3DISIS-2021-001

Phase 1 Study Report

8/30/2021

Xcel Energy

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1.0 Summary

The Phase 1 of the 3DISIS-2021-001 Definitive Interconnection Study Cluster includes seven (7) GIRs: GI-2021-1, GI-2021-2, GI-2021-3, GI-2021-4, GI-2021-6, GI-2021-8 and GI-2021-9.

GI-2021-1 is a 200MW$_{ac}$ net rated Solar PV Generating Facility requesting ERIS. The requested POI is the Comanche 230kV substation.

GI-2021-2 is an incremental increase to the existing Ft. St. Vrain #2 natural gas fired combustion turbine capacity. The requested increase is ERIS of 38MW(summer)/49MW(winter).

GI-2021-3 is an incremental increase to the existing Ft. St. Vrain #3 natural gas fired combustion turbine capacity. The requested increase is ERIS of 24MW(summer)/35MW(winter).

GI-2021-4 is a 42MW$_{ac}$ net rated Solar PV plus Battery Energy Storage hybrid Generating Facility requesting NRIS. The requested POI is a tap on the Romeo – Old40Tap 69kV line.

GI-2021-6 is a 199MW$_{ac}$ net rated Solar PV plus Battery Energy Storage hybrid Generating Facility requesting NRIS. The requested POI is a tap on the Green Valley – Sky Ranch 230kV line.

GI-2021-8 is a 400MW$_{ac}$ net rated Solar PV plus Battery Energy Storage hybrid Generating Facility requesting NRIS. The requested POI is the Pawnee 345kV Substation.

GI-2021-9 is a 199MW$_{ac}$ net rated Solar PV Generating Facility requesting ERIS. The requested POI is the Tundra 345kV Switching Station.

GI-2021-1 and GI-2021-9 were studied under the Southern Colorado study pocket. GI-2021-4 was studied under the San Luis Valley study pocket. GI-2021-2, GI-2021-3, and GI-2021-6 were studied under the Northern Colorado study pocket. GI-2021-8 was studied under the Eastern Colorado study pocket.

The Generation Interconnection Service identified in this report in and of itself does not convey any transmission service.

1.1 GI-2021-1 Results

The total cost of the upgrades required to interconnect GI-2021-1 at the Comanche 230kV Substation for ERIS is $2.603 Million (Tables 21 and 27).

Maximum allowable output of GI-2021-1 before Network Upgrades is 200MW.

Energy Resource Interconnection Service of GI-2021-1 is: 200MW.

1.2 GI-2021-2 Results

The total cost of the upgrades required to allow GI-2021-2 expansion at the Fort Saint Vrain#2 generator for ERIS is $0.05 Million (Table 28).

Maximum allowable output of GI-2021-2 before Network Upgrades is 49MW

Energy Resource Interconnection Service of GI-2021-2 is: 49MW

1.3 GI-2021-3 Results

The total cost of the upgrades required to allow GI-2021-3 expansion at the Fort Saint Vrain#3 generator for ERIS is $0.05 Million (Table 29).

Maximum allowable output of GI-2021-3 before Network Upgrades is 35MW.

Energy Resource Interconnection Service of GI-2021-2 is: 35MW

1.4 GI-2021-4 Results

The total cost of the upgrades required to interconnect GI-2021-4 on the Romeo – Old40Tap 69kV line for NRIS is $14.685 Million (Tables 22 and 30).

Network Resource Interconnection of GI-2021-4 is 42MW

1.5 GI-2021-6 Results

The total cost of the upgrades required to interconnect GI-2021-6 on the Green Valley – Sky Ranch 230kV line for NRIS is $20.694 Million (Tables 23 and 31).

Network Resource Interconnection of GI-2021-6 is 199MW.

The construction of the GI-2021-6 230kV switching station tapping the Green Valley – Sky Ranch 230kV line will require a CPCN and, the estimated time frame for regulatory activities and to site, design, procure and construct the switching station is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the 12/31/2024 COD of GI-2021-6.

1.6 GI-2021-8 Results

The total cost of the upgrades required to interconnect GI-2021-8 at the Pawnee 345kV Substation for NRIS is $10.052 Million (Tables 24, 26 and 32).

Network Resource Interconnection of GI-2021-8 is 400MW.

The Grid charging study for the 100MW BES Generating Facility did not identify any impacts. There are no additional costs identified in the Grid Charging study.

TSGT has been identified as an impacted Affected System to GI-2021-8. The cost or the improvements required to mitigate the TSGT impacts have not been identified in this report, they will be identified in the Phase 2 report.

1.7 GI-2021-9 Results

The total cost of the upgrades required to interconnect GI-2021-9 at the Tundra 345kV Switching Station for ERIS is $5.591 Million (Tables 25 and 33).

Maximum allowable output of GI-2021-9 before Network Upgrades is 199MW

Energy Resource Interconnection Service of GI-2021-9 is: 199MW

2.0 Introduction

Public Service Company of Colorado (PSCo) received nine (9) Generation Interconnection Request (GIR)s in the 3DISIS-2021-001 out of which seven (7) GIRs moved to Phase 1. The total Interconnection Service requested in the 3DISIS-2021-001 Phase 1 is 1124MW.

Out of the seven (7) GIRs; GI-2021-1, GI-2021-2, GI-2021-3, and GI-2021-9 requested Energy Resource Interconnection Service (ERIS)[1] and, GI-2021-4, GI-2021-6, and GI-2021-8 requested Network Resource Interconnection Service (NRIS)[2]. A summary of the requests is given in Table 1.

Table 1– Summary of GIRs in the DISIS-2021-001

GI#	Resource Type	Interconnection Service	COD	POI	Location	Service Type
GI-2021-1	PV Solar	200MW	12/31/2022	Comanche 230kV Substation	Pueblo County, CO	ERIS
GI-2021-2	Gas CT	38MW (summer) / 49MW (Winter)	4/1/2022	Fort Saint Vrain #2	Weld County, CO	ERIS

[1] 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 or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service

[2] 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.

GI-2021-3	Gas CT	24MW (summer) / 35MW (winter)	11/1/2021	Fort Saint Vrain #3	Weld County, CO	ERIS
GI-2021-4	PV Solar +BES	42MW	5/15/2024	Romeo 69kV	Conejos County, CO	NRIS
GI-2021-6	PV Solar +BES	199MW	12/31/2024	Green Valley - Sky Ranch 230kV line	Adams County, CO	NRIS
GI-2021-8	PV Solar +BES	400MW	12/31/2025	Pawnee 345kV Substation	Morgan County, CO	NRIS
GI-2021-9	PV Solar	199MW	12/1/2024	Tundra 345kV Switching Station	Pueblo County, CO	ERIS

3.0 Description of the GIRs

3.1 GI-2021-1

GI-2020-1 is a 200MW$_{ac}$ net rated Solar Photovoltaic (PV) Generating Facility located in Pueblo County, Colorado. The Customer submitted a Technological Change Request to change the inverters from SMA4200 to TMEIC 880 and the generator tie line length from 0.5mi to 3.5mi, which were approved on 8/13/2021 and 8/5/2021 respectively. The new Generating Facility configuration consists of two-hundred-sixty-five (265) TMEIC PV-L0880 inverters derated to 0.832MVA at +/-0.92pf. Each inverter will have its own 0.66/34.5kV, 4MVA Delta/Wye, Z=6.0% and X/R=8 pad-mount transformer. The 34.5kV collector system will connect to one (1) 135/180/225MVA, 230/34.5/13.8kV Wye-grounded/Wye-grounded/Delta Z=8.5% and X/R=47.1 main step-up transformer which will connect to the PSCo transmission system via a 3.5 mile 230kV generation tie-line. The Point of Interconnection (POI) is the Comanche 230kV substation.

The proposed Commercial Operation Date (COD) of GI-2021-1 is December 31, 2022. The back-feed date is assumed to be June 30, 2022, approximately six (6) months before the COD.

3.2 GI-2021-2

GI-2021-2 is a 38MW(summer)/49MW(winter) incremental capacity in the output of the existing Fort Saint Vrain#2 Combustion Turbine generator located in Weld County, Colorado. The incremental output is driven by turbine prime mover changes being performed as part of maintenance and modernizing the equipment, and no changes to the electrical generator set are anticipated. The net generating capacity of Fort Saint Vrain#2 after GI-2021-2 addition will be 165MW(summer)/187MW(winter).

The POI of the incremental capacity is the existing Fort Saint Vrain Substation where Fort Saint Vrain#2 currently interconnects.

The proposed Commercial Operation Date (COD) is April 1, 2022. Since the POI is existing and operational, backfeed date is not applicable to GI-2021-2.

3.3 GI-2021-3

GI-2021-3 is a 34MW(summer)/35MW(winter) incremental capacity in the output of the existing Fort Saint Vrain#3 Combustion Turbine generator located in Weld County, Colorado. The incremental output is driven by turbine prime mover changes being performed as part of maintenance and modernizing the equipment and no changes to the electrical generator set are anticipated. The net generating capacity of Fort Saint Vrain#3 after GI-2021-3 addition will be 156MW(summer)/178MW(winter).

The POI of the incremental capacity is the existing Fort Saint Vrain Substation where Fort Saint Vrain#3 currently interconnects.

The proposed Commercial Operation Date (COD) is November 1, 2021. Since the POI is existing and operational, backfeed date is not applicable to GI-2021-3.

3.4 GI-2021-4

GI-2021-4 is a 42MW$_{ac}$ net rated AC-coupled Hybrid Generating Facility located in Conejos County, Colorado. The Hybrid Generating Facility is composed of a 42MW$_{ac}$ Solar PV Generating Facility and a 10.5MW$_{ac}$ Battery Energy Storage (BES) Generating Facility, with the net output at the POI limited to 42MW. The Solar Generating Facility will consist of thirteen (13) Power Electronics FS3510M PV inverters and the BES Generating Facility will consist of three (3) Power Electronics FP3510M storage inverters, each with its own 0.66/34.5kV, 3.51MVA Delta/Wye Z=5.75%, X/R=8 pad-mount transformer. The 34.5kV collector system of the PV and BES resources will connect to one (1) 69/34.5kV, 27.52/36.39/45.63MVA Wye-grounded/Delta Z=8% and X/R=53 main step-up transformer which will interface with a 69kV, 242ft generation tie-line. The POI is a tap on PSCo's Romeo – Old40Tap 69kV line, at approximately 1.63 miles from the Romeo Substation. The tap point at the POI will require a new switching station which is referred to as "GI-2021-4 69kV Switching Station" in this report.

The BES facility has a maximum state of charge of 10.5MW and minimum state of charge of 0MW.

Per the Interconnection request, the NRIS output of GI-2021-4 will be serving PSCo native load.

The proposed Commercial Operation Date (COD) of GI-2021-4 is May 15, 2024. For the study purpose, the back-feed date is assumed to be November 15, 2023, approximately six (6) months before the COD.

3.5 GI-2021-6

GI-2021-6 is a 199MW_{ac} net rated AC-coupled Hybrid Generating Facility located in Adams County, Colorado. The Hybrid facility is composed of a 207.8MW_{ac} Solar PV Generating Facility and a 100MW_{ac} , 4hr BES Generating Facility, with the net output at the POI limited to 199MW. The solar PV Generation Facility will consist of fifty-four (54) Power Electronics FS4200M inverters and the BES Generating Facility will consist of twenty-eight (28) Power Electronics FP4200M inverters; each inverter will utilize the built-in 0.60/34.5kV, 4.20MVA Wye/Delta Z=6.5%, X/R=8 pad-mount transformer to interface with the 34.5kV collector system. The 34.5kV collector system of the PV and BES units will connect to one (1) 150/188/250MVA, 34.5/230kV Wye-grounded/Wye-grounded/Delta, Z=9.5%, X/R=70 main step-up transformer, which will connect to PSCo's Green Valley-Sky Ranch 230kV line, at approximately 2.16miles from the Sky Ranch Substation. The tap point at the POI will require a new switching station which is referred to as "GI-2021-6 230kV Switching Station" in this report. The Generating Facility configuration also includes a 31Mvar capacitor bank installed on the 34.5kV collector system.

