Xcel Energy Services, Inc.
Public Service Company of Colorado
Comanche Unit 2
(Repl-2024-001)
Retirement & Replacement Study

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Disclaimer

The information contained in this report is subject to change based on assumptions. The best available information has been used to model the future transmission and generation facilities in this study. Should any of these assumptions change, the results and conclusions from the study are subject to reevaluation. This draft report is yet to be reviewed by the affected Transmission Owners and the results/conclusions of the study report could change based on the findings of the review process.

0 Certifications

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the Laws of the State of Colorado.

12/23/2024

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1 Executive Summary

This report details the results of the generator replacement study performed for the replacement request Repl-2024-001 located at Comanche substation in Pueblo, CO. The new solar plant will replace the existing 335 MW Comanche unit 2. The existing Comanche Unit 2 will be retired effective December 31st,2025 and the replacement generator will be in operation by August 17th,2026.

This study was conducted in accordance with the criteria outlined in Xcel Energy PSCo Business Practice Manual Attachment N. The study includes steady-state thermal and voltage, stability, and short circuit analysis.

1.1 Project Overview

Replacement request Repl-2024-001 (Arroyo 2 solar) consists of 90 Sungrow SG4400UD-MV-US solar inverters interconnecting through three 94/125.3/156.7 MVA main power transformers to 230kV line. Repl-2024-001connects to the Comanche 230kV substation through ~3.5 miles 230kV transmission line.

The study involved analyzing the replacement of existing generators which included evaluating system reliability during the gap period between generator retirement and the commercial operation of the replacement generator.

All data necessary for the modeling of this generator was provided by the interconnection customer. See Appendix A for an equivalent oneline of the project.

1.2 Steady State Voltage and Thermal Analysis

Steady state analysis was performed to identify any thermal overloads and voltage violations resulting from the replacement of Comanche Unit 2. There were no violations that were identified due to the retirement or replacement of Comanche Unit 2.

1.3 Stability Analysis

Stability analysis was performed to verify if the generator replacement meets reliability requirements. Corrective measures will be needed to mitigate the transient voltage violations resulting due to Comanche 2 retirement prior to generator replacement. Comanche 2 can be replaced with Repl-2024-001 after conversion to synchronous condenser is completed to reduce transient violations.

1.4 Short Circuit

Short circuit current and breaker duty analysis indicates that there are no breakers that need to be replaced due to Comanche Unit 2 replacement with Repl-2024-001.

1.5 Reactive Power Capability

The Repl-2021-001 is capable of maintaining 0.95-1.05 pu voltage at the high side of transformer and POI while operating within limits.

2 Study Assumptions and Methodology

2.1 Study Assumptions

The study is based on the analysis methods established by PSCo Attachment N LGIP to evaluate generator interconnection and retirement. The evaluation was done by comparing the cases within each season due to multiple network changes in the area between study years. The case with the retiring unit on is the bench case. The case names are given in **Error! Reference source not found.**.

Table 2.1-1 Steady State Case Assumptions Discharging Scenarios

Model Name	Loads	Topology	Replacement Unit Repl-2024-001	Retiring Units Comanche 2
2026 Bench	Summer Peak	2026	**OFF**	**ON**
2026 Study	Summer Peak	2026	**OFF**	**OFF**
2027 Bench	Summer Peak	2027	**OFF**	**ON**
2027 Study	Summer Peak	2027	**ON**	**OFF**

Steady state analysis was performed using PSLF power flow program version V23.

2.2 Criteria

The following steady state analysis criteria is used to identify violations for the PSCo and Affected Systems. Anything outside the criteria below is considered a violation.

2.2.1 Steady State

1. P0 - System Intact conditions:
   Thermal Loading: <=100% of the normal facility rating
   Voltage range: 0.95 to 1.05 per unit
2. P1 & P2-1 – Single Contingencies:
   Thermal Loading: <=100% normal facility rating
   Voltage range: 0.90 to 1.10 per unit
   Voltage deviation: <=8% of pre-contingency voltage
3. P2 (except P2-1), P4, P5 & P7 – Multiple Contingencies:
   Thermal Loading: <=100% emergency facility rating
   Voltage range: 0.90 to 1.10 per unit
   Voltage deviation: <=8% of pre-contingency voltage

2.2.2 Stability assessment criteria

Transient voltage stability criteria require that all generating machines remain in synchronism and all power swings shall be well damped following a contingency event. Also, transient voltage performance shall meet the following WECC criterion “TPL-001-WECC-CRT-3.2:

1. Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds for all contingencies for each BES bus serving load.
2. For all contingencies, following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.
3. For contingencies without a fault, voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.

