Provisional Interconnection Study Report for PI-2023-4

4/15/2024

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1.0 Executive Summary

The PI-2023-4 project is a Provisional Interconnection request for a 100 MW Battery Energy Storage System (BESS) with a Point of Interconnection (POI) at the Mirasol 230 kV substation. PI-2023-4 is the Provisional Interconnection request as associated with Generation Interconnection Request 3RSC-2023-2 in the 3RSC cluster.

Since the Provisional Interconnection Service for PI-2023-3 was not available, the total estimated cost of the transmission system improvements required for PI-2023-4 to qualify for Provisional Interconnection Service would be $5.929 million (Table 12 and Table 13). This estimated cost is subject to change with the execution of the PLGIA for PI-2023-3, which will be utilizing the same interconnection facilities. This project shares a common generator tie-line with the higher queued Provisional Interconnection Request PI-2023-3.

The initial maximum permissible output of PI-2023-4 Generating Facility is 100 MW. The maximum permissible output of the Generating Facility in the PLGIA[1] would be reviewed quarterly and updated, if there are changes to the system conditions assumed in this analysis, to determine the maximum permissible output.

Security: PI-2023-4 is a request for NRIS. For NRIS requests, security shall estimate the risk associated with the Network Upgrades and the Interconnection Facilities and is assumed to be a minimum of $25 million.

In addition, the Interconnection Customer would assume all risk and liabilities with respect to changes between the PLGIA and the LGIA[2], including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.

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

[1] 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.

[2] 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

The PI-2023-4 is the Provisional Interconnection Service[3] request for a 100 MW Battery Energy Storage System (BESS) Generating Facility located in Pueblo County, Colorado.

- The POI of this project is the existing Mirasol 230 kV substation.
- The Commercial Operation Date (COD) to be studied for PI-2023-3 as noted on the Provisional request form is 12/31/2025.
- Note this project shares a common generator tie-line with the higher queued Provisional Interconnection Request PI-2023-3.

The geographical location of the transmission system near the POI is shown in Figure 1.

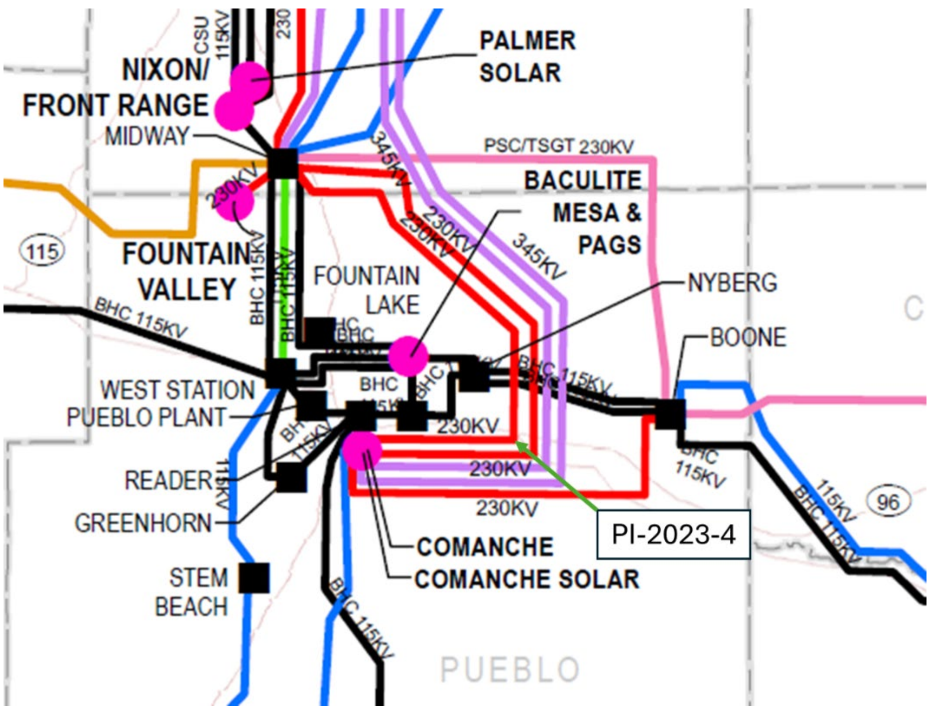

Figure 1: Point of Interconnection of PI-2023-4

[3] **Provisional Interconnection Service** 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.

3.0 Study Scope

The purpose of this study is to determine the impacts to the PSCo system and the Affected Systems from interconnecting PI-2023-4 for Provisional Service. Consistent with the assumption in the study agreement, PI-2023-4 selected Network Resource Interconnection Service (NRIS)[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 Interconnection Facilities and Station Network Upgrades. The study also identifies the estimated Security[5] and Contingent Facilities associated with the Provisional 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] **Network Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission system (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market-based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

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

The Provisional Interconnection request should meet the Transient stability criteria stated in Section 3.1. If the addition of the GIR causes any violations, the maximum permissible Provisional Interconnection Service before violations is identified.

