DISIS-2020-002

2020 Fall DISIS Cluster

Phase 1 Study Report

3/1/2021

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1.0 Summary

The 2020 Fall Definitive Interconnection System Impact Study Cluster (DISIS-2020-002) includes five (5) Generation Interconnection Request (GIR)s – GI-2020-12, GI-2020-13, GI-2020-14, GI-2020-15, and GI-2020-16.

GI-2020-12 is a 400MW$_{ac}$ net rated wind Generating Facility requesting Energy Resource Interconnection Service (ERIS). The requested Point of Interconnection (POI) is a tap on the Waterton – Midway 345kV line.

GI-2020-13 is a 374MW$_{ac}$ net rated AC-coupled solar Photovoltaic (PV) plus Battery Energy Storage (BES) Generating Facility requesting ERIS. The requested POI is a tap on the Boone – Midway 230kV line.

GI-2020-14 is a 700MW$_{ac}$ net rated wind Generating Facility requesting ERIS. The requested POI is a tap on the Waterton – Midway 345kV line.

GI-2020-15 is a 250MW$_{ac}$ net rated wind Generating Facility requesting ERIS. The requested POI is a tap on the Fort Lupton – Pawnee 230kV line.

GI-2020-16 is a 199.5MW$_{ac}$ net rated solar PV Generating Facility requesting Network Resource Interconnection Service (NRIS). The requested POI is the Barr Lake 230kV Substation.

The GI-2020-12, GI-2020-13, and GI-2020-14 GIRs were studied under the Southern Colorado study pocket analysis. The GI-2020-15 and GI-2020-16 were studied under the Northern Colorado study pocket analysis.

TSGT has been identified as an Affected System to GI-2020-13 and GI-2020-16.

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

1.1 GI-2020-12 Results

The total cost of the required Upgrades for GI-2020-12 to interconnect on the Midway – Waterton 345kV line is **$22.386 Million** (Tables 25, 29 and 30).

Energy Resource Interconnection of GI-2020-12 before Network Upgrades is: 213.8MW

Energy Resource Interconnection Service of GI-2020-12 is: 400MW (after required transmission system improvements in Tables 25, 29 and 30).

GI-2020-12 and GI-2020-14 interconnect at the same POI. The construction of the GI-2020-12/GI-2020-14 345kV Switching Station tapping the Midway – Waterton 345kV line will require a Certificate of Public Convenience & Necessity (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 12/1/2024 Commercial Operation Date (COD) of GI-2020-12.

1.2 GI-2020-13 Results

The total cost of the required Upgrades for GI-2020-13 to interconnect on the Boone - Midway – 230kV line is **$27.065 Million** (Tables 26, 29 and 31).

Energy Resource Interconnection of GI-2020-13 before Network Upgrades is: 303.0MW

Energy Resource Interconnection Service of GI-2020-13 is: 374MW (after required transmission system improvements in Tables 26, 29 and 31).

The construction of the GI-2020-13 230kV Switching Station tapping the Boone – Midway 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 12/1/2024 COD of GI-2020-13.

The output of the GI-2020-13 hybrid Generating Facility will be limited to 374MW 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.

1.3 GI-2020-14 Results

The total cost of the required Upgrades for GI-2020-14 to interconnect on the Midway – Waterton 345kV line is **$36.415 Million** (Tables 25, 29 and 32).

Energy Resource Interconnection of GI-2020-14 before Network Upgrades is: 345.6MW

Energy Resource Interconnection Service of GI-2020-14 is: 700MW (after required transmission system improvements in Tables 24, 28 and 31).

GI-2020-12 and GI-2020-14 interconnect at the same POI. The construction of the GI-2020-12/GI-2020-14 345kV Switching Station tapping the Midway – Waterton 345kV 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 12/1/2024 COD of GI-2020-14.

1.4 GI-2020-15 Results

The total cost of the required Upgrades for GI-2020-15 to interconnect on the Fort Lupton – Pawnee 230kV line is **$23.403 Million** (Tables 27 and 33).

Energy Resource Interconnection of GI-2020-15 before Network Upgrades is: 250MW

Energy Resource Interconnection Service of GI-2020-15 is: 250MW (after required transmission system improvements in Tables 27 and 33).

The construction of the GI-2020-15 230kV Switching Station tapping the Fort Lupton – Pawnee 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 12/31/2023 COD of GI-2020-15.

1.5 GI-2020-16 Results

The total cost of the required Upgrades for GI-2020-16 to interconnect at the Barr Lake 230kV Substation is **$12.397 Million** (Tables 28 and 34).

Energy Resource Interconnection of GI-2020-16 before Network Upgrades is: 199.5MW

Energy Resource Interconnection Service of GI-2020-16 is: 199.5MW (after required transmission system improvements in Tables 28 and 34).

The interconnection of GI-2020-16 will require expansion of the existing Barr Lake Substation, which is expected to require a CPCN approval. The estimated time frame for regulatory activities and to site, design, procure and construct the substation expansion is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the 10/31/2023 COD of GI-2020-16.

2.0 Introduction

Public Service Company of Colorado (PSCo) received five (5) Generation Interconnection Request (GIR)s in the DISIS-2020-002. The total Interconnection Service requested in the DISIS-2020-002 cluster is 1923.5MW. The GIRs are identified by their queue numbers – GI-2020-12, GI-2020-13, GI-2020-14, GI-2020-15, and GI-2020-16. Out of the five (5) GIRs; GI-2020-12, GI-2020-13, GI-2020-14, and GI-2020-15 requested Energy Resource Interconnection Service (ERIS)[1] and GI-2020-16 requested Network Resource Interconnection Service (NRIS)[2]. A summary of the requests in the DISIS-2020-002 is given in Table 1.