Transient angular stability criteria shall meet the following criteria:
1. P1 - No generating unit shall pull out of synchronism. A generator being disconnected from the system by fault clearing or by a special protection system is not considered an angular instability.
2. P2-P7 - One or more generators may pull out of synchronism, provided the resulting apparent impedance swings shall not result in the tripping of other generation facilities.
3. P1-P7 - The relative rotor angle oscillations are characterized by positive damping > 5% within 30 seconds.

Generators tripped due to Lhvrt or Lhfrt model settings are not considered stability issues.

2.3 Power Flow Model Development

The starting case for this analysis was provided by PSCo for the year 2025. Automation files were also provided to update the PSCo area network topology, loads and generation dispatch to derive the bench cases for years 2026 and 2027.
The study cases were derived from these starting cases by turning on the generation for replacement generator and turning off the existing Comanche Unit 2 according to study scenario as given in **Error! Reference source not found.**. The steady state starting cases received are listed as follows:

- 25HS4a.sav

2.4 Steady State Input Files

The contingency file tailored for TPL-30HS was received from PSCo in PSS/E format and were converted to run in PSLF. The contingencies were modified to include the topology change respective to the case year. Appendix B contains a complete list of contingencies and respective contingency events used for steady state analysis. The monitored areas include all of Area 70 and 73 to capture any violation that occurs in the system.

2.5 Stability Files

The stability files were received from PSCo for each case year. The dynamic models for the replacement generator were added to the base case to derive the study case. Dynamic model parameters for the replacement generator were received from the interconnection customer. Planned conversions of Comanche Unit 2 to synchronous condenser after retirement was also assessed with the replacement generator. Additional scenarios were simulated with and without synchronous condenser for the year 2027 case.

2.6 Short Circuit Model

The short circuit model for PSS CAPE software was provided by PSCo. The replacement generator was added to the model as per the information provided by the interconnect customer. Due to software data export limitation, the short circuit model did not include any breaker data. The breaker data was extracted from the breaker duty report provided by PSCo to compare the available short circuit current at each bus with the breaker interrupting rating. The short circuit and breaker duty analysis was limited to Comanche and neighboring substations only.

3 Steady State Results

Steady state analysis was performed to ensure that full output of the replacement generator Repl-2024-001 can be exported without violating PSCo Transmission Planning Criteria.

3.1 Voltage Results

There were no voltage violations associated with the Comanche Unit 2 retirement and replacement with Repl-2024-001 that affects the transmission grid reliability.

There were several buses in the area with voltage violations, but these violations are not associated with the Comanche Unit 2 retirement and replacement. Comanche Unit 2 does not have a significant effect on these buses as the voltage does not change before and after retirement and replacement.

Refer to Appendix C for a full listing of Steady state results,

3.2 Overloads Results

A full test of evaluation criteria was performed for base and study cases for the years 2026 and 2027 to account for any pre-existing overloads and identify the overloads caused by generation retirement and replacement. There are some pre-existing overloads for each case, but these overloads are not associated with Comanche Unit 2's retirement or replacement. Comanche Unit 2 does not cause or contribute significantly to these branch overloads.

There were no thermal violations associated with the Comanche Unit 2 retirement and replacement with Repl-2024-001 that affects the transmission grid reliability.

A full listing of the steady state results is in Appendix C.

4 Stability Results

4.1 Stability Analysis for Comanche Unit 2 Retirement

Stability analysis was performed for the year 2026 case with and without Comanche Unit 2 to assess the stability of the system after the generator is retired and the replacement generator is not yet in service. The results show that all generating units within PSCo Transmission System remain in synchronism and have positive damping. The system voltages recover by the end of simulation to nominal levels. Transient voltage violations were identified at several buses for multiple faults. Although some of the transient violations were common to both bench and study case, there were additional transient voltage violations for the study case with the faults on Cherokee and Midway substations being the worst.

It is recommended to develop a mitigation plan to reduce these violations before the generator is retired.

The summary of results for the faults simulated is given in Table 4.1-1. Appendix D contains the output stability plots for the simulated faults. Stability output detailed tables are available in Appendix E.

Table 4.1-1 Stability Analysis Results in Reliability Cases

Fault	Description	2026 Bench	2026 Study
F1	Fault at bus 70654 Comanche 345 kV: Trip Comanche-Tundra 345	Stable	Stable
F2	Fault at bus 70654 Comanche 345 kV: Trip Comanche 345 Gen3	Stable	Stable
F3	Fault at bus 70654 Comanche 345 kV: Trip Comanche-TX4 345-230	Stable	Stable
F4	Fault at bus 70031 Baculite 115 kV: Trip Baculite Mesa Gen1 GSU	Stable	Stable
F5	Fault at bus 70107 Cherokee 230 kV: Trip Cherokee-Lacombe 230	Stable*	Stable*
F6	Fault at bus 70122 Comanche 230 kV: Trip Comanche-Boone 230 ckt 1	Stable	Stable
F7	Fault at bus 70601 Daniel 345 kV: Trip Daniel Park-Tundra 345 ckt 2	Stable*	Stable*
F8	Fault at bus 70601 Daniel 345 kV: Trip Daniel Park-Missil Site 345	Stable*	Stable*
F9	Fault at bus 70410 Ft St Vrain 230 kV: Trip Ft St Vrain-Isabelle 230	Stable	Stable
F10	Fault at bus 70286 Midwy 230 kV: Trip Midwy-Milasol 230	Stable*	Stable*
F11	Fault at bus 70464 Waterton 230 kV: Trip Waterton Tx 345-230	Stable*	Stable*

