Provisional Interconnection Study Report for PI-2024-15

12/09/2024

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1.0 Executive Summary

PI-2024-15 is a 300 MW Provisional Interconnection Service (PIS)[1] request for a 312.8 MW Solar Photovoltaic (PV) and a 107.5 MW Battery Energy Storage System (BESS) Generating Facility with a Point of Interconnection (POI) on the Boone to Midway 230 kV line. The maximum output will be controlled via power plant controller not to exceed 300 MW. This PIS request is associated with Generation Interconnection Request 5RSC-2024-06 in the 5RSC cluster.

The total estimated cost of the transmission system improvements required for PI-2024-15 to qualify for Provisional Interconnection Service is $29.615 million (Table 19 and

Table 20).

The initial maximum permissible output of the PI-2024-15 Generating Facility is 300 MW in Discharging mode at the POI and 107.5 MW in Grid Charging mode at the generator terminal. The maximum permissible output of the Generating Facility in the PLGIA[2] would be reviewed quarterly (or more often as needed) and updated, if there are changes to the system conditions assumed in this analysis, to determine the maximum permissible output.

Security: Based on 5RSC-2024-06 in the 5RSC selection of Energy Resource Interconnection Service (ERIS), the security associated with the Network Upgrades that might be identified at the conclusion of the 5RSC-2024-06 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is $5 million.

The Interconnection Customer assumes all risk and liabilities with respect to changes between the PLGIA and the LGIA[3], including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.

The Provisional Interconnection Service in and of itself does not convey transmission service.

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[1] **Provisional Interconnection Service (PIS)** shall mean an Interconnection Service provided by Transmission Provider associated with interconnecting the Interconnection Customer's Generating Facility to Transmission Provider's Transmission System and enabling that Transmission System to receive electric energy and capacity from the Generating Facility at the Point of Interconnection, pursuant to the terms of the Provisional Large Generator Interconnection Agreement and, if applicable, the Tariff.

[2] **Provisional Large Generator Interconnection Agreement (PLGIA)** shall mean the interconnection agreement for Provisional Interconnection Service established between Transmission Provider and/or the Transmission Owner and the Interconnection Customer. The pro forma agreement is provided in Appendix 8 and takes the form of the Large Generator Interconnection Agreement, modified for provisional purposes.

[3] **Large Generator Interconnection Agreement (LGIA)** shall mean the form of interconnection agreement applicable to an Interconnection Request pertaining to a Large Generating Facility that is included in the Transmission Provider's Tariff.

2.0 Introduction

PI-2024-15 is a 300 MW Provisional Interconnection Service request for a 312.8 MW Solar Photovoltaic (PV) and a 107.5 MW Battery Energy Storage System (BESS) Generating Facility located in Pueblo County, Colorado.

- The POI of this project is at a new 230 kV switching station on the Boone to Midway 230 kV line.
- The Commercial Operation Date (COD) to be studied for PI-2024-15 was June 1, 2028 as noted on the Provisional Interconnection Service request form.

The geographical location of the transmission system near the POI is shown in Figure 1. Note an approximation was used to overlay the new Colorado Power Pathway onto the current one-line diagram.

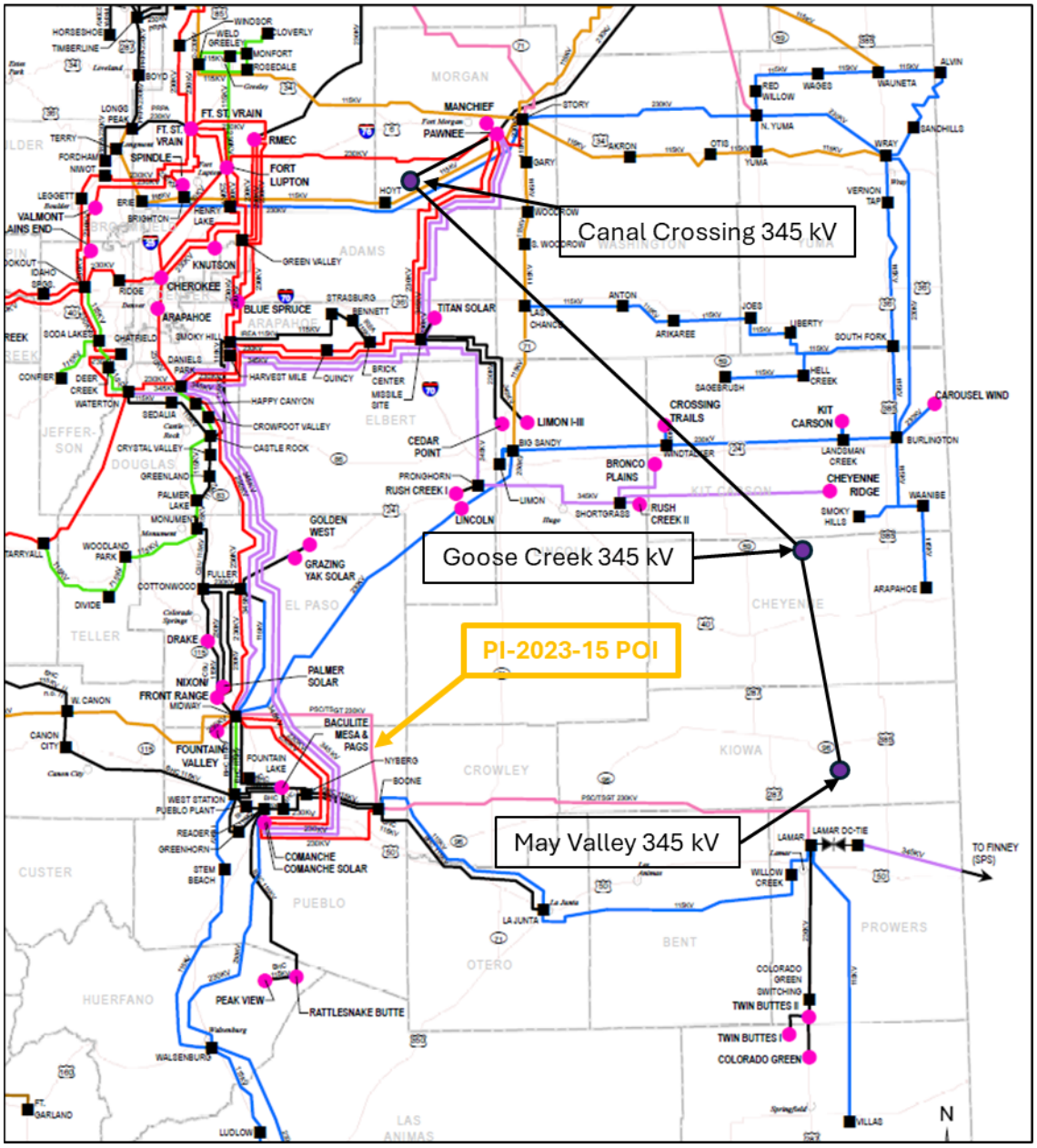

Figure 1: Approximate Point of Interconnection of PI-2024-15

3.0 Study Scope

The purpose of this study is to determine the impacts to the PSCo Transmission System and Affected Systems from interconnecting PI-2024-15 for Provisional Interconnection Service. Consistent with the assumption in the study agreement, PI-2024-15 selected Energy Resource Interconnection Service (ERIS)[4].

The scope of this report includes voltage and reactive capability evaluation, steady state (thermal and voltage) analysis, transient stability analysis, short-circuit analysis, and cost estimates for Transmission Provider's Interconnection Facilities and Station Network Upgrades. The study also identifies the estimated Security[5] and Contingent Facilities associated with the Provisional Interconnection Service.

3.1 Steady-State Criteria

The following Criteria are used for the reliability analysis of the PSCo system and Affected Systems:

P0—System Intact conditions:

Thermal Loading: <=100% of the normal facility rating

Voltage range: 0.95 to 1.05 per unit

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

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

[4] **Energy Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission system to be eligible to deliver the Generating Facility's electric output using the existing firm and non-firm capabilities of the Transmission Provider's Transmission System on an as available basis.

[5] **Security** estimates the risk associated with the Network Upgrades and Interconnection Facilities that could be identified in the corresponding LGIA.

3.2 Transient Stability Criteria

The transient voltage stability criteria are as follows:

a. Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds of the initiating event for all P1 through P7 events for each applicable Bulk Electric System (BES) bus serving load.
b. 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, for all P1 through P7 events.
c. For Contingencies without a fault (P2.1 category event), 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.

The transient angular stability criteria are as follows:

a. P1—No generating unit shall pull out of synchronism. A generator being disconnected from the system by fault clearing action or by a special Protection System is not considered an angular instability.
b. P2–P7—One or more generators may pull out of synchronism, provided the resulting apparent impedance swings shall not result in the tripping of any other generating facilities.
c. P1–P7—The relative rotor angle (power) oscillations are characterized by positive damping (i.e., amplitude reduction of successive peaks) > 5% within 30 seconds.

3.3 Breaker Duty Analysis Criteria

Fault Current after PI addition should not exceed 100% of the Breaker Duty rating. PSCo can only perform breaker duty analysis on the PSCo system. Before the PI goes in-service the Affected Systems may choose to perform a breaker duty analysis to identify breaker duty violations on their system.

3.4 Study Methodology

For PSCo and non-PSCo owned facilities, thermal violations attributed to the request include all new facility overloads with a thermal loading >100% and increased by 1% or more from the benchmark case overload post the Generator Interconnection Request (GIR) addition.

The voltage violations assigned to the request include new voltage violations which resulted in a further variation of 0.01 per unit.

Since the request is for Provisional Interconnection Service, if thermal or voltage violations are seen, the maximum permissible Provisional Interconnection Service before violations is identified. For voltage violations caused by reactive power deficiency at the POI, voltage upgrades are identified.

The Provisional Interconnection Service request should meet the transient stability criteria stated in Section 3.2. If the addition of the GIR causes any violations, the maximum permissible Provisional Interconnection Service before violations is identified and cannot be mitigated with re-dispatch option.

3.5 Contingency Analysis

The transmission system on which steady state contingency analysis is run includes the WECC designated areas 70 and 73.

The transient stability analysis is performed for the following worst-case contingencies shown in Table 1.

Table 1 – Transient Stability Contingencies

Ref. No.	Fault Location	Outage(s)	Clearing Time (Cycles)
1	-	Flat Run	-
2	Boone - PI-2024-15 POI 230kV CKT 1	Boone - PI-2024-15 POI 230kV CKT 1	5
3	Midway-PS - PI-2024-15 POI 230kV CKT 1	Midway-PS - PI-2024-15 POI 230kV CKT 1	5
4	PI-2024-15 POI 230 kV	PI-2024-15 Generation	5
5	Comanche - Boone 230kV CKT 1	Comanche - Boone 230kV CKT 1	5
6	Lamar_Swyd - Boone_230kV CKT 1	Lamar_Swyd - Boone_230kV CKT 1	5
7	HucklBry - Boone 230kV CKT 1	HucklBry - Boone 230kV CKT 1	5
8	Boone 230/115 kV Transformer T1	Boone 230/115 kV Transformer T1	5
9	Midway-PS - Comanche 230kV CKT 1	Midway-PS - Comanche 230kV CKT 1	5
10	Midway-PS - Mirasol 230kV CKT 1	Midway-PS - Mirasol 230kV CKT 1	5

Ref. No.	Fault Location	Outage(s)	Clearing Time (Cycles)
11	Midway-PS - MidwayBR 230kV CKT 1	Midway-PS - MidwayBR 230kV CKT 1	5
12	Midway-PS - Fuller 230kV CKT 1	Midway-PS - Fuller 230kV CKT 1	5
13	Midway PS – Fountain Valley Gens 230kV CKT 1	Midway PS - Fountain Valley -Gens 230kV CKT 1 PI-2024-15 Generation	5
14	Midway PS 230/115 kV Transformer T1	Midway-PS 230/115 kV Transformer T1	5
15	Midway PS 345/230 kV Transformer T3	Midway-PS 345/230 kV Transformer T3	4
16	Boone - PI-2024-15 POI 230kV CKT 1 (BF-19B)	Boone - PI-2024-15 POI 230kV CKT 1 Midway-PS - PI-2024-15 POI 230kV CKT 1 Boone 230/115 kV Transformer T1 PI-2024-15 Generation	17
17	Boone - PI-2024-15 POI 230kV CKT 1 (BF-19D)	Boone - PI-2024-15 POI 230kV CKT 1 Midway-PS - PI-2024-15 POI 230kV CKT 1 Lamar Swyd - Boone_230kV CKT 1 PI-2024-15 Generation	17
18	Midway PS - PI-2024-15 POI 230kV CKT 1 (BF-94B)	Midway-PS - PI-2024-15 POI 230kV CKT 1 Boone - PI-2024-15 POI 230kV CKT 1 Midway-PS 230/345 kV Transformer T3 PI-2024-15 Generation	17
19	Midway PS - PI-2024-15 POI 230kV CKT 1 (BF-94D)	Midway PS – Midway BR 230kV CKT 1 Midway PS - Fuller 230kV CKT 1 Midway BR 230/115 kV Transformer 1 Midway BR - RD-Nixon 230kV CKT 1 Midway BR - Hambone Tap 230kV CKT 1 Hambone Tap - W Canon 230kV CKT 1	17
20	Comanche - Hucklbry 230kV CKT 1 (P7-52)	Comanche - Hucklbry 230kV CKT 1 Comanche - Midway-PS 230kV CKT 1	5
21	Comanche – Midway PS 230kV CKT 1 (P7-53)	Comanche - Midway-PS 230kV CKT 1 Midway PS - Mirasol 230kV CKT 1	5
22	Midway PS - Fuller 230kV CKT 1 (P7-130)	Midway PS - Fuller 230kV CKT 1 Midway PS - Waterton 345kV CKT 1	5/4

3.6 Study Area

The Southern Colorado study area includes WECC designated zone 704. As described in Section 3.11 of the BPM, this pocket is comprised of South-central Colorado and Southeast Colorado transmission system.