3.0 Description of the GIRs

3.1 Description of GI-2020-12

GI-2020-12 is a 400MW$_{ac}$ net rated wind Generating Facility located in Elbert County, Colorado. The Generating Facility will consist of two-hundred (200) Vestas V100 2.0MW MK10D, ±0.95PF wind turbines each with its own 0.69/34.5kV, 2.1MVA Delta/Wye-grounded, Z=9.5% and X/R=10.6 pad mount transformer. The 34.5kV collector system will connect to two (2) 131/164/218MVA, 345/34.5/13.8kV Wye-grounded/Wye-grounded/Delta Z=10% and X/R=51 main step up transformer which will connect to the PSCo transmission system via a 30 mile 345kV generation tie-line. The Point of Interconnection (POI) is a tap on the Waterton – Midway 345kV line, at approximately 50 miles from the Midway Substation.

The generator configuration and epc modeling data provided by the Interconnection Customer only resulted in 385MW at the POI, so the study was performed by increasing the Pmax to achieve 400MW at the POI. The customer is required to provide updated turbine numbers and any relevant Generating Facility configuration information that allows the project to achieve 400MW at the POI before Phase 2 begins.

[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.

The proposed Commercial Operation Date (COD) of GI-2020-12 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.

GI-2020-12 shares the same POI as GI-2020-14 described below. The interconnection at the tap point will require building a new switching station will be referred to as "GI-2020-12/GI-2020-14 345kV Switching Station" in this report.

3.2 Description of GI-2020-13

GI-2020-13 is a 250MW$_{ac}$ solar Photovoltaic (PV) plus 124MW$_{ac}$ Battery Energy Storage (BES) Hybrid Generating Facility located in Pueblo County, Colorado. The hybrid facility will be AC-Coupled with the net output at the POI limited to 374MW$_{ac}$ using a Power Plant Controller. The Solar PV Generating Facility will consist of seventy-four (74) Sungrow SG3600UD 3.6MVA, ±0.95PF inverters, each with its own 0.63/34.5kV, 3.6 MVA Delta/Wye-grounded, Z=8.5% and X/R=10.8 pad mount transformer. The BES Generating Facility will consist of thirty-seven (37) Power Electronics FP3510K 3.51MVA, ±0.95PF inverters, each with its own 0.66/34.5kV, 3.5MVA Delta/Wye-grounded, Z=8.5% and X/R=10.8 pad mount transformer. The 34.5kV Collector system of the solar PV and BES generators will connect to (3) 99/124/165MVA, 230/34.5/13.8kV Wye-grounded/Wye-grounded/Delta, Z=10% and X/R=51 main step up transformer that will connect to the PSCo transmission system via a 0.5 mile, 230kV generation tie-line. The POI requested is a tap on the Boone – Midway 230kV line at approximately 26 miles from the Midway Substation.

The BES inverters have a maximum and minimum state of charge of 100% and 5% respectively.

The generator configuration and epc modeling data provided by the Interconnection Customer only resulted in 369MW at the POI, so the study was performed by increasing the Pmax to achieve 374MW at the POI. The customer is required to provide updated inverter numbers and any relevant Generating Facility configuration information that allows the project to achieve 374MW at the POI before Phase 2 begins.

The interconnection at the tap point will require building a new switching station will be referred to as "GI-2020-13 230kV Switching Station" in this report.

The proposed Commercial Operation Date (COD) of GI-2020-12 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.

3.3 Description of GI-2020-14

GI-2020-14 is a 700MW$_{ac}$ net rated wind Generating Facility located in Cheyenne County, Colorado. The Wind Generation Facility will consist of three hundred seventy-seven (377) Vestas V100 2.0MW MK10D, 2.1 MVA, ±0.95PF wind turbines each with its own 0.69/34.5kV, 2.1MVA, Delta/Wye-grounded Z = 9.5%, X/R = 10.6 pad-mount transformer. The 34.5kV collector system will connect to three (3) 175/218/290MVA, 345/34.5/13.8kV Wye-grounded/Wye-grounded/Delta, Z = 10%, X/R = 51 main step-up transformer which will connect to the PSCo transmission system via a 105 mile, 345kV generation tie-line. The POI is a tap on the Waterton – Midway 345kV line, at approximately 50 miles from the Midway Substation.

The generator configuration and epc modeling data provided by the Interconnection Customer only resulted in 650MW at the POI, so the study was performed by increasing the Pmax to achieve 700MW at the POI. The customer is required to provide updated turbine numbers and any relevant Generating Facility configuration information that allows the project to achieve 700MW at the POI before Phase 2 begins.

The proposed Commercial Operation Date (COD) of GI-2020-12 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.

GI-2020-14 shares the same POI as GI-2020-12 described above. The interconnection at the tap point will require building a new switching station will be referred to as “GI-2020-12/GI-2020-14 345kV Switching Station” in this report.

3.4 Description of GI-2020-15

GI-2020-15 is a 250MW$_{ac}$ net rated wind Generating Facility located in Morgan County, Colorado. The Generation Facility will consist of one-hundred-seventeen (117) Vestas V120, 2.2MVA, ±0.945PF turbines, each with its own 0.69/34.5kV, 2.3MVA Delta/Wye Z=9.6%, X/R=10.9 pad-mount transformer. The 34.5kV collector system will connect to one (1) 230/34.5/13.8kV, 274/338MVA Wye-grounded/Wye-grounded/Delta Z=9%, X/R=47 main step-up transformer

which will connect to the PSCo transmission system via a 0.037mile 230kV generation tie-line. The POI is a tap on the Fort Lupton – Pawnee 230kV line, at approximately 22 miles from the Pawnee Substation.

The proposed Commercial Operation Date (COD) of GI-2020-15 is December 31, 2023. For the study purpose, the back-feed date is assumed to be July 1, 2023, approximately six (6) months before the COD.