Fault	Description	2026 Bench	2026 Study
F12	Fault at bus 70459 Walsenburg 230 kV: Trip Walsenburg-Valent 230	Stable	Stable
F13	Fault at bus 70624 Missle Site 345 kV: Trip Missle Site-Smoky Hills 345	Stable	Stable
F14	Fault at bus 70597 Harvest_MI 345 kV: Trip Daniels Park-Harvest_MI 345	Stable	Stable
F15	Fault at bus 70654 Comanche 345 kV: Trip Comanche-Tundra 345 +7014-GSU3	Stable	Stable
F16	Fault at bus 70601 Daniels Park 345 kV: Trip Daniels Park- Tundra 345 +7032-Tx4 345-230	Stable*	Stable*
F17	Fault at bus 70139 Daniels Park 230 kV: Trip Daniels Park-Waterton 230 +5102-Daniels Park-Fuller230	Case Diverged	Case Diverged
F18	Fault at bus 70286 Midway 115 kV: Trip Midway-Boone 230 +5128-Tx1 230-115	Instable	Instable
F19	Fault at bus 70061 Boone 230 kV: Trip Boone-Comanche 230 (Comanche)+5337-Boone-Lamar 230	Stable	Stable
F20	Fault at bus 70653 Tundra 2 kV: Trip Tundra-Daniel Park 345 1+2	Stable*	Stable*

* Transient voltage violations at multiple buses. The voltage recovers by the end of simulations. The number of transient bus voltage violations are different between the bench and study cases.

4.2 Stability Analysis for Comanche Unit 2 Replacement

Stability analysis was performed for the year 2027 case with Comanche Unit 2 in service as bench case and the replacement generator with synchronous condenser as study case. The results show that all generating units within PSCo Transmission System remain in synchronism and have positive damping. The system voltages recover by the end of simulation to nominal levels. Transient voltage violations were identified at several buses for multiple faults. Although some of the transient violations were common to both bench and study case, there were some additional transient voltage violations for the study case. Most of these violations occur within 20 cycles after the faults clear and are not sustained beyond 2 seconds after the fault clearing.

Additional scenarios were simulated to identify if the transient voltage violations were due to replacement of Comanche Unit 2 with Repl-2024-001. The results show that the replacement of Comanche Unit 2 with Repl-2024-001 without the synchronous condenser results in a significant number of transient voltage violations. Transient voltage performance following addition of the synchronous condenser to the model is acceptable, meeting TPL-001-WECC-CRT-3.2 criteria. No material adverse impact is identified.

The study concludes that the addition of synchronous condenser provides adequate inertial support to address the transient voltage issues. The replacement of Comanche 2 with Repl-2024-001 does not have any adverse impact on the system stability when the synchronous condenser is in-service.

The summary of results for the faults simulated is given in Table 4.2-1. Appendix D contains the output stability plots for the simulated faults.