4.0 Base Case Modeling Assumptions

The 2029HS2a WECC case released on May 8, 2023, was selected as the Starting Case and has been modified to represent a 2028 heavy summer loading conditions. The following potential transmission expansion projects were added to the Base Case, shown in Table 2.

Table 2 – Potential Transmission Expansion Projects Included in the 2028HS Base Case

Projects Description
Leetsdale – Monroe L5283 uprate to 796 MVA
Cherokee – Federal Heights – Broomfield line uprate to 398 MVA
Daniels Park – Prairie – Greenwood L5111 uprate to 916 MVA
Arapahoe – Greenwood L5709 uprate to 956 MVA
New Arapahoe 230/115 kV transformer #6
Monroe – Elati – Denver Terminal line uprate to 796 MVA
Leetsdale – Harrison L9955 uprate to 378 MVA
Spruce – High Point 230 kV line uprate to 741.4 MVA

Additionally, the following segments of the Colorado Power Pathway (CPP) were included in the Base Case:

- Segment #1: Fort St. Vrain – Canal Crossing 345 kV Double Circuit
- Segment #2: Canal Crossing – Goose Creek 345 kV Double Circuit
- Segment #3: Goose Creek – May Valley 345 kV Double Circuit
- Segment #4: May Valley – Sandstone – Tundra 345 kV Double Circuit
- Segment #5: Sandstone – Harvest Mile 345 kV Double Circuit

The Base Case model includes the existing PSCo generation resources and all Affected Systems' existing resources. While the higher-queued NRIS requests were dispatched at 100%, the higher-queued ERIS requests were modeled offline.

4.1 Benchmark Case Modeling

The Benchmark Case was created from the Base Case described in Section 4.0 by changing the study pocket generation dispatch to reflect heavy generation in the Southern Colorado study pocket. This was accomplished by adopting the stressed generation dispatch given in Table 3.

Additionally, 4050 MW of Native Load Priority (NLP) was modeled on the Colorado's Power Pathway (CPP), as shown in Table 4.

Table 3 – Generation Dispatch to Create the Southern Colorado Benchmark Case (MW is Gross Capacity)

Ref. No.	Generator Bus No.	Bus Name	Base kV	ID	Status	Pgen (MW)	Max Power (MW)
1	70120	COMAN_2	24.00	C2	1	365.00	365.00
2	70577	FTNVL1&2	13.80	G1	1	35.40	40.00
3	70577	FTNVL1&2	13.80	G2	1	35.40	40.00
4	70578	FTNVL3&4	13.80	G3	1	35.40	40.00
5	70578	FTNVL3&4	13.80	G4	1	35.40	40.00
6	70579	FTNVL5&6	13.80	G5	1	35.40	40.00
7	70579	FTNVL5&6	13.80	G6	1	35.40	40.00
8	70777	COMAN_3	27.00	C3	1	804.90	804.90
9	70934	COMAN_S1	0.42	S1	1	102.00	120.00
10	70017	SI_GEN 0	0.60	1	1	15.10	30.10
11	70878	BIGHORN_S	0.63	S1	1	210.38	247.50
12	70756	NEPTUNE_B1	0.48	B1	1	106.25	125.00
13	70758	NEPTUNE_S1	0.66	S1	1	212.93	250.50
14	70761	THNDWLF_B1	0.48	B1	1	85.00	100.00
15	70763	THNDWLF_S1	0.66	S1	1	170.00	200.00
16	70859	SUN_MTN_S1	0.66	S1	1	172.30	202.70
17	700142	GI_2020_10	0.63	S1	1	103.70	154.10
18	700146	GI_2020_10	0.63	S2	1	103.70	154.10
19	70256	CO_GRN_W	0.58	W2	1	64.80	81.00
20	70708	CO_GRN_E	0.58	W1	1	64.80	81.00
21	70704	TBI_GEN	0.58	W1	1	60.00	75.00
22	70663	GLDNWST_W1	0.69	W1	1	199.52	249.40
23	70010	TBII_GEN	0.69	W	1	62.40	78.00
24	700119	REPL_21_1	0.66	S1	1	75.00	121.20
25	700120	REPL_21_1	0.66	S2	1	75.00	121.20
26	700121	REPL_21_1	0.66	S3	1	75.00	121.20
27	70725	SPANPKS2_GEN	0.60	PV	1	20.20	40.20
28	70994	SP_GEN	0.62	PV	1	50.20	100.20
34	700172	GI_2014_6	0.63	S	1	100.20	100.90
Total (MW)						**3510.76**	**4163.20**

Table 4 – NLP Generation Included

Generator Bus Number	Name	ID	Status	Pgen (MW)
700043	24_14_B	B	1	192.30
700057	24_13_W2	W2	1	143.30
700060	24_13_W3	W3	1	143.30
700063	24_13_W4	W4	1	122.90
700067	24_13_W1	W1	1	143.30
700076	24_12_W1	W1	1	109.20
700077	24_12_W2	W2	1	122.90
700078	24_12_W3	W3	1	109.20
700079	24_9_W1	W1	1	116.00
700082	24_9_W2	W2	1	122.90
700085	24_9_W3	W3	1	102.40
700088	24_9_W4	W4	1	116.00
700095	24_18_W	W	1	235.80
700182	24_28_W	W	1	389.20
700196	24_19_W1	W1	1	419.80
700226	24_6_S	S	1	336.40
700232	24_22_S	S	1	384.90
700235	24_26_S1	S1	1	116.00
700237	24_26_B1	B1	1	76.60
700239	24_26_S2	S2	1	116.00
700241	24_26_B2	B2	1	76.60
700244	24_27_B1	B1	1	82.90
700245	24_27_B2	B2	1	79.30
700246	24_27_S1	S1	1	96.80
700247	24_27_S2	S2	1	96.80
Total (MW)				**4050.80**

4.2 Study Case Modeling

A Study Case was created from the Benchmark Case by turning on the PI-2024-15 generation. The additional 312.8 MW output minus any losses from PI-2024-15 was balanced against PSCo generation outside of the southern Colorado study pocket.

The Grid Charging Study Case was developed from the Benchmark Case by modeling PI-2024-15 as a load at its respective POI. The -107.5 MW load from was balanced against PSCo generation connected to the PSCo Transmission System outside the southern Colorado study pocket.

The PI-2024-15 GIR is modeled as follows for Discharging scenario:

Solar PV: Pgen = 225.0 MW, Qgen= -25.95 MVAr

BESS: Pgen = 77.10 MW, Qgen= -25.95 MVAr

The PI-2024-15 GIR is modeled as follows for Grid Charging scenario:

Solar PV: Pgen = 0.0 MW, Qgen= 0.0 MVAr

BESS: Pgen = -107.5 MW, Qgen= 0.16 MVAr

4.3 Short-Circuit Modeling

This request is for the interconnection of a 312.8 MW Solar Photovoltaic (PV) and a 107.5 MW Battery Energy Storage System (BESS) Generating Facility with a Point of Interconnection (POI) on the Boone to Midway 230 kV line. The output will not exceed 300 MW at the POI.

This project assumes the use of ninety-six (96) PE FS3430M 3.43 MW Solar PV operating at +/- 0.95 pf, and thirty-three (33) 3.43 MW BESS generators for PI-2024-15. Each of the BESS generators is connected to a collector transformer, 0.645/34.5 kV, rated at 3.51 MVA. Per the supplied single-line diagram, the collector transformers for the solar generation have the same impedance and MVA rating. Two 230/34.5/13.8 kV main GSU transformers rated at 102/136/170 MVA step the voltage up from the collector transformer voltage to the POI voltage. The fault current from the interconnection is shared equally between the two GSUs. An approximately 13.8-mile generation tie line connecting the project to PSCo transmission line via a new switching station.

All connected generating facilities were assumed capable of producing maximum fault current. As such, all generation was modeled at full capacity, whether NRIS or ERIS is requested. Generation is modeled as a separate generating resource in CAPE and included at full capacity in the short circuit study, regardless of any limitations to the output that would be imposed otherwise.

5.0 Provisional Interconnection Service Analysis

5.1 Voltage and Reactive Power Capability Evaluation

Per Section 4.1.1.1 of the BPM, the following voltage regulation and reactive power capability requirements are applicable to non-synchronous generators:

- 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.
- It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAr), and the locations (on the Interconnection Customer's facility) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/- 0.95 power factor at the high side of the main step-up transformer.
- It is the responsibility of the Interconnection Customer to compensate their generation tie-line to ensure minimal reactive power flow under no load conditions.

Per Section 4.1.1.2 in the BPM, the following voltage regulation and reactive power capability requirements are applicable to synchronous generators:

- Xcel Energy's OATT requires all synchronous Generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the POI.
- The reactive power analysis performed in this report is an indicator of the reactive power requirements at the POI and the capability of the generator to meet those requirements. The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and the regulating voltage of the POI.

Per Section 4.4.1 in the BPM, the following steps shall be followed to perform the reactive power capability evaluation for synchronous generators:

a. The reactive power evaluation of the Synchronous generators is done by dispatching the generator at Pmax and changing the POI voltage till Qmax and Qmin are reached.
b. This step is repeated for Pmin.
c. The POI voltage and power factor for the two evaluations are noted. If the POI power factor of 0.95 is reached and the POI voltage stays under the voltage guidance values noted (1-1.04 p.u. for the 230kV system, 1-1.05 for the 345kV system and 1-1.03 for 115kV system), the GIR is considered to meet reactive power requirements. If not, additional dynamic reactive support would be identified.

All proposed reactive devices in customer provided models are switched favorably to provide appropriate reactive compensation in each test, therefore identified deficiencies are in addition to any proposed reactive compensation.

All summary tables representing GIRs' Voltage and Reactive Power Capability tests adhere to the following color formatting representing the different aspects of the tests:

- Values highlighted in red indicate a failed reactive power requirement.
- Voltages outside of 0.95 – 1.05 p.u. are highlighted in yellow to provide additional information.

The PI-2024-15 GIR is modeled as follows:

Solar PV: Pgen = 225.3 MW, Pmin = 0.0 MW, Qmax = 102.8 MVAr, Qmin= -102.8 MVAr

BESS: Pgen = 77.10 MW, Pmin = 0.0 MW, Qmax = 35.4 MVAr, Qmin= -35.4 MVAr

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2024-15 is:

- During the test with both units online, 0.95 lagging pf is not met. Additional cap bank of 2.15 MVAr is required to meet the lagging pf.
- During the test with individual units online with solar unit only online, 0.95 lagging pf is not met. Additional cap bank of 31.00 MVAr is required to meet the lagging pf.
- During the test with individual units online with battery unit only online, 0.95 lagging pf is not met. Additional cap bank of 13.50 MVAr is required to meet the lagging pf.
- During the test with both units online, 0.95 lagging pf is not met. Additional cap bank of 2.15 MVAr is required to meet the lagging pf.