The interconnection at the tap point will require building a new switching station will be referred to as “GI-2020-15 230kV Switching Station” in this report

3.5 Description of GI-2020-16

GI-2020-16 is a 199.5MW_{ac} net rated solar PV Generating Facility located in Adams County, Colorado. The solar PV Generation Facility will consist of fifty-seven (57) SMA Sunny Central SC4400 UP-US 4.40MVA/3.52MW ±0.80PF inverters, each with its own 0.66/34.5kV, 4.40MVA Wye-Grounded/Delta Z=6.5%, X/R=8.58 pad-mount transformer. The 34.5kV collector system will connect to one (1) 134/178/222MVA, 34.5/230/13.8kV Wye-grounded/Wye-grounded/Delta, Z=11.5%, X/R=34.52 main step-up transformer which will connect to the PSCo transmission system via a 0.13 mile, 230kV generation tie-line. The POI is the Barr Lake 230kV substation.

The generator configuration and epc modeling data provided by the Interconnection Customer only resulted in 195MW at the POI, so the study was performed by increasing the Pmax to achieve 199.5MW at the POI. The customer is required to provide updated inverter numbers and any relevant Generating Facility configuration information that allows the project to achieve 199.5MW at the POI before Phase 2 begins.

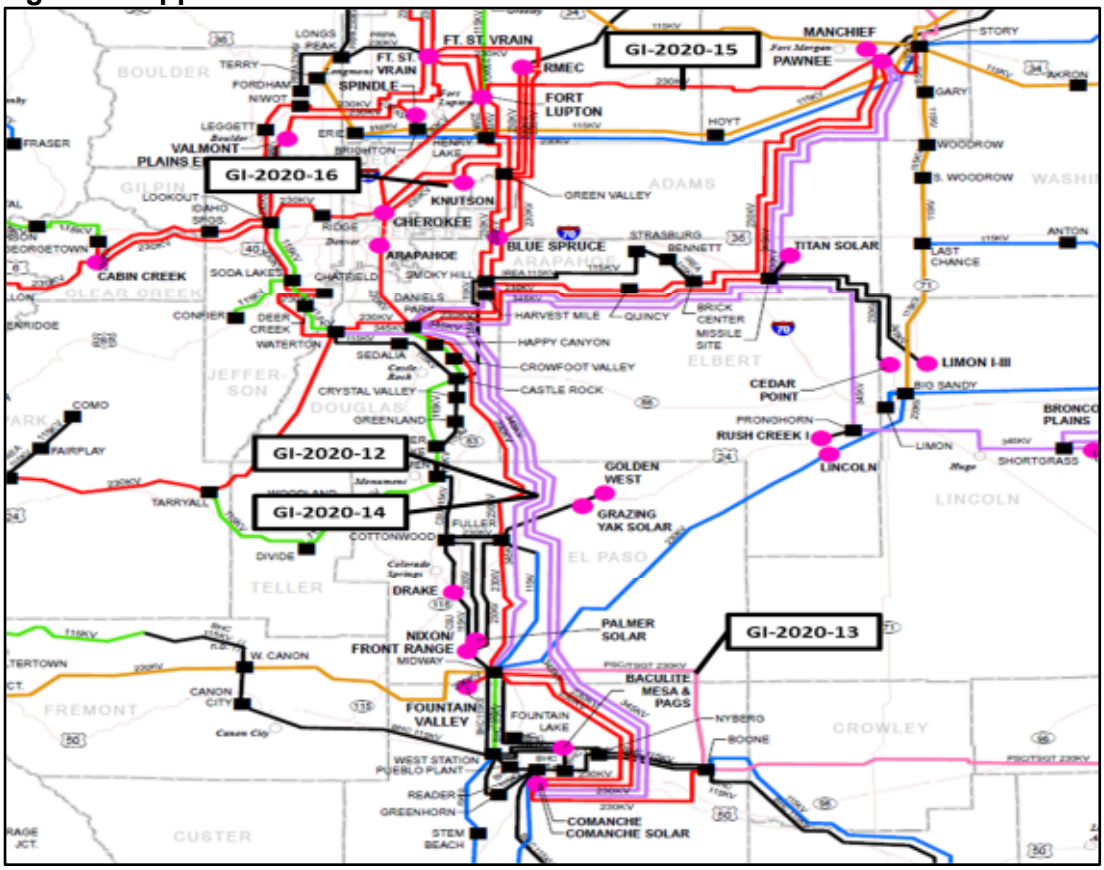
The proposed Commercial Operation Date (COD) of GI-2020-16 is October 31, 2023. For the study purpose, the back-feed date is assumed to be May 1, 2023, approximately six (6) months before the COD.

Table 1– Summary of GIRs in the DISIS-2020-002

Generation Interconnection Number	Current Cluster	Date of Valid Request	Capacity (MW)	Maximum MW Output-Summer	Maximum MW Output-Winter	Location (County/State)	Station or Transmission Line POI	Projected In- Service Date	Service Type	Generating Facility Type
GI-2020-12	DISIS-2020-002	9/22/2020	400	400	400	Elbert County, CO	Waterton-Midway 345 kV line	12/1/2024	ERIS	Wind
GI-2020-13	DISIS-2020-002	9/22/2020	374	374	374	Pueblo County, CO	Boone-Midway 230 kV line	12/1/2024	ERIS	Battery+ Solar
GI-2020-14	DISIS-2020-002	9/22/2020	700	700	700	Cheyenne County, CO	Waterton-Midway 345 kV line	12/1/2024	ERIS	Wind
GI-2020-15	DISIS-2020-002	10/5/2020	250	250	250	Morgan County, CO	Ft. Lupton-Pawnee 230kV Line	12/31/2023	ERIS	Wind
GI-2020-16	DISIS-2020-002	10/6/2020	199.5	200.64	200.64	Adams County, CO	Barr Lake 230 kV	10/31/2023	NRIS	Solar

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

Figure 1– Approximate Locations of the POIs of the GIRs in the DISIS-2020-002



4.0 Study Scope

The purpose of the study is to determine the system impact of interconnecting all five GIRs in the DISIS-2020-002 for Interconnection Service. The Interconnection Service requested by each GIR is summarized in Table 1.

