventional and inverter-based resources, as described further, below. Therefore, the contribution of any single unit to frequency management and regulation must be viewed in the larger context, where an individual contribution is far less important than maintaining adequate response and regulation services in aggregate across the entire grid – services that can be provided by many different resource types.

Most utility-scale resources are technically capable of providing system regulation because they are able to accept and follow a power command with a minimum speed of response. Such resources include conventional thermal generation (gas, coal), renewable generation (wind, solar, hydro), and battery energy storage systems. Nuclear generation is generally prohibited from ramping and is therefore considered not capable of system regulation.

The response of a resource is subject to the limits of the equipment and availability of a resource. For instance, a solar plant cannot increase power production beyond what the solar irradiance at the time will allow any more than a gas turbine plant can increase power any further than its rating and the ambient temperature will allow. When reducing power, other limits may apply to different resources. For instance, gas-fired and coal-fired plants have a minimum power level below which they cannot operate due to emissions constraints or boiler stability limits, respectively, while wind and solar plants can be curtailed to zero. Because most resources have different limits when provide upward regulation (ability to increase power on demand) and downward regulation (ability to decrease power on demand), it is recommended to separate regulation services into upward and downward services instead of lumping all regulation into one market service so that the grid operator can procure the lowest-cost services from a mix of resources.

Battery energy systems have the ability to produce and consume power on demand, up to their power limits (inverter size) and energy limits (battery size). Inverter-based resources like wind, solar, and battery energy systems can change power output extremely quickly (fractions of a second) whereas conventional resources like thermal and hydro plants require seconds or tens of seconds to change power output because of the time required for large mechanical and hydraulic systems to act safely. From this speed-of-response standpoint, inverter-based resources have superior performance capability to conventional resources.

It is most economic for a system operator to supply as much load as possible from “free fuel” resources like renewable resources. Therefore, these renewable resources are typically allowed to run at maximum available power output while gas, coal, and battery resources are adjusted to “fill in the gaps” between ever-changing load and generation. The decision to historically procure upward regulation services (the ability to increase power) from conventional generation and not from variable generation (wind, solar) is largely an economic one. A grid operator could decide to curtail variable generation and therefore enable it to provide upward regulation. One example of this is from Texas, where transmission limits restrict the flow of power from renewable generation centers in the West to load centers in the East. The Electric Reliability Council of Texas has been forced to curtail renewable generation[42] on numerous occasions due to transmission system limit, during which time, the renewable plants are responsive to command to both decrease and increase power, and do so at a very fast rate typical of inverter-based resources.

---

[42] West Texas Export Stability Assessment, ERCOT, Revision 1.0. Accessed on November 25, 2020. http://www.ercot.com/content/wcm/lists/197392/2020_West_Texas_Export_report_final.pdf

12 Appendix E: Contingency Analysis Background

This appendix is included to provide background on the causes of violations, the reasons violations must be addressed, and to specifically outline the criteria for determining what is a violation and what is not.

The transmission planning process is mandated by the North American Electric Reliability Council (NERC) Standard TPL-001-4[43], which specifies the evaluations and types of contingencies (equipment outages) that must be considered, but it leaves the acceptance criteria up to the individual TSO. An assessment of thermal limits is part of a typical transmission planning analysis, which evaluates the anticipated power flows on a power grid during for selected scenarios of high stress, which is often during peak load (summer or winter) or minimum load (spring and fall "shoulders"). It also includes contingency analysis in which one or more significant power lines is out of service, contributing to higher loading levels on the remaining lines and transformers in service.

Each power-carrying component in a grid has a limit to its ability to handle the power flowing through it, which is called a thermal limit. The major pieces of power-carrying equipment are transmission lines and power transformers. As with all equipment, these components are not perfectly efficient, and therefore heat up due to losses when carrying power. Engineers must respect the design limits of this equipment to avoid overheating of transformers, which can reduce lifetime, and overheating of lines, which can lead to excessive sag and increased risk of short-circuits through contact with vegetation. In many cases, these thermal design limits have a time component, where a normal rating can be exceeded for a short period of time (for instance, an "emergency rating" with a duration of 30 minutes) without violating design criteria.

During the transmission planning process, transmission system operators (TSOs) set criteria for evaluating thermal violations when running transmission planning studies to determine if certain cases warrant mitigations. For the TSOs evaluated in this study work, their thermal violation criteria are shown in Table 14, where P0 is NERC nomenclature for normal operation where all equipment is in-service and P1-P7 is NERC nomenclature for a category of contingency where one or more pieces of equipment is out-of-service.