With the updates mentioned above the Voltage and Reactive Power Capability Evaluation for PI-2024-15 is:

- The GIR is capable of meeting ±0.95 pf at the high side of the main step-up transformer while maintaining a normal operating voltage at the POI.
- The GIR is capable of meeting ±0.95 pf at its terminals while meeting the interconnection service request.
- The reactive power exchange and voltage change across the gen-tie are acceptable under no load conditions.
- The addition of 31 MVAr cap bank did not result in voltage violation for any of the operating points of above.

The Voltage and Reactive Power Capability tests performed for PI-2024-15 are summarized in Table 5. Please note the terminal voltage of the GIR unit exceeded the upper limit of 1.05 p.u. during the 0.95 lagging power factor assessment.

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Table 5 – Reactive Power Capability Evaluation for PI-2024-15

PV Generator Terminals					BESS Generator Terminals					High Side of Main Transformer				POI			
Pgen (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)	V (p.u.)	Pgen (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)	V (p.u.)	P (MW)	Q (Mvar)	V (p.u.)	PF	P (MW)	Q (Mvar)	V (p.u.)	PF
225.3	102.8	102.8	-102.8	1.10	77.1	35.4	35.4	-35.4	1.13	300.4	96.6	1.05	0.9520	300.2	96.1	1.05	0.9524
225.3	-25.9	102.8	-102.8	0.98	77.1	-25.9	35.4	-35.4	1.01	300.0	-99.0	1.01	-0.9496	300.0	-99.6	1.01	-0.9491
302.5	102.8	102.8	-102.8	1.08	OFFLINE					300.4	67.8	1.04	0.9755	300.3	67.3	1.04	0.9758
OFFLINE					107.5	35.4	35.4	-35.4	1.08	106.6	21.6	1.03	0.9801	106.6	21.7	1.03	0.9799
302.5	-58.7	102.8	-102.8	0.98	OFFLINE					300.0	-99.0	1.01	-0.9496	300.0	-99.6	1.01	-0.9491
OFFLINE					107.5	-35.4	35.4	-35.4	0.96	106.4	-53.1	1.01	-0.8948	106.4	-53.0	1.01	-0.8951
0.0	-26.0	102.8	-102.8	1.02	0.0	-26.0	35.4	-35.4	1.02	0.0	0.9	1.02	0.0000	0.0	1.9	1.02	0.0000

5.2 Steady-State Analysis

Contingency analysis was performed on the southern Colorado study pocket using the Study Case model. Steady state analysis was performed on two different scenarios.

The results obtained with the Study Case model for Grid Charging scenario are summarized below:

- The diverged P1 contingencies, shown in Table 6, occurred both in the Study case as well as Benchmark case. Divergence contingencies first appeared in the Benchmark case and were not resolved so they were not attributed by the study GIR.
- System Intact analysis showed no thermal or voltage violations attributable to PI-2024-15.
- Single contingency analysis showed thermal overloads attributable to PI-2024-15 which are shown in Table 7. No voltage violations attributable to PI-2024-15 were observed.
    - All single contingency violations were alleviated via re-dispatch.
- Multiple contingency analysis showed thermal violations attributable to PI-2024-15 which are shown in Table 8. No voltage violations attributable to PI-2024-15 were observed. Per TPL-001-5, multiple contingency violations are mitigated using system adjustments, including generation redispatch (includes GIRs under study) and/or operator actions.

The results obtained with the Discharging Study Case model for Discharging scenario are summarized below:

- The diverged P1 contingencies, shown in Table 9, occurred both in the Study case as well as Benchmark case. Divergence contingencies first appeared in the Benchmark case and were not resolved so they were not attributed by the study GIR.
- System Intact showed thermal overloads attributable to PI-2024-15 which are shown in Table 10. Voltage violations attributable to PI-2024-15 are shown in Table 11.
    - All System Intact violations were alleviated via redispatch.
- Single contingency analysis showed thermal overloads attributable to PI-2024-15 which are shown in Table 12. No voltage violations attributable to PI-2024-15 were observed. All single contingency violations were alleviated via redispatch.
- Multiple contingency analysis showed thermal violations attributable to PI-2024-15 which are shown in Table 13. Voltage violations attributable to PI-2024-15 are shown in Table 14. Per TPL-001-5, multiple contingency violations are mitigated using system

adjustments, including generation redispatch (includes GIRs under study) and/or operator actions.

- P7 contingencies, shown in Table 15, were divergent in the analysis. P7_55 was divergent in both Benchmark and Study Cases. Therefore, the divergence is not attributable to PI-2024-15. P7_51 and P7_159 were divergent in the study case, these divergences are attributed to PI-2024-15. It was discussed previously that diverged multiples will be mitigated using system adjustments, including generation redispatch and/or operator actions.

Table 6 – Diverged P1 Contingencies for Grid Charging scenario

Diverged Contingency	Contingency Description	Case
PLANT: 79016 CRAIG 2 22.0 73 790	P1: Loss of Craig 2 generation	Study/Benchmark
PLANT:700182 24-28-W 0.69 70 706	P1: Loss of PI-2024-28-W generation	Study/Benchmark
12181 GLDSTNPS 230 70990 VALENT 230 1 1	P1: Gladstone PS - Valent 230 kV circuit 1	Study/Benchmark

Table 7 – Single Contingency Thermal Overloads for Grid Charging Scenario

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
1	FT_ST_VRAIN 230/345 kV (70410/70916) TRANSFORMER T8	FT_ST_VRAIN 230/345 kV T7	230/345	70	560	124.93	126.98	2.05	100.00
2	FT_ST_VRAIN 230/345 kV (70410/70916) TRANSFORMER T7	FT_ST_VRAIN 230/345 kV T8	230/345	70	560	124.93	126.98	2.05	100.00

Table 8 – Multiple Contingency Thermal Overloads for Grid Charging Scenario

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	STORY (73192) – PAWNEE (70598) 230 kV CKT 1	P7_160 (Lines 7329 7297)	230	70/73	581	110.32	114.83	4.51
2	FT_ST_VRAIN 230/345 kV (70410/70916) TRANSFORMER T8	P7_135 (Lines 7081 7109)	230/345	70	560	100.85	102.69	1.84
3	FT_ST_VRAIN 230/345 kV (70410/70916) TRANSFORMER T7	P7_135 (Lines 7081 7109)	230/345	70	560	100.85	102.69	1.84

Table 9 – Diverged P1 Contingencies for Grid Discharging scenario

Diverged Contingency	Contingency Description	Case
PLANT: 79016 CRAIG 22.0 73 790	P1: Loss of Craig 2 generation	Study/Benchmark
PLANT:700182 24 28 W 0.69 70 706	P1: Loss of PI-2024-28-W generation	Study/Benchmark
12181 GLDSTNPS 230 70990 VALENT 230 1 1	P1: Gladstone PS - Valent 230 kV circuit 1	Study/Benchmark
SWSHUNT: 70628 PRONGHORN 345	P1: Loss of Pronghorn shunt ID v	Study/Benchmark

Table 10 – System Intact Thermal Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
1	FOXRUN (73414) – FLYHORSE N2 (73738) 115 kV CKT 1	System Intact	115	73	142	103.99	116.52	12.53	99.36
2	FLYHORSE S (73576) – KETTLECK N (73711) 115 kV CKT 1	System Intact	115	73	162	103.59	114.68	11.09	99.58
3	CTTNWD N (73391) – KETTLECK S (73410) 115 kV CKT 1	System Intact	115	73	162	102.88	110.70	7.82	100.04

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Table 11 – System Intact Voltage Violations for Discharging Scenario

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
1	LITTLET1	70263	115	70	System Intact	0.9674	0.9489	-0.0185
2	PALMRDIV	72419	69	73	System Intact	0.9559	0.9446	-0.0113
3	WATERTON	70466	345	70	System Intact	0.9559	0.9381	-0.0178

Table 12 – Single Contingency Thermal Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
1	PONCHA_W (77642) – SMELTER (70394) 115 kV CKT 1	W CANON – PONCHABR CKT 1	115	70	60	180.45	194.36	13.91	47.16
2	CTTNWD N (73391) – KETTLECK S (73410) 115 kV CKT 1	BRIARGATE S – BRIARGATE N CKT 1	115	73	162	169.28	180.50	11.22	100.00
3	FOXRUN (73414) – FLYHORSE N2 (73738) 115 kV CKT 1	VOLLMERT – FULLER CKT 1	115	73	142	158.80	174.34	15.54	53.72
4	FT_ST_VRAIN 230/345 kV (70410/70916) TRANSFORMER T8	FT_ST_VRAIN 230/345 kV T7	230/345	70	560	164.28	167.62	3.34	99.66
5	FT_ST_VRAIN 230/345 kV (70410/70916) TRANSFORMER T7	FT_ST_VRAIN 230/345 kV T8	230/345	70	560	164.28	167.62	3.34	99.66
6	W.CANON (70550) – HOGBACK115 (71025) 115 kV CKT 1	MIDWAYBR – HAMBONE TAP CKT 1	115	70	120	156.50	165.95	9.45	50.00

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
7	FLYHORSE S (73576) – KETTLECK N (73711) 115 kV CKT 1	VOLLMERT – FULLER CKT 1	115	73	162	151.66	165.40	13.74	58.53
8	SMELTER (70394) – W.CANON (70550) 115 kV CKT 1	W CANON – PONCHABR CKT 1	115	70	73	152.82	164.27	11.45	43.38
9	MIDWAY_PS (70286) – MIDWAYBR (73413) 230 kV CKT 1	MIDWAY_PS – FULLER CKT 1	230	70/73	478	137.51	158.65	21.14	62.44
10	MIDWAY_PS (70286) – PI_2024_15 (700015) 230 kV CKT 1	MIDWAY_PS – MIRASOL CKT 1	230	70	319	87.05	140.74	53.69	83.37
11	FTN_VLY (70193) – MIDWAYBR (73412) 115 kV CKT 1	MIDWAY_PS – MIDWAYBR CKT 1	115	70/73	179	123.67	131.97	8.30	19.00
12	BRIARGATE N (73710) – KETTLECK N (73711) 115 kV CKT 1	CTTNWD N – KETTLECK S CKT 1	115	73	186	118.83	127.38	8.55	65.16
13	PALMER_LK (70308) – FOXRUN (73414) 115 kV CKT 1	DANIEL_PK – FULLER CKT 1	115	70/73	156	108.06	124.26	16.20	9.87
14	MIDWAY_PS (70286) – FULLER (73477) 230 kV CKT 1	MIDWAY_PS – MIDWAYBR CKT 1	230	70/73	478	107.92	122.33	14.41	54.99
15	SMOKY_HL (70396) – POWHATON (70532) 230 kV CKT 1	SMOKY_HL – SPRUCE CKT 1	230	70	740	116.23	121.92	5.69	19.68
16	SMOKY_HL (70396) – SPRUCE (70528) 230 kV CKT 1	SMOKY_HL – POWHATON CKT 1	230	70	740	115.37	121.06	5.69	18.57

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
17	SMOKY_HL (70396) – HARVEST_MI (70596) 230 kV CKT 1	LoTC_151 (Line: 7087)	230	70	956	114.69	120.93	6.24	49.52
18	KELKER E (73408) – TEMPLTON (73422) 115 kV CKT 1	KELKER E – ROCKISLD CKT 1	115	73	131	115.11	120.52	5.41	88.88
19	VOLLMERT (72413) – FULLER (73481) 115 kV CKT 1	FLYHORSE S – KETTLECK N CKT 1	115	73	173	109.24	117.42	8.18	52.76
20	SPRUCE (70528) – POWHATON (70532) 230 kV CKT 1	SMOKY_HL – SPRUCE CKT 1	230	70	717	111.17	117.05	5.88	10.73
21	KELKER E (73408) – ROCKISLD (73420) 115 kV CKT 1	KELKER E – TEMPLTON CKT 1	115	73	162	110.54	115.15	4.61	88.70
22	DESRTCOV (70449) – W.STATON (70456) 115 kV CKT 1	MIDWAY_PS – MIDWAYBR CKT 1	115	70	221	108.29	115.08	6.79	23.47
23	DANIEL_PK (70139) – FULLER (73477) 230 kV CKT 1	MIDWAY_PS – WATERTON CKT 1	230	70/73	478	100.53	114.22	13.69	7.26
24	VOLLMERT (72413) – BLK_SQMV (73460) 115 kV CKT 1	FLYHORSE S – KETTLECK N CKT 1	115	73	173	104.01	112.14	8.13	47.46
25	BRIARGATE S (73389) – CTTNWD S (73393) 115 kV CKT 1	CTTNWD N – KETTLECK S CKT 1	115	73	150	101.75	111.59	9.84	49.61
26	PORTLAND (70330) – SKALA (70390) 115 kV CKT 1	N_PENROSE – TRK_CRK POI CKT 1	115	70	110	106.98	110.55	3.57	46.56