Per the Interconnection request, the NRIS output of GI-2021-4 will be serving PSCo native load.

The BES facility has a maximum state of charge of 100% and minimum state of charge of 4%.

The proposed Commercial Operation Date (COD) of GI-2021-6 is December 31, 2024. For the study purpose, the back-feed date is assumed to be July 1, 2024, approximately six (6) months before the COD.

3.6 GI-2021-8

GI-2021-8 is a 400MW_{ac} net rated AC-coupled Hybrid Generating Facility located in Morgan County, Colorado. The Hybrid facility is composed of a 400MW_{ac} Solar PV Generating Facility and a 100MW_{ac} , 4hr BES Generating Facility, with the net output at the POI limited to 400MW.

The hybrid facility will be arranged in two groups. The configuration of each group includes – 200MW solar PV generator composed of sixty-three (63) Power Electronics HEMK FS3270K 3.38MW inverters and a 100MW BES generator composed of sixteen (16) Power Electronics PCSK FP3270K 3.38MW inverters. Each inverter will use an individual 0.615/34.5kV, 4MVA, Wye/Delta Z=5.75%, 4MVA pad-mount transformer to interface with the 34.5kV Collector System. The 34.5kV collector system of each group interfaces with one (1) 34.5/345kV, 141/188/235MVA, Wye-grounded/Wye-grounded/Delta Z=9% and X/R= 46 main step-up transformer each. The 34.5kV collector system of each group also includes a 32Mvar capacitor bank. The 345kV system of each group will interface with a 2mi generation tie-line which will connect to the PSCo system at the Pawnee 345kV Substation.

Per the Interconnection request, the NRIS output of GI-2021-8 will be serving PSCo native load.

The BES facility has a maximum state of charge of 100% and minimum state of charge of 0%.

The proposed Commercial Operation Date (COD) of GI-2021-8 is December 31, 2025. For the study purpose, the back-feed date is assumed to be July 1, 2024, approximately six (6) months before the COD.

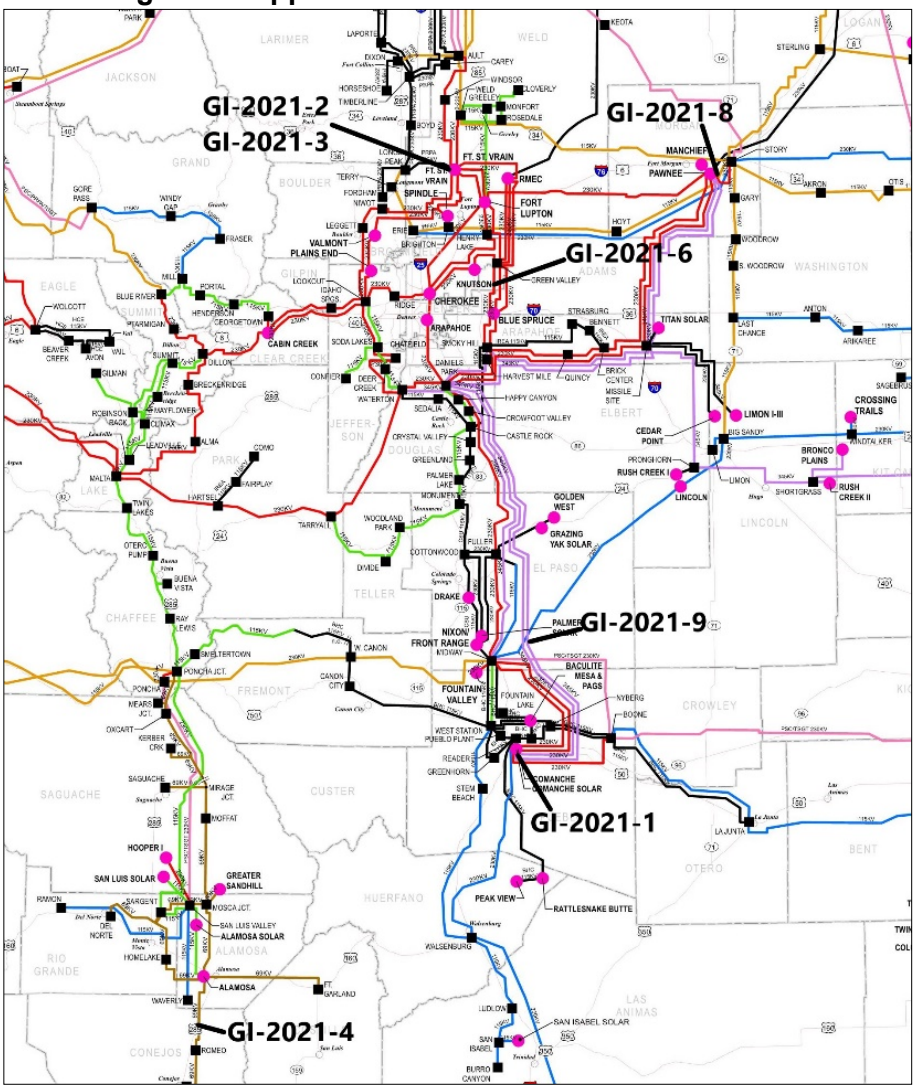
3.7 GI-2021-9

GI-2021-9 is a 199MW_{ac} net rated solar PV Generating Facility located in Pueblo County, Colorado. The Generation Facility will consist of sixty-eight (68) Power Electronics FS3350M inverters rated at 3.02MW, each with its own 0.66/34.5kV, 3.63 MVA Delta/Wye Z=8.5%, X/R=10.5 pad-mount transformer. The 34.5kV collector system will connect to one (1) 345/34.5/13.8kV, 135/180/225 MVA Wye-grounded/Wye-grounded/Delta Z=8.5%, X/R=35 main step-up transformer which will connect to the PSCo transmission system via a 0.5mile 345kV generation tie-line. The POI is the Tundra 345kV Switching Station (POI identified for GI-2018-24).

The proposed Commercial Operation Date (COD) of GI-2021-8 is December 1, 2024. For the study purpose, the back-feed date is assumed to be June 1, 2024, approximately six (6) months before the COD.

The geographical location of the Transmission System near the POI is shown in Figure 1 below.

Figure 1– Approximate Locations of the GIR POIs



4.0 Study Scope

The purpose of the Phase 1 study is to determine the system impact of interconnecting all seven (7) GIRs in the DISIS-2021-001 for Interconnection Service.

The scope of the study includes steady state (thermal and voltage) analysis and cost estimates. The cost estimates provide total costs and each GIR's cost responsibility for Transmission Provider Interconnection Facilities and Network Upgrades (Station Network Upgrades and other Network Upgrades).

Additionally, GI-2021-8 was evaluated for the 100MW BES operating in grid charging mode.

4.1 Study Pocket Determination

GI-2021-1 and GI-2021-9 are in the Southern Colorado study pocket. GI-2021-2, GI-2021-3 and GI-2021-6 fall under the Northern Colorado study pocket. GI-2021-8 is in the Eastern Colorado study pocket. GI-2021-4 is in the San Luis Valley study pocket. Each study pocket analysis only modeled the GIRs with POI in that study pocket.

The Affected Systems included in the Southern Colorado study pocket analysis includes Tri-State Generation and Transmission Inc. (TSGT), Black Hills Energy (BHE), Colorado Spring Utilities (CSU), Intermountain Rural Electric Association (IREA) and Western Area Power Administration (WAPA).

The Affected Systems included in the San Luis Valley study pocket analysis include TSGT and WAPA.

The Affected System included in the Eastern Colorado study pocket analysis includes TSGT.

The Affected System included in the Northern Colorado study pocket analysis includes TSGT.

4.2 Study Criteria

The following steady state analysis criteria is used to identify violations on the PSCo system and the 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

4.3 Study Methodology

The steady state assessment is performed using the PSSE V35 and ACCC tool. The generation redispatch for ERIS is identified using TARA.

Thermal violations are identified if a facility (i) resulted in a thermal loading >100% in the Study Case after the Study Pocket GIR cluster addition and (ii) contributed to an incremental loading increase of 1% or more to the benchmark case loading.

Voltage violations are identified if a bus voltage has a further variation of 0.05p.u.

DFAX criteria for identifying contribution to thermal overloads is ≥1%.

DFAX criteria for identifying contribution to the voltage violations is 0.005p.u.

When the study pocket has a mix of NRIS and ERIS requests, it is studied by first modeling the NRIS GIRs at their full requested amount and modeling the ERIS GIRs offline. Network Upgrades required to mitigate the thermal and/or voltage violations are only allocated to NRIS requests because other GIR's output is modeled at zero.

The NRIS GIRs and their associated Network Upgrades are then modeled in the NRIS Study Case, and ERIS GIRs are dispatched at 100% to study the system impact. Violations are identified and the study evaluates if a generation redispatch combination eliminates the violation. If generation redispatch is unable to eliminate the violation, upgrades will be identified.

The resources included in the OPF redispatch are:

1. All PSCo and Non-PSCo resources connected to the PSCo Transmission System
2. Higher-queued NRIS generation in the PSCo queue
3. Generation connected to an Affected System Transmission System if that generation is a designated network resource to serve load connected to PSCo
4. All other generation connected to an Affected System Transmission System and Stressed in the Study Case may be dispatched to the Base Case level

5.0 Base Case Modeling Assumptions

The 2026HS2a WECC case released on July 21, 2020 was selected as the starting case. The Base Case was created from the Starting Case by including the following modeling changes. The following approved transmission projects in PSCo's 10-year transmission plan, with an in-

service date before summer 2026 were modeled: (http://www.oasis.oati.com/woa/docs/PSCO/PSCOdocs/FERC_890_Q1_2020_Transmission_Plan_Presentation.pdf)

- Cloverly 115kV Substation – ISD 2021
- Graham Creek 115kV Substation – ISD 2022
- Husky 230/115kV Substation – ISD 2022
- Mirasol 230kV Substation – ISD 2022
- Avery Substation – ISD 2021
- Barker Substation – Bank1 ISD: 2021, Bank 2 ISD: 2022
- High Point Substation – ISD 2022
- Titan Substation – ISD 2022
- Dove Valley Substation – ISD 2023
- Monument – Flying Horse 115kV Series Reactor – ISD 2022
- Ault – Husky 230kV line – ISD 2022
- Husky – Graham Creek – Cloverly 115kV line – ISD 2022
- Gilman – Avon 115kV line – ISD 2022
- Climax – Robinson Rack – Gilman 115kV – ISD 2022
- Greenwood – Arapahoe – Denver Terminal 230kV – ISD 2022
- Upgrade Villa Grove – Poncha 69kV Line to 73MVA – ISD 2021
- Upgrade Poncha – Sargent - San Luis Valley 115kV line to 120MVA – ISD 2021
- Upgrade Antonito – Romeo – Old40Tap – Alamosa Terminal – Alamosa Switchyard 69kV line to 143MVA – ISD 2022/2023

All transmission facilities were modeled at their expected ratings for 2023 Summer season. Also, the following facility uprate projects were modeled at their planned future ratings:

- Upgrade Allison – SodaLakes 115kV line to 318MVA – ISD 2021
- Upgrade Buckley34 – Smokyhill 230kV line to 506MVA – ISD 2021
- Upgrade Daniels Park – Priarie1 230kV line to 756MVA – ISD to be determined
- Upgrade Greenwood – Priarie1 230kV line to 576MVA – ISD 2021
- Upgrade Daniels Park – Priarie3 230kV line to 756MVA – ISD to be determined
- Upgrade Greenwood – Priarie3 230kV line to 576MVA – ISD 2021
- Upgrade Midway 230kV bus tie to 576MVA – ISD 2023

- Upgrade Waterton – Martin2 tap 115kV line to 189MVA – ISD 2021
- Upgrade Daniels Park 345/230kV # T4 to 560MVA – ISD 2021
- Upgrade Leetsdale – Monaco 230kV line to 560MVA – ISD 2021
- Upgrade Greenwood – Monaco 230kV line to 560MVA – ISD 2021
- Upgrade Waterton – Martin1 tap 115kV line to 189MVA – ISD 2023

The following additional changes were made to the TSGT model in the Base Case per further review and comment from TSGT:

- Fuller – Vollmer – Black Squirrel 115 kV line modeled at 173 MVA – ISD 2022
- Fuller 230/115kV, 100MVA #2 transformer – ISD 2023

The following additional changes were made to the BHE model in the Base Case per further review and comment from BHE:

- Pueblo West substation – ISD 4/13/2021
- Pueblo Reservoir – Burnt Mill 115kV Rebuild – ISD 8/31/2021
- Boone - South Fowler 115kV Project – ISD 10/1/2021
- North Penrose Substation – ISD 1/31/2022
- West Station – Pueblo Res 115kV Rebuild – ISD 1/31/2022

The following additional changes were made to the CSU model in the Base Case per further review and comment from CSU:

- The Cottonwood – Tesla 34.5kV line is modeled open and Kettle Creek – Tesla 34.5kV line is modeled closed on the CSU system – ISD 2023
- Briargate South 115/230kV transformer project tapping the Cottonwood – Fuller 230kV line – ISD 2023

The Base Case model includes the existing PSCo generation resources and all Affected System's existing resources.

In addition, the following higher-queued generation from PSCo's queue were modeled in the Base Case: GI-2014-6, GI-2014-9, GI-2014-13, GI-2016-15, Transitional Cluster (GI-2018-24 , GI-2018-25, and GI-2019-6), 1RSC-2020 (1RSC-2020-1 and 1RSC-2020-2), DISIS-2020-001 (GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5, GI-2020-6, GI-2020-7, and GI-2020-10), 2RSC-2020 and DISIS-2020-002 (GI-2020-12, GI-2020-13, GI-2020-14, GI-2020-15 and GI-2020-16). While

the higher-queued NRIS requests were dispatched at 100%, the higher-queued ERIS requests were modeled offline.

The following future generation connected to the Affected Systems are modeled in the Base Case:

IREA:

- 80MW Pioneer Solar PV Generating Facility interconnecting on the Victory – Brick Center 115kV line – COD 12/31/2020
- 45MW Hunter Solar PV Generating Facility interconnecting at Brick Center 115kV Substation – COD 2/1/2022
- 54.5MW Kiowa Solar PV Generating Facility interconnecting at Victory 115kV Substation – COD 4/1/2023

TSGT:

- TI-18-0809, 100MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line
- TI-19-1016, 40MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line

6.0 Study Analysis

The Interconnection Service of GI-2021-1 and GI-2021-9 is determined using the Southern Colorado study pocket analysis. The Interconnection Service of GI-2021-4 is determined using the San Luis Valley Colorado study pocket analysis. The Interconnection Service of GI-2021-2, GI-2021-3, and GI-2021-6 is determined using the Northern Colorado study pocket analysis. The Interconnection Service of GI-2021-8 is determined using the Eastern Colorado study pocket analysis.

6.1 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. Finally, it is the responsibility of the Interconnection Customer to compensate their generation tie-line to ensure minimal reactive power flow under no load conditions.

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.

6.1.1 GI-2021-1

According to the modeling data provided by the Interconnection Customer, GI-2021-1 generator model is as follows: Pmax = 202.95MW, Pmin = 0MW, Qmax = 86.16MVAr, Qmin=-86.16MVAr.

Additionally, there is a 15Mvar capacitor bank on the 34.5kV bus.

The reactive capability analysis indicates that GI-2021-1 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining at normal operating voltage at the POI for 100%, 10% and 0% output. However, the generator terminal voltage for 100% output is outside the normal acceptable range.

Table 2- Reactive capability evaluation of GI-2021-1

Gen MW / Mvar	15Mvar Cap bank Status	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
			Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
202.7MW/ 86.2Mvar	On	1.078	1.018	200.2	66.3	0.949 (lag)	0.999	200.2	66.3	0.949 (lag)
202.7MW/ 86.2Mvar	Off	1.068	1	200.2	50.6	0.969 (lag)	1	200.2	50.6	0.969 (lag)
202MW/ -35.2Mvar	Off	1.01	1.01	199.5	-69.5	0.944 (lead)	1.01	199.5	-69.5	0.944 (lead)
20.7MW/ 7.6Mvar	Off	1.012	1.016	20.7	8.8	0.920 (lag)	1.015	20.7	8.8	0.920 (lag)
20.7MW/ -9.2Mvar	Off	0.996	1.015	20.7	-8.1	0.931 (lead)	1.015	20.7	-8.1	0.931 (lead)
0MW/ 0Mvar	Off	1.0	0.99	0	-1.5	NA	0.99	0	-1.5	NA

6.1.2 GI-2021-2

The Fort Saint Vrain #2 generator is currently capable of voltage control at the POI, since the reactive capability curve of the generator is not expected to change due to the prime mover modifications, the GI-2021-2 is modeled by increasing the Pmax value of Fort Saint Varin#2 by 49MW. The analysis indicates that the GI-2021-2 is capable of meeting +/-0.95 power factor at the POI.

Table 3 – Reactive capability evaluation of GI-2021-2

Gen MW/Mvar	Gen Terminal Voltage (p.u.)	POI Voltage (p.u.)	POI MW	POI MVar	POI power Factor
187MW / 111.5Mvar	1.04	1.02	182.5	80.8	0.898 (lag)
187MW / -69.0Mvar	0.95	1.01	182.6	-91.4	0.894 (lead)

6.1.3 GI-2021-3

The Fort Saint Vrain #3 generator is currently capable of voltage control at the POI, since the reactive capability curve of the generator is not expected to change due to the prime mover modifications, the GI-2021-3 is modeled by increasing the Pmax value of Fort Saint Varin#3 by 35MW. The analysis indicates that the GI-2021-3 is capable of meeting +/-0.95 power factor at the POI.

Table 4 – Reactive capability evaluation of GI-2021-3

Gen MW/Mvar	Gen Terminal Voltage (p.u.)	POI Voltage (p.u.)	POI MW	POI MVar	POI power Factor
183MW / 104.5Mvar	1.04	1.02	183	80.8	0.91 (lag)
183MW / -63.0Mvar	0.95	1.01	183	-87.5	0.90 (lead)

6.1.4 GI-2021-4

According to the modeling data provided by the Interconnection Customer, GI-2021-4 generator model is as follows:

PV- Pmax = 42.3MW, Pmin = 0.0MW, Qmax = 16.21Mvar, Qmin=-16.21Mvar

BES- Pmax = 10.5MW, Pmin = 0.0MW, Qmax = 10.5Mvar, Qmin=-10.5Mvar

The reactive capability analysis indicates that GI-2021-4 is not capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining normal operating voltage at the POI for 100%, 10%, and 0% output. However, the generator terminal voltage for 100% output is outside the normal acceptable range. Since the PV and BES individually can meet the reactive power, it is concluded that the PV plus BES combination can meet the reactive power requirements.

Table 3 - Reactive capability evaluation of GI-2021-4

	Gen	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
			Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
PV	42.3MW/ 16.2Mvar	1.349	1.177	42.1	13.6	0.95 (lag)	1.177	42.1	13.6	0.95 (lag)
PV	42.7MW/ -9.2Mvar	1.005	1.02	42	-13.9	0.949 (lead)	1.029	42	-14.0	0.949 (lead)
PV	4.3MW/ 1 Mvar	1.005	0.975	4.3	1.5	0.944 (lag)	0.975	4.3	1.5	0.944 (lag)
PV	4.3MW/ -2Mvar	0.997	0.956	4.3	-1.6	0.937 (lead)	0.956	4.3	-1.6	0.937 (lead)
PV	0MW/ 7Mvar	1.006	1	0	7.3	NA	1	0	7.3	NA
BES	10.5MW/ 4Mvar	1.308	1.036	10.4	4.1	0.93 (lag)	1.036	10.4	4.1	0.93 (lag)

	Gen	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
			Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
BES	10.5MW/ -4Mvar	1.199	0.987	10.4	-4.1	0.93 (lead)	0.987	10.4	-4.1	0.93 (lead)
BES	1.05MW/ 1Mvar	1.02	0.976	1	0.4	0.93 (lag)	0.976	1	0.4	0.93 (lag)
BES	1.05MW/ -1Mvar	1.02	0.976	1	-0.4	0.93 (lead)	0.976	1	-0.4	0.93 (lead)
BES	0 MW/ -1Mvar	1.02	0.976	0	-0.4	NA	0.976	0	-0.4	NA

6.1.5 GI-2021-6

According to the modeling data provided by the Customer, GI-2021-6 model is as follows:

PV - Pmax = 207.8MW, Pmin = 0.0MW, Qmax = 90.87Mvar, Qmin=-90.87Mvar.

BES - Pmax = 100MW, Pmin = -100MW, Qmax = 61.88Mvar, Qmin=-61.88Mvar.

Additionally, the Generating Facility includes a 31Mvar shunt capacitor bank modeled at the 34.5kV bus.

The reactive capability analysis indicates that GI-2020-16 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining normal operating range voltage at the POI for 100%, 10% and 0% output values when PV and BES operate in combination.

Table 4 - Reactive capability evaluation of GI-2021-6

	Gen MW/ Mvar	31 Mvar Cap bank Status	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
				Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
PV+ BES	203.3MW / 68Mvar	Off	1.034 / 1.019	1.019	199.4	37.1	0.983 (lag)	1.016	199	35.9	0.984 (lag)
PV+ BES	203.3MW / 68Mvar	On	1.059 / 1.024	1.024	199.6	68.6	0.946 (lag)	1.019	199.1	67.3	0.947 (lag)
PV+ BES	203.3MW / -30Mvar	Off	0.93 / 1.004	1.004	199	-66.2	0.949 (lead)	1.005	198.5	-67.6	0.947 (lead)
PV+ BES	20.3MW / 1.4Mvar	Off	0.969 / 1.011	1.011	20.3	7.4	0.940 (lag)	1.01	20.3	8.1	0.929 (lag)
PV+ BES	20.3MW / -18.5Mvar	Off	0.947 / 1.008	1.008	20.3	-12.9	0.844 (lead)	1.008	20.3	-12.2	0.857 (lead)
PV+ BES	0MW / -64Mvar	Off	0.892 /1	1	0	-62.3	NA	1.003	0	-61.7	NA
PV	207.8MW /90.9MVar	Off	1.0673	0.997	198.8	45.2	0.975 (lag)	0.993	198.4	43.9	0.976 (lag)

PV	207.8MW /82MVar	on	1.079	1.001	199.2	69.1	0.944 (lag)	0.996	198.8	67.7	0.946 (lag)
PV	207.8MW / -25Mvar	Off	0.906	0.977	197.3	-80.3	0.926 (lead)	0.979	196.8	-81.9	0.923 (lead)
PV	20.8MW / 9MVar	Off	0.96	0.989	20.7	14.8	0.813 (lag)	0.988	20.7	15.5	0.8 (lag)
PV	20.8MW / -9Mvar	Off	0.935	0.986	20.7	-3.3	0.987 (lead)	0.986	20.7	-3.3	0.987 (lead)
PV	0MW / -9Mvar	Off	0.935	0.986	0	-3.3	NA	0.986	0	-3.3	NA
BES	100MW / 61.9Mvar	Off	1.013	0.998	99.9	60.3	0.856 (lag)	0.994	99.7	60.4	0.855 (lag)
BES	100MW / -32Mvar	Off	0.94	0.983	99.9	-33.2	0.949 (lead)	0.983	99.8	-33	0.949 (lead)
BES	10MW /6.2Mvar	Off	0.972	0.989	10	12.5	0.62 (lag)	0.988	10	13.2	0.60 (lag)
BES	10MW / -6.2Mvar	Off	0.962	0.987	10	0	1	0.986	10	0.8	1
BES	0MW /0 Mvar	Off	0.967	0.987	0	-6.4	NA	0.987	0	-7.1	NA

6.1.6 GI-2021-8

According to the modeling data provided by the Customer, GI-2021-8 model is as follows: The 400MW is arranged in two groups. Each group includes:

PV: Pmax = 205.5MW, Pmin = 0.0MW, Qmax = 67.6Mvar, Qmin=-67.6Mvar.

BES: Pmax = 51.4MW, Pmin = -51.4MW, Qmax = 16.9Mvar, Qmin=-16.9Mvar

Additionally, the Generating Facility includes a 2 x 32Mvar shunt capacitor bank modeled at the 34.5kV bus. The modeling data was sufficient and met 400MW at the POI.

The reactive capability analysis indicates that GI-2021-8 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining normal operating range voltage at the POI for 100%, 10% and 0% output when the PV and BES operate in combination. However, the generator terminal voltage for 100% output is outside the normal acceptable range

Table 7 - Reactive capability evaluation of GI-2021-8

	Gen MW/ Mvar	2x32 Mvar Cap bank Status	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
				Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
PV+ BES	410.6MW / 167Mvar	Off	1.109/ 1.105/ 1.109/ 1.105	1.029	401	98.8	0.971 (lag)	1.028	400.7	100.4	0.970 (lag)
PV+ BES	410.6MW / 167Mvar	On	1.139/ 1.136/ 1.139/ 1.136	1.039	401.4	172	0.919 (lag)	1.036	400.9	174.9	0.917 (lag)
PV+ BES	410.6MW / -59.2Mvar	Off	0.981/ 0.966/ 0.981/ 0.966	1.001	400	-138.6	0.945 (lead)	1.001	399.5	-137	0.946 (lead)
PV+ BES	40MW / 10.8Mvar	Off	1.028/ 1.029/ 1.028/ 1.029	1.019	41	17.4	0.921 (lag)	1.019	40.9	20.1	0.897 (lag)

PV+ BES	41MW / -21.2Mvar	Off	1.011/ 1.007/ 1.011/ 1.007	1.015	41	-14.6	0.942 (lead)	1.015	40.9	-11.9	0.960 (lead)
PV+ BES	0MW / -138.6Mvar	Off	0.935/ 0.931/ 0.935/ 0.931	1	-1.2	-141.6	NA	1.001	-1.2	-139	NA
PV	410.6MW / 135.2Mvar	Off	1.052/1.052	1.001	400.8	64.4	0.987 (lag)	1.000	400.5	66	0.987 (lag)
PV	410.6MW / 135.2Mvar	On	1.099/1.099	1.009	401.2	134.8	0.948 (lag)	1.007	400.7	136.6	0.947 (lag)
PV	410.6MW / -135.2Mvar	Off	0.903/0.903	0.973	398	-169.8	0.920 (lead)	0.978	397	-238.0	0.858 (lead)
PV	41MW / 135.2Mvar	Off	1.081/1.081	1.016	40	134.4	0.285 (lag)	1.015	40	137	0.280 (lag)
PV	41MW / -135.2Mvar	Off	0.922/0.922	0.987	39.8	-139.4	0.275 (lead)	0.987	39.7	-137	0.278 (lead)
PV	0MW / 29.2Mvar	Off	0.988/0.988	1.000	0	-22.4	NA	1.000	0	-19.7	NA
BES	102.8MW / 33.8Mvar	Off	1.036/1.036	1.000	101.6	32.2	0.953 (lag)	1.000	101.7	34.7	0.946 (lag)
BES	102.8MW / 33.8Mvar	On	1.064/1.064	1.008	101.6	99.4	0.715 (lag)	1.007	101.6	102.0	0.706 (lag)
BES	102.8MW / -33.8Mvar	Off	0.974/0.974	0.993	101.6	-36.6	0.941 (lead)	0.993	101.5	-34.2	0.948 (lead)
BES	10.2MW / 33.8Mvar	Off	1.032/1.032	1.002	10.2	40.2	0.246 (lag)	1.001	10.1	42.7	0.230 (lag)
BES	10.2MW / -33.8Mvar	Off	0.969/0.969	0.994	10.2	-27.8	0.344 (lead)	0.994	10.2	-25.1	0.376 (lead)
BES	0MW / -16.8Mvar	Off	1.016/1.016	1.000	0	-23.8	NA	1.000	0	-26.4	NA

6.1.7 GI-2021-9

According to the modeling data provided by the Customer, GI-2021-9 model is as follows: Pmax = 205.02MW, Pmin = 0.0MW, Qmax = 99.3Mvar, Qmin=-99.3Mvar. Additionally, the Generating Facility includes a 31Mvar shunt capacitor bank modeled at the 34.5kV bus.

The reactive capability analysis indicates that GI-2020-9 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining normal operating range voltage at the POI for 100%, 10% and 0% output when the Pmax is increased.

Table 8 - Reactive capability evaluation of GI-2021-9

Gen MW/ Mvar	31 Mvar Cap bank Status	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
			Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
201.5MW/ 89Mvar	On	1.075	1.003	198.9	75.9	0.934 (lag)	1.002	198.9	75.7	0.934 (lag)
201.5MW/ 89Mvar	Off	1.068	1.002	198.9	60.3	0.957 (lag)	1.001	198.9	60.1	0.957 (lag)

201.5MW/ -41.8Mvar	Off	0.959	0.99	198.7	-73.2	0.938 (lead)	0.99	198.6	-73.4	0.938 (lead)
20.15MW/ 4.5Mvar	Off	1.003	0.998	20.1	7.2	0.941 (lag)	0.997	20.1	7.4	0.941 (lag)
20.15MW/ -10.1Mvar	Off	0.991	0.996	20.1	-7.5	0.937 (lead)	0.996	20.1	-7.3	0.937 (lead)
0 MW/ 33.3Mvar	Off	1.025	1	0	35.7	NA	1	0	35.7	NA

6.2 Southern Colorado Study Pocket Analysis

6.2.1 Benchmark Case Modeling

The Benchmark Case was created from the Base Case by changing the Study Pocket generation dispatch to reflect a heavy south to north flow on the Comanche – Midway – Jackson Fuller – Daniels Park transmission system. This was accomplished by adopting the generation dispatch in Table 9.

Table 9 – Generation Dispatch Used to Create the Southern Colorado Benchmark Case (MW is Gross Capacity)

Bus Name	Id	Status	PGen (MW)	Pmax (MW)
COMAN_1 24.000	C1	1	360	360
COMAN_2 24.000	C2	1	365	365
COMAN_3 27.000	C3	1	853.3	853.3
COMAN_S1 0.418	S1	1	106.25	125
CO_GRN_E 34.500	W1	1	64.8	81
CO_GRN_W 34.500	W2	1	64.8	81
FTNVL1&2 13.800	G1	1	36	40
FTNVL1&2 13.800	G2	1	36	40
FTNVL3&4 13.800	G3	1	36	40
FTNVL3&4 13.800	G4	1	36	40
FTNVL5&6 13.800	G5	1	36	40
FTNVL5&6 13.800	G6	1	36	40
GLDNWST_W1 0.6900	W1	1	99.3	124.1
GLDNWST_W2 0.6900	W2	1	100	125
LAMAR_DC 230.00	DC	0	0	210
TWNBUTTE 34.500	W1	1	60	75
CEP6_S1 0.6600	S1	1	212.5	250

Bus Name	Id	Status	PGen (MW)	Pmax (MW)
CEP5_S1 0.6600	S1	1	170	200
SI_GEN 0.6000	1	1	25.5	30
TBII_GEN 0.6900	W	1	60.8	76
TI-18-0809 0.6300	PV	1	85	100
TI-19-1016 0.6300	PV	0	0	40
APT_DSLS 4.1600	G1	0	0	10
BAC_MSA GEN113.800	G1	1	90	90
BAC_MSA GEN213.800	G1	1	90	90
BAC_MSA GEN413.800	G1	1	40	40
BAC_MSA GEN413.800	G2	1	40	40
BAC_MSA GEN413.800	S1	1	24.8	24.8
BAC_MSA GEN513.800	G1	1	40	40
BAC_MSA GEN513.800	G2	1	40	40
BAC_MSA GEN513.800	S1	1	24.8	24.8
BAC_MSA GEN613.800	G1	1	40	40
BUSCHRNCH_LO0.7000	W1	0	0	59.4
BUSCHRWTG1 0.7000	G1	1	1.4	28.8
PEAKVIEWLO 0.7000	G1	1	3	60
PUB_DSLS 4.1600	G1	0	0	10
R.F.DSLS 4.1600	G1	0	0	10

6.2.2 Study Case Modeling

An ERIS Study Case was created from the Benchmark Case by modeling GI-2021-1 at Comanche 230kV bus and GI-2021-9 at the Tundra 345kV Substation (POI built for GI-2018-24). The total 399MW output from the 2 GIRs was balanced against all PSCo and non-PSCo generation connected to the PSCo Transmission System outside the study pocket on a pro-rata basis.

6.2.3 Steady State Analysis Results

The results of the single contingency analysis are given in Table 10.

Table 10 – Southern Colorado Study Pocket ERIS Results – overloads identified in single contingency analysis

Overloaded Facility	Type	Owner	Facility Normal Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to study pocket GIRs	Single Contingency Definition	OPF Identified
				MVA Flow	% Line Loading	MVA Flow	% Line Loading			
Daniels Park – Fuller 230kV	Line	PSCo	478	428	90.4%	525	113.2%	22.8%	Midway – Waterton 345kV line	Yes
Deer Creek – Soda Lakes 115kV	Line	PSCo	120	102	84.2%	124	103.8%	19.6%	Chatfield – Waterton 230kV line	Yes
Greenwood – Prairie13 230kV	Line	PSCo	576	545	97.4%	633	113.9%	16.5%	Daniels Park – Prarie2 230kV line	Yes
Palmer Lake – Monument 115kV	Line	PSCo/CSU	151	117	79.2%	146	100.6%	21.4%	Daniels Park – Fuller 230kV line	Yes
Waterton 345/230 kV #2	Xfmr	PSCo	560	503	89.8%	608	108.6%	18.8%	Waterton 345/230 kV #1	Yes
Waterton 345/230 kV #1	Xfmr	PSCo	560	503	89.8%	608	108.6%	18.8%	Waterton 345/230 kV #2	Yes
Monument – Gresham 115kV	Line	TSGT	145	117	81.9%	142	101.4%	19.5%	Daniels Park – Fuller 230kV line	Yes
Daniels Park – Prarie2 230kV	Line	PSCo	576	562	100.5%	650	116.9%	16.4%	Greenwood – Prairie13 230kV line	Yes
West Canyon - Hogback 115kV	Line	PSCo	120	118	101.3%	146	126.1%	24.8%	MidwayBR – West Canyon 230kV line	Yes
Drake N – Drake S 115kV	Line	CSU	171	178	103.7%	186	109.4%	5.7%	Kelker E – SanteFe S 230kV line	Yes

The OPF identified redispatch scenarios that mitigated all new overloads and incremental increase in the pre-existing overloads shown in Table 10.

The results of the multiple contingency analysis on the Study Case are given in Table 11.

Table 11 – Southern Colorado Study Pocket ERIS Results – overloads identified in multiple contingency analysis

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Daniels Park – Fuller 230kV	Line	PSCo	478	453	96.3%	494	106.2%	9.9%	Daniels Park 230/345kV #T4 & Mirasol – Daniels Park 345kV
Pueblo Plant – Reader 115kV	Line	BHE	160	140	88.1%	174	110.6%	22.5%	Midway – Fuller 230kV breaker Failure
MidwayBR – RD_Nixon 230kV	Line	CSU	195	159	82.5%	204	107.6%	25.1%	Midway – Fuller 230kV breaker Failure
Drake N – Drake S 115kV	Line	CSU	189	182	97.6%	184	100.5%	2.9%	CW_F-CW_S
West Canyon 230/115kV # T1	Trf	PSCo	100	91	91.5%	124	124.3%	32.8%	Midway – Fuller 230kV breaker Failure
Fountain Valley – Desert Cove 115kV	Line	BHE	222	264	120.7%	324	150.3%	29.6%	Midway – Fuller 230kV breaker Failure
Fountain Valley – MidwayBR 115kV	Line	BHE	173	264	152.6%	324	187.3%	34.7%	Midway – Fuller 230kV breaker Failure
Desert Cove – West Station 115kV	Line	BHE	222	292	133.0%	353	162.8%	29.8%	Midway – Fuller 230kV breaker Failure
West Station – Hogback 115kV	Line	BHE	120	121	103.3%	150	132.0%	28.7%	Midway – Fuller 230kV breaker Failure

The multiple contingency analysis shows several new overloads and increases to existing overloads after the addition of the Southern Colorado Pocket Cluster ERIS GIRs. Per TPL1-4, multiple contingency overloads are mitigated using system adjustments, including generation redispatch and/or operator actions. Also, PSCo is in the process of identifying system mitigations which may include

automatic generation adjustments schemes for the common corridor multiple contingencies. These future mitigations will address the existing and new overloads, and all GIRs in the Southern Colorado study pocket may become part of the mitigations and may be subject to automatic generation adjustments. Since these contingencies will be mitigated through automatic schemes, they were not included in Table 11.

The study did not identify any overloads attributable to GI-2021-1 and GI-2021-9.

6.2.4 Affected Systems

The study did not identify any impacts to the Affected Systems.

6.2.5 Summary of Southern Study Pocket Analysis

The maximum allowable output of GI-2021-1 before Network Upgrades is 200MW.

The maximum allowable output of GI-2021-9 before Network Upgrades is 199MW.

ERIS of GI-2021-1 is 200MW.
ERIS of GI-2021-9 is 199MW.

6.3 Northern Colorado Study Pocket Analysis

6.3.1 Benchmark Case Modeling

The Benchmark Case was created from the Base Case by adopting the generation dispatch in Table 12.

Table 12 – Generation Dispatch Used to Create the Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)
CEDAR2_W1 0.66	W1	1	100	125
CEDAR2_W2 0.69	W2	1	80.6	100.8
CEDAR2_W3 0.66	W3	1	20	25
CEDARCK_1A 34.50	W1	1	176	220
CEDARCK_1B 34.50	W2	1	64	80
FTLUP1-2 13.80	G1	1	45	50
FTLUP1-2 13.80	G2	1	45	50
JMSHAFR1 13.80	G1	1	32.2	35.8
JMSHAFR1 13.80	G2	1	31.5	35

Bus Name	ID	Status	PGen (MW)	PMax (MW)
JMSHAFR2 13.80	ST	1	45.6	50.7
JMSHAFR3 13.80	G3	1	32.5	36.1
JMSHAFR3 13.80	ST	1	45	50
JMSHAFR4 13.80	G4	1	31.3	34.8
JMSHAFR4 13.80	G5	1	29.7	33
KNUTSON1 13.80	G1	1	65.3	72.5
KNUTSON2 13.80	G2	1	65.3	72.5
PAWNEE 22.00	C1	1	535	535
MANCHEF1 16.00	G1	0	0	140
MANCHEF2 16.00	G2	0	0	140
PLNENDG1_1 13.80	G0	1	4.9	5.4
PLNENDG1_1 13.80	G1	1	4.9	5.4
PLNENDG1_1 13.80	G2	1	4.9	5.4
PLNENDG1_1 13.80	G3	1	4.9	5.4
PLNENDG1_1 13.80	G4	1	4.9	5.4
PLNENDG1_1 13.80	G5	1	4.9	5.4
PLNENDG1_1 13.80	G6	1	4.9	5.4
PLNENDG1_1 13.80	G7	1	4.9	5.4
PLNENDG1_1 13.80	G8	1	4.9	5.4
PLNENDG1_1 13.80	G9	1	4.9	5.4
PLNENDG1_2 13.80	G0	1	4.9	5.4
PLNENDG1_2 13.80	G1	1	4.9	5.4
PLNENDG1_2 13.80	G2	1	4.9	5.4
PLNENDG1_2 13.80	G3	1	4.9	5.4
PLNENDG1_2 13.80	G4	1	4.9	5.4
PLNENDG1_2 13.80	G5	1	4.9	5.4
PLNENDG1_2 13.80	G6	1	4.9	5.4
PLNENDG1_2 13.80	G7	1	4.9	5.4
PLNENDG1_2 13.80	G8	1	4.9	5.4
PLNENDG1_2 13.80	G9	1	4.9	5.4
PLNENDG2_1 13.80	G1	1	7.3	8.1
PLNENDG2_1 13.80	G2	1	7.3	8.1

Bus Name	ID	Status	PGen (MW)	PMax (MW)
PLNENDG2_1 13.80	G3	1	7.3	8.1
PLNENDG2_1 13.80	G4	1	7.3	8.1
PLNENDG2_1 13.80	G5	1	7.3	8.1
PLNENDG2_1 13.80	G6	1	7.3	8.1
PLNENDG2_1 13.80	G7	1	7.3	8.1
PLNENDG2_2 13.80	G1	1	7.3	8.1
PLNENDG2_2 13.80	G2	1	7.3	8.1
PLNENDG2_2 13.80	G3	1	7.3	8.1
PLNENDG2_2 13.80	G4	1	7.3	8.1
PLNENDG2_2 13.80	G5	1	7.3	8.1
PLNENDG2_2 13.80	G6	1	7.3	8.1
PLNENDG2_2 13.80	G7	1	7.3	8.1
PLNENDG2_2 13.80	G1	1	7.3	8.1
RMEC1 15.00	G1	1	139.5	155
RMEC2 15.00	G2	1	139.5	155
RMEC3 23.00	ST	1	309.6	344
SPNDLE1 18.00	G1	1	141.3	157
SPNDLE2 18.00	G2	1	141.3	157
ST.VRAIN 22.00	ST	1	279	310
ST.VR_2 18.00	G2	1	146	146
ST.VR_3 18.00	G3	1	133.2	148
ST.VR_4 18.00	G4	1	137.7	153
ST.VR_5 18.00	G5	1	164.7	183
ST.VR_6 18.00	G6	1	164.7	183
VALMONT6 13.80	G6	0	0	53
VALMNT7 13.80	G7	0	0	44.3
VALMNT8 13.80	G8	0	0	44.3
MTNBRZ_W1 34.50	W1	1	135.2	169

6.3.2 Study Case Modeling

The NRIS Study Case was created from the Benchmark Case by modeling GI-2021-6 tapping the Green Valley-Sky Ranch 230kV line. GI-20201-2 and GI-20201-3 were modeled by increasing

the Fort Saint Vrain #2 and Fort Saint Vrain #3 capacity by 49MW and 35MW respectively but modeled offline. The 199MW NRIS output of GI-2021-6 was balanced by reducing Comanche3.

6.3.3 Steady State Analysis Results

The single contingency analysis of the NRIS Study Case did not identify any overloads.

The results of the multiple contingency analysis on the NRIS Study Case are given in Table 13.

Table 13 – Northern Colorado Study Pocket NRIS Results – overloads identified in multiple contingency analysis

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
BarrLake – Reunion 230kV	Line	PSCo	478	483	103.6%	500	107.2%	3.6%	Spruce – SmokyHill 230kV & Spruce – Green Valley – Imboden 230kV

The ERIS Study Case was created from the NRIS Study Case by turning on GI-2021-2 and GI-2021-3 in the NRIS study case. The 84MW total output from the two GIRs was balanced by reducing the PSCo and non-PSCo resources connected to the PSCo Transmission System outside the study pocket on a pro-rata basis. The study did not identify any single contingency overloads in the ERIS Study Case. The results of the multiple contingency analysis on the ERIS Study Case are given in Table 14.

Table 14 – Northern Colorado Study Pocket ERIS Results – overloads identified in multiple contingency analysis

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
BarrLake – Reunion 230kV	Line	PSCo	478	483	107.2%	500	109.1%	3.6%	Spruce – SmokyHill 230kV & Spruce – Green Valley – Imboden 230kV

Per TPL1-4, 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.

6.3.4 Affected Systems

The study did not identify any impacts to the Affected System.

6.3.5 Summary of Northern Study Pocket Analysis

The NRIS identified for GI-2021-6 is 199MW.

The maximum allowable output of GI-2021-2 before Network Upgrades is 49MW.

The maximum allowable output of GI-2021-3 before Network Upgrades is 35MW.

ERIS identified for GI-2021-2 is 49 MW.

ERIS identified for GI-2021-3 is 35 MW.

6.4 Eastern Colorado Study Pocket Analysis

6.4.1 Benchmark Case Modeling

The Benchmark Case was created from the Base Case by adopting the generation dispatch in Table 15.

Table 15 – Generation Dispatch Used to Create the Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)
ARAP5&6 13.800	G5	1	35	39
ARAP5&6 13.800	G6	1	35	39.5
ARAP7 13.800	ST	1	45	47
CHEROK2 15.500	SC	1	0	0
CHEROK4 22.000	G4	1	350	350
CHEROK5 18.000	G5	1	170	202.8
CHEROK6 18.000	G6	1	170	194
CHEROK7 18.000	ST	1	220	255
SPRUCE1 18.000	G1	0	0	162
SPRUCE2 18.000	G2	0	0	162
MANCHEF1 16.000	G1	1	136.1	151.3
MANCHEF2 16.000	G2	1	136.1	151.3

PAWNEE 22.000	C1	1	536	536
PTZLOGN1 34.500	W1	1	160.8	201
PTZLOGN2 34.500	W2	1	96	120
PTZLOGN3 34.500	W3	1	63.6	79.5
PTZLOGN4 34.500	W4	1	140	175
CEDARPOINT 34.500	W1	1	200	250
TITAN-PV 34.500	S1	1	42.5	50
CHEYRGE_W1 0.6900	W1	1	99.2	124
CHEYRGE_W2 0.6900	W2	1	100.8	126
CHEYRGW_W1 0.6900	W1	1	99.2	124
CHEYRGW_W2 0.6900	W2	1	100.8	126
LIMON1_W 34.500	W1	1	160.8	201
LIMON2_W 34.500	W2	1	160.8	201
LIMON3_W 34.500	W3	1	160.8	201
BRONCO_W1 0.6900	W1	1	240	300
RUSHCK_W1 34.500	W1	1	304	380
RUSHCK_W2 34.500	W2	1	176	220
KNUTSON1 13.800	G1	1	64.5	64.5
KNUTSON2 13.800	G2	1	64.5	64.5
CEDAR2_W1 0.6600	W1	1	31.5	125
CEDAR2_W2 0.6900	W2	1	5.25	100.8
CEDAR2_W3 0.6600	W3	1	25	25
CEDARCK_1A 34.500	W1	1	46.2	220
CEDARCK_1B 34.500	W2	1	16.8	80

6.4.2 Study Case Modeling

The NRIS Study Case was created from the Benchmark Case by modeling GI-2021-8 at the Pawnee 345kV Substation. The 400MW output of GI-2021-8 was balanced by reducing Comanche 3.

6.4.3 Steady State Analysis Results

The results of the single contingency analysis are given in Table 16.

Table 16 – Eastern Colorado Study Pocket NRIS Results – overloads identified in single contingency analysis

Overloaded Facility	Type	Owner	Facility Normal Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to study pocket GIRs	Single Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Pawnee – Story	Line	PSCo	581	542	93.7%	596.7	102.7%	9.0%	System intact
Buckley2 – Tollgate 230kV	Line	PSCo	484	453	97.4%	486	104.6%	7.2%	Greenwood – Monaco 230kV line
Pawnee – Story 230kV	Line	PSCo	581	714	122.9%	789	135.8%	12.9%	Smoky Hill – Missile 345kV line
Beaver Creek – Adena 115kV	Line	TSGT	163	153.1	93.9%	169.0	103.7%	9.8%	Beaver Creek – Brush Tap 115kV

The overload on the Buckley2 – Tollgate 230kV line are mitigated by fixing the terminal equipment limitations and increasing the line rating to 490MVA or the next standard rating.

TSGT has been identified as an impacted Affected System because of the overload on the Beaver Creek – Adena 115kV line. The mitigations for this violations will be coordinated with TSGT and are expected to be available in the Phase 2 report.

The Pawnee – Story 230kV line overload exists in the Benchmark Case and is expected to be mitigated by a PSCo project (to be finalized). This project is expected to mitigate the 12.9% overload caused by the study GIR. If the project is not able to mitigate the Study Case overload, the incremental cost of the mitigation will be assigned to GI-2021-8.

The results of the multiple contingency analysis on the Study Case are given in Table 17. Per TPL1-4, 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.

Table 17 – Eastern Colorado Study Pocket NRIS Results – overloads identified in multiple contingency analysis

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Clark – Jordan 230kV	Line	PSCo	364	425	119.7%	473	133.8%	14.1%	Smoky Hill – Sullivan 230kV & Smoky Hill – Leetsdale 230kV
Meadows – Smoky Hill 230kV	Line	PSCo	621	598	98.8%	647	107.1%	8.3%	Smoky Hill – Sullivan 230kV & Smoky Hill – Leetsdale 230kV
Pawnee – Story 230kV	Line	PSCo	589	611	104.3%	1047	185.2%	80.9%	Missile Site – Daniels Park 230kV & Missile Site – Smoky Hill 345kV

6.4.4 Affected Systems

TSGT has been identified as an impacted Affected System.

6.4.5 Summary of Eastern Study Pocket Analysis

NRIS of GI-2021-8 is 400MW

6.5 San Luis Valley Study Pocket Analysis

The San Luis Valley study pocket analysis was performed for both heavy load and a light load (28%) load scenario.

6.5.1 Benchmark Case Modeling

The heavy load Benchmark Case was created from the Base Case by adopting the generation dispatch in Table 18.

Table 18 – Generation Dispatch Used to Create the Heavy Load Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)
ALMSACT1 13.800	G5	1	17.5	19.4
ALMSACT2 13.800	G6	1	16.2	18.0
GSANDHIL_PV 34.500	ST	1	10.5	12.4
HOOPER_PV 34.500	SC	1	25.5	30.0
COGENTRIX_PV34.500	G4	1	25.5	30.0
SUNPOWER 34.500	G5	1	44.2	52.0
GI-2014-13 34.500	G6	0	0	52.0
GI-2014-2 34.500	ST	0	0	35.0

The light load Benchmark Case was created from the heavy load Benchmark case by scaling the San Luis Valley loads to 28% and turning off Alamosa CT1 and Alamosa CT2 units.

Table 19 – Generation Dispatch Used to Create the Light Load Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)
ALMSACT1 13.800	G5	0	0	19.4
ALMSACT2 13.800	G6	0	0	18.0
GSANDHIL_PV 34.500	ST	1	10.5	12.4
HOOPER_PV 34.500	SC	1	25.5	30.0
COGENTRIX_PV34.500	G4	1	25.5	30.0
SUNPOWER 34.500	G5	1	44.2	52.0
GI-2014-13 34.500	G6	0	0	52.0
GI-2014-2 34.500	ST	0	0	35.0

6.5.2 Study Case Modeling

The 2026HS heavy load Study Case and 2026LS light load Study Cases are created from the respective Benchmark Cases by modeling GI-2021-4 tapping the Romeo – Old40Tap 69kV line. The 42MW output of GI-2021-4 is balanced by reducing the Pawnee generator.

6.5.3 Steady State Analysis Results

The single contingency analysis on the heavy load case and the light load case did not identify any thermal or voltage violations.

The multiple contingency analysis on the heavy load case did not identify any overloads.

The multiple contingency analysis on the light load case did not identify any overloads.

6.5.4 Affected Systems

The study did not identify any impacts to the Affected Systems.

6.5.5 Summary of San Luis Valley Study Pocket Analysis

NRIS of GI-2021-4 is 42MW

7.0 Cost Estimates and Assumptions

There are three types of costs identified in the study

- Transmission Provider's Interconnection Facilities which are directly assigned to each GIR
- Station equipment Network Upgrades, which are allocated each GIR connecting to that station on a per-capita basis per Section 4.2.4(a) of the LGIP
- All other Network Upgrades which are allocated by the proportional impact per Section 4.2.4(b) of the LGIP

7.1 Station Network Upgrades

The total cost of Station Network Upgrades for each POI and each GIRs cost assignment are given in Table 20.

Table 20 – Total cost of Station Network Upgrades by POI

POI	Total Cost (Million)	GIRs Sharing the POI	Allocation
Comanche 230kV Substation	$1.339	GI-2021-1	100%

Fort Saint Vrain 230kV Substation	0	GI-2021-2 and GI-2021-3	
GI-2021-4 69kV Substation	$12.041	GI-2021-4	100%
GI-2021-6 230kV Switching Station	$19.037	GI-2021-6	100%
Pawnee 345kV Substation	$4.027	GI-2021-8	100%
Tundra 345kV Switching Station	$3.291	GI-2021-9	100%

The details of the Station Network Upgrades required at the Comanche 230kV Substation POI are shown in Table 21. These costs are 100% assigned to GI-2021-1.

Table 21 –Station Network Upgrades – Comanche 230kV Substation

Element	Description	Cost Est. (Millions)
PSCo's Comanche 230kV Substation	Expand the Comanche 230kV Substation to accommodate GI-2021-1 interconnection. The new equipment includes: • (1) 230kV 3000A circuit breaker • (1) 230kV 3000A disconnect switch • (6) 230kV CCVTs • (6) 230kV Surge Arresters • (1) 230kV Deadends • (1) Electrical Equipment Enclosure • (2) Line Traps • Station controls and wiring • Associated foundations and structures	$1.239
	Siting and Land Rights support for substation construction	$0.100
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$1.339**
Time Frame	**Site, design, procure and construct**	**18 Months**

The total cost and details of the Station Network Upgrades required at the GI-2021-4 69kV Switching Station tapping the Romeo – Old40Tap 69kV line are shown in Table 22. These Station Network Upgrade costs are 100% assigned to GI-2021-4. Construction of GI-2021-4 69kV Switching Station may be impacted by the availability of outages on the Romeo – Old40Tap 69kV radial line.

Table 22 –Station Network Upgrades – GI-2021-4 69kV Switching Station

Element	Description	Cost Est. (Millions)

PSCo's New GI-2021-4 69kV Switching Station	Construct GI-2021-4 69kV Switching Station tapping the Romeo – Old40Tap 69kV line. The new equipment includes: • (2) 69kV circuit breakers • (6) 69kV disconnect switches • (6) 69kV Surge Arresters • (2) 69kV Deadends • (1) Electrical Equipment Enclosure • Station controls and wiring • Associated foundations and structures	$10.034
	Install required communication in the EEE	$0.421
PSCo's Romeo 69kV Substation	6914 Line Terminal Upgrade	$0.848
PSCo's Alamosa Terminal Substation	6914 Line Terminal Upgrade	$0.488
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.250
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$12.041**
Time Frame	**Site, design, procure and construct**	**18 Months**

The total cost and details of the Station Network Upgrades required at the GI-2021-6 230kV Switching Station tapping the Green Valley – Sky Ranch 230kV line are shown in Table 23. Construction of the GI-2021-6 230kV Switching Station requires a CPCN. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following CPCN approval is estimated to take up to 18 months, so the total time required regulatory activities and to site, design, procure and construct the switching station is expected to take up to 36 months.

Table 23 –Station Network Upgrades – GI-2021-6 230kV Switching Station

Element	Description	Cost Est. (Millions)
PSCo's New GI-2021-6 230kV Switching Station	Build the new 230kV Swtiching Station and accommodate GI-2021-6 interconnection. The new equipment includes: • (3) 230kV 3000A circuit breaker • (8) 230kV 3000A disconnect switch • (6) 230kV CCVTs • (6) 230kV Surge Arresters • (12) 230kV Deadends • (1) Electrical Equipment Enclosure • (2) Line Traps • Station controls and wiring • Associated foundations and structures	$15.392
	Install required communication in the EEE	$0.886
PSCo's Sky Ranch Substation	5275 Line Terminal Upgrade	$1.247

PSCo's Green Valley Substation	5275 Line Terminal Upgrade	$1.262
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.250
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$19.037**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost and details of the Station Network Upgrades required at the Pawnee 345kV Substation POI are shown in Table 24. These Station Network Upgrade costs are 100% assigned to GI-2021-8.

Table 24 –Station Network Upgrades – Pawnee 345kV Substation

Element	Description	Cost Est. (Millions)
PSCo's Pawnee 345kV Substation	Expand the Pawnee 345kV Substation to accommodate interconnection of GI-2021-8. The new equipment includes: • (1) 345kV 3000A circuit breaker • (4) 345kV 3000A disconnect switch • (1) 345kV Deadends • (1) Electrical Equipment Enclosure • Station controls and wiring • Associated foundations and structures	$3.927
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.100
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$4.027**
Time Frame	**Site, design, procure and construct**	**18 Months**

The estimated total cost and details of the Station Network Upgrades required at the Tundra 345kV Switching Station are shown in Table 25. These Station Network Upgrade costs are 100% assigned to GI-2021-9. Tundra is a new station built for GI-2018-24 in the Transitional Cluster. As noted in the Transitional Cluster study report, construction of the Tundra Switching Station requires a CPCN. The interconnection of GI-2021-9 is impacted by the Tundra CPCN approval and schedule.

Table 25 –Station Network Upgrades – Tundra 345kV Substation

Element	Description	Cost Est. (Millions)

PSCo's Tundra 345kV Switching Station	Expand the Tundra 345kV Switching Station to accommodate interconnection of GI-2021-9. The new equipment includes: • (1) 345kV 3000A circuit breaker • (4) 345kV 3000A disconnect switch • (1) 345kV Deadends • Station controls and wiring • Associated foundations and structures	$3.191
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.100
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$3.291**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.2 Cost of Other Network Upgrades

The only study pocket which identified Network Upgrades is the Eastern Colorado Study Pocket. Since GI-2021-8 is the only GIR studied in this study pocket, all Network Upgrade costs shown in Table 26 are 100% assigned to GI-2021-8.

Table 26 – Other Network Upgrades – Eastern Colorado Study Pocket

Element	Description	Cost Est. (Millions)	GI-2021-8 Impact
PSCo's Buckley - SmokyHill Line 5285	Reconductor 5.25 miles of 230kV line 5285	$2.625	100%
PSCo's Tollgate 230kV Substation	5285 Line Terminal Upgrade	$0.300	100%
PSCo's Smoky Hill 230kV Substation	5285 Line Terminal Upgrade	$0.600	100%
	Siting and Land Rights support for substation construction	$0.200	100%
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Network Upgrades	**$3.725**	100%
Time Frame	**Site, design, procure and construct**	**18 Months**	

7.3 Summary of Costs assigned to GI-2021-1

The total cost of the required Upgrades for GI-2021-1 to interconnect at the Comanche 230kV Substation is $2.603 Million.

- **The cost of Transmission Provider's Interconnection Facilities is $1.264 Million (Table 27)**

- **The cost of Station Network Upgrades is $1.339 Million (Table 21)**
- **The cost of other Network Upgrades is 0**

Figure 2 is a conceptual one-line of the GI-2021-1 POI at the Comanche 230kV Substation.

The list of improvements required to accommodate the interconnection of GI-2021-1 are given in Tables 21 and 27.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 27 – GI-2021-1 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Comanche 230kV Substation	Interconnection GI-2021-1 at the Comanche 230kV Substation. The new equipment includes: • (3) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$1.064
	Transmission line tap into substation.	$0.100
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.100
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.264**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.4 Summary of Costs assigned to GI-2021-2

The total cost of the required Upgrades to allow GI-2021-2 expansion at the Fort Saint Vrain#2 generator is $0.05 Million.

- **The cost of Transmission Provider's Interconnection Facilities is $0.05 Million (Table 28)**
- **The cost of Station Network Upgrades is 0**
- **The cost of other Network Upgrades is 0**

The list of improvements required to accommodate the interconnection of GI-2021-2 are given in Tables 28. System improvements are subject to revision as a more detailed and refined design is produced.

Table 28 – GI-2021-2 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's FSV Unit #2	Confirmation testing of incremental increase in generation output due to plant equipment upgrade	$0.05
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$0.05**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.5 Summary of Costs assigned to GI-2021-3

The total cost of the required Upgrades to allow GI-2021-3 expansion at the Fort Saint Vrain#3 generator is $0.05 Million.

- **The cost of Transmission Provider's Interconnection Facilities is $0.05 Million (Table 29)**
- **The cost of Station Network Upgrades is 0**
- **The cost of other Network Upgrades is 0**

The list of improvements required to accommodate the interconnection of GI-2021-3 are given in Tables 29. System improvements are subject to revision as a more detailed and refined design is produced.

Table 29 – GI-2021-3 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's FSV Unit #3	Confirmation testing of incremental increase in generation output due to plant equipment upgrade	$0.05
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$0.05**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.6 Summary of Costs assigned to GI-2021-4

The total cost of the required Upgrades for GI-2021-4 to interconnect on the Romeo – Old40Tap 69kV line is **$14.685 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $2.644 Million (Table 30)**
- **The cost of Station Network Upgrades is $12.041 Million (Table 22)**
- **The cost of other Network Upgrades is 0**

Figure 3 is a conceptual one-line of the GI-2021-4 69kV Switching Statin tapping the Romeo – Old40Tap 69kV line. The list of improvements required to accommodate the interconnection of GI-2021-3 are given in Tables 22 and 30.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 30 – GI-2021-4 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's proposed GI-2021-4 69kV Switching Station	Interconnect GI-2021-4 at the GI-2021-4 69kV Switching Station. The new equipment includes: • (1) 69kV Circuit Breaker • (2) 69kV deadend/girder • (3) 69kV Surge Arresters • (2) 69kV disconnect switch • (1) set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$2.294
	Transmission line tap into substation.	$0.100
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.250
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$2.644**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.7 Summary of Costs assigned to GI-2021-6

The total cost of the required Upgrades to interconnect GI-2021-6 on the Green Valley – Sky Ranch 230kV line is **$20.694 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.657 Million (Table 31)**
- **The cost of Station Network Upgrades is $19.037 Million (Table 23)**
- **The cost of other Network Upgrades is 0**

Figure 4 is a conceptual one-line of the GI-2021-6 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-16 are given in Tables 23 and 31. A CPCN will be required to construct the GI-2021-6 230kV Switching Station. The estimated time frame for regulatory activities and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 31 – GI-2021-6 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2021-6 230kV Switching Station	Interconnection GI-2021-6 at the GI-2021-6 230kV Switching Station. The new equipment includes: • (4) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$1.457
	Transmission line tap into substation.	$0.100
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.100
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.657**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.8 Summary of Costs assigned to GI-2021-8

The total cost of the required Upgrades to interconnect GI-2021-8 at the Pawnee 345kV Substation is **$10.052 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $2.3 Million (Table 32)**
- **The cost of Station Network Upgrades is $4.027 Million (Table 24)**
- **The cost of other Network Upgrades is $3.725 Million (Table 26)**

Figure 5 is a conceptual one-line of the GI-2021-8 POI at the Pawnee 345kV Substation. The list of improvements required to accommodate the interconnection of GI-2021-8 are given in Tables 24, 26 and 32.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 32 – GI-2021-8 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Pawnee 345kV Substation	Interconnection GI-2021-8 at the Pawnee 345kV Substation. The new equipment includes: • (1) 345kV deadend/girder • (3) 345kV Surge Arresters • (1) 345kV 3000A disconnect switch • (1) set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$2.100
	Transmission line tap into substation.	$0.100
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.100
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$2.3**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.9 Summary of Costs assigned to GI-2021-9

The total cost of the required Upgrades to interconnect GI-2021-9 at the Tundra 345kV Switching Station is **$5.591 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $2.3 Million (Table 33)**
- **The cost of Station Network Upgrades is $3.291 Million (Table 25)**
- **The cost of other Network Upgrades is 0**

Figure 5 is a conceptual one-line of the GI-2021-8 POI at the Pawnee 345kV Substation. The list of improvements required to accommodate the interconnection of GI-2021-9 at the Tundra 345kV Switching Station are given in Tables 25 and 33.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 33 – GI-2021-9 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Tundra 345kV Substation	Interconnection GI-2021-9 at the Tundra 345kV Switching Station. The new equipment includes: • (1) 345kV deadend/girder • (3) 345kV Surge Arresters • (1) 345kV 3000A disconnect switch • (1) set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$2.100
	Transmission line tap into substation.	$0.100
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.100
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$2.3**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.10 Cost Estimate Assumptions

The cost estimates are in 2021 dollars with escalation and contingencies applied. Allowances for Funds Used During Construction (AFUDC) is not included. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of these new PSCo facilities. This estimate does not include the cost for any Interconnection Customer owned equipment and associated design and engineering. A level of accuracy is not specified for the estimates.

- Labor is estimated for straight time only – no overtime included
- Lead times for materials were considered for the schedule
- The GIRs are not located in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates

- PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities
- Customer will install two (2) redundant fiber optics circuits into the Transmission provider's substation as part of its interconnection facilities construction scope
- Breaker duty study determined that no breaker replacements are needed in neighboring substations
- Line outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date
- 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 / Xcel will need indications, readings and data from the LFAGC RTU

8.0 Summary of Generation Interconnection Service

This report is the Phase 1 study results and does not include short circuit or stability analysis. If there is a change in status of one or more higher-queued Interconnection Requests due to withdrawal from the queue, a restudy of the power flow analysis will be performed as needed during Phase 2 and study results and costs will be updated.

The Customer is required to design and build the Generating Facility to mitigate for any potential inverter interactions with the neighboring inverter based Generating Facility(ies) and/or the inverters of the hybrid Generating Facility.

This report only evaluated Interconnection Service of GIRs in 3DISIS-2021-001 and Interconnection Service in and itself does not convey transmission service.

8.1 GI-2021-1

The total cost of the upgrades required to interconnect GI-2021-1 at the Comanche 230kV Substation for ERIS is $2.603 Million (Tables 21 and 27).

Maximum allowable output of GI-2021-1 before Network Upgrades is 200MW.

Energy Resource Interconnection Service of GI-2021-1 is: 200MW.

8.2 GI-2021-2

The total cost of the upgrades required to allow GI-2021-2 expansion at the Fort Saint Vrain#2 generator for ERIS is $0.05 Million (Table 28).

Maximum allowable output of GI-2021-2 before Network Upgrades is 49MW.

Energy Resource Interconnection Service of GI-2021-2 is: 49MW

8.3 GI-2021-3

The total cost of the upgrades required to allow GI-2021-3 expansion at the Fort Saint Vrain#3 generator for ERIS is $0.05 Million (Table 29).

Maximum allowable output of GI-2021-3 before Network Upgrades is 35MW.

Energy Resource Interconnection Service of GI-2021-2 is: 35MW.

8.4 GI-2021-4

The total cost of the upgrades required to interconnect GI-2021-4 on the Romeo – Old40Tap 69kV line for NRIS is $14.685 Million (Tables 22 and 30).

Network Resource Interconnection of GI-2021-4 is 42MW.

The output of the GI-2021-4 hybrid Generating Facility will be limited to 42MW at the POI using centralized power plant controller. The GIR output will also be monitored by PSCo operations. Additional monitoring and control requirements will be added to the LGIA to ensure the Interconnection Service amount is not exceeded.

8.5 GI-2021-6

The total cost of the upgrades required to interconnect GI-2021-6 on the Green Valley – Sky Ranch 230kV line for NRIS is $20.694 Million (Tables 23 and 31).

Network Resource Interconnection of GI-2021-6 is 199MW.

The output of the GI-2021-6 hybrid Generating Facility will be limited to 42MW at the POI using centralized power plant controller. The GIR output will also be monitored by PSCo operations. Additional monitoring and control requirements will be added to the LGIA to ensure the Interconnection Service amount is not exceeded.

A CPCN is needed for the expansion of the construction of the GI-2021-6 230kV Switching Station. The estimated time frame for regulatory activities and to site, design, procure and construct the interconnection facilities is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2021-6.

8.1 GI-2021-8

The total cost of the upgrades required to interconnect GI-2021-8 at the Pawnee 345kV Substation for NRIS is $10.052 Million (Tables 24, 26 and 32).

Network Resource Interconnection of GI-2021-8 is 400MW.

The output of the GI-2021-8 hybrid Generating Facility will be limited to 400MW at the POI using centralized power plant controller. The GIR output will also be monitored by PSCo operations. Additional monitoring and control requirements will be added to the LGIA to ensure the Interconnection Service amount is not exceeded.

The Grid charging study for the 100MW BES Generating Facility did not identify any impacts. There are no additional costs identified in the Grid Charging study.

8.2 GI-2021-9

The total cost of the upgrades required to interconnect GI-2021-9 at the Tundra 345kV Switching Station for ERIS is $5.591 Million (Tables 25 and 33).

Maximum allowable output of GI-2021-9 before Network Upgrades is 199MW.

Energy Resource Interconnection Service of GI-2021-9 is: 199MW.

Figure 2 – Preliminary One-line of the GI-2021-1 POI at the Comanche 230kV Substation

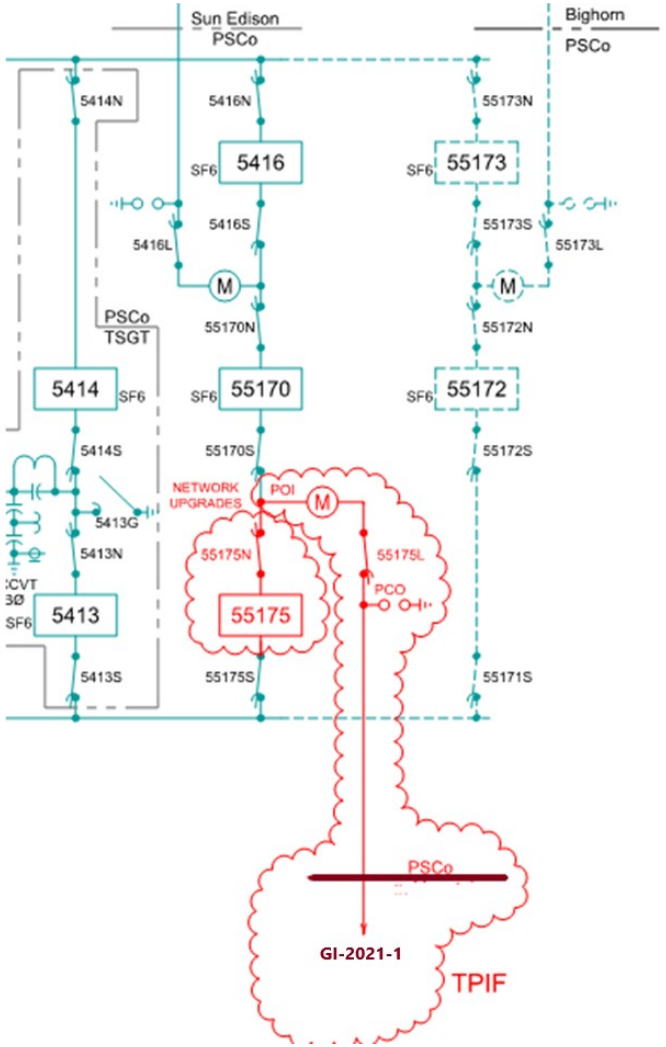


Figure 3 – Preliminary One-line of GI-2021-4 69kV Switching Station tapping the Romeo – Old40Tap 69kV line

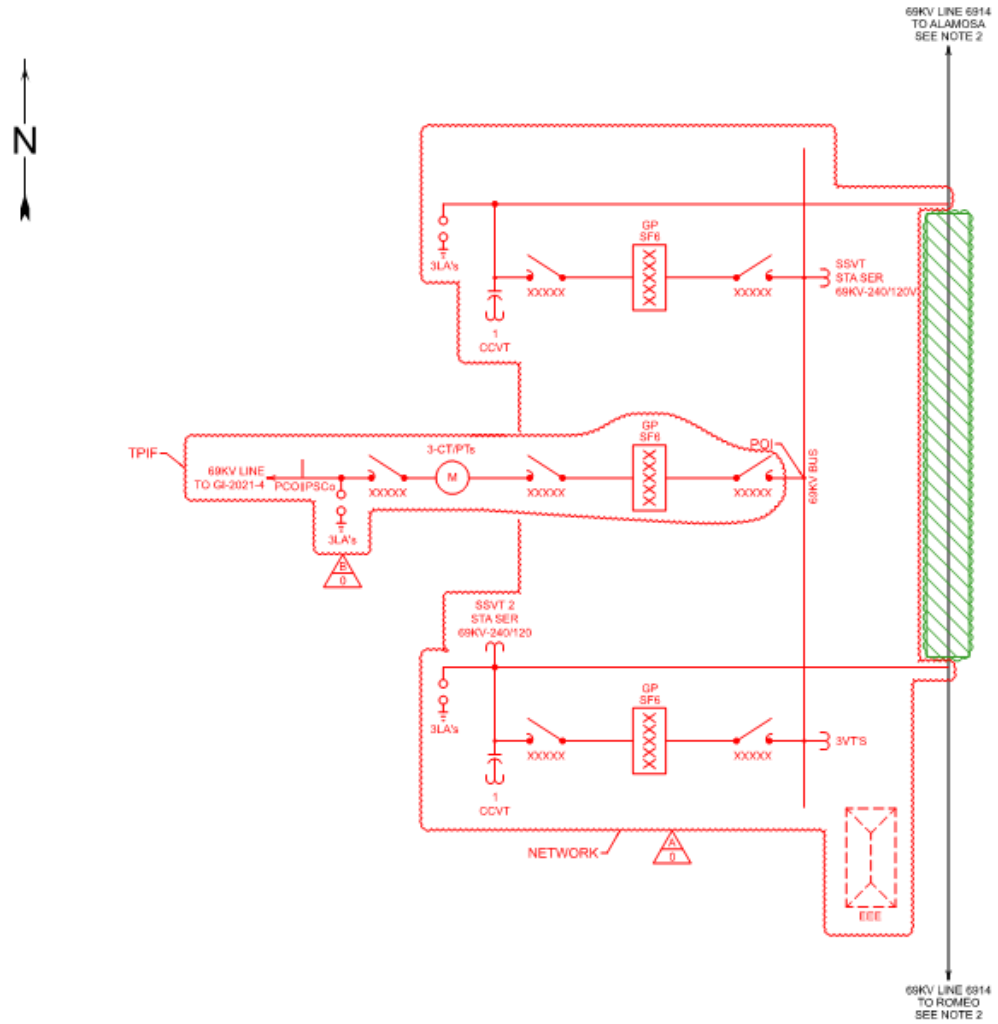


Figure 4 – Preliminary One-line of the GI-2021-6 230kV Switching Station tapping the Green Valley – Sky Ranch 230kV line

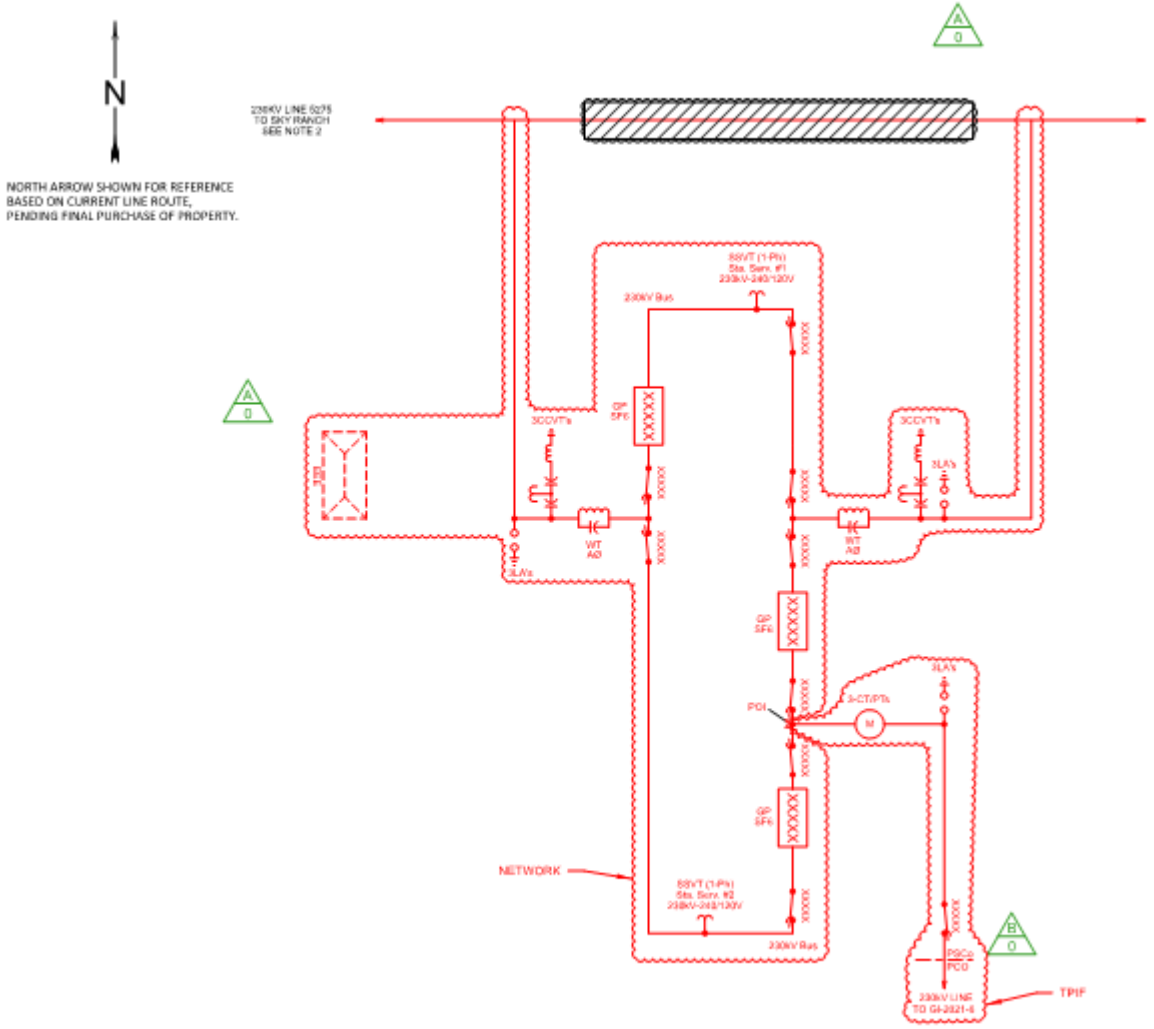


Figure 5 – Preliminary One-line of the GI-2021-8 POI at the Pawnee 345kV Substation

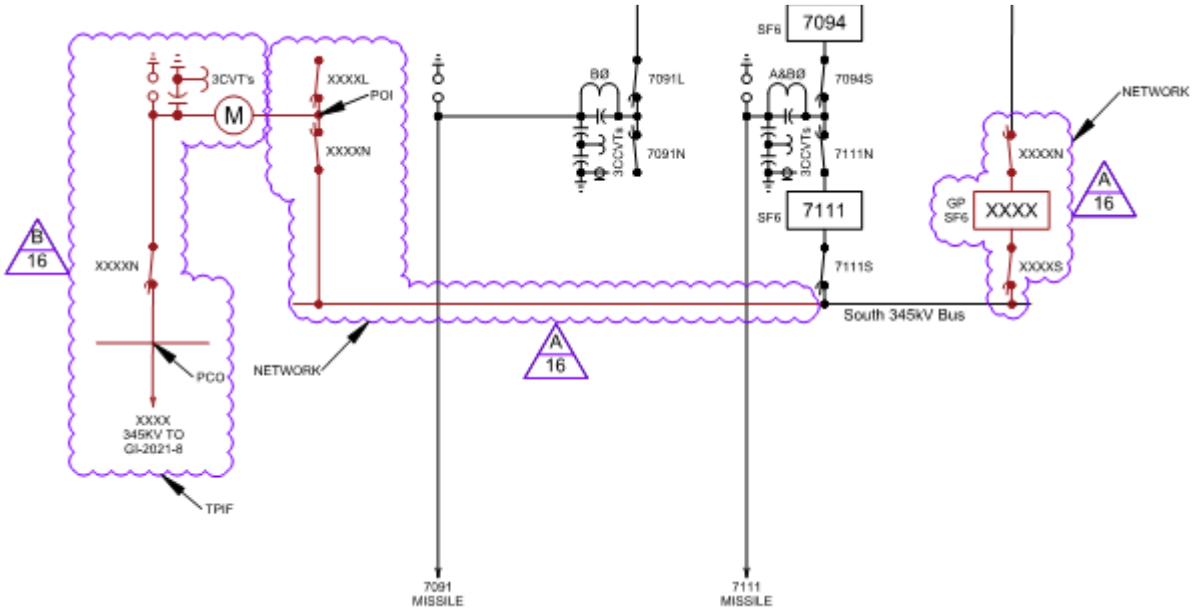


Figure 6 – Preliminary One-line of the GI-2021-9 POI at the Tundra 345kV Switching Station