Table 14: Thermal Violation Criteria for TSOs

TSO	P0	P1-P7
XEL	<100%	<100%
GRE	<100%	<100%
MP	<100%	<110% lines, < 125% transformers
ATC	<100%	<100%
DPC	<100%	<100%
SMMPA	<100%	<100%
OTP	<100%	<110% lines, < 125% transformers

Maintaining close control over voltages in the system, especially at major substations, is critical to the ability to transfer power reliably across transmission lines. The voltages in a grid are impacted by many factors, including the number of generators on the system, how those generators are configured to

[43] NERC Reliability Standards for the Bulk Electric Systems of North America, updated July 29, 2020

control their local voltage, the load and its characteristics, the topology of the grid, and the power flow through the grid. As was done for the thermal violations, voltage violations are assessed for the same set of cases that are deemed realistic, high-stress conditions for the grid and the voltage at each node in the network is evaluated against the planning criteria established by each TSO. The voltage criteria are listed in Table 15.

Table 15: Voltage Violation Criteria for TSOs

TSO	P0	P1-P7
XEL	95%-105%	92%-105%
GRE	95%-105%	92%-105%
MP	100%-105%, 97%-105% Western MP, ND; 90%-120% for Warroad 500kV	95%-110%, some exceptions
ATC	95%-105%	90% - 110%
DPC	95%-105%, some exceptions 90%-105%	90% - 110%
SMMPA	95%-105%	90% - 110%
OTP	97%-105% for 115kV+; 97% - 107%	92% - 110%

Per the NERC TPL-001-4 standard, system adjustments following the first of multiple contingencies (for P3 and P6 contingency categories) is allowed, but this is not to say it is mandated.

For nuclear generating plants, which includes the Monticello and Prairie Island plants, there are more restrictive criteria on the voltage and frequency excursions that are permissible. NERC NUC-001[44] requires that transmission entities establish mutually agreed-upon requirements with the generation owner (GO), known as the Nuclear Power Interface Requirements (NPIR), but NERC does not define the limits or restrictions, as these are left to the TSO and GO. For Monticello[45], the frequency excursions must remain between [TRADE SECRET BEGINS] [TRADE SECRET ENDS], which is a very large range for the Eastern Interconnect, and is not restrictive. The voltage limits from the Siemens and previous Y-2 studies, are more restrictive, and are as follows:

[TRADE SECRET BEGINS]

[TRADE SECRET ENDS]

It is important to note that the low-voltage requirement for the 115kV bus at Monticello is actually [TRADE SECRET BEGINS] [TRADE SECRET ENDS] in the NPIR dated May 1, 2019, and not [TRADE SECRET BEGINS] [TRADE SECRET ENDS] as stated in previous Y-2 studies conducted prior to 2019.

[44] NERC Reliability Standards for the Bulk Electric Systems of North America, updated July 29, 2020.
[45] Nuclear Plant Operating Agreement (NPIR) for Monticello Nuclear Generating Plant, dated May 1, 2019, between Northern States Power Company and Great River Energy.

13 Appendix F: Power Systems Analysis Expertise

This analysis was conducted by Matthew Richwine of Telos Energy. Matthew is a founding partner of Telos Energy and is an industry leader in power systems engineering, power electronic controls, and system stability. For the past twelve years, he has been designing, testing, and analyzing thermal and renewable power generation equipment and studying the stability of power systems ranging from tens of megawatts to tens of gigawatts.

Matthew draws on his in-depth understanding of inverter-based resources and conventional synchronous generation equipment to model and analyze power systems to draw out meaningful conclusions and explore a large variety of mitigation measures to address challenges. He brings a passion for technology and for helping clients to understand new technologies in the context of their system.

He's played a leadership role in industry working groups, including Chair of the IEEE Renewable Energy Machines and Systems Subcommittee, contributing member of the NERC Inverter-Based Resource Performance Task Force and Power Plant Modeling and Validation Task Force, and IEEE P2800 Standard Drafting Committee on Inverter-Based Resources for Transmission Systems. As such, he's delivered dozens of presentations, drafted reliability guidelines and written many peer-reviewed papers on renewable generation technologies, modeling, and system stability.

Prior to founding Telos Energy, Matthew worked for General Electric for ten years in its Energy Consulting department as the Senior Manager of the Renewables and Controls team. In that role, he led a team in the development of new control systems for power converters and transmission planning models for GE's Renewables business. His experience also includes grid code compliance testing, transmission and interconnection studies for markets around the world, including North America, Ireland, UK, and Australia.

Matthew holds bachelor's and master's degrees from Cornell University in Electrical and Computer Engineering and Systems Engineering.