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
27	DANIEL_PK (70139) – PRAIRIE_3 (70323) 230 kV CKT 2	DANIEL_PK – PRAIRIE_1 CKT 1	230	70	916	102.19	109.46	7.27	54.18
28	SMOKY_HL 345/230 kV (70599/70396) TRANSFORMER T5	SMOKY_HL – HARVEST_MI CKT 1	345/230	70	560	105.84	109.08	3.24	63.63
29	SMOKY_HL 345/230 kV (70599/70396) TRANSFORMER T4	SMOKY_HL – HARVEST_MI CKT 1	345/230	70	560	105.84	109.08	3.24	63.63
30	SMOKY_HL 345/230 kV (70599/70396) TRANSFORMER T6	SMOKY_HL – HARVEST_MI CKT 1	345/230	70	560	105.84	109.08	3.24	63.63
31	DANIEL_PK (70139) – PRAIRIE_1 (70331) 230 kV CKT 1	DANIEL_PK – PRAIRIE_3 CKT 1	230	70	916	101.56	108.71	7.15	54.00
32	FTN_VLY (70193) – DESRTCOV (70449) 115 kV CKT 1	MIDWAY_PS – MIDWAYBR CKT 1	115	70	221	100.75	107.48	6.73	15.98
33	W.CANON 115/230 kV (70550/73551) TRANSFORMER T1	MIDWAYBR – HAMBONE TAP CKT 1	115/230	70/73	100	98.98	105.61	6.63	21.19
34	KETTLECK S (73410) – KETTLECK N (73711) 115 kV CKT 1	BRIARGATE S – BRIARGATE N CKT 1	115	73	239	98.03	105.49	7.46	51.00
35	DEER_CK (70142) – SODA_LAKES (70400) 115 kV CKT 1	CHATFLD – WATERTON CKT 1	115	70	120	95.49	104.83	9.34	29.71
36	MIDWAYBR (73412) – RANCHO (73416) 115 kV CKT 1	LoTC_28 (Line: 5129)	115	73	119	98.56	104.24	5.68	59.80

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)	Re-dispatched Study Case Loading (%)
37	EAST_1 (70162) – EAST_2 (70171) 115 kV CKT 1	SMOKY_HL – POWHATON CKT 1	115	70	119.5	95.24	103.69	8.45	42.28
38	GREENWOOD_2 (70189) – PRAIRIE_3 (70323) 230 kV CKT 1	DANIEL_PK – PRAIRIE_1 CKT 1	230	70	916	96.48	103.66	7.18	48.54
39	DRAKE E (73575) – FONTERO E (73706) 115 kV CKT 1	DRAKE N – FAIRVWCS CKT 1	115	73	167	98.43	103.44	5.01	74.33
40	ARAPAHOE (70038) – SANTA_FE (70527) 230 kV CKT 1	LoTC_120 (Line: 5709)	230	70	505	93.61	102.03	8.42	45.95
41	MONACO_12 (70481) – SULLIVAN_2 (70365) 230 kV CKT 1	LoTC_120 (Line: 5709)	230	70	445	92.56	101.81	9.25	47.28
42	GREENWOOD_2 (70189) – GREE_SR (70105) 230 kV CKT 2	LoTC_120 (Line: 5709)	230	70	484	93.04	101.69	8.65	51.61
43	HARVEST_MI 345/230 kV (70597/70596) TRANSFORMER T1	HARVEST_MI – SMOKY_HL CKT 1	345/230	70	560	97.08	100.90	3.82	42.63
44	HARVEST_MI 345/230 kV (70597/70596) TRANSFORMER T2	HARVEST_MI – SMOKY_HL CKT 1	345/230	70	560	97.08	100.90	3.82	42.63
45	GREENWOOD_1 (70212) – PRAIRIE_1 (70331) 230 kV CKT 2	DANIEL_PK – PRAIRIE_3 CKT 1	230	70	916	93.44	100.47	7.03	45.83

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Table 13 – Multiple Contingency Thermal Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	EAST_1 (70162) – EAST_2 (70171) 115 kV CKT 1	P7_149 (Lines: 5177 5171 5277)	115	70	119.5	215.11	229.07	13.96
2	FOXRUN (73414) – FLYHORSE N2 (73738) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	73	142	190.10	213.84	23.74
3	MIDWAY_PS (70286) – MIDWAYBR (73413) 230 kV CKT 1	P7_130 (Lines: 5129 7051)	230	70/73	478	188.97	215.34	26.37
4	FLYHORSE S (73576) – KETTLECK N (73711) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	73	162	178.82	199.74	20.92
5	FTN_VLY (70193) – MIDWAYBR (73412) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	70/73	179	166.48	182.31	15.83
6	W.CANON (70550) – HOGBACK115 (71025) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	70	120	159.52	169.44	9.92
7	PALMER_LK (70308) – FOXRUN (73414) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	70/73	156	151.45	172.86	21.41
8	CTTNWD N (73391) – KETTLECK S (73410) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	73	162	150.55	164.66	14.11
9	DESRTCOV (70449) – W.STATON (70456) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	70	221	143.15	156.05	12.90
10	SMOKY_HL (70396) – HARVEST_MI (70596) 230 kV CKT 1	P7_137 (Lines: 7081 7087)	230	70	956	137.49	144.96	7.47
11	FTN_VLY (70193) – DESRTCOV (70449) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	70	221	135.44	148.26	12.82
12	CLARK (70112) – JORDAN (70241) 230 kV CKT 1	P7_58 (Lines: 5707 5111)	230	70	331	131.66	140.91	9.25

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
13	EAST_2 (70171) – SMOKY_HL_N (70395) 115 kV CKT 2	P7_149 (Lines: 5177 5171 5277)	115	70	120	129.84	137.18	7.34
14	EAST_2 (70171) – SMOKY_HL_N (70395) 115 kV CKT 1	P7_149 (Lines: 5177 5171 5277)	115	70	120	129.84	137.17	7.33
15	ARAPAHOE (70038) – SANTA_FE (70527) 230 kV CKT 1	BF_064c (Greenwood Bus Tie)	230	70	505	125.94	136.78	10.84
16	FT_ST_VRAIN (70410) – FT_ST_VRAIN (70916) 345 kV CKT T8	P7_135 (Lines: 7081 7109)	230/345	70	560	120.14	122.80	2.66
17	FT_ST_VRAIN (70410) – FT_ST_VRAIN (70916) 345 kV CKT T7	P7_135 (Lines: 7081 7109)	230/345	70	560	120.14	122.80	2.66
18	DENVER_TM (70149) – LACOMBE (70324) 230 kV CKT 1	P7_148 (Lines: 5177 5171)	230	70	486	120.10	129.43	9.33
19	LITTLET1 (70263) – WATERTON (70463) 115 kV CKT 1	BF_004a (Arapahoe 230 bus)	115	70	159	119.36	128.38	9.02
20	SMOKY_HL (70396) – POWHATON (70532) 230 kV CKT 1	BF_129r (Smoky Hill 5177 stuck)	230	70	740	116.59	122.28	5.69
21	CHATFLD (70100) – WATERTON (70464) 230 kV CKT 1	BF_064c (Greenwood Bus Tie)	230	70	478	114.66	123.74	9.08
22	MIDWAY_PS (70285) – W.STATON (70456) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	70	79	113.88	129.38	15.50
23	MONACO_12 (70481) – SULLIVAN_2 (70365) 230 kV CKT 1	BF_004a (Arapahoe 230 bus)	230	70	445	113.49	124.83	11.34
24	HARVEST_MI (70597) – HARVEST_MI (70596) 230 kV CKT T1	P7_137 (Lines: 7081 7087)	345/230	70	560	113.33	117.10	3.77

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
25	HARVEST_MI (70597) – HARVEST_MI (70596) 230 kV CKT T2	P7_137 (Lines: 7081 7087)	345/230	70	560	113.33	117.10	3.77
26	GREENWOOD_2 (70189) – GREE_SR (70105) 230 kV CKT 2	BF_004a (Arapahoe 230 bus)	230	70	484	112.34	122.93	10.59
27	SPRUCE (70528) – POWHATON (70532) 230 kV CKT 1	BF_129r (Smoky Hill 5177 stuck)	230	70	717	111.52	117.41	5.89
28	DRAKE E (73575) – FONTERO E (73706) 115 kV CKT 1	P7_130 (Lines: 5129 7051)	115	73	167	111.50	119.00	7.50
29	SMOKY_HL (70396) – SPRUCE (70528) 230 kV CKT 1	BF_129q (Smoky Hill 5171 stuck)	230	70	740	111.30	117.02	5.72
30	DEER_CK (70142) – SODA_LAKES (70400) 115 kV CKT 1	BF_130a (Soda Lakes 230 kV 5023 stuck)	115	70	120	109.92	119.09	9.17
31	DANIEL_PK (70139) – SANTA_FE (70527) 230 kV CKT 1	BF_064c (Greenwood Bus Tie)	230	70	637	109.47	118.26	8.79
32	DANIEL_PK (70139) – MARCY (70278) 230 kV CKT 1	P7_65 (Lines: 5109 7051)	230	70	478	109.33	113.77	4.44
33	SMOKY_HL_N (70395) – mid_99185 (99185) 230 kV CKT T1	P7_149 (Lines: 5177 5171 5277)	115/230	70	144.2	108.82	112.44	3.62
34	KELKER E (73408) – ROCKISLD (73420) 115 kV CKT 1	P7_130 (Lines: 5129 7051)	115	73	162	108.62	114.27	5.65
35	MONACO_12 (70481) – GREE_SR (70105) 230 kV CKT 1	BF_004a (Arapahoe 230 bus)	230	70	503	108.10	118.29	10.19
36	CHEROKEE (70107) – LACOMBE (70324) 230 kV CKT 1	P7_148 (Lines: 5177 5171)	230	70	435	108.03	116.90	8.87
37	SMOKY_HL (70396) – mid_99185 (99185) 230 kV CKT T1	P7_149 (Lines: 5177 5171 5277)	230	70	144	107.95	111.18	3.23

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
38	SMOKY_HL (70599) – SMOKY_HL (70396) 230 kV CKT T6	BF_073c (Harvest Mile 7153)	345/230	70	560	106.22	108.99	2.77
39	SMOKY_HL (70599) – SMOKY_HL (70396) 230 kV CKT T5	BF_073c (Harvest Mile 7153)	345/230	70	560	106.22	108.99	2.77
40	SMOKY_HL (70599) – SMOKY_HL (70396) 230 kV CKT T4	BF_073c (Harvest Mile 7153)	345/230	70	560	106.22	108.99	2.77
41	MEADOW_HLS (70283) – SMOKY_HL (70396) 230 kV CKT 1	P7_58 (Lines: 5707 5111)	230	70	564	105.77	111.83	6.06
42	PAWNEE (70598) – mid_99600 (99600) 345 kV CKT T2	P7_160 (Lines 7329 7297)	345	70	560	100.40	102.10	1.70
43	PAWNEE (70598) – mid_99599 (99599) 345 kV CKT T3	P7_160 (Lines 7329 7297)	345	70	560	100.40	102.10	1.70
44	PAWNEE (70311) – mid_99599 (99599) 345 kV CKT T3	P7_160 (Lines 7329 7297)	230/345	70	560	100.39	102.09	1.70
45	PAWNEE (70311) – mid_99600 (99600) 345 kV CKT T2	P7_160 (Lines 7329 7297)	230/345	70	560	100.39	102.09	1.70
46	PORTLAND (70330) – SKALA (70390) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	70	110	100.12	106.58	6.46
47	DANIEL_PK (70139) – PRAIRIE_3 (70323) 230 kV CKT 2	BF_064b (Greenwood Bus 1)	230	70	916	100.09	107.90	7.81
48	DANIEL_PK (70139) – PRAIRIE_1 (70331) 230 kV CKT 1	BF_045s (Daniels Park 5707)	230	70	916	99.98	107.01	7.03
49	CASTL_RK_CR (70091) – CASTL_RK_T1 (70020) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	70	129	99.80	114.24	14.44
50	W.CANON (70550) – W CANON (73551) 230 kV CKT T1	BF_094d (Midway 5120 stuck)	115/230	70/73	100	98.90	105.62	6.72