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

The steady state analysis identifies thermal and voltage violations in the PSCo system and the Affected Systems using the study criteria in Section 4.2 and study methodology in Section 4.3

4.1 Study Pocket Determination

As shown in Figure 1, GI-2020-12, GI-2020-13, and GI-2020-14 are in the “Southern Colorado” study pocket. GI-2020-15 and GI-2020-16 fall under the “Northern Colorado” study pocket. Each study pocket analysis only modeled the GIRs with POI in that study pocket.

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 V33 and ACCC tool. The generation redispatch for ERIS is identified using TARA.

4.3.1 Steady State Assessment Methodology

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 0.1p.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 per the criteria mentioned above are identified for the NRIS with the ERIS offline. These upgrades 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 by using the Optimum Power Flow (OPF) software tool. If generation redispatch is unable to eliminate the violation, upgrades will be required to provide the requested ERIS.

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

4.4 Study Area

4.4.1 Southern Colorado Study Area

The study area selected for the Southern Colorado study pocket includes WECC designated zones 121, 700, 703, 704, 710, 712, 752 and 757. The Affected Systems included in the analysis include 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) transmission systems in the study area.

4.4.2 Northern Colorado Study Area

The study area selected for the Northern study pocket includes WECC designates zones 700, 703 and 706. The Affected Systems included in the analysis includes the TSGT transmission system in the study area.

5.0 Base Case Modeling Assumptions

The 2023HS WECC case released on November 25, 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 2023 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
- Ault – Husky 230kV line – ISD 2022
- Husky – Graham Creek – Cloverly 115kV line – ISD 2022
- Monument – Flying Horse 115kV Series Reactor – ISD 2022
- Avery Substation – ISD 2021
- Barker Substation (Bank1: 2021, Bank 2: 2022) – ISD 2021/2022
- High Point Substation – ISD 2022
- Titan Substation – ISD 2022
- Dove Valley Substation – ISD 2023
- Gilman – Avon 115kV line – ISD 2022

- Upgrade Villa Grove – Poncha 69kV Line to 73MVA – ISD 2021
- Upgrade Poncha - Sargent - San Luis Valley 115kV line to 120MVA – ISD 2021
- Climax – Robinson Rack – Gilman 115kV – ISD 2022
- Greenwood – Arapahoe - Denver Terminal 230kV – ISD 2022

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 576MVA – ISD 2021
- Upgrade Greenwood – Priarie1 230kV line to 576MVA – ISD 2021
- Upgrade Daniels Park – Priarie3 230kV line to 576MVA – ISD 2021
- 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-2014-8, GI-2014-9, GI-2014-12, 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), 2020 Spring DISIS (GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5, GI-2020-6, GI-2020-7, and GI-2020-10) and 2RSC-2020. While the higher-queued NRIS requests were dispatched at 100% nameplate, the higher-queued ERIS requests were modeled offline.

The following Network Upgrades identified in the higher-queued GIRs are modeled:

- Uprate Daniels Park – Prairie1 230kV line to 756MVA (identified in DISIS-2020-001)
- Uprate Daniels Park – Prairie3 230kV line to 756MVA (identified in DISIS-2020-001)

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-2020-12, GI-2020-13, and GI-2020-14 is determined using the Southern Colorado study pocket analysis. Similarly, the Interconnection Service of GI-2020-15 and GI-2020-16 is determined using the Northern Colorado study pocket analysis.

6.1 Voltage and Reactive Power Capability Evaluation

The following voltage regulation and reactive power capability requirements at the POI are applicable to the generator:

- 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 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-2020-12 Reactive Capability Evaluation

According to the modeling data provided by the Interconnection Customer, GI-2020-12 generator model is as follows: Pmax = 400MW, Pmin = 0MW, Qmax = 128.1Mvar, Qmin=-128.1Mvar. Additionally, the Generating Facility includes a 90Mvar fixed shunt capacitor bank modeled at the 34.5kV bus. The modeling data was deficient and did not meet 400MW at the POI.

Modifications to the generator model were made as follows in order to result in 400MW at the POI: Pmax = 416MW, Pmin = 0MW, Qmax = 133.2Mvar, Qmin=-133.2Mvar. An additional 5Mvar shunt capacitor bank modeled at the 34.5kV bus.

The reactive capability analysis indicates that GI-2020-12 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 when the Pmax is increased and an additional 5Mvar capacitor bank is assumed at the 34.5kV bus. As previously stated, Interconnection Customer is required to provide accurate modeling data representing 400MW injection at the POI. The updated model will be re-evaluated as needed, including the need for a 5Mvar shunt capacitor bank during Phase 2 and Network Upgrades will be identified if the revised model is found to be deficient.

Table 2- Reactive capability evaluation of GI-2020-12

Gen MW / Mvar	95 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
415.5MW/ 133.2Mvar	On	1.026	1.046	403	134.7	0.948 (lag)	1.028	400	122.9	0.956 (lag)
415.5MW/ 133.2Mvar	Off	1.008	1.016	402.4	41.9	0.995 (lag)	1.005	400	30.5	0.997
415.5MW/ -55.3Mvar	Off	0.959	0.95	402.9	-142.9	0.942 (lead)	0.962	399.5	-160	0.928 (lead)
41.5MW/ -10.7Mvar	Off	0.951	1.005	41.4	13.7	0.949 (lag)	1.002	41.4	20.6	0.895 (lag)
41.5 MW/ -44.2Mvar	Off	0.965	0.993	41.4	-20.3	0.898 (lead)	0.996	41.3	-13.6	0.950 (lead)
0 MW/ -23.4Mvar	Off	0.971	1	0	2.3	N/A	0.999	0	9.3	N/A

6.1.2 GI-2020-13 Reactive Capability Evaluation

According to the modeling data provided by the Interconnection Customer, the GI-2020-13 generator model is as follows:

PV: Pmax = 250MW, Pmin =0MW, Qmax = 83.18Mvar, Qmin= -83.18Mvar

BES: Pmax = 124MW, Pmin =0MW, Qmax = 40.77Mvar, Qmin= -40.77Mvar

The Generating Facility includes an 85Mvar shunt capacitor bank at the 34.5kV bus. As previously mentioned, the modeling data was deficient in modeling a 374MW unit at the POI, so the following modifications to the generator model were made:

PV: Pmax = 256.5MW, Pmin =0MW, Qmax = 84.3Mvar, Qmin= - 84.3Mvar.

BES: Pmax = 124MW, Pmin =0MW, Qmax = 40.77Mvar, Qmin= -40.77Mvar

The reactive capability analysis indicates that GI-2020-13 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 when the Pmax is increased. As previously stated, Interconnection Customer is required to provide accurate modeling data representing 374MW injection at the POI. The updated model will be re-evaluated as needed during Phase 2 and Network Upgrades will be identified if the revised model is found to be deficient.

Table 3 - Reactive capability evaluation of GI-2020-13

Gen MW / Mvar	Configuration	85 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
378.5 MW/ 125.1 Mvar	PV+BES	On	1.019/ 1.023	1.050	373.9	125	0.948 (lag)	1.049	374.0	123.4	0.950 (lag)
378.5 MW/ -125.1 Mvar	PV+BES	Off	1.005/ 1.009	1.032	373.9	43.5	0.993 (lag)	1.031	374.0	43	0.993 (lag)
378.5 MW/ -113.5 Mvar	PV+BES	Off	0.956/ 0.95	0.964	373.5	-202.3	0.879 (lead)	0.965	374.0	-203.3	0.878 (lead)
255 MW/ 84.3 Mvar	PV	On	1.01/0. 979	1.05	251.7	123.6	0.898 (lag)	1.049	251.7	123.4	0.898 (lag)
254.5MW/ 84.3Mvar	PV	Off	1.005/ 0.973	1.031	251.8	43.3	0.986 (lag)	1.031	251.8	43.1	0.986 (lag)
254.5 MW/ -84.3Mvar	PV	Off	0.951/ 0.975	0.985	251.5	-130.1	0.888 (lead)	0.986	251.5	-130.4	0.888 (lead)
124 MW/ 40.8 Mvar	BES	On	0.978/ 1.014	1.046	122.5	109.5	0.746 (lag)	1.045	122.5	109.5	0.746 (lag)
124 MW/ 40.8 Mvar	BES	Off	0.976/ 1.012	1.026	122.6	28.4	0.974 (lag)	1.026	122.5	28.5	0.974 (lag)
124 MW/ -40.8 Mvar	BES	Off	0.977/ 0.95	1.005	122.4	-55.2	0.912 (lead)	1.006	122.4	-55.1	0.912 (lead)
0 MW/ -65.7 Mvar	PV+BES	Off	0.965/ 0.941	1	-0.2	-63.1	N/A	1	-0.2	-62.9	N/A

6.1.3 GI-2020-14 Reactive Capability Evaluation

According to the modeling data provided by the Customer, GI-2020-14 generator model is as follows: Pmax = 700MW, Pmin = 0MW, Qmax = 224.1Mvar, Qmin=-224.1Mvar. Additionally, the Generating Facility includes a 120Mvar and 180Mvar shunt capacitor bank modeled at 34.5kV bus and 345kV bus respectively. Modifications to the generator model were made as follows in order to result in 700MW at the POI: Pmax = 754MW, Pmin = 0MW, Qmax = 241.4Mvar, Qmin=-241.4Mvar.

The reactive capability analysis indicates that GI-2020-14 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining at least unity voltage at the POI for 100%, 10% and 0% output, but the Generating Facility voltages exceed the normal acceptable range. The Interconnection Customer is required to provide accurate modeling data showing acceptable generator bus voltages once detailed design of the Generating Facility is complete.

Table 4 - Reactive capability evaluation of GI-2020-14

Gen MW / Mvar	120/180 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
751.3MW/ 11.2 Mvar	On/On	1.287	1.219	733.7	472	0.841 (lag)	1.05	704.1	263.9	0.936 (lag)
751.3MW/ 241.4Mvar	On/Off	1.325	1.192	731.9	414.7	0.870 (lag)	1.04	703.1	212.6	0.957 (lag)
751.3MW/ 202.7Mvar	Off/On	1.312	1.219	732.6	470.4	0.841 (lag)	1.05	703.1	263.9	0.936 (lag)
751.3 MW 241.4 Mvar	Off/Off	1.158	1.053	726.8	167.5	0.974 (lag)	0.985	698.7	-36.6	0.999 (lead)
751.3 MW/ 165.2 Mvar	Off/Off	1.043	0.963	723	46.4	0.998 (lag)	0.950	690.4	-183.5	0.966 (lead)
75.1MW/ -61.2Mvar	Off/Off	1.021	1.020	74.8	28.8	0.933 (lag)	1.004	74.4	27.8	0.937 (lag)
75.1MW/ -106.0Mvar	Off/Off	0.968	0.986	74.5	-25.5	0.946 (lead)	0.992	74.2	-26.6	0.941 (lead)
0MW/ -73.3 Mvar	Off/Off	1.005	-0.1	11.9	1.005	N/A	1	-0.1	13.4	N/A

6.1.4 GI-2020-15 Reactive Capability Evaluation

According to the modeling data provided by the Interconnection Customer, GI-2020-15 generator model is as follows: Pmax = 255MW, Pmin = 0.0MW, Qmax = 88.4Mvar, Qmin=-88.4Mvar. Additionally, the Generating Facility includes a 55Mvar shunt capacitor bank modeled at the 34.5kV bus.

The reactive capability analysis indicates that GI-2020-15 is 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.

Table 5 - Reactive capability evaluation of GI-2020-15

Gen MW / Mvar	55 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
255MW/ 64.6Mvar	On	1.05	1.033	250.1	81.8	0.950 (lag)	1.033	250.14	81.1	0.950 (lag)
255MW/ 88.4 Mvar	Off	1.04	1.024	249.8	47.9	0.982 (lag)	1.024	249.8	47.9	0.982 (lag)
255MW/ -88.4Mvar	Off	0.958	0.97	249.1	-136.6	0.877 (lead)	0.97	249.1	-136.6	0.877 (lead)
25.5MW/ 0.9Mvar	Off	1.017	1.008	24.9	8.2	0.950 (lag)	1.008	24.9	8.2	0.950 (lag)
25.5MW/ -15.1Mvar	Off	1.001	1.003	24.8	-8.2	0.949 (lead)	1.003	24.8	-8.2	0.949 (lead)
0 MW / -22.1Mvar	Off	0.991	1	-0.6	-15.9	N/A	1	-0.6	-15.9	N/A

6.1.5 GI-2020-16 Reactive Capability Evaluation

According to the modeling data provided by the Customer, GI-2020-16 model is as follows: Pmax = 200.6MW, Pmin = 0.0MW, Qmax = 150.5Mvar, Qmin=-150.5Mvar. Additionally, the Generating Facility includes a 10Mvar shunt capacitor bank modeled at the 34.5kV bus. The modeling data was deficient and did not meet 199.5MW at the POI. Modifications to the generator model were made as follows: Pmax = 204.2MW, Pmin = 0.0MW, Qmax = 153.1Mvar, Qmin=-153.1Mvar.

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 when the Pmax is increased. As previously stated, Interconnection Customer is required to provide accurate modeling data representing a 199.5MW injection at the POI. The updated model will be re-evaluated during Phase 2 if necessary and Network Upgrades will be identified if the revised model is found to be deficient.

Table 6 - Reactive capability evaluation of GI-2020-16

Gen MW/ Mvar	10 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
204.2MW/ 153.1Mvar	On	1.026	0.999	199	97.1	0.899 (lag)	0.999	199.5	97.2	0.899 (lag)
204.2MW/ 153.1Mvar	Off	1.018	0.998	199	88	0.899 (lag)	0.998	199.5	88.1	0.899 (lag)

204.2MW/ -97.1Mvar	Off	1.005	0.97	199.4	-157.5	0.785 (lead)	0.97	199.4	-157.5	0.785 (lead)
20.4 MW/ 5.7Mvar	Off	1.002	0.986	20.3	7.2	0.942 (lag)	0.986	20.3	7.2	0.942 (lag)
20.4 MW/ -8.5Mvar	Off	0.997	0.985	20.3	-7.1	0.944 (lead)	0.985	20.3	-7.0	0.945 (lead)
0 MW/ 153.1Mvar	Off	1.026	1	-1.9	131.1	N/A	1	-1.9	131.1	N/A

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 7.

Table 7 – 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
CEP5_S1 0.6600	S1	1	170	200
SI_GEN 0.6000	1	1	25.5	30

Bus Name	Id	Status	PGen (MW)	PMax (MW)
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	3.0	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-2020-12 and GI-2020-14 on the Waterton – Midway 345kV line and modeling GI-2020-13 on the Boone – Midway 230kV line. The total 1474MW output from the 3 GIRs was balanced against the 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 8.

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Table 8 – 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	Type of Overload	OPF Identified
				MVA Flow	% Line Loading	MVA Flow	% Line Loading				
Daniels Park - Fuller 230kV #1	Line	PSCo	576	353.3	61.3%	578.9	100.5%	39.2%	System Intact	Beyond POI Sub	Yes
MidwayPS - GI-2020-13 Switching Station 230kV #1	Line	PSCo	319	219.4	68.8%	415.5	130.3%	61.5%	System Intact	Connected to POI Sub	Yes
Waterton 345/230kV #3	Xfmr	PSCo	560	380.2	67.9%	1069.7	191.0%	123.1%	System Intact	Beyond POI Sub	No
MidwayPS - GI-2020-13 Switching Station 230kV #1	Line	PSCo	319	286.3	89.7%	506.2	158.7%	69.0%	Daniels Park - Tundra 345kV Line #2	Connected to POI Sub	Yes
Waterton - GI-2020-12/GI-2020-14 Switching Station 345kV #1	Line	PSCo	1183	505.3	42.7%	1310.7	110.8%	68.1%	Daniels Park - Tundra 345kV Line #2	Connected to POI Sub	Yes
Boone - GI-2020-13 Switching Station 230kV #1	Line	PSCo/ TSGT	319	0	0%	365.9	114.7%	114.7%	GI-2020-13 Switching Station - MidwayPS 230kV Line #1	Connected to POI Sub	No
Palmer – Monument 115kV #1	Line	PSCo /CSU	151	124.1	82.2%	210.4	139.3%	57.1%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Waterton 345/230/13.8kV #3	Xfmr	PSCo	560	481.1	85.9%	1232.2	220.0%	134.1%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	No
Vollmer Tap – Black Squirrel 115kV # 1	Line	TSGT	173	167.1	96.6%	236.4	136.7%	40.0%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Vollmer Tap - Fuller 115kV # 1	Line	TSGT	193	176.0	91.2%	245.6	127.2%	36.0%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Fuller 230/115kV #1	Xfmr	TSGT	100	81.7	81.7%	108.4	108.4%	26.7%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Fuller 230/115kV #2	Xfmr	TSGT	100	81.7	81.7%	108.4	108.4%	26.7%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Monument – Gresham 115 kV #1	Line	TSGT	145	121.7	83.9%	190.2	131.2%	47.3%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Gresham – Black Forest Tap 115kV # 1	Line	TSGT	173	125.5	72.6%	194.1	112.2%	39.7%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes

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	Type of Overload	OPF Identified
				MVA Flow	% Line Loading	MVA Flow	% Line Loading				
Black Forest Tap - Black Squirrel 115kV # 1	Line	TSGT	143	130.7	91.4%	199.4	139.5%	48.1%	Daniels Park - Fuller 230kV Line #1	Beyond POI Sub	Yes
Deer Creek - Sodalake 115kV # 1	Line	PSCo	120	92.8	77.3%	150.5	125.4%	48.0%	Chatfield - Waterton 230kV Line #1	Beyond POI Sub	Yes
Waterton – Martin Tap 115kV # 1	Line	PSCo	189	149.6	79.1%	205.5	108.8%	29.6%	Chatfield - Waterton 230kV Line #1	Beyond POI Sub	Yes
Comanche 345/230kV #4	Xfmr	PSCo	560	306.6	54.7%	605.1	108.0%	53.3%	Comanche 345/230kV Xfmr #3	Beyond POI Sub	Yes
Comanche 345/230kV #3	Xfmr	PSCo	560	306.6	54.7%	605.1	108.0%	53.3%	Comanche 345/230kV Xfmr #4	Beyond POI Sub	Yes
Daniels Park - Prairie 1 230kV #1	Line	PSCo	756	628.7	83.2%	821.1	108.6%	25.4%	Daniels Park - Prairie 3 230kV Line #1	Beyond POI Sub	Yes
Greenwood - Prairie 1 230kV #2	Line	PSCo	576	554.7	96.3%	747.6	129.8%	33.5%	Daniels Park - Prairie 3 230kV Line #1	Beyond POI Sub	Yes
Daniels Park - Prairie 3 230kV #2	Line	PSCo	756	621.8	82.3%	814.3	107.7%	25.5%	Daniels Park - Prairie 1 230kV Line #2	Beyond POI Sub	Yes
Greenwood - Prairie 3 230kV #1	Line	PSCo	576	571.1	99.2%	763.4	132.5%	33.4%	Daniels Park - Prairie 1 230kV Line #2	Beyond POI Sub	Yes
MidwayPS - West Station 115kV #1	Line	BHE	80	79.6	99.4%	80.9	101.1%	1.7%	MidwayPS 230/115kV Xfmr #1	Beyond POI Sub	Yes
MidwayBr - RD_NIXON 230kV #1	Line	CSU	531	341.2	64.3%	559.8	105.4%	41.2%	MidwayPS - Fuller 230 kV Line #1	Beyond POI Sub	Yes
Florence - Highland 69kV #1	Line	BHE	35	34.2	97.3%	36.1	103.0%	5.7%	Portland - Skala 115kV Line #1	Beyond POI Sub	Yes
Daniels Park - Comanche 345kV #1	Line	PSCo	1195	1044.3	87.4%	1329.4	111.3%	23.9%	Daniels Park - Tundra 345kV Line #2	Beyond POI Sub	Yes
Daniels Park - Tundra 345kV #2	Line	PSCo	1195	1055.2	88.3%	1342.3	112.3%	24.0%	Daniels Park - Comanche 345kV Line #1	Beyond POI Sub	Yes

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	Type of Overload	OPF Identified
				MVA Flow	% Line Loading	MVA Flow	% Line Loading				
West Canon 230/115kV #1	Xfmr	BHE	100	88.6	88.6%	126.0	126.0%	37.3%	MidwayBr - West Canon 230kV Line #1	Beyond POI Sub	Yes
Boone - GI-2020-3 Switching Station 230kV #1	Line	PSCo	319	128.8	40.4%	408.7	128.1%	87.7%	GI-2020-13 Switching Station - MidwayPS 230kV Line #1	Beyond POI Sub	Yes
Comanche - GI-2020-3 Switching Station 230kV #1	Line	PSCo	319	127.2	39.9%	408.1	127.9%	88.1%	GI-2020-13 Switching Station - MidwayPS 230kV Line #1	Beyond POI Sub	Yes
MidwayPS 345/230kV #3	Xfmr	PSCo	560	0.0	0.00%	1064.7	190.1%	190.1%	GI-2020-12/GI-2020-14 Switching Station - Waterton 345kV Line #1	Beyond POI Sub	No
Daniels Park - Fuller 230kV #1	Line	PSCo	576	488.2	84.8%	963.7	162.6%	77.9%	GI-2020-12/GI-2020-14 Switching Station - Waterton 345kV Line #1	Beyond POI Sub	Yes
MidwayBR 230/115kV #1	Xfmr	PSCo	100	69	69.0%	125.7	125.7%	56.6%	MidwayBR - RD_NIXON Line #1	Beyond POI Sub	Yes
MidwayPS - Fuller 230kV #1	Line	PSCo	478	387.2	81.0%	644.5	134.8%	53.8%	GI-2020-12/GI-2020-14 Switching Station - Waterton 345kV Line #1	Beyond POI Sub	Yes
MidwayPS - MidwayBR 230kV #1	Line	PSCo	756	523.5	69.2%	1131.3	149.6%	80.4%	GI-2020-12/GI-2020-14 Switching Station - Waterton 345kV Line #1	Beyond POI Sub	Yes

The OPF identified redispatch scenarios for all overloads except the following three overloads:

- Waterton 345/230kV # T3 xfmr

- Boone – GI-2020-13 POI 230kV line
- Midway 345/230kV # T2 xfmr

The maximum allowable ERIS of the 3 GIRs before Network Upgrades is as follows:

- **ERIS of GI-2020-12: 213.8MW**
- **ERIS of GI-2020-13: 303.0MW**
- **ERIS of GI-2020-14: 345.6MW**

Since the overload on the Boone – GI-2020-13 230kV line is caused by the injection from GI-2020-13. The cost-effective mitigation that can eliminate the overload is to increase the line rating to 394MVA by fixing terminal limitations. No other alternatives were studied.

The study evaluated the following alternatives to mitigate the overloads on the Waterton 345/230kV#T3 Xfmr and Midway 345/230kV#T2 Xfmr:

Alternative -1: Loop Comanche – Daniels Park 345kV line into the GI-2012 and GI-2014 345kV Switching Station

Alternative -2: Loop Tundra – Daniels Park 345kV line into the GI-2012 and GI-2014 345kV Switching Station

Table 10 shows the results of the two alternatives in mitigating the overloads. Both Alternatives 1 and 2 were effective in mitigating the Midway # T2 overload but were not effective in mitigating the Waterton # T3 xfmr overload. The final alternatives identified are given in Table 11. Alternative 1 was cost effective compared to Alternative 2 as it simplifies the line crossings.

Table 10 – Alternatives Studied for Southern Colorado Mitigations

Overloaded Facility	Normal Rating	CONTINGENCY	Study Case	Alternative 1	Alternative 2
Waterton 345/230kV #T3 xfmr	560	System Intact	191.0%	153.9%	149.4%
Waterton 345/230kV #T3 xfmr	560	Daniels Park – Fuller 230kV line	220.0%		
		GI-2020-12/GI-2020-14 Switching Station – Daniels Park 345kV line #1		237.2%	
		GI-2020-12/GI-2020-14 Switching Station – Daniels Park 345kV line #2			238.8%
Midway 345/230kV #T2 xfmr	560	GI-2020-12/GI-2020-14 Switching Station – Waterton 345kV line #1	190.1%		

		GI-2020-12/GI-2020-14 Switching Station – Comanche 345kV line #1		82.4%	
		GI-2020-12/GI-2020-14 Switching Station – Tundra 345kV line #2			86.5%

Table 11 – Network Upgrades identified in Southern Colorado Study Pocket analysis

Overloaded Facility	Mitigation/Network Upgrade Identified
Waterton 345/230kV, 560MVA #T2 xfmr	Install a second Waterton 345/230kV, 560MVA xfmr
Midway 345/230kV, 560MVA #T3 xfmr	Loop Comanche – Daniels Park 345kV line into GI-2012/GI-2014 345kV Switching Station
Boone – GI-2020-13 Switching Station	Uprate the line rating of the Boone – GI-2020-13 switching station segment from 319MVA to 394MVA

The impact of each GIR to the identified Network Upgrades are given in Tables 12, 13 and 14.

Table 12 – Allocation of Cost of Waterton 345/230kV Transformer Network Upgrades

Network Upgrades	GIR	GIR MW	DFAX	MW Impact	Cost Allocation Factor
Install a second Waterton 345/230kV, 560MVA xfmr	GI-2020-12	400	0.1379	55.1600	32.0%
	GI-2020-13	374	0.0774	28.9476	16.8%
	GI-2020-14	700	0.1261	88.2700	51.2%

Table 13 – Allocation of Cost of GI-2020-12/GI-2020-14 Substation Network Upgrades

Network Upgrades	GIR	GIR MW	DFAX	MW Impact	Cost Allocation Factor
Loop Comanche – Daniels Park 345kV line into GI-2012 and GI-2014 345kV Switching Station	GI-2020-12	400	0.3038	121.5200	32.5%
	GI-2020-13	374	0.1542	57.6708	15.4%
	GI-2020-14	700	0.2784	194.8800	52.1%

Table 14 – Allocation of Cost of Boone – MidwayPS 230kV Network Upgrades

Network Upgrades	GIR	GIR MW	DFAX	MW Impact	Cost Allocation Factor
Boone – GI-2020-13 230kV line uprate to 394MVA	GI-2020-13	374	0.3486	130.3764	100.0%

The results of the multiple contingency analysis on the Study Case are given in Table 15.

Table 15 – 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- Surrey Ridge 230kV # 1	Line	PSCo	478	410.1	85.8%	564.0	118.0%	32.2%	Daniels Park - Greenwood 230kV Lines #1 & #2
Daniels Park – Prairie 3 230kV # 2	Line	PSCo	756	571.3	75.6%	790.3	104.5%	29.0%	Daniels Park - Greenwood 230kV line & Daniels Park - Missile Site 230kV line #1
Daniels Park - Waterton 230kV # 1	Line	PSCo	478	84.6	17.7%	623.5	130.4%	112.7%	Waterton - Soda Lakes 230kV Line & Waterton - Daniels Park 230kV Line
Daniels Park - Fuller 230kV # 1	Line	PSCo	576	484.8	84.2%	767.1	133.2%	49.0%	Comanche – Tundra 345kV Line #2 & Comanche 345/230kV Xfmr #4
Deer Creek - Sodalake 115kV # 1	Line	PSCo	154	110.1	71.5%	158.3	102.8%	31.3%	Soda Lake 230kV Substation
Florence - Highland 69kV # 1	Line	BHE	35	28.7	81.9%	35.7	102.0%	20.0%	MidwayPS – Fuller 230kV Breaker failure
Fountain Valley – Desert Cove 115kV # 1	Line	BHE	222	229.6	103.4%	336.6	151.6%	48.2%	MidwayPS – Fuller 230kV Breaker failure
Fountain Valley - MidwayBr 115kV # 1	Line	BHE	171	228.2	133.4%	335.2	196.0%	62.6%	MidwayPS – Fuller 230kV Breaker failure
Greenwood – Prairie 3 230kV # 1	Line	PSCo	576	520.8	90.4%	739.7	128.4%	38.0%	Daniels Park - Greenwood 230kV line & Daniels Park - Missile Site 230kV line #1
Greenwood – Prairie 1 230kV # 2	Line	PSCo	576	448.7	77.9%	625.8	108.6%	30.7%	Greenwood - Leetsdale 230kV Line & Greenwood - Daniels Park 230kV Line

MidwayPS – West Station 115kV # 1	Line	BHE	80	71