Table 4.2-1 Stability Analysis Results in Replacement Cases

Fault	Description	2027 Bench	2027 Study
F1	Fault at bus 70654 Comanche 345 kV: Trip Comanche-Tundra 345	Stable	Stable
F2	Fault at bus 70654 Comanche 345 kV: Trip Comanche 345 Gen3	Stable	Stable
F3	Fault at bus 70654 Comanche 345 kV: Trip Comanche-TX4 345-230	Stable	Stable
F4	Fault at bus 70031 Baculite 115 kV: Trip Baculite Mesa Gen1 GSU	Stable	Stable
F5	Fault at bus 70107 Cherokee 230 kV: Trip Cherokee-Lacombe 230	Stable*	Stable*
F6	Fault at bus 70122 Comanche 230 kV: Trip Comanche-Boone 230 ckt 1	Stable	Stable
F7	Fault at bus 70601 Daniel 345 kV: Trip Daniel Park-Tundra 345 ckt 2	Stable*	Stable*
F8	Fault at bus 70601 Daniel 345 kV: Trip Daniel Park-Missil Site 345	Stable*	Stable*
F9	Fault at bus 70410 Ft St Vrain 230 kV: Trip Ft St Vrain-Isabelle 230	Stable*	Stable*
F10	Fault at bus 70286 Midwy 230 kV: Trip Midwy-Milasol 230	Stable*	Stable*
F11	Fault at bus 70464 Waterton 230 kV: Trip Waterton Tx 345-230	Stable*	Stable*
F12	Fault at bus 70459 Walsenburg 230 kV: Trip Walsenburg-Valent 230	Stable	Stable
F13	Fault at bus 70624 Missle Site 345 kV: Trip Missle Site-Smoky Hills 345	Stable	Stable
F14	Fault at bus 70597 Harvest_MI 345 kV: Trip Daniels Park-Harvest_MI 345	Stable	Stable
F15	Fault at bus 70654 Comanche 345 kV: Trip Comanche-Tundra 345 +7014-GSU3	Stable	Stable
F16	Fault at bus 70601 Daniels Park 345 kV: Trip Daniels Park- Tundra 345 +7032-Tx4 345-230	Stable*	Stable*
F17	Fault at bus 70139 Daniels Park 230 kV: Trip Daniels Park-Waterton 230 +5102-Daniels Park-Fuller230	Case Diverged	Case Diverged
F18	Fault at bus 70286 Midway 115 kV: Trip Midway-Boone 230 +5128-Tx1 230-115	Stable*	Stable*
F19	Fault at bus 70061 Boone 230 kV: Trip Boone-Comanche 230 (Comanche)+5337-Boone-Lamar 230	Stable*	Stable*
F20	Fault at bus 70653 Tundra 2 kV: Trip Tundra-Daniel Park 345 1+2	Stable*	Stable*

* Transient voltage violations at multiple buses. The voltage recovers by the end of simulations. The number of transient bus voltage violations are different between the bench and study cases.

5 Short circuit Results

Short circuit and breaker duty analysis was performed to assess the change in short circuit current due to the generator replacement.

The short circuit current for a fault at Comanche 230kV bus given below in Table 5.1-1.

Table 5.1-1 Short Circuit Current at Comanche 230 kV Bus

	2024				2026			
	With Comanche 2		Without Comanche 2		Without Comanche 2		With Repl-2024-001	
Bus Fault at Comanche 230kV S	**3ph**	**SLG**	**3ph**	**SLG**	**3ph**	**SLG**	**3ph**	**SLG**
Fault Current (A)	20508.1	24655.7	17983	22159	18331	21778	19664	22379.84

The study identified no breakers requiring replacement due to the replacement of Comanche Unit 2 with Repl-2024-001.

Breaker duty report is attached in Appendix F.

6 Reactive Power Capability

Xcel Energy's OATT requires all non-synchronous generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the high side of the generator substation. Furthermore, Xcel Energy requires every Generating Facility to have dynamic voltage control capability to assist in maintaining the POI voltage schedule specified by the Transmission Operator.

The plant was modelled based on the parameters provided by the interconnection customer. The equivalent oneline diagram and the modelling data is in Appendix A.

The reactive power capability analysis in Table 3.4-1 indicates that for Pgen at Pmax when Q is dispatched at its upper and lower limits, the POI voltage is within the acceptable range of 0.95-1.05 pu. For Pgen at 10% of Pmax with the main step-up transformer at +/-0.95 power factor the POI voltage is within the acceptable range.

Table 6.1-1 Reactive Power Capability

		*Main Step-up Transformer High				POI			
***Gen MW/MVAr**	**Terminal Voltage (p.u.)**	**Voltage (p.u.)**	**MW**	**Mvar**	**Power factor**	**Voltage (p.u.)**	**MW**	**MVAr**	**Power Factor**
113.5MW/67.4Mvar	1.062	1.001	111.90	42.30	0.935	1.001	335.60	126.40	0.935

		*Main Step-up Transformer High				POI			
*Gen MW/MVAr	Terminal Voltage (p.u.)	Voltage (p.u.)	MW	Mvar	Power factor	Voltage (p.u.)	MW	MVAr	Power Factor
113.5MW/-67.4Mvar	0.944	0.996	111.40	-99.20	-0.746	0.997	334.60	-298.20	-0.746
11.35MW/5.2Mvar	1.009	1.000	11.10	4.80	0.917	1.000	33.10	14.50	0.916
11.35MW/-4.8Mvar	0.992	0.999	10.90	-5.30	-0.899	0.999	33.10	-15.50	-0.905
0MW/-67.4	0.991	0.996	-0.90	-77.30	-0.011	0.997	-2.30	-231.80	-0.010

* Values are for each aggregate generator with associated MSU

7 Conclusion

The retirement of Comanche Unit 2 prior to the in-service of Repl-2024-001 causes transient stability issues on multiple buses in the area requiring additional corrective actions before the generator is retired.

The results of this study indicate Comanche Unit 2 can be replaced with Repl-2024-001 solar plant with no material adverse impact on the transmission system after the synchronous condenser is in-service.