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
51	SODA_LAKES (70018) – CHATFLD (70100) 230 kV CKT 1	BF_064c (Greenwood Bus Tie)	230	70	483	98.08	106.79	8.71
52	FONTERO W (73411) – RAMPART S (73490) 115 kV CKT 1	P7_130 (Lines: 5129 7051)	115	73	154	97.76	105.69	7.93
53	KELKER E (73408) – TEMPLTON (73422) 115 kV CKT 1	P7_130 (Lines: 5129 7051)	115	73	131	96.55	102.88	6.33
54	LEETSDALE (70260) – SULLIVAN_2 (70365) 230 kV CKT 1	BF_004a (Arapahoe 230 bus)	230	70	425	96.52	107.91	11.39
55	VOLLMERT (72413) – FULLER (73481) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	73	173	95.93	103.31	7.38
56	LEETSDALE_2 (70282) – LEETSDALE (70260) 230 kV CKT T5	BF_087a (Leetsdale 5283 stuck)	115/230	70	280	95.28	109.64	14.36
57	MEADOW_HLS (70283) – ORCHARD (70313) 230 kV CKT 1	P7_58 (Lines: 5707 5111)	230	70	546	95.02	100.98	5.96
58	GREENWOOD_2 (70189) – PRAIRIE_3 (70323) 230 kV CKT 1	BF_064b (Greenwood Bus 1)	230	70	916	94.36	102.07	7.71
59	BUCKLEY2 (70046) – TOLLGATE (70491) 230 kV CKT 1	BF_064c (Greenwood Bus Tie)	230	70	796	94.05	102.08	8.03
60	BUCKLEY2 (70046) – SMOKY_HL (70396) 230 kV CKT 1	BF_064c (Greenwood Bus Tie)	230	70	796	94.04	102.07	8.03
61	TUNDRA (70653) – COMANCHE (70654) 345 kV CKT 2	BF_140a (Tundra 7015)	345	70	1183	92.77	103.88	11.11
62	CASTL_RK_T1 (70020) – PALMER_LK (70308) 115 kV CKT 1	P7_129 (Lines: 5119 7051)	115	70	140	92.16	105.46	13.30
63	BOONE (70061) – mid_99176 (99176) 230 kV CKT T1	BF_039o (Comanche 115 Bus tie)	230	70	147	92.03	100.40	8.37

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
64	MIDWAYBR (73413) – RD_NIXON (73419) 230 kV CKT 1	P7_130 (Lines: 5129 7051)	230	73	531	91.79	105.61	13.82
65	MIDWAYBR (73412) – RD_NIXON (73417) 115 kV CKT 1	BF_094d (Midway 5120 stuck)	115	73	195	91.41	102.28	10.87

Table 14 – Multiple Contingency Voltage Violations for Discharging Scenario

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
1	PRARI_TS	72025	115	73	BF_118a (Reunion 5876)	0.9082	0.8970	-0.0112
2	FTGARLND	70187	69	70	BF_017c (Blanca Peak 9433)	0.9065	0.8953	-0.0112
3	REUNION	72028	115	73	BF_118a (Reunion 5876)	0.9029	0.8916	-0.0113
4	FTGARLND	70187	69	70	BF_017a (Blanca Peak 9431)	0.9049	0.8936	-0.0113
5	REUNION	72026	230	73	BF_118a (Reunion 5876)	0.8944	0.8830	-0.0114
6	MOFFAT	70289	69	70	BF_128f (SLV 115 kV Bus 2)	0.9061	0.8940	-0.0121
7	MIRGEJCT	70505	69	70	BF_128f (SLV 115 kV Bus 2)	0.9045	0.8923	-0.0122
8	SAGUACHE	70506	69	70	BF_128f (SLV 115 kV Bus 2)	0.9013	0.8890	-0.0123
9	ROMEO_TAP	70552	69	70	BF_017c (Blanca Peak 9433)	0.8388	0.8262	-0.0126
10	ROMEO	70367	69	70	BF_017a (Blanca Peak 9431)	0.8367	0.8241	-0.0126
11	ROMEO	70367	69	70	BF_017c (Blanca Peak 9433)	0.8385	0.8259	-0.0126
12	ANTONITO	70029	69	70	BF_017a (Blanca Peak 9431)	0.8310	0.8183	-0.0127
13	ANTONITO	70029	69	70	BF_017c (Blanca Peak 9433)	0.8328	0.8201	-0.0127
14	ROMEO_TAP	70552	69	70	BF_017a (Blanca Peak 9431)	0.8370	0.8243	-0.0127
15	ROMEO	70367	69	70	BF_128f (SLV 115 kV Bus 2)	0.8512	0.8358	-0.0154
16	ROMEO_TAP	70552	69	70	BF_128f (SLV 115 kV Bus 2)	0.8515	0.8361	-0.0154

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
17	ANTONITO	70029	69	70	BF_128f (SLV 115 kV Bus 2)	0.8456	0.8301	-0.0155
18	WATERTON	70466	345	70	BF_155b (Goose Creek 7254)	0.9257	0.8953	-0.0304
19	DELCAMIN	72208	69	73	P7_135 (Lines: 7081 7109)	0.9200	0.8892	-0.0308
20	NCAR	70295	115	70	P7_135 (Lines: 7081 7109)	0.9318	0.8996	-0.0322
21	BOULDER_CN2	70058	115	70	P7_135 (Lines: 7081 7109)	0.9303	0.8972	-0.0331
22	BOULDER_CN1	70423	115	70	P7_135 (Lines: 7081 7109)	0.9303	0.8972	-0.0331
23	BOULDER_HYD	70492	115	70	P7_135 (Lines: 7081 7109)	0.9303	0.8972	-0.0331
24	SUNSHINE	70424	115	70	P7_135 (Lines: 7081 7109)	0.9317	0.8982	-0.0335
25	PALMRDIV	72419	69	73	P7_135 (Lines: 7081 7109)	0.9288	0.8939	-0.0349
26	HENRYLAK	72024	115	73	P7_135 (Lines: 7081 7109)	0.9367	0.8967	-0.0400
27	PALMER_LK	70308	115	70	P7_135 (Lines: 7081 7109)	0.9344	0.8942	-0.0402
28	LOUISVILLE	70269	115	70	P7_135 (Lines: 7081 7109)	0.9227	0.8821	-0.0406
29	GREENLND_CR	70582	115	70	P7_135 (Lines: 7081 7109)	0.9338	0.8928	-0.0410
30	BROMLEY	72019	115	73	P7_135 (Lines: 7081 7109)	0.9334	0.8924	-0.0410
31	PRARI_TS	72025	115	73	P7_135 (Lines: 7081 7109)	0.9358	0.8937	-0.0421
32	PLATTE_VLY	70307	115	70	P7_135 (Lines: 7081 7109)	0.9394	0.8973	-0.0421
33	NIWOT	70297	230	70	P7_135 (Lines: 7081 7109)	0.9370	0.8942	-0.0428
34	GUNBARREL_3	70972	230	70	P7_135 (Lines: 7081 7109)	0.9370	0.8941	-0.0429
35	GUNBARREL_2	70211	230	70	P7_135 (Lines: 7081 7109)	0.9370	0.8941	-0.0429
36	GUNBARREL_1	70213	230	70	P7_135 (Lines: 7081 7109)	0.9370	0.8941	-0.0429
37	LEYDEN_TP	70262	115	70	P7_135 (Lines: 7081 7109)	0.9388	0.8958	-0.0430
38	QUAKER_1	70340	115	70	P7_135 (Lines: 7081 7109)	0.9326	0.8894	-0.0432
39	BROOMFIELD	70065	115	70	P7_135 (Lines: 7081 7109)	0.9229	0.8794	-0.0435
40	CRSTL_VA_CR	70584	115	70	P7_135 (Lines: 7081 7109)	0.9322	0.8886	-0.0436
41	FAIR_GRNDS	70081	115	70	P7_135 (Lines: 7081 7109)	0.9319	0.8880	-0.0439
42	LEGGETT	70261	230	70	P7_135 (Lines: 7081 7109)	0.9346	0.8903	-0.0443

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
43	CASTL_RK_T1	70020	115	70	P7_135 (Lines: 7081 7109)	0.9325	0.8877	-0.0448
44	CASTL_RK_CR	70091	115	70	P7_135 (Lines: 7081 7109)	0.9326	0.8877	-0.0449
45	CASTL_RK_T2	70021	115	70	P7_135 (Lines: 7081 7109)	0.9326	0.8876	-0.0450
46	SEMPER	70382	115	70	P7_135 (Lines: 7081 7109)	0.9197	0.8745	-0.0452
47	THORNTON	70099	115	70	P7_135 (Lines: 7081 7109)	0.9292	0.8837	-0.0455
48	CROWFT_VLY	70117	115	70	P7_135 (Lines: 7081 7109)	0.9308	0.8848	-0.0460
49	FEDERHT23	70174	115	70	P7_135 (Lines: 7081 7109)	0.9242	0.8782	-0.0460
50	WATERTON	70466	345	70	P7_135 (Lines: 7081 7109)	0.9187	0.8724	-0.0463
51	JLGREEN	70529	230	70	P7_135 (Lines: 7081 7109)	0.9390	0.8925	-0.0465
52	WOLFSBRG_CR	70519	115	70	P7_135 (Lines: 7081 7109)	0.9256	0.8786	-0.0470
53	WASHINGTON	70461	230	70	P7_135 (Lines: 7081 7109)	0.9385	0.8915	-0.0470
54	FEDERHT1	70175	115	70	P7_135 (Lines: 7081 7109)	0.9250	0.8780	-0.0470
55	CITADEL_CR	71502	115	70	P7_135 (Lines: 7081 7109)	0.9250	0.8778	-0.0472
56	DAWSONRG_CR	71501	115	70	P7_135 (Lines: 7081 7109)	0.9248	0.8774	-0.0474
57	HAPPY_CNYN	70115	115	70	P7_135 (Lines: 7081 7109)	0.9300	0.8826	-0.0474
58	VALMONT	70447	230	70	P7_135 (Lines: 7081 7109)	0.9267	0.8792	-0.0475
59	MEADOWS_CR	70575	115	70	P7_135 (Lines: 7081 7109)	0.9248	0.8771	-0.0477
60	METRO_WATER	70494	115	70	P7_135 (Lines: 7081 7109)	0.9309	0.8831	-0.0478
61	PLUM_CK_CR	70514	115	70	P7_135 (Lines: 7081 7109)	0.9253	0.8773	-0.0480
62	CHEROKEE_N	70110	115	70	P7_135 (Lines: 7081 7109)	0.9315	0.8834	-0.0481
63	SIMMS	70543	230	70	P7_135 (Lines: 7081 7109)	0.9291	0.8809	-0.0482
64	PLAINS_END	70570	230	70	P7_135 (Lines: 7081 7109)	0.9331	0.8847	-0.0484
65	MOONGLCH	70574	230	70	P7_135 (Lines: 7081 7109)	0.9320	0.8836	-0.0484
66	PLAINS_NG1	70431	230	70	P7_135 (Lines: 7081 7109)	0.9331	0.8847	-0.0484
67	PLAINS_NG2	70433	230	70	P7_135 (Lines: 7081 7109)	0.9333	0.8848	-0.0485
68	DERBY_2	70153	115	70	P7_135 (Lines: 7081 7109)	0.9326	0.8840	-0.0486