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	Midway 230 kV	Midway 230/115 kV transformer 'T1'	5
2	Midway 230 kV	Midway 230/345 kV transformer 'T3'	5
3	Midway 230 kV	Midway - Comanche 230 kV ckt 1	5
4	Midway 230 kV	Midway - Fuller 230 kV ckt 1	5
5	Midway 230 kV	Midway - Midway BR 230 kV ckt 1	5
6	Mirasol 230 kV	Mirasol - Midway 230 kV ckt 1	5
7	Mirasol 230 kV	Mirasol - PI-2023-4 230 kV ckt 1 PI-2023-4 generation	5
8	Mirasol 230 kV	Mirasol - GI_2020_10 230 kV ckt 1	5
9	Comanche 230 kV	GI_2020_10 - Commanche 230 kV ckt 1	5

Ref. No.	Fault Location	Outage(s)	Clearing Time (Cycles)
10	GI_2020_10 230 kV	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 generation GI_2020_10 load	5
11	Mirasol 230 kV	Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation	5
12	Midway 230 kV	Midway - Boone 230 kV ckt 1	5
13	Midway 230 kV	Midway - Fountain Valley 230 kV ckt 1 Fountain Valley generation	5
14	Comanche 345 kV	Tundra - Comanche 345 kV ckt 1 Comanche 345/230 kV transformer 'T4'	12
15	Comanche 230 kV	CF&I Furnace - Comanche 230 kV ckt 1 Comanche - Midway 230 kV ckt 1 CF&I Furnace load 'IN'	17
16	Mirasol 230 kV	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation Mirasol - Midway 230 kV ckt 1 Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation PI-2023-4 generation	17
17	Comanche 230 kV	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation	17
18	May Valley 345 kV	May Valley - Goose Creek 345 kV ckt 1 May Valley SVD	12
19	Comanche 230 kV	Comanche - Huckleberry 230 kV ckt 1 Comanche - Boone 230 kV ckt 1	17

3.6 Study Area

The Southern Colorado study area includes WECC designated zones 704, 710, 712, 751, 757, and 785. The Affected Systems included in the analysis are the Tri-State Generation and Transmission (TSGT) and Black Hills Energy (BHE) systems in the study area.

4.0 Base Case Modeling Assumptions

The study was performed using the 2024HS3 WECC base case that has been modified to represent a 2026 heavy summer loading conditions. The following planned transmission projects are modeled in the Base Case:

- Canal Crossing 345 kV substation
- Fort Saint Vrain 345 kV substation
- Goose Creek 345 kV substation
- May Valley 345 kV substation
- Kestrel 230 kV substation
- Coyote 230 kV substation
- Poder 115 kV substation
- Metro Water 115 kV substation
- Pintail 115 kV substation
- DCPL Tap 115 kV substation
- Carl Tap 69 kV substation

The following additional changes were made to the Intermountain Regional Electric Co-Op (CORE) model in the Base Case:

- Citadel 115 kV substation
- Spring Valley 115 kV substation
- Deer Trail 115 kV substation

The Base Case model includes higher-queued and existing PSCo and Affected System generation resources.

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 2.

Table 2 – Generation Dispatch Used to Create the Southern Colorado Benchmark Case (MW is Gross Capacity)

Generator Bus No.	Bus Name/kV	Base kV	ID	Status	Pgen (MW)	Pmax (MW)
70120	COMAN_2	24.00	C2	1	365.00	365.00
70577	FTNVL1&2	13.80	G1	1	36.00	40.00
70577	FTNVL1&2	13.80	G2	1	36.00	40.00
70578	FTNVL3&4	13.80	G3	1	36.00	40.00
70578	FTNVL3&4	13.80	G4	1	36.00	40.00
70579	FTNVL5&6	13.80	G5	1	36.00	40.00
70579	FTNVL5&6	13.80	G6	1	36.00	40.00
70777	COMAN_3	27.00	C3	1	804.90	804.90
70934	COMAN_S1	0.42	S1	1	102.00	120.00
70017	SI_GEN 0	0.60	1	1	25.60	30.10
70878	BIGHORN_S	0.63	S1	1	210.40	247.50
70756	NEPTUNE_B1	0.48	B1	1	106.30	125.00
70758	NEPTUNE_S1	0.66	S1	1	212.90	250.50
70761	THNDWLF_B1	0.48	B1	1	80.00	100.00
70763	THNDWLF_S1	0.66	S1	1	170.00	200.00
70859	SUN_MTN_S1	0.66	S1	1	172.30	202.70
700142	GI_2020_10	0.63	S1	1	115.00	118.30
700146	GI_2020_10	0.63	S2	1	115.00	118.30
70256	CO_GRN_W	0.58	W2	1	64.80	81.00
70708	CO_GRN_E	0.58	W1	1	64.80	81.00
70704	TBI_GEN	0.58	W1	1	60.00	75.00
70663	GLDNWST_W1	0.69	W1	1	199.50	249.40
70010	TBII_GEN	0.69	W	1	60.00	75.00
700119	REPL_21_1	0.66	S1	1	108.33	121.22
700120	REPL_21_1	0.66	S2	1	108.33	121.22
700121	REPL_21_1	0.66	S3	1	108.33	121.22
Total					3469.49	3847.36

4.2 Grid Charging Benchmark Case Modeling

The Grid Charging Benchmark Case was created from Base Case described in Section 4.0 by changing the study pocket generation dispatch to reflect a Grid Charging scenario as outlined in Section 3.16 of the BPM. This was accomplished by adopting the stressed generation dispatch given in Table 3.

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

Generator Bus No.	Bus Name/kV	Base kV	ID	Status	Pgen (MW)	Pmax (MW)
70120	COMAN_2	24.00	C2	1	365.00	365.00
70577	FTNVL1&2	13.80	G1	1	36.00	40.00
70577	FTNVL1&2	13.80	G2	1	36.00	40.00
70578	FTNVL3&4	13.80	G3	1	36.00	40.00
70578	FTNVL3&4	13.80	G4	1	36.00	40.00
70579	FTNVL5&6	13.80	G5	1	36.00	40.00
70579	FTNVL5&6	13.80	G6	1	36.00	40.00
70777	COMAN_3	27.00	C3	1	804.90	804.90
70934	COMAN_S1	0.42	S1	1	0.00	120.00
70017	SI_GEN 0	0.60	1	1	0.00	30.10
70878	BIGHORN_S	0.63	S1	1	0.00	247.50
70756	NEPTUNE_B1	0.48	B1	1	-112.90	125.00
70758	NEPTUNE_S1	0.66	S1	1	0.00	250.50
70761	THNDWLF_B1	0.48	B1	1	-50.00	100.00
70763	THNDWLF_S1	0.66	S1	1	0.00	200.00
70859	SUN_MTN_S1	0.66	S1	1	0.00	202.70
700142	GI_2020_10	0.63	S1	1	115.00	118.30
700146	GI_2020_10	0.63	S2	1	115.00	118.30
70256	CO_GRN_W	0.58	W2	1	13.61	81.00
70708	CO_GRN_E	0.58	W1	1	13.61	81.00
70704	TBI_GEN	0.58	W1	1	12.60	75.00
70663	GLDNWST_W1	0.69	W1	1	41.90	249.40
70010	TBII_GEN	0.69	W	1	12.60	75.00
700119	REPL_21_1	0.66	S1	1	108.33	121.22
700120	REPL_21_1	0.66	S2	1	108.33	121.22
700121	REPL_21_1	0.66	S3	1	108.33	121.22
Total					1872.30	3847.36

4.3 Study Case Modeling

A Study case was created from the Benchmark Case by adding the PI-2023-4 BESS Generating Facility. The additional 100 MW output from PI-2023-4 was balanced against PSCo generation outside of the Southern Colorado study pocket. Although the requirement in part C under section 7.3 of the BPM states that generation associated with higher-queued Provisional Interconnection requests will be modeled but dispatched at zero MW unless connected to the same Gen-tie or POI, it was determined that PI-2023-3 request will not be modeled due to a breaker replacement (system Network Upgrade) required for the interconnection service.

A Grid Charging Study Case was created from the Grid Charging Benchmark Case by adding the PI-2023-4 BESS Generating Facility modeled as a load.

4.4 Short-Circuit Modeling

This request is for the interconnection of a 100 MW BESS (PI-2023-4) Generating Facility to the Mirasol 230 kV Switching Station. The output will not exceed 100 MW at the POI.

This project assumes the use of twenty-eight Power Electronics FreeSun FS4200M inverters rated at 4.2 MVA operating at +/-0.87pf. Each of the 4.2 MVA inverters is connected to a collector transformer, 0.66/34.5 kV, rated at 4.2 MVA. A 230/34.5/13.8 kV main GSU transformer rated at 99/132/165 MVA steps the voltage up from the collector transformer voltage to the POI voltage. A 1.27-mile-long generation tie line interconnects the project to Mirasol 230 kV substation.

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

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.

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 the 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 the range of 0.95 p.u. to 1.05 p.u. are highlighted in yellow to provide additional information.

The PI-2023-4 GIR is modeled as follows:

BESS: Pmax = 102.31 MW, Pmin = -102.31 MW, Qmax = 57.98 MVar, Qmin= -57.98 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2023-4 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 Voltage and Reactive Power Capability tests performed for PI-2023-4 are summarized in Table 4. Please note the generator terminal voltage during the lagging test exceeds 1.10 p.u.

Table 4 – Reactive Capability Evaluation for PI-2023-4

Reactive Power Capability - Project PI-2023-4 - MPT High Side PF Checks												
Generator Terminals					High Side of Main Transformer				POI			
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
101.8	54.9	58.0	-58.0	1.10	100.3	33.7	1.01	0.9479	100.2	33.9	1.01	0.9473
101.8	-12.1	58.0	-58.0	0.97	100.2	-33.7	1.00	-0.9478	100.1	-33.6	1.00	-0.9480
0.0	0.2	58.0	-58.0	1.01	0.0	0.8	1.00	0.0000	0.0	1.2	1.00	0.0000

5.2 Steady State Analysis

Contingency analysis was performed on the South study pocket for both Discharging and Grid Charging scenarios.

The results of the system intact analysis did not identify any overloads in either scenario.

The results of the single contingency analysis on the Study Case for the Discharging scenario are shown in Table 5. The single contingency analysis on the Study Case for the Grid Charging scenario did not identify any overloads.

The results of the multiple contingency analysis on the Study Case for the Discharging scenario are shown in Table 6. Results of the multiple contingency analysis for the Grid Charging scenario are shown in Table 7.

All the single contingency overloads identified in Table 5 are alleviated through generation redispatch. The System Network Upgrades shown in Table 8 are not attributable to the study GIR because of the overloads occurring in the Benchmark Case. The projects shown are considered mitigation to address Benchmark Case overloads. They are included for informational purposes. Mitigation for these facility overloads will be determined at a later date.

Per TPL-001-5, multiple contingency overloads are mitigated using system adjustments, including generation redispatch (includes GIRs under study) and/or operator actions. None of the multiple contingency overloads are attributed to the study GIRs.

Single contingency and multiple contingency analysis showed no voltage violations attributed to the study GIR in either scenario.

Table 5 – South Pocket - Single Contingency Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	Daniels Park - Prairie - Greenwood (#5111)	230	70	PSCo	478	149.76	153.63	3.57
2	Daniels Park (70139) - Prairie 1 (70331) 230 kV ckt 1	Daniels Park - Prairie - Greenwood (#5707)	230	70	PSCo	571	125.73	129.94	3.21
3	Greenwood 2 (70189) - Prairie 3 (70323) 230 kV ckt 1	Daniels Park - Prairie - Greenwood (#5111)	230	70	PSCo	572	116.82	120.06	3.24
4	Greenwood 1 (70212) - Prairie 1 (70331) 230 kV ckt 2	Daniels Park - Prairie - Greenwood (#5707)	230	70	PSCo	572	113.71	116.95	3.24
5	Vollmert (72413) - Fuller (73481) 115 kV ckt 1	Daniels Park - Jackson Fuller (#5119)	115	73	TSGT	173	110.94	114.08	3.14
6	Vollmert (72413) - Black Squirrel (73460) 115 kV ckt 1	Daniels Park - Jackson Fuller (#5119)	115	73	TSGT	173	108.77	111.90	3.13
7	Monaco (70481) - Sullivan (70365) 230 kV ckt 1	Smoky Hill - Buckley - Tollgate - Jewell - Leetsdale (#5285)	230	70	PSCo	445	107.56	109.55	1.99
8	Greenwood 2 (70189) - Monaco (70481) 230 kV ckt 1	Smoky Hill - Buckley - Tollgate - Jewell - Leetsdale (#5285)	230	70	PSCo	484	106.09	107.91	1.82
9	Midway 230/115 kV (70286/70285) Transformer T1	Daniels Park - Tundra 345 kV ckt 1	115/230	70	PSCo	97	105.41	107.68	2.27

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
10	Daniels Park (70139) - Fuller (73477) 230 kV ckt 1	Daniels Park - Tundra 345 kV ckt 1	230	70/73	PSCo	478	100.17	105.08	4.91
11	Pueblo (70339) - Reader (70352) 115 kV ckt 1	Daniels Park - Tundra 345 kV ckt 1	115	70	BHE	159	101.33	104.02	2.69

Table 6 – South Pocket - Multiple Contingency Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	BF_045t: Daniels Park 5111	230	70	PSCo	478	150.24	154.17	3.94
2	Vollmert (72413) - Fuller (73481) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73	TSGT	173	143.91	148.80	4.89
3	Vollmert (72413) - Black Squirrel (73460) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73	TSGT	173	141.67	146.54	4.87
4	Foxrun (73414) - Gresham (73445) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73	TSGT	145	132.28	137.88	5.60
5	Midway_PS (70286) - Midway_BR (73413) 230 kV ckt 1	P7_130: Lines 5129, 7051	230	70/73	WAPA	637	124.03	129.99	5.96
6	Midway 230/115 kV (70286/70285) Transformer T1	P7_53: Lines 5411, 55255	115/230	70	PSCo	120	121.42	126.65	5.23
7	Monaco (70481) - Sullivan (70365) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCO	445	123.65	126.52	2.87

Ref. No.	Monitored Facility	Contingency Name	kV	Are as	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
8	Pueblo (70339) - Reader (70352) 115 kV ckt 1	P7_53: Lines 5411, 55255	115	70	BHE	159	118.68	123.32	4.64
9	BLKFORTP (73455) - Black Squirrel (73460) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73	TSGT	173	117.56	122.30	4.74
10	Gresham (73445) - BLKFORTP (73455) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73	TSGT	173	113.80	118.51	4.71
11	Daniels Park (70139) - Prairie 1 (70331) 230 kV ckt 1	BF_045s: Daniels Park 5707	230	70	PSCo	628	114.31	117.24	2.93
12	Buckley 2 (70046) - Smoky Hill (70396) 230 kV ckt 1	BF_064a: Greenwood Bus 2	230	70	PSCo	478	115.96	117.02	1.06
13	Comanche (70122) - Huckleberry (230) 77300 kV ckt 1	P7_53: Lines 5411, 55255	230	70	TSGT	358	110.40	114.73	4.33
14	Leetsdale (70260) - Sullivan (70365) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	425	110.52	113.58	3.06
15	Boone (70061) - Midway (70286) 230 kV ckt 1	P7_53: Lines 5411, 55255	230	70	PSCo/ TSGT	319	105.49	110.55	5.06
16	Greenwood 2 (70189) - Prairie 3 (70323) 230 kV ckt 1	BF_045t: Daniels Park 5111	230	70	PSCo	629	106.60	109.60	3.00
17	Greenwood 2 (70189) - Monaco (70481) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	553	105.81	108.10	2.29
18	Leetsdale (70260) - MONROEPS (70291) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	398	104.37	107.76	3.39

Ref. No.	Monitored Facility	Contingency Name	kV	Are as	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
19	Hydepark (70236) - Pueblo Plant (70339) 115 kV ckt 1	P7_53: Lines 5411, 55255	115	70	BHE	159	102.47	107.08	4.61
20	Midway (73412) - Rancho (73416) 115 kV ckt 1	P7_130: Lines 5129, 7051	115	73	TSGT	119	104.08	106.94	2.86
21	Greenwood 1 (70212) - Prairie 1 (70331) 230 kV ckt 2	BF_045s: Daniels Park 5707	230	70	PSCo	629	103.40	106.35	2.95
22	Daniels Park (70139) - Fuller (230) 73477 kV ckt 1	P7_65: Lines 5109, 7051	230	70/ 73	PSCo	478	100.98	105.97	4.99

Table 7 – South Pocket - Multiple Contingency Overloads for Grid Charging Scenario

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Story (73192) - Pawnee (70311) 230 kV ckt 1	P7_135: Lines 7081, 7109	230	73/70	TSGT	589	100.74	107.75	7.01

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Table 8 – South Pocket – Mitigations to Benchmark Case

Ref No.	Network Upgrade	Owner	Facility Type	Minimum Required Rating (MVA)
1	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	PSCo	Line	734.35
2	Daniels Park (70139) - Prairie 1 (70331) 230 kV ckt 1	PSCo	Line	741.96
3	Greenwood 2 (70189) - Prairie 3 (70323) 230 kV ckt 1	PSCo	Line	686.74
4	Greenwood 1 (70212) - Prairie 1 (70331) 230 kV ckt 2	PSCo	Line	668.95
5	Vollmert (72413) - Fuller (73481) 115 kV ckt 1	TSGT	Line	197.36
6	Vollmert (72413) - Black Squirrel (73460) 115 kV ckt 1	TSGT	Line	193.59
7	Monaco (70481) - Sullivan (70365) 230 kV ckt 1	PSCo	Line	487.50
8	Greenwood 2 (70189) - Monaco (70481) 230 kV ckt 1	PSCo	Line	522.28
9	Daniels Park (70139) - Fuller (230) 73477 kV ckt 1	PSCo	Line	502.28
10	Pueblo (70339) - Reader (70352) 115 kV ckt 1	BHE	Line	165.39

5.3 Transient Stability Results

The following results were obtained for the disturbances analysed:

- ✓ 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 for Discharging scenario are shown in Table 9. Results of the contingency analysis for Grid Charging scenario are shown in Table 10. The transient stability plots for the Discharging and Grid Charging scenarios are shown in Appendix A and Appendix B, respectively, in Section 10.0 of this report.

Table 9 – Transient Stability Analysis Results for Discharging Scenario

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Midway 230 kV	P1	Midway 230/115 kV transformer 'T1'	5	Stable	Stable
2	Midway 230 kV	P1	Midway 230/345 kV transformer 'T3'	5	Stable	Stable
3	Midway 230 kV	P1	Midway - Comanche 230 kV ckt 1	5	Stable	Stable
4	Midway 230 kV	P1	Midway - Fuller 230 kV ckt 1	5	Stable	Stable
5	Midway 230 kV	P1	Midway - Midway BR 230 kV ckt 1	5	Stable	Stable
6	Mirasol 230 kV	P1	Mirasol - Midway 230 kV ckt 1	5	Stable	Stable
7	Mirasol 230 kV	P1	Mirasol - PI-2023-4 230 kV ckt 1 PI-2023-4 generation	5	Stable	Stable
8	Mirasol 230 kV	P1	Mirasol - GI_2020_10 230 kV ckt 1	5	Stable	Stable
9	Comanche 230 kV	P1	GI_2020_10 - Commanche 230 kV ckt 1	5	Stable	Stable
10	GI_2020_10 230 kV	P1	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 generation GI_2020_10 load	5	Stable	Stable
11	Mirasol 230 kV	P1	Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation	5	Stable	Stable
12	Midway 230 kV	P1	Midway - Boone 230 kV ckt 1	5	Stable	Stable
13	Midway 230 kV	P1	Midway - Fountain Valley 230 kV ckt 1 Fountain Valley generation	5	Stable	Stable
14	Comanche 345 kV	P4	Tundra - Comanche 345 kV ckt 1 Comanche 345/230 kV transformer 'T4'	12	Stable	Stable
15	Comanche 230 kV	P4	CF&I Furnace - Comanche 230 kV ckt 1 Comanche - Midway 230 kV ckt 1 CF&I Furnace load 'IN'	17	Stable	Stable

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
16	Mirasol 230 kV	P4	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation Mirasol - Midway 230 kV ckt 1 Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation PI-2023-4 generation	17	Stable	Stable
17	Comanche 230 kV	P4	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation	17	Stable	Stable
18	May Valley 345 kV	P4	May Valley - Goose Creek 345 kV ckt 1 May Valley SVD	12	Stable	Stable
19	Comanche 230 kV	P4	Comanche - Huckleberry 230 kV ckt 1 Comanche - Boone 230 kV ckt 1	17	Stable	Stable

Table 10 – Transient Stability Analysis Results for Grid Charging Scenario

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Midway 230 kV	P1	Midway 230/115 kV transformer 'T1'	5	Stable	Stable
2	Midway 230 kV	P1	Midway 230/345 kV transformer 'T3'	5	Stable	Stable
3	Midway 230 kV	P1	Midway - Comanche 230 kV ckt 1	5	Stable	Stable
4	Midway 230 kV	P1	Midway - Fuller 230 kV ckt 1	5	Stable	Stable
5	Midway 230 kV	P1	Midway - Midway BR 230 kV ckt 1	5	Stable	Stable
6	Mirasol 230 kV	P1	Mirasol - Midway 230 kV ckt 1	5	Stable	Stable
7	Mirasol 230 kV	P1	Mirasol - PI-2023-4 230 kV ckt 1 PI-2023-4 generation	5	Stable	Stable

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
8	Mirasol 230 kV	P1	Mirasol - GI_2020_10 230 kV ckt 1	5	Stable	Stable
9	Comanche 230 kV	P1	GI_2020_10 - Commanche 230 kV ckt 1	5	Stable	Stable
10	GI_2020_10 230 kV	P1	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 generation GI_2020_10 load	5	Stable	Stable
11	Mirasol 230 kV	P1	Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation	5	Stable	Stable
12	Midway 230 kV	P1	Midway - Boone 230 kV ckt 1	5	Stable	Stable
13	Midway 230 kV	P1	Midway - Fountain Valley 230 kV ckt 1 Fountain Valley generation	5	Stable	Stable
14	Comanche 345 kV	P4	Tundra - Comanche 345 kV ckt 1 Comanche 345/230 kV transformer 'T4'	12	Stable	Stable
15	Comanche 230 kV	P4	CF&I Furnace - Comanche 230 kV ckt 1 Comanche - Midway 230 kV ckt 1 CF&I Furnace load 'IN'	17	Stable	Stable
16	Mirasol 230 kV	P4	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation Mirasol - Midway 230 kV ckt 1 Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation PI-2023-4 generation	17	Stable	Stable
17	Comanche 230 kV	P4	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation	17	Stable	Stable
18	May Valley 345 kV	P4	May Valley - Goose Creek 345 kV ckt 1 May Valley SVD	12	Stable	Stable
19	Comanche 230 kV	P4	Comanche - Huckleberry 230 kV ckt 1 Comanche - Boone 230 kV ckt 1	17	Stable	Stable

5.4 Short-Circuit and Breaker Duty Analysis Results

The fault currents at the POI for three-phase and phase-to-ground faults can be found in Table 11 below, along with the Thevenin impedance at the POI. Both the base case and the case with the GIR added are shown.

Table 11 – Short-Circuit Parameters at PI-2023-4 POI (Mirasol 230 kV substation)

	Before the PI Addition	**After the PI Addition**
Three Phase		
Three Phase Current	10790 A	10950 A
Positive Sequence Impedance	1.28826 + j12.2467 ohms	1.28826 + j12.2467 ohms
Negative Sequence Impedance	1.30907+ j12.2664 ohms	1.30907+ j12.2664 ohms
Zero Sequence Impedance	2.57656 + j14.9004 ohms	1.81918 + j12.3371 ohms
Phase-to-Ground		
Single Line to Ground Current	10310 A	11340 A
Positive Sequence Impedance	1.44887 + j12.1213 ohms	1.44887 + j12.1213 ohms
Negative Sequence Impedance	1.47015 + j12.1387 ohms	1.47015 + j12.1387 ohms
Zero Sequence Impedance	2.57656 + j14.9004 ohms	1.81918 + j12.3371 ohms

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied because of adding the BESS generation PI-2023-4.

5.5 Affected Systems

TSGT and BHE were identified as an Affected System as a result of overloads on their facilities as listed in Table 5.

5.6 Summary of Provisional Interconnection Analysis

All single contingency thermal violations were alleviated through generation redispatch, therefore, the maximum allowable output of the GIR without requiring any additional System Network Upgrades is 100 MW. Since this project's affiliated request is for NRIS, the study also identified all the suitable mitigations necessary to alleviate the overloads caused by the study GIR.

Additionally, a Grid Charging study was performed. The study did not identify any voltage or thermal overloads attributed to the GIR. Grid Charging capabilities without any additional System Network Upgrades for PI-2023-4 is 100 MW.

During the 0.95 lagging power factor test, as shown in Section 5.1, the generating facility terminal voltage is reaching 1.10 p.u. This over voltage will need to be corrected by the generator owner.

6.0 Cost Estimates

Since the Provisional Interconnection Service for PI-2023-3 was not available, the total estimated cost of the required upgrades for PI-2023-4 to interconnect for Provisional Interconnection Service at the Mirasol 230 kV switching substation would be **$5.929 million.**

- **Cost of Transmission Provider's Interconnection Facilities is $2.430 million** (Table 12)
- **Cost of Station Network Upgrades is $3.499 million** (Table 13)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the Provisional Interconnection of PI-2023-4 are given in Table 12 and Table 13.

Table 12– Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (million)
PSCo's Mirasol 230 kV switching station	Interconnection of PI-2023-4 at the Mirasol 230 kV Switching Station. The new equipment includes: • (1) 230 kV dead end bay • (1) 230 kV 3-phase arrester • (1) 230 kV 3000 A line disconnect switch • (1) 230 kV 3-phase CT for metering • (1) 230 kV 3-phase 3-winding CCVT • Dual fiber communication equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$2.380
PSCo's Mirasol 230 kV Switching Station	Transmission line tap into substation from customer's dead-end structure on gen-tie. Three spans, conductor, insulators, hardware, and labor.	$0.050
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$2.430**

Table 13– Station Network Upgrades – Mirasol 230 kV

Element	Description	Cost Est. (million)
PSCo's Mirasol 230 kV switching substation	Interconnection of PI-2023-4 at Mirasol 230 kV switching station on a new breaker-and-a-half bay. The new equipment includes: • (2) 230 kV dead end structures • (2) 230 kV 3000 A SF6 circuit breakers • (3) 230 kV 3000 A double end break disconnect switches • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$3.416
PSCo's Mirasol 230 kV switching substation	Install communication equipment in the Mirasol 230 kV EEE to accommodate PI-2023-4	$0.083
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$3.499**

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2023-4 for Provisional Interconnection Service. This estimated cost is subject to change with the execution of the PLGIA for PI-2023-3, which will be utilizing the same interconnection facilities. This project shares a common generator tie-line with the higher queued Provisional Interconnection Request PI-2023-3. 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.
- 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 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

6.1 Schedule

This section provides proposed milestones for the interconnection of PI-2023-4 to the Transmission Provider's Transmission System. The customer requested a back-feed date (In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection) for the Provisional Interconnection of September 2025, this is not 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 14.

Table 14 – Proposed Milestones for PI-2023-4

Milestone	Responsible Party	Estimated Completion Date
PLGIA Execution	Interconnection Customer and Transmission Provider	July 2024
In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection	Transmission Provider	Jul 31, 2027
In-Service Date & Energization of Interconnection Customer's Interconnection Facilities	Interconnection Customer	August 31, 2027
Initial Synchronization Date	Interconnection Customer	August 31, 2027

Begin trial operation & testing	Interconnection Customer and Transmission Provider	August 31, 2027
Commercial Operation Date	Interconnection Customer	October 31, 2027

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

- Construction permitting (if required) for new facilities would be completed within 12 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.

7.0 Summary of Provisional Interconnection Service Analysis

Since the Provisional Interconnection Service for PI-2023-3 was not available, the total estimated cost of the required Upgrades for PI-2023-4 to interconnect for Provisional Interconnection Service at the Mirasol 230 kV switching substation would be $5.929 million.

The initial maximum permissible output of PI-2023-4 Generating Facility is 100 MW. The maximum permissible output of the Generating Facility in the PLGIA would be reviewed quarterly and updated if there are changes to system conditions compared to the system conditions previously used to determine the maximum permissible output.

Security: PI-2023-4 is a request for NRIS. For NRIS requests, security shall estimate the risk associated with the Network Upgrades and the Interconnection Facilities and is assumed to be a minimum of $25 million.

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

8.0 Contingent Facilities

The portions of Colorado Power Pathway outlined in Section 4.0 are assumed to be completed prior to this GIR COD. Any capacity or lack thereof is based on these segments being completed. In the event these facilities are delayed, not constructed, reconfigured, redesigned, or otherwise changed from the manner and timing currently modeled for this study, the ability to provide Provisional Interconnection Service would need to be re-evaluated.

The Contingent Facilities identified for PI-2023-4 are:

1) Huckleberry – Boone 230 kV Line #1 – ISD 2026 (TSGT)
2) Burlington – Lamar 230 kV Line #1 – ISD 2025 (TSGT)
3) Flying Horse 115 kV Series Reactor – ISD 2024 (CSU)
4) West Station – Hogback 115 kV Line #1 – ISD TBD (BHE)

Additional Contingent Facilities identified for PI-2023-4 include the TPIF and Station Network Upgrades identified in Table 12 and Table 13, respectively.

Tables C-1 through C-4, included in Appendix C, summarize the worst-case branch overloads when an unbuilt facility is excluded from the Study Case.

9.0 Conceptual POI One-Line Diagram of PI-2023-4

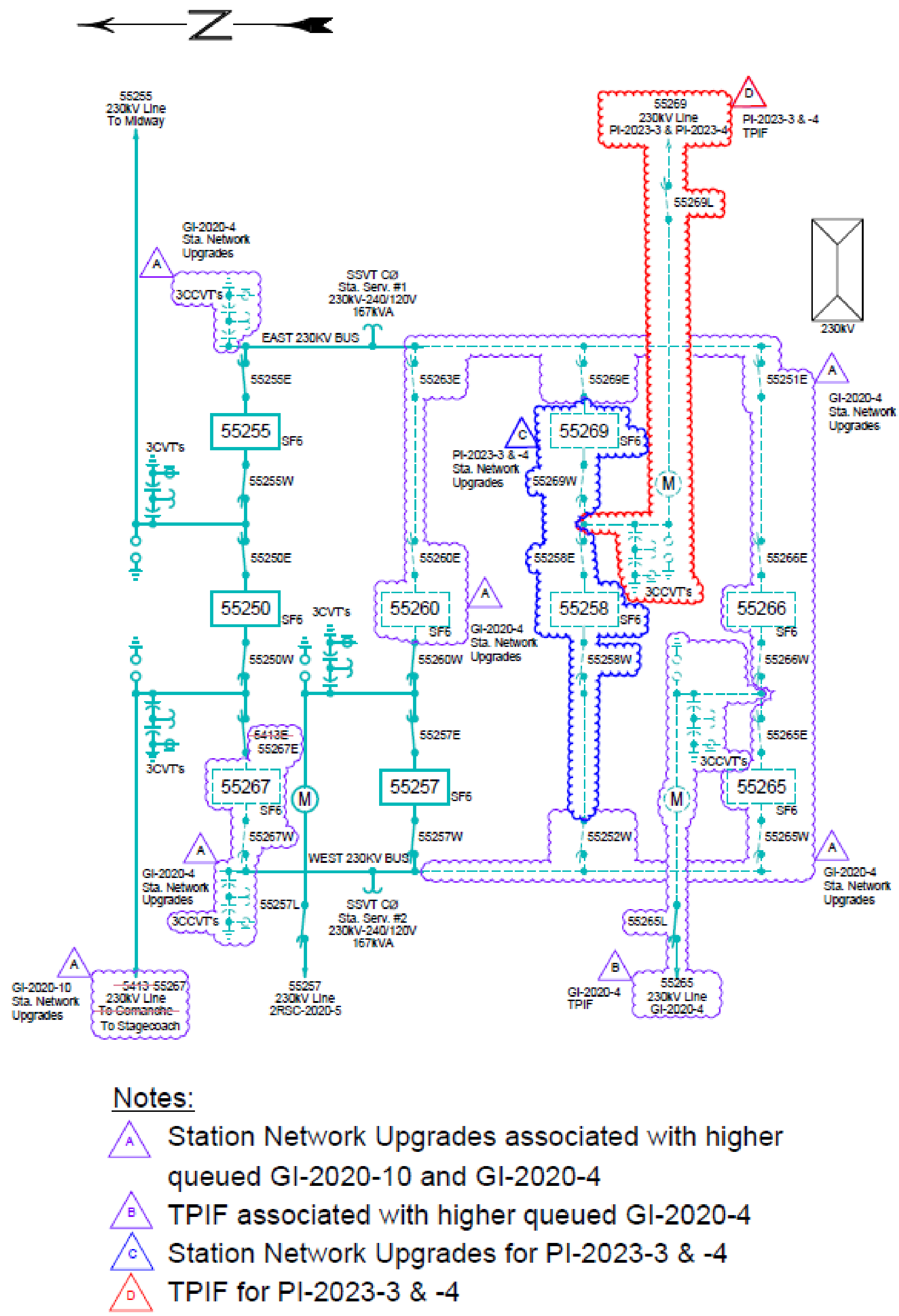

Figure 2: Preliminary One-Line for PI-2023-4 at Mirasol 230 kV Switching Station

10.0 Appendices

Appendix A: Transient Stability Plots (Discharge)	PI-2023-4_Discharging_Transient Stabili
Appendix B: Transient Stability Plots (Grid Charging)	PI-2023-4_GridCharging_Transient Stab
Appendix C: Contingent Facility Results	PI-2023-4_Contingent Facilities.pdf