Provisional Interconnection Study Report for PI-2023-3 (Revised)

6/3/2024

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1.0 Executive Summary

The PI-2023-3 project is a Provisional Interconnection request for a 200 MW Solar Generating Facility with a Point of Interconnection (POI) at the Mirasol 230 kV substation. PI-2023-3 is the Provisional Interconnection request later submitted as Generation Interconnection Request 3RSC-2023-1 in the 3RSC cluster.

If Provisional Interconnection Service was available, the total estimated cost of the transmission system improvements required for PI-2023-3 to qualify for Provisional Interconnection Service would be $6.809 million (Table 12, Table 13 and Table 14). Included in the total estimated cost of the transmission system improvements is the cost of replacing one of the circuit breakers at Midway 230 kV substation. This breaker is located beyond the POI and is overstressed due to the addition of PI-2023-3. Provisional Interconnection Service is not available when network upgrades such as this are required to provide any amount of the requested service.

This Provisional Interconnection Service is not available because there is a Network Upgrade beyond the POI substation required to connect the requested generating facility regardless of output.

Had Provisional Interconnection Service been available, 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-2023-3 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.

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[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.

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

2.0 Introduction

PI-2023-3 is the Provisional Interconnection Service[3] request for a 200 MW Solar Generating Facility located in Pueblo County, Colorado.

- The POI of this project 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.

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

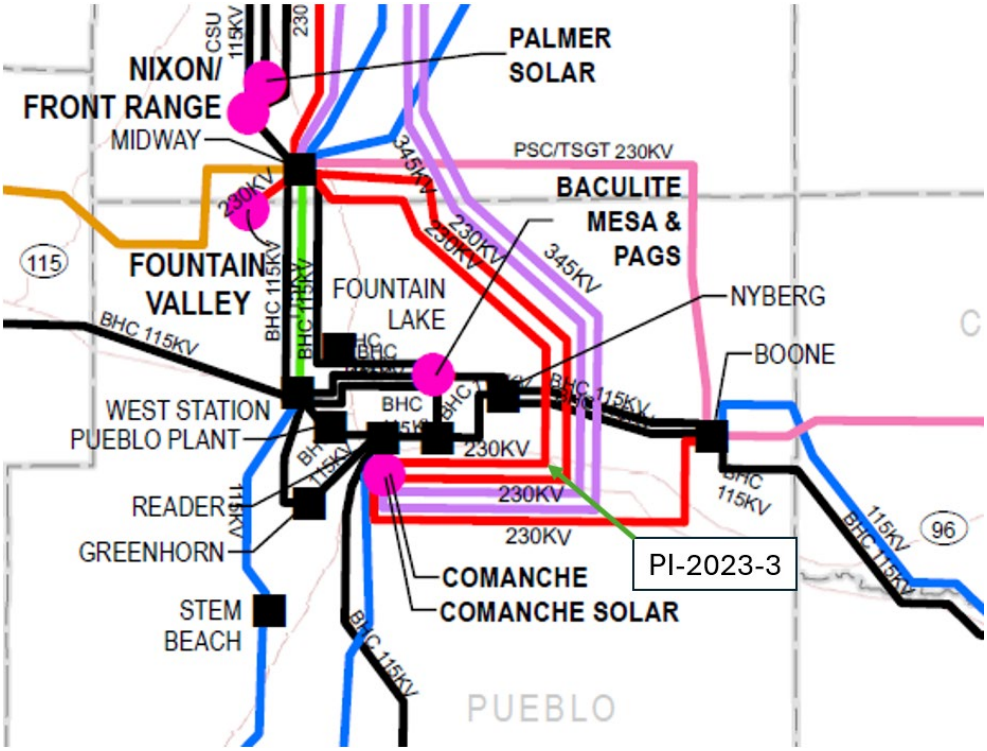

Figure 1: Point of Interconnection of PI-2023-3

[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-2023-3 for Provisional Service. Consistent with the assumption in the study agreement, PI-2023-3 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-2023-3 230 kV ckt 1 PI-2023-3 generation	5
8	Mirasol 230 kV	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation	5

Ref. No.	Fault Location	Outage(s)	Clearing Time (Cycles)
9	Mirasol 230 kV	Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation	5
10	Midway 230 kV	Midway - Boone 230 kV ckt 1	5
11	Midway 230 kV	Midway - Fountain Valley 230 kV ckt 1 Fountain Valley generation	5
12	Comanche 345 kV	Tundra - Comanche 345 kV ckt 1 Comanche 345/230 kV transformer 'T4'	12
13	Comanche 230 kV	CF&I Furnace - Comanche 230 kV ckt 1 Comanche - Midway 230 kV ckt 1 CF&I Furnace load 'IN'	17
14	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-2023-3 generation	17
15	Comanche 230 kV	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Comanche 230 kV ckt 1 GI_2020_10 generation	17
16	May Valley 345 kV	May Valley - Goose Creek 345 kV ckt 1 May Valley SVD	12
17	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, 785. The Affected Systems included in the analysis are the Tri-State Generation and Transmission (TSGT), Black Hills Energy (BHE), and City of Lamar (COL) 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 Study Case Modeling

A Study Case was created from the Benchmark Case by turning on the PI-2023-3 Solar Generating Facility. The additional 200 MW output from PI-2023-3 was dispatched against generation outside of the Southern Colorado study pocket.

4.3 Short-Circuit Modeling

The Transmission Planning Department has requested Fault Studies for a Provisional Interconnection request. This request is for the interconnection of a 200 MW Solar (PI-2023-3) Generating Facility to the Mirasol 230 kV switching station. The output will not exceed 200 MW at the POI.

This project assumes the use of fifty-six Power Electronics FreeSun FS4200M inverters rated at 4.2 MVA operating at +/-0.87 pf. Each of the 4.2 MVA inverters is connected to a collector transformer, 0.66/34.5 kV, rated at 4.2 MVA. Two 230/34.5/13.8 kV main GSU transformers rated at 99/132/165 MVA step the voltage up from the collector transformer voltage to the POI voltage. A 1.27-mile-long generation tie line interconnects PI-2023-3 to the 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 was requested. Generation is modeled as a separate generating resource in CAPE and is 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 favourably 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-2023-3 GIR is modeled as follows:

Solar Gen 1: Pmax = 102.31 MW, Pmin = 0 MW, Qmax = 57.98 MVar, Qmin= -57.98 MVar

Solar Gen 2: Pmax = 102.31 MW, Pmin = 0 MW, Qmax = 57.98 MVar, Qmin= -57.98 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2023-3 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-2023-3 are summarized in Table 3.

Table 3 – Reactive Capability Evaluation for PI-2023-3

Reactive Power Capability - Project PI-2023-3 - MPT High Side PF Checks																	
Generator 1 Terminals					Generator 2 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
101.5	50.4	58.0	-58.0	1.09	101.6	50.3	58.0	-58.0	1.09	200.0	66.3	1.01	0.9492	199.9	65.9	1.01	0.9497
101.5	-15.1	58.0	-58.0	0.97	101.6	-15.1	58.0	-58.0	0.97	199.9	-66.1	1.00	-0.9494	199.8	-66.5	1.00	-0.9488
0.0	-0.1	58.0	-58.0	1.00	0.0	-0.1	58.0	-58.0	1.00	0.0	1.7	1.00	0.0000	0.0	-2.1	1.00	0.0000

5.2 Steady State Analysis

Contingency analysis was performed on the South study pocket Study Case.

The results of the system intact analysis are shown in Table 4.

The results of the single contingency analysis on the Study Case are shown in Table 5 and Table 6. Regarding the voltage results in Table 6, the analysis identified low voltage violations in Zone West Plains under one contingency “Boone - Lamar (#5337) w/LAMU RAS”, which trips Boone – Lamar 230 kV followed by a RAS (tripping entire Lamar substation including the Lamar generator). The TARA simulation results for both Benchmark and Study Cases showed converged solution but very low voltages (as low as 0.63 p.u. on some buses), indicating a potential voltage collapse. This contingency or its RAS may require further investigation by affected utilities.

The results of the multiple contingency analysis on the Study Case are shown in Table 7.

All the single contingency overloads identified in Table 4 and Table 5 are alleviated through generation redispatch. The System Network Upgrades Reference Nos. 1 and 11 shown in Table 8 are located within an Affected System. The remaining System Network Upgrades shown in Table 8 are not attributable to the study GIR because of the overloads occurring in the Benchmark Case. 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 GIR.

Multiple contingency analysis showed no voltage violations attributed to the study GIR.

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Table 4 – South Pocket – System Intact Condition Overloads

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Normal Rating (MVA)	Owner	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	Base Case	230	70	478	PSCo	97.06	101.80	4.74

Table 5 – South Pocket - Single Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Comanche (70122) - Huckleberry (230) 77300 kV ckt 1	Daniels Park - Tundra 345 kV ckt 1	230	70/73 (TSGT)	TSGT	358	95.38	100.56	5.18
2	Daniels Park (70139) - Prairie 1 (70331) 230 kV ckt 1	Daniels Park - Prairie - Greenwood (#5707)	230	70	PSCo	571	125.73	132.02	6.29
3	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	Daniels Park - Prairie - Greenwood (#5111)	230	70	PSCo	478	149.76	157.33	7.57
4	Daniels Park 345/230 (70601/70139) Transformer T4	Daniels Park 345/230 T3	230/345	70	PSCo	560	101.41	103.00	1.59
5	Daniels Park 345/230 (70601/70139) Transformer T5	Daniels Park 345/230 T3	230/345	70	PSCo	560	101.41	103.00	1.59
6	Greenwood (70189) - Monaco (70481) 230 kV ckt 1	Smoky Hill - Buckley - Jewell - Leetsdale (#5285)	230	70	PSCo	484	106.09	109.51	3.42
7	Greenwood 1 (70212) - Prairie 1 (70331) 230 kV ckt 2	Daniels Park - Prairie - Greenwood (#5707)	230	70	PSCo	572	113.71	120.04	6.33

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
8	Greenwood 2 (70189) - Prairie 3 (70323) 230 kV ckt 1	Daniels Park - Prairie - Greenwood (#5111)	230	70	PSCo	572	116.82	123.16	6.34
9	Harrison (70215) - Leetsdale (70282) 115 kV ckt 1	Cherokee gen drop (70145)	115	70	PSCo	141	115.93	117.62	1.69
10	Monaco (70481) - Sullivan (70365) 230 kV ckt 1	Smoky Hill - Buckley - Jewell - Leetsdale (#5285)	230	70	PSCo	445	107.55	111.31	3.76
11	Pueblo (70339) - Reader (70352) 115 kV ckt 1	Boone - Comanche #5415	115	70	BHE	159	105.93	110.32	4.39
12	Foxrun (73414) - Gresham (73445) 115 kV ckt 1	Daniels Park - Jackson Fuller #5119	115	73 (WAPA - RMR)	TSGT	145	93.75	100.94	7.19
13	Vollmert (72413) - Black Squirrel (73460) 115 kV ckt 1	Daniels Park - Jackson Fuller #5119	115	73 (WAPA - RMR)	TSGT	173	108.77	114.99	6.22
14	Vollmert (72413) - Fuller (73481) 115 kV ckt 1	Daniels Park - Jackson Fuller #5119	115	73 (WAPA - RMR)	TSGT	173	110.94	117.18	6.24
15	Daniels Park (70139) - Fuller (230) 73477 kV ckt 1	Daniels Park - Tundra 345 kV ckt 1	230	70/73	PSCo	478	100.17	109.97	9.80

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Table 6 – South Pocket - Single Contingency Voltage Violations

Ref. No.	Bus #	Bus Name	Base kV	Area	Owner	Contingency Name	Benchmark Case Contingency Voltage (p.u.)	Study Case Contingency Voltage (p.u.)	Voltage Difference (p.u.)
1	70079	LAMSO	115	70	COL	line_133_SGL_230_055 Lamar RAS	0.6676	0.6565	-0.0111
2	70080	STONINGT	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6699	0.6589	-0.0110
3	70101	CHEN_TAP	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6629	0.6517	-0.0112
4	70102	CHENEY	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6625	0.6513	-0.0112
5	70136	CTY_LAM	69	70	COL	line_133_SGL_230_055 Lamar RAS	0.6565	0.6453	-0.0112
6	70161	EADS	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6498	0.6384	-0.0114
7	70184	FT.HOLLY	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6576	0.6463	-0.0113
8	70203	GRANTAP	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6593	0.6481	-0.0112
9	70204	GRANADA	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6592	0.6479	-0.0113
10	70222	HILLTOP	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6704	0.6595	-0.0109
11	70223	HLTP_TP	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6703	0.6594	-0.0109
12	70225	HOLL_TP	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6592	0.6480	-0.0112
13	70253	LAMAR_CO	115	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6686	0.6575	-0.0111
14	70333	PROWERS	69	70	COL	line_133_SGL_230_055 Lamar RAS	0.6550	0.6438	-0.0112

Ref. No.	Bus #	Bus Name	Base kV	Area	Owner	Contingency Name	Benchmark Case Contingency Voltage (p.u.)	Study Case Contingency Voltage (p.u.)	Voltage Difference (p.u.)
15	70404	SPRNGFLD	69	70	COL	line_133_SGL_230_055 Lamar RAS	0.6681	0.6571	-0.0110
16	70425	T.BUTTES	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6673	0.6562	-0.0111
17	70452	VILAS	115	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6788	0.6676	-0.0112
18	70453	VILAS	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6712	0.6602	-0.0110
19	70460	WALSH	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6697	0.6587	-0.0110
20	70472	WILOW_CK	115	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6656	0.6545	-0.0111
21	70473	WILOW_CK	69	70	TSGT	line_133_SGL_230_055 Lamar RAS	0.6616	0.6505	-0.0111

Table 7 – South Pocket - Multiple Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	BLKFORTP (73455) - Black Squirrel (73460) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73 (WAPA - RMR)	TSGT	173	117.56	127.08	9.52

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
2	Boone (70061) - Midway (70286) 230 kV ckt 1	P7_53: Lines 5411, 55255	230	70	PSCo/ TSGT	319	105.50	115.78	10.28
3	Buckley_2 (70046) - Smoky Hill (70396) 230 kV ckt 1	BF_064a: Greenwood Bus 2	230	70	PSCo	478	115.97	117.90	1.93
4	Buckley_2 (70046) - Tollgate (70491) 230 kV ckt 1	BF_064a: Greenwood Bus 2	230	70	PSCo	554	100.08	101.74	1.66
5	CLAREMNT (73380) - Fuller (73477) 230 kV ckt 1	P7_130: Lines 5129, 7051	230	73 (WAPA - RMR)	CSU	376	93.63	101.12	7.49
6	Comanche (70122) - GI_2020_10 (700139) 230 kV ckt 1	P7_53: Lines 5411, 55255	230	70	PSCo	559	77.37	113.18	35.81
7	Comanches (70122) - Huckleberry (230) 77300 kV ckt 1	P7_53: Lines 5411, 55255	230	70	TSGT	358	110.41	119.37	8.96
8	Daniels Park (70139) - Fuller (230) 73477 kV ckt 1	P7_65: Lines 5109, 7051	230	70/73	PSCo	478	100.97	110.91	9.94
9	Daniels Park (70139) - Prairie 1 (70331) 230 kV ckt 1	BF_045s: Daniels Park 5707	230	70	PSCo	628	114.32	120.04	5.72
10	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	BF_045t: Daniels Park 5111	230	70	PSCo	478	150.24	157.94	7.70
11	East_1 (70162) - East_2 (70171) 115 kV ckt 1	P7_29: Lines 5185, 5187	115	70	PSCo	119.5	145.83	147.41	1.58

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
12	Foxrun (73414) - Gresham (73445) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73 (WAPA - RMR)	TSGT	145	132.28	143.53	11.25
13	Greenwood (70189) - Monaco (70481) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	553	105.82	110.21	4.39
14	Greenwood 1 (70212) - Prairie 1 (70331) 230 kV ckt 2	BF_045s: Daniels Park 5707	230	70	PSCo	629	103.41	109.16	5.75
15	Greenwood 2 (70189) - Prairie 3 (70323) 230 kV ckt 1	BF_045t: Daniels Park 5111	230	70	PSCo	629	106.61	112.48	5.87
16	Gresham (73445) - BLKFORTP (73455) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73 (WAPA - RMR)	TSGT	173	113.79	123.27	9.48
17	Hydepark (70236) - Pueblo Plant (70339) 115 kV ckt 1	P7_53: Lines 5411, 55255	115	70	BHE	159	102.47	111.89	9.42
18	Leetsdale (70260) - MONROEPS (70291) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	398	104.39	110.78	6.39
19	Leetsdale (70260) - Sullivan (70365) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	425	110.54	116.39	5.85
20	Midway (73412) - Rancho (73416) 115 kV ckt 1	P7_130: Lines 5129, 7051	115	73 (WAPA - RMR)	TSGT	119	104.08	109.77	5.69
21	Midway_BR (73413) - RD_NIXON (73419) 230 kV ckt 1	P7_130: Lines 5129, 7051	230	73 (WAPA - RMR)	CSU	531	94.25	102.67	8.42

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
22	Midway_PS (70286) - Midway_BR (73413) 230 kV ckt 1	P7_130: Lines 5129, 7051	230	70/73	WAPA	637	124.04	135.94	11.90
23	Monaco (70481) - Sullivan (70365) 230 kV ckt 1	BF_004a: Arapahoe 230 bus inc SGL_230_006	230	70	PSCo	445	123.67	129.16	5.49
24	Palmer Lake (70308) - Foxrun (73414) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	70/73	PSCo	162	93.16	102.72	9.56
25	Pueblo (70339) - Reader (70352) 115 kV ckt 1	P7_53: Lines 5411, 55255	115	70	BHE	159	118.69	128.18	9.49
26	Vollmert (72413) - Black Squirrel (73460) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73 (WAPA - RMR)	TSGT	173	141.66	151.47	9.81
27	Vollmert (72413) - Fuller (73481) 115 kV ckt 1	P7_129: Lines 5119, 7051	115	73 (WAPA - RMR)	TSGT	173	143.90	153.74	9.84

Table 8 – South Pocket – Mitigations to Benchmark Case

Ref No.	Network Upgrade	Owner	Facility Type	Minimum Required Rating (MVA)
1	Comanche (70122) - Huckleberry (230) 77300 kV ckt 1	TSGT	Line	360.00
2	Daniels Park (70139) - Prairie 1 (70331) 230 kV ckt 1	PSCo	Line	753.83
3	Daniels Park (70139) - Prairie 3 (70323) 230 kV ckt 2	PSCo	Line	752.04
4	Add New Daniels Park 345/230 Transformer T6	PSCo	Transformer	560.00
5	Greenwood (70189) - Monaco (70481) 230 kV ckt 1	PSCo	Line	530.03
6	Greenwood 1 (70212) - Prairie 1 (70331) 230 kV ckt 2	PSCo	Line	686.63
7	Greenwood 2 (70189) - Prairie 3 (70323) 230 kV ckt 1	PSCo	Line	704.48
8	Harrison (70215) - Leetsdale (70282) 115 kV ckt 1	PSCo	Line	165.84
9	Monaco (70481) - Sullivan (70365) 230 kV ckt 1	PSCo	Line	495.33
10	Pueblo (70339) - Reader (70352) 115 kV ckt 1	BHE	Line	175.41
11	Foxrun (73414) - Gresham (73445) 115 kV ckt 1	TSGT	Line	146.36
12	Vollmert (72413) - Black Squirrel (73460) 115 kV ckt 1	TSGT	Line	198.93
13	Vollmert (72413) - Fuller (73481) 115 kV ckt 1	TSGT	Line	202.72
14	Daniels Park (70139) - Fuller (230) 73477 kV ckt 1	PSCo	Line	525.66

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 are shown in Table 9. The transient stability plots are shown in Appendix A in Section 10.0 of this report.

Table 9 – Transient Stability Analysis Results

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-2023-3 230 kV ckt 1 PI-2023-3 generation	5	Stable	Stable
8	Mirasol 230 kV	P1	Mirasol - GI_2020_10 230 kV ckt 1 GI_2020_10 - Commanche 230 kV ckt 1 GI_2020_10 generation	5	Stable	Stable
9	Mirasol 230 kV	P1	Mirasol - Thunderwolf 230 kV ckt 1 Thunderwolf generation	5	Stable	Stable
10	Midway 230 kV	P1	Midway - Boone 230 kV ckt 1	5	Stable	Stable
11	Midway 230 kV	P1	Midway - Fountain Valley 230 kV ckt 1 Fountain Valley generation	5	Stable	Stable
12	Comanche 345 kV	P4	Tundra - Comanche 345 kV ckt 1 Comanche 345/230 kV transformer 'T4'	12	Stable	Stable
13	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
14	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-2023-3 generation	17	Stable	Stable
15	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
16	May Valley 345 kV	P4	May Valley - Goose Creek 345 kV ckt 1 May Valley SVD	12	Stable	Stable
17	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 10 below, along with the Thevenin impedance at the POI. Both the base case and the case with the GI added are shown.

Table 10 – Short-Circuit Parameters at PI-2023-3 POI (Mirasol 230 kV substation)

	Before the PI Addition	After the PI Addition
Three Phase		
Three Phase Current	10790 A	11050 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	1.41225 + j10.6522 ohms
Phase-to-Ground		
Single Line to Ground Current	10310 A	12210 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	1.41225+ j10.6522 ohms

A breaker duty study on the PSCo transmission system identified one circuit breaker that became over-dutied because of adding the Solar (PI-2023-3). Table 11 listed the overstressed breaker.

Table 11 – Overstressed Breakers Due to PI-2023-3 Addition

				Pre-fault		Post-fault	
Substation	Breaker Name	Max Interrupting (kA)	IEEE Factor	three-phase	single-phase	three-phase	single-phase
Midway	5126	31.5	1.11	0.7% underdutied	5.9% underdutied	3.1% overdutied	5.0% underdutied

5.5 Affected Systems

TSGT, BHE, and COL are identified as Affected Systems as a result of violations on their facilities as listed in Table 5 and Table 6.

5.6 Summary of Provisional Interconnection Analysis

All single contingency thermal violations were alleviated through generation redispatch, except for the breaker identified in Table 11. But for that breaker, the maximum allowable output of the GIR without requiring any additional System Network Upgrades would be 200 MW. Since this project request is for NRIS, the study also identified all the suitable mitigations necessary to alleviate the overloads caused by the study GIR.

During the 0.95 lagging power factor test, as shown in Section 5.1, the generating facility terminal voltage is reaching 1.09 p.u. This over voltage will need to be corrected by the generator owner.

6.0 Cost Estimates

If Provisional Interconnection Service was available, the total cost of the required upgrades for PI-2023-3 to interconnect for Provisional Interconnection Service at the Mirasol 230 kV substation would be **$6.809 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 $0.880 million** (Table 14)

The list of improvements required to accommodate the Provisional Interconnection of PI-2023-3 are given in Table 12, Table 13 and Table 14.

Table 12 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (million)
PSCo's Mirasol 230 kV switching station	Interconnection of PI-2023-3 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-2023-3 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-2023-3	$0.083
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$3.499**

Table 14 – System Network Upgrades Attributed to PI-2023-3

Element	Description	Cost Est. (million)
Midway 230 kV breaker	Replace one 230 kV circuit breaker identified as overstressed due to PI-2023-3 addition	$0.880
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$0.880**

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2023-3 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.
- 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

Although Provisional Interconnection Service is unavailable due to the need for system network upgrades, PSCo has nevertheless provided the following milestones for the interconnection of PI-2023-3 to the Transmission Provider's Transmission System to provide transparency regarding the expected timing for commercial operation in the event service could be provided. 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. If such service could be provided, the milestones provided below in Table 14 would apply.

Table 14 – Proposed Milestones for PI-2023-3

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

The total estimated cost of the PSCo transmission system improvements required for PI-2023-3 to qualify for Provisional Interconnection Service would be $6.809 million. Included in the total estimated cost of the transmission system improvements is the cost of replacing one of the circuit breakers at Midway 230 kV substation (Table 14) This breaker is located beyond the POI and is overstressed due to the addition of PI-2023-3. Provisional Interconnection Service is not available when network upgrades such as this are required to provide any amount of the requested service.

Provisional Interconnection Service is not available because there is a Network Upgrade beyond the POI substation required to connect the requested generating facility regardless of output.

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-2023-3 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 coming online. 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-2023-3 are:

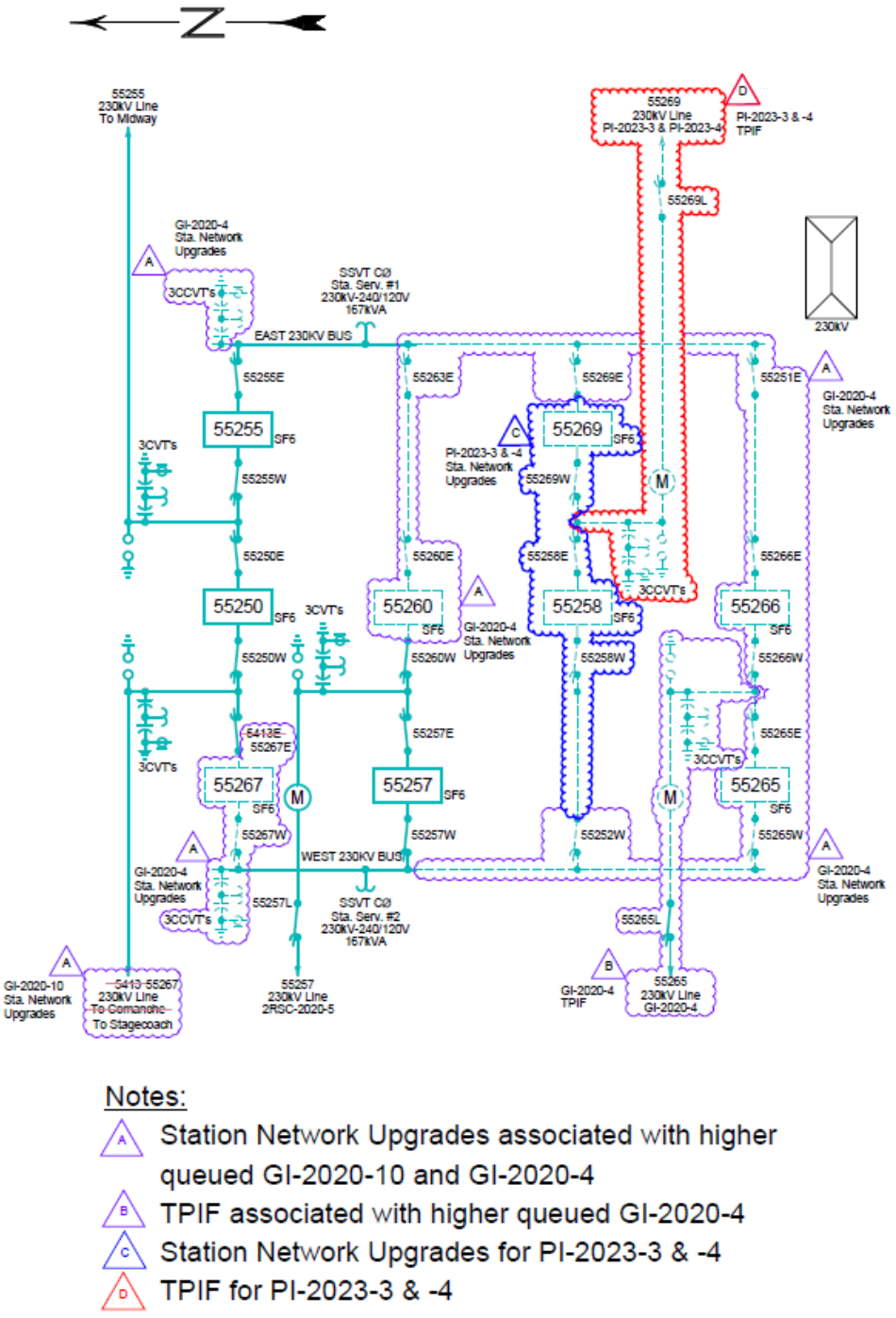
1) Huckleberry – Boone 230 kV Line #1 – ISD 2026 (TSGT)
2) Burlington – Lamar 230 kV Line #1 – ISD 2025 (TSGT)
3) Flying Horse 115 kV Series Reactor – ISD 2024 (CSU)
4) West Station – Hogback 115 kV Line #1 – ISD TBD (BHE)

Additional Contingent Facilities identified for PI-2023-3 include the TPIF and Station Network Upgrades identified in Table 12, Table 13 and Table 14, respectively.

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

Short-Circuit Contingent Breakers: Section 4.7 of the Business Practice Manual states that "All future breaker replacements which have a short-circuit current contribution from the GIR are contingent facilities". A series of fault studies were run to determine which of these breakers had any contribution from any of the GIRs in the DISIS. Results are shown in Table B-5, included in Appendix B.

9.0 Conceptual POI One-Line Diagram of PI-2023-3



Notes:

A Station Network Upgrades associated with higher queued GI-2020-10 and GI-2020-4

B TPIF associated with higher queued GI-2020-4

C Station Network Upgrades for PI-2023-3 & -4

D TPIF for PI-2023-3 & -4

Figure 2: Preliminary One-Line for PI-2023-3 at Mirasol 230 kV Switching Station

10.0 Appendices

Appendix A: Transient Stability Plots	PI-2023-3_Transient Stability Plots.pdf
Appendix B: Contingent Facility Results	PI-2023-3_Contingent Facilities.pdf