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
69	DANIEL_PK	70138	115	70	P7_135 (Lines: 7081 7109)	0.9331	0.8845	-0.0486
70	DERBY_1	70154	115	70	P7_135 (Lines: 7081 7109)	0.9334	0.8847	-0.0487
71	SEDALIA_CR	70381	115	70	P7_135 (Lines: 7081 7109)	0.9289	0.8798	-0.0491
72	DANIEL_PK	70601	345	70	P7_135 (Lines: 7081 7109)	0.9228	0.8736	-0.0492
73	ARSENAL	70040	115	70	P7_135 (Lines: 7081 7109)	0.9370	0.8878	-0.0492
74	WATE_DST	70959	230	70	P7_135 (Lines: 7081 7109)	0.9388	0.8889	-0.0499
75	WATERTON	70464	230	70	P7_135 (Lines: 7081 7109)	0.9391	0.8891	-0.0500
76	LOOKOUT	70266	230	70	P7_135 (Lines: 7081 7109)	0.9364	0.8864	-0.0500
77	BUCKLEY1	70067	230	70	P7_135 (Lines: 7081 7109)	0.9398	0.8893	-0.0505
78	MARCY	70278	230	70	P7_135 (Lines: 7081 7109)	0.9369	0.8864	-0.0505
79	ROXBOROU_CR	70522	115	70	P7_135 (Lines: 7081 7109)	0.9349	0.8843	-0.0506
80	WEST_PS	70480	230	70	P7_135 (Lines: 7081 7109)	0.9345	0.8837	-0.0508
81	MEADOW_HLS	70283	230	70	P7_135 (Lines: 7081 7109)	0.9387	0.8878	-0.0509
82	ORCHARD	70313	230	70	P7_135 (Lines: 7081 7109)	0.9377	0.8866	-0.0511
83	SURREY_RG	70284	230	70	P7_135 (Lines: 7081 7109)	0.9370	0.8858	-0.0512
84	CONOCO	70126	115	70	P7_135 (Lines: 7081 7109)	0.9333	0.8821	-0.0512
85	RIDGE	70355	230	70	P7_135 (Lines: 7081 7109)	0.9372	0.8860	-0.0512
86	REUNION	72028	115	73	P7_135 (Lines: 7081 7109)	0.9493	0.8981	-0.0512
87	PRAIRIE_1	70331	230	70	P7_135 (Lines: 7081 7109)	0.9375	0.8862	-0.0513
88	JEWELL1	70512	230	70	P7_135 (Lines: 7081 7109)	0.9365	0.8852	-0.0513
89	CHATFLD	70100	230	70	P7_135 (Lines: 7081 7109)	0.9335	0.8822	-0.0513
90	PRAIRIE_3	70323	230	70	P7_135 (Lines: 7081 7109)	0.9376	0.8863	-0.0513
91	SODA_LAKES	70018	230	70	P7_135 (Lines: 7081 7109)	0.9344	0.8829	-0.0515
92	WATERTON	70463	115	70	P7_135 (Lines: 7081 7109)	0.9395	0.8879	-0.0516
93	ARVADA_PS	70041	230	70	P7_135 (Lines: 7081 7109)	0.9385	0.8869	-0.0516
94	BUCKLEY2	70046	230	70	P7_135 (Lines: 7081 7109)	0.9373	0.8857	-0.0516

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
95	SULLIVAN_1	70417	230	70	P7_135 (Lines: 7081 7109)	0.9355	0.8838	-0.0517
96	MARTIN_1	70279	115	70	P7_135 (Lines: 7081 7109)	0.9382	0.8865	-0.0517
97	JORDAN	70241	230	70	P7_135 (Lines: 7081 7109)	0.9360	0.8843	-0.0517
98	TBD_2025	70103	115	70	P7_135 (Lines: 7081 7109)	0.9347	0.8829	-0.0518
99	TECH_CENTER	70428	230	70	P7_135 (Lines: 7081 7109)	0.9351	0.8833	-0.0518
100	HOMESTEAD	70513	230	70	P7_135 (Lines: 7081 7109)	0.9358	0.8839	-0.0519
101	CLARK	70112	230	70	P7_135 (Lines: 7081 7109)	0.9355	0.8836	-0.0519
102	LEETSDALE_2	70282	115	70	P7_135 (Lines: 7081 7109)	0.9326	0.8806	-0.0520
103	LEETSDALE_1	70259	115	70	P7_135 (Lines: 7081 7109)	0.9327	0.8807	-0.0520
104	GREENWOOD_1	70212	230	70	P7_135 (Lines: 7081 7109)	0.9358	0.8838	-0.0520
105	LEMON_GLCH	70533	230	70	P7_135 (Lines: 7081 7109)	0.9351	0.8831	-0.0520
106	GREENWOOD_2	70189	230	70	P7_135 (Lines: 7081 7109)	0.9355	0.8834	-0.0521
107	HARRISON_P2	70182	115	70	P7_135 (Lines: 7081 7109)	0.9319	0.8797	-0.0522
108	HARRISON_P1	70215	115	70	P7_135 (Lines: 7081 7109)	0.9319	0.8797	-0.0522
109	CALIFORNIA	70073	115	70	P7_135 (Lines: 7081 7109)	0.9314	0.8790	-0.0524
110	SULPHUR	70524	230	70	P7_135 (Lines: 7081 7109)	0.9338	0.8813	-0.0525
111	SANTA_FE	70527	230	70	P7_135 (Lines: 7081 7109)	0.9323	0.8798	-0.0525
112	CAPITOL_HL	70087	115	70	P7_135 (Lines: 7081 7109)	0.9313	0.8787	-0.0526
113	LACOMBE	70324	230	70	P7_135 (Lines: 7081 7109)	0.9358	0.8831	-0.0527
114	BARKER	70152	230	70	P7_135 (Lines: 7081 7109)	0.9357	0.8830	-0.0527
115	SANDOWN	70377	115	70	P7_135 (Lines: 7081 7109)	0.9345	0.8818	-0.0527
116	CALIFORN_TP	70074	115	70	P7_135 (Lines: 7081 7109)	0.9323	0.8795	-0.0528
117	DENVER_TM	70149	230	70	P7_135 (Lines: 7081 7109)	0.9317	0.8788	-0.0529
118	TOLLGATE	70491	230	70	P7_135 (Lines: 7081 7109)	0.9321	0.8792	-0.0529
119	MARTIN_2	70280	115	70	P7_135 (Lines: 7081 7109)	0.9339	0.8809	-0.0530
120	MARTIN_TP	70484	115	70	P7_135 (Lines: 7081 7109)	0.9351	0.8821	-0.0530

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
121	DAKOTA	70141	230	70	P7_135 (Lines: 7081 7109)	0.9314	0.8783	-0.0531
122	GREE_SR	70105	230	70	P7_135 (Lines: 7081 7109)	0.9319	0.8787	-0.0532
123	ELATI1	70163	230	70	P7_135 (Lines: 7081 7109)	0.9311	0.8779	-0.0532
124	ARAPAHOE	70038	230	70	P7_135 (Lines: 7081 7109)	0.9321	0.8788	-0.0533
125	SOUT	70075	230	70	P7_135 (Lines: 7081 7109)	0.9318	0.8785	-0.0533
126	MAPLETO2	70277	115	70	P7_135 (Lines: 7081 7109)	0.9373	0.8840	-0.0533
127	MONACO_12	70481	230	70	P7_135 (Lines: 7081 7109)	0.9305	0.8771	-0.0534
128	PODER	70177	115	70	P7_135 (Lines: 7081 7109)	0.9362	0.8827	-0.0535
129	JEWELL2	70239	230	70	P7_135 (Lines: 7081 7109)	0.9308	0.8773	-0.0535
130	SULLIVAN_2	70365	230	70	P7_135 (Lines: 7081 7109)	0.9296	0.8760	-0.0536
131	MONROEPS	70291	230	70	P7_135 (Lines: 7081 7109)	0.9307	0.8770	-0.0537
132	LEETSDALE	70260	230	70	P7_135 (Lines: 7081 7109)	0.9307	0.8769	-0.0538
133	MAPLETO1	70276	115	70	P7_135 (Lines: 7081 7109)	0.9378	0.8840	-0.0538
134	DEER_CK	70142	115	70	P7_135 (Lines: 7081 7109)	0.9359	0.8820	-0.0539
135	NORTH_PS	70298	115	70	P7_135 (Lines: 7081 7109)	0.9361	0.8822	-0.0539
136	CHEROKEE_S	70108	115	70	P7_135 (Lines: 7081 7109)	0.9392	0.8852	-0.0540
137	SOUTH	70402	115	70	P7_135 (Lines: 7081 7109)	0.9389	0.8848	-0.0541
138	UNIVERS1	70441	115	70	P7_135 (Lines: 7081 7109)	0.9348	0.8804	-0.0544
139	AIR_LIQ_TP	70531	115	70	P7_135 (Lines: 7081 7109)	0.9381	0.8837	-0.0544
140	LITTLET1	70263	115	70	P7_135 (Lines: 7081 7109)	0.9219	0.8675	-0.0544
141	ARAPAHOE_A	70036	115	70	P7_135 (Lines: 7081 7109)	0.9381	0.8837	-0.0544
142	ARAPAHOE_B	70037	115	70	P7_135 (Lines: 7081 7109)	0.9381	0.8837	-0.0544
143	AIR_LIQ	70027	115	70	P7_135 (Lines: 7081 7109)	0.9374	0.8830	-0.0544
144	ARAP_GEn	70035	115	70	P7_135 (Lines: 7081 7109)	0.9380	0.8835	-0.0545
145	ENGLE_WD_TP	70165	115	70	P7_135 (Lines: 7081 7109)	0.9306	0.8759	-0.0547
146	SHERIDAN	70384	115	70	P7_135 (Lines: 7081 7109)	0.9340	0.8793	-0.0547

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
147	ENGLEWD3	70168	115	70	P7_135 (Lines: 7081 7109)	0.9308	0.8760	-0.0548
148	CONI_DST_CR	71516	115	70	P7_135 (Lines: 7081 7109)	0.9367	0.8819	-0.0548
149	SOUTH_TAP	70401	115	70	P7_135 (Lines: 7081 7109)	0.9368	0.8820	-0.0548
150	CONIFER_CR	70124	115	70	P7_135 (Lines: 7081 7109)	0.9367	0.8819	-0.0548
151	PINEJCT_CR	71507	115	70	P7_135 (Lines: 7081 7109)	0.9381	0.8833	-0.0548
152	ENGLEWD1	70166	115	70	P7_135 (Lines: 7081 7109)	0.9283	0.8733	-0.0550
153	ENGLEWD2	70167	115	70	P7_135 (Lines: 7081 7109)	0.9283	0.8732	-0.0551
154	ALLISON	70023	115	70	P7_135 (Lines: 7081 7109)	0.9330	0.8778	-0.0552
155	KENDRICK	70242	115	70	P7_135 (Lines: 7081 7109)	0.9315	0.8760	-0.0555
156	RALSTON2	70346	115	70	P7_135 (Lines: 7081 7109)	0.9559	0.8991	-0.0568
157	RALSTON1	70345	115	70	P7_135 (Lines: 7081 7109)	0.9565	0.8996	-0.0569
158	GLENNPS	70200	230	70	P7_135 (Lines: 7081 7109)	0.9498	0.8915	-0.0583
159	HAVANA1	70216	115	70	P7_135 (Lines: 7081 7109)	0.9518	0.8934	-0.0584
160	SMOKY_HL	70396	230	70	P7_135 (Lines: 7081 7109)	0.9544	0.8958	-0.0586
161	HAVANA2	70217	115	70	P7_135 (Lines: 7081 7109)	0.9508	0.8922	-0.0586
162	HARVEST_MI	70596	230	70	P7_135 (Lines: 7081 7109)	0.9549	0.8963	-0.0586
163	RIVERDALE	70362	230	70	P7_135 (Lines: 7081 7109)	0.9555	0.8968	-0.0587
164	HARVEST_MI	70597	345	70	P7_135 (Lines: 7081 7109)	0.9546	0.8957	-0.0589
165	SMOKY_HL	70599	345	70	P7_135 (Lines: 7081 7109)	0.9542	0.8953	-0.0589
166	MURPHY	70551	230	70	P7_135 (Lines: 7081 7109)	0.9514	0.8923	-0.0591
167	DANIEL_PK	70139	230	70	P7_135 (Lines: 7081 7109)	0.9490	0.8898	-0.0592
168	LAKEWOOD_1	70251	115	70	P7_135 (Lines: 7081 7109)	0.9559	0.8957	-0.0602
169	LAKEWOOD_2	70252	115	70	P7_135 (Lines: 7081 7109)	0.9528	0.8923	-0.0605
170	RUSSELL	70369	230	70	P7_135 (Lines: 7081 7109)	0.9509	0.8898	-0.0611
171	CHEROKEE	70107	230	70	P7_135 (Lines: 7081 7109)	0.9569	0.8956	-0.0613
172	GRAY_STREET	70208	115	70	P7_135 (Lines: 7081 7109)	0.9579	0.8952	-0.0627

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
173	FED_CTR_TP	70173	115	70	P7_135 (Lines: 7081 7109)	0.9606	0.8977	-0.0629
174	FED_CTR	70172	115	70	P7_135 (Lines: 7081 7109)	0.9603	0.8974	-0.0629
175	QUAKER_TP	70342	115	70	P7_135 (Lines: 7081 7109)	0.9623	0.8994	-0.0629
176	HOGBACK	70224	115	70	P7_135 (Lines: 7081 7109)	0.9625	0.8995	-0.0630
177	BERGENPK	70050	115	70	P7_135 (Lines: 7081 7109)	0.9599	0.8967	-0.0632
178	ARGO	70039	115	70	P7_135 (Lines: 7081 7109)	0.9547	0.8914	-0.0633
179	QUAKER_2	70341	115	70	P7_135 (Lines: 7081 7109)	0.9564	0.8930	-0.0634
180	SODA_LAKES	70400	115	70	P7_135 (Lines: 7081 7109)	0.9542	0.8907	-0.0635
181	TINY_TWN_CR	70429	115	70	P7_135 (Lines: 7081 7109)	0.9501	0.8861	-0.0640
182	BANCROFT	70045	115	70	P7_135 (Lines: 7081 7109)	0.9496	0.8854	-0.0642

Table 15 – Diverged P7 Contingencies for Discharging Scenario

Diverged Contingency	Contingency Description	Benchmark Case	Study Case
P7_51	Daniels Park – Comanche 345 kV circuit 2 Daniels Park – Tundra 345 kV circuit 1 Daniels Park – Tundra 345 kV circuit 2	Converged	Diverged
P7_55	Comanche – Tundra 345 kV circuit 1 Comanche – Tundra 345 kV circuit 2 Daniels Park – Comanche 345 kV circuit 2	Diverged	Diverged
P7_159	Canal Crossing – Goose Creek 345 kV circuit 1 Canal Crossing – Goose Creek 345 kV circuit 2	Converged	Diverged

5.3 Transient Stability Results

Instability was observed in the generating units around the study area in the Discharging scenario during contingencies Ref. Nos. 11, 12, 13, 14, 15, 18, 21 and 22. To solve this issue nearby generation was re-dispatched until the contingencies were stable. Note the re-dispatched case that was derived from this project's power flow analysis was used to resolve initial instability in this analysis. This redispatch solution is shown in Table 16.

One P4 contingency, Ref. No. 19 presented oscillations after fault clearing throughout the simulation in both Study and Benchmark Case for Discharging as well as Grid Charging scenarios. These oscillations are not attributed to the study unit. The response occurring during the P4 contingency shown in Ref. No. 19 may require a Corrective Action Plan (CAP) to resolve benchmark stressing.

Apart from contingency Ref. 19, all the disturbances analysed for both Discharging and Grid Charging scenarios presented the following results:

- ✓ No machines lost synchronism with the system.
- ✓ No transient voltage drop violations were observed.
- ✓ Machine rotor angles displayed positive damping.

The results of the contingency analysis are shown in Table 17. The transient stability plots for Discharging and Grid Charging scenarios are shown in Appendix A and Appendix B, respectively, in Section 10.0 of this report.

Table 16 – Generation Dispatch to Resolve the Unstable P1 Contingency

Bus No.	Bus Name	Base kV	ID	Original Pgen (MW)	Modified Pgen (MW)
70120	COMAN_2	24.00	C2	355.00	0 (Offline)
70777	COMAN_3	27.00	C3	804.90	0 (Offline)
70761	THNDWLF_B1	0.48	B1	85.00	0 (Offline)
70763	THNDWLF_S1	0.66	S1	170.00	0 (Offline)
70758	NEPTUNE_S1	0.66	S1	212.90	0 (Offline)

Table 17 – Transient Stability Analysis Results

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Discharging		Grid Charging	
					Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability
1	-	P0	Flat Run	-	Stable	Stable	Stable	Stable
2	Boone - PI-2024-15 POI 230kV CKT 1	P1	Boone - PI-2024-15 POI 230kV CKT 1	5	Stable	Stable	Stable	Stable
3	Midway PS - PI-2024-15 POI 230kV CKT 1	P1	Midway PS - PI-2024-15 POI 230kV CKT 1	5	Stable	Stable	Stable	Stable
4	PI-2024-15 POI 230 kV	P1	PI-2024-15 Generation	5	Stable	Stable	Stable	Stable
5	Comanche - Boone 230kV CKT 1	P1	Comanche - Boone 230kV CKT 1	5	Stable	Stable	Stable	Stable
6	Lamar Swyd – Boone 230kV CKT 1	P1	Lamar Swyd - Boone_230kV CKT 1	5	Stable	Stable	Stable	Stable
7	HucklBry - Boone 230kV CKT 1	P1	HucklBry - Boone 230kV CKT 1	5	Stable	Stable	Stable	Stable
8	Boone 230/115 kV Transformer T1	P1	Boone 230/115 kV Transformer T1	5	Stable	Stable	Stable	Stable
9	Midway PS - Comanche 230kV CKT 1	P1	Midway PS - Comanche 230kV CKT 1	5	Stable	Stable	Stable	Stable
10	Midway PS - Mirasol 230kV CKT 1	P1	Midway PS - Mirasol 230kV CKT 1	5	Stable	Stable	Stable	Stable
11	Midway PS – Midway BR 230kV CKT 1	P1	Midway PS – Midway BR 230kV CKT 1	5	Stable	Stable	Stable	Stable
12	Midway PS - Fuller 230kV CKT 1	P1	Midway PS - Fuller 230kV CKT 1	5	Stable	Stable	Stable	Stable

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Discharging		Grid Charging	
					Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability
13	Midway PS – Fountain Valley Gens 230kV CKT 1	P1	Midway PS - Fountain Valley Gens 230kV CKT 1 PI-2024-15 Generation	5	Stable	Stable	Stable	Stable
14	Midway PS 230/115 kV Transformer T1	P1	Midway PS 230/115 kV Transformer T1	5	Stable	Stable	Stable	Stable
15	Midway PS 345/230 kV Transformer T3	P1	Midway PS 345/230 kV Transformer T3	4	Stable	Stable	Stable	Stable
16	Boone - PI-2024-15 POI 230kV CKT 1 (BF-19B)	P4	Boone - PI-2024-15 POI 230kV CKT 1 Midway PS - PI-2024-15 POI 230kV CKT 1 Boone 230/115 kV Transformer T1 PI-2024-15 Generation	17	Stable	Stable	Stable	Stable
17	Boone - PI-2024-15 POI 230kV CKT 1 (BF-19D)	P4	Boone - PI-2024-15 POI 230kV CKT 1 Midway PS - PI-2024-15 POI 230kV CKT 1 Lamar Swyd – Boone 230kV CKT 1 PI-2024-15 Generation	17	Stable	Stable	Stable	Stable

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Discharging		Grid Charging	
					Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability
18	Midway PS - PI-2024-15 POI 230kV CKT 1 (BF-94B)	P4	Midway PS - PI-2024-15 POI 230kV CKT 1 Boone - PI-2024-15 POI 230kV CKT 1 Midway PS 230/345 kV Transformer T3 PI-2024-15 Generation	17	Stable	Stable	Stable	Stable
19	Midway PS - PI-2024-15 POI 230kV CKT 1 (BF-94D)	P4	Midway PS – Midway BR 230kV CKT 1 Midway PS - Fuller 230kV CKT 1 Midway BR 230/115 kV Transformer 1 Midway BR - RD-Nixon 230kV CKT 1 Midway BR - Hambone Tap 230kV CKT 1 Hambone Tap - W Canon 230kV CKT 1	17	Unstable	Unstable	Unstable	Unstable
20	Comanche - Hucklbry 230kV CKT 1 (P7-52)	P7	Comanche - Hucklbry 230kV CKT 1 Comanche – Midway PS 230kV CKT 1	5	Stable	Stable	Stable	Stable
21	Comanche – Midway PS 230kV CKT 1 (P7-53)	P7	Comanche – Midway PS 230kV CKT 1 Midway PS - Mirasol 230kV CKT 1	5	Stable	Stable	Stable	Stable

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Discharging		Grid Charging	
					Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability
22	Midway PS - Fuller 230kV CKT 1 (P7-130)	P7	Midway PS - Fuller 230kV CKT 1 Midway PS - Waterton 345kV CKT 1	5/4	Stable	Stable	Stable	Stable

5.4 Short-Circuit and Breaker Duty Analysis Results

A study was completed to determine whether any overstressed breakers resulted when several Provisional Interconnection Service requests were added to the PSCo Transmission System in the order of their estimated Commercial Operation Dates (CODs). If the addition of the interconnection resulted in a requirement that one or more breakers be replaced in the PSCo Transmission System, it was considered that that customer would not be able to connect under a provisional interconnection agreement and it was removed from the study.

Taken into consideration were any existing plans for breaker replacement by PSCo. Breakers that had already been assigned to projects were not considered as needing replacement by the interconnection customer.

The Short Circuit study on the PSCo Transmission System did not identify any circuit breakers that became over-dutied because of adding the PI-2024-15. The fault currents at the POI for can be made available upon request by the Customer.

5.5 Summary of Provisional Interconnection Analysis

The maximum permissible output of the Provisional Interconnection Service without requiring any additional system Network Upgrades is 300 MW in Discharging mode at the POI and 107.5 MW in Grid Charging mode at the generator terminal.

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2024-15 is:

- During the test with both units online, 0.95 lagging pf is not met. Additional cap bank of 2.15 MVAr is required to meet the lagging pf.
- During the test with individual units online with solar unit only online, 0.95 lagging pf is not met. Additional cap bank of 31.00 MVAr is required to meet the lagging pf.
- During the test with individual units online with battery unit only online, 0.95 lagging pf is not met. Additional cap bank of 13.50 MVAr is required to meet the lagging pf.
- During the test with both units online, 0.95 lagging pf is not met. Additional cap bank of 2.15 MVAr is required to meet the lagging pf.

With the updates mentioned above the Voltage and Reactive Power Capability Evaluation for PI-2024-15 is:

- The GIR is capable of meeting ±0.95 pf at the high side of the main step-up transformer while maintaining a normal operating voltage at the POI.

- The GIR is capable of meeting ±0.95 pf at its terminals while meeting the interconnection service request.
- The reactive power exchange and voltage change across the gen-tie are acceptable under no load conditions.

During the 0.95 lagging power factor test, as shown in Section 5.1, the generating facility generator terminal each reach above 1.05 p.u. voltage. This over voltage will need to be corrected by the generator owner.

6.0 Cost Estimates

The total estimated cost of the required upgrades for PI-2024-15 to interconnect for Provisional Interconnection Service is estimated to be **$29.615 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $2.379 million** (Table 19)
- **Cost of Station Network Upgrades is $27.236 million** (Table 20)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the Provisional Interconnection of PI-2024-15 are given in Table 19, and Table 20.

Since the POI is a new switching station, a CPCN would be required to accommodate the interconnection.

Table 18 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Million)
PSCo's New 230 kV switching station on the BOON - MIDW 230 kV Line	Interconnection of PI-2024-15 at the new 230 kV switching station on the BOON - MIDW 230 kV Line. The new equipment includes: • (1) 230 kV single bay dead end structure • (1) 230 kV 3-phase arrester • (1) 230 kV 3000 A disconnect switch • (3) 230 kV 1-phase CT's for metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying	$2.129
PSCo's New 230 kV switching station on the BOON - MIDW 230 kV Line	Transmission Provider's dead-end structure at the Point of Change of Ownership (PCO) outside the switching station fence line and transmission line into new switching station from the PCO. Single span, dead end structure, 3 conductors, insulators, hardware, jumpers and labor.	$0.250
Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities		**$2.379**

Table 19 – Station Network Upgrades

Element	Description	Cost Est. (Million)
PSCo's New 230 kV switching station on the BOON - MIDW 230 kV Line	Install new 230 kV switching station tapping the BOON - MIDW 230 kV line. The new equipment includes: • (3) 230 kV deadend structures • (3) 230 kV 3000 A circuit breakers • (8) 230 kV 3000 A disconnect switches • (6) 230 kV CCVTs • (2) 230 kV SSVTs • (2) 230 kV 3-phase arresters • (2) 230 kV wave traps • (1) Electrical Equipment Enclosure (EEE) • Site grading and fencing • Associated electrical equipment, bus, wiring and grounding • Station controls and wiring • Associated foundations and structures	$20.571
PSCo's New 230 kV switching station on the BOON - MIDW 230 kV Line	Install required communication in the EEE at the new 230 kV switching station	$1.465
PSCo's BOON 230 kV Substation	Remote end upgrade at the BOON 230 kV substation, replace the line relaying associated with the 5335 line, which will now be going to the new 230 kV switching station	$1.419
PSCo's MIDW 230 kV substation	Remote end upgrade at the MIDW 230 kV substation, replace the line relaying associated with the 5335 line, which will now be going to the new 230 kV switching station	$1.419
PSCO's CKT 5335 Highland - BOON	CKT 5335 - Removal of hardware, insulators, and conductor and adding (1) steel monopole corner deadend structure, (1) steel monopole in-line deadend structures, 1272 kcmil 45/7 strand "Bittern" ACSR, 48 count OPGW from BOON into new 230 kV switching station	$0.931
PSCO's CKT 5335 Highland - MIDW	CKT 5335 - Removal of hardware, insulators, and conductor and adding (1) steel monopole corner deadend structure, (1) steel monopole in-line deadend structures, 1272 kcmil 45/7 strand "Bittern" ACSR, 48 count OPGW from MIDW into new 230 kV Switching Station	$0.931
PSCo's New 230 kV switching station on the BOON - MIDW 230 kV Line	Siting and Land Rights land acquisition and permitting, no land purchase costs included	$0.500
Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities		**$27.236**

PSCo has developed cost estimates for Transmission Provider's Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2024-15 for Provisional

Interconnection Service. The estimated costs provided in this report are based upon the following assumptions:

- The estimated costs are in 2024 dollars with escalation and contingencies applied.
- Allowances for Funds Used During Construction (AFUDC) is not included.
- The estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of these new PSCo facilities.
- Land for new switching station can be acquired at fair market value.
- The estimated costs do not include the cost for any Customer owned equipment and associated design and engineering.
- Labor is estimated for straight time only—no overtime included.
- PSCo (or its Contractor) will perform all construction, wiring, testing, and commissioning for PSCo owned and maintained facilities.

The customer requirements include:

- Customer will facilitate the fee simple ownership of the property required for the new switching station, approximately 15 acres, to interconnect the Highland PV/BESS development.
- Customer will install two (2) redundant fiber optic circuits (one primary circuit with a redundant backup) into the Transmission Provider's substation as part of its interconnection facilities construction scope.
- Power Quality Metering (PQM) will be required on the Customer's generation tie-line terminating into the POI.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer substation. PSCo will be provided with indications, readings, and data from the LF/AGC RTU.
- The Interconnection Customer will comply with the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW, as amended from time to time, and available at: XEL-POL-Transmission Interconnection Guideline Greater 20MW (https://corporate.my.xcelenergy.com/s/transmission/interconnection)

6.1 Schedule

This section provides proposed milestones for the interconnection of PI-2024-15 to the Transmission Provider's Transmission System. The customer requested a back-feed date (In-Service Date for Transmission Provider's Interconnection Facilities and Station Network Upgrades required for interconnection) for the Provisional Interconnection of October 1, 2027. This is attainable by the Transmission Provider, based upon the current schedule developed for this interconnection request. The Transmission Provider proposes the milestones provided below in Table 21.

Table 20 – Proposed Milestones for PI-2024-15

Milestone	Responsible Party	Estimated Completion Date
LGIA Execution	Interconnection Customer and Transmission Provider	March 2025
In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection	Transmission Provider	October 1, 2027
In-Service Date & Energization of Interconnection Customer's Interconnection Facilities	Interconnection Customer	October 1, 2027
Initial Synchronization Date	Interconnection Customer	January 1, 2028
Begin trial operation & testing	Interconnection Customer and Transmission Provider	February 1, 2028
Commercial Operation Date	Interconnection Customer	June 1, 2028

Some schedule elements are outside of the Transmission Provider's control and could impact the overall schedule. The following schedule assumptions provide the basis for the schedule milestones:

- Construction permitting (if required) for new facilities will be completed within 18 months of PLGIA execution.
- The Transmission Provider is currently experiencing continued increases to material lead times which could impact the schedule milestones. The schedule milestones are based upon material lead times known at this time.
- Availability of line outages to interconnect new facilities to the transmission system.

- A Certificate of Public Convenience and Necessity (CPCN) may be required for the construction of the Interconnection Facilities and Station Network Upgrades. The expected time to obtain a CPCN approval is 18 months, which could impact the start of construction for the interconnection facilities.

7.0 Summary of Provisional Interconnection Service Analysis

The total estimated cost of the PSCo transmission system improvements required for PI-2024-15 to qualify for Provisional Interconnection Service is $29.615 million.

The initial maximum permissible output of PI-2024-15 Generating Facility is 300 MW in Discharging mode at the POI and 107.5 MW in Grid Charging mode at the generator terminal. The maximum permissible output of the Generating Facility in the PLGIA would be reviewed quarterly (or more often as needed) and updated if there are changes to system conditions compared to the system conditions previously used to determine the maximum permissible output.

Security: Based on 5RSC-2024-06 in the 5RSC selection of Energy Resource Interconnection Service (ERIS), the security associated with the Network Upgrades that might be identified at the conclusion of the 5RSC-2024-06 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is $5 million.

The Provisional Interconnection Service in and of itself does not convey transmission service.

8.0 Contingent Facilities

The Contingent Facilities identified for PI-2024-15 include the TPIF and Station Network Upgrades identified in Table 19 and Table 20, respectively.

9.0 Preliminary One-Line Diagram and General Arrangement for PI-2024-15

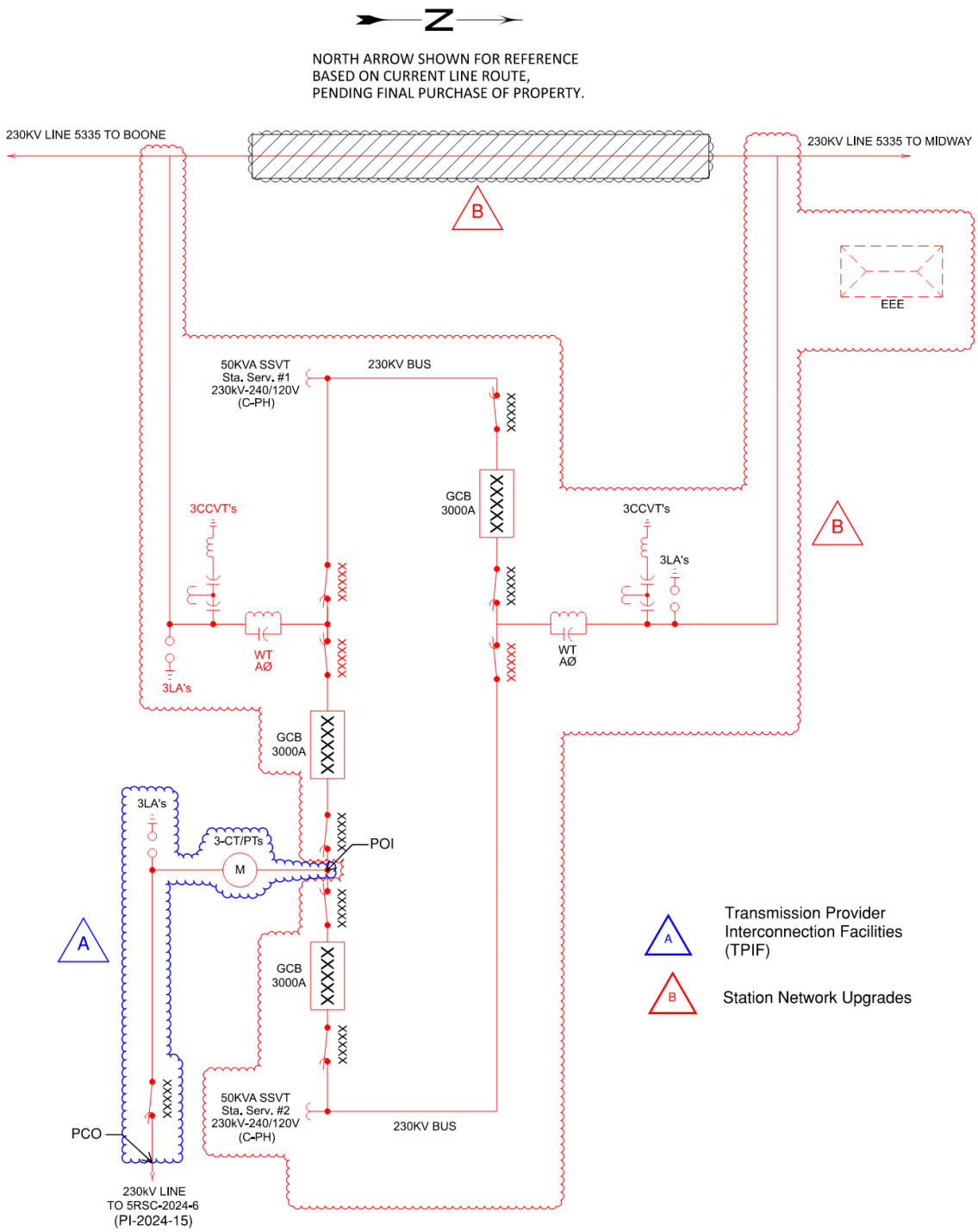

Figure 2: Preliminary one-line for PI-2024-15, tapping the Boone – Midway 230 kV line

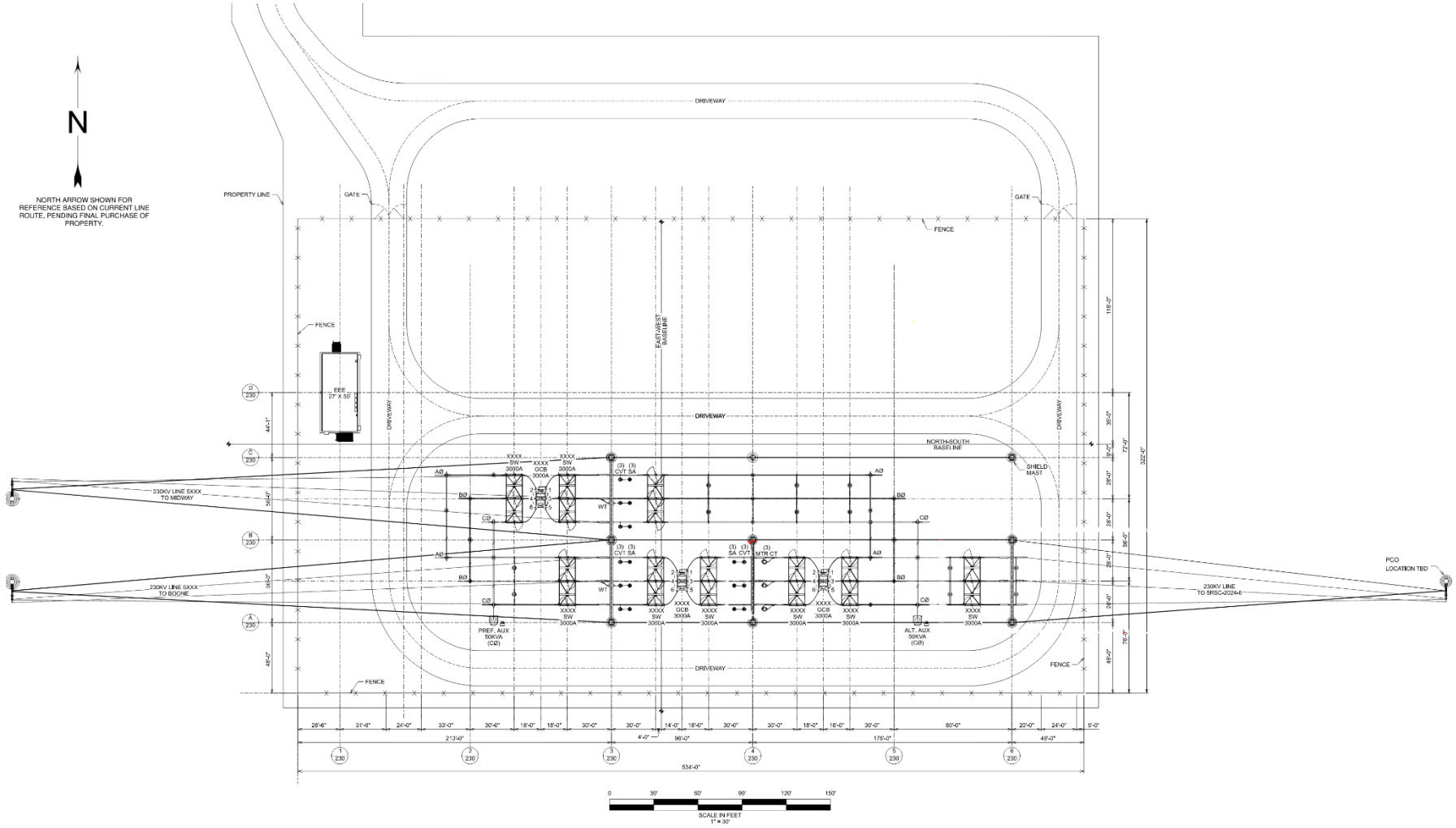

Figure 3: Preliminary General Arrangement for PI-2024-15

10.0 Appendices

Appendix A: Discharging Scenario Transient Stability Plots	PI-2024-15_Transient Stability Plots.pdf
Appendix B: Grid Charging Scenario Transient Stability Plots	PI-2024-15_Transient Stability Plots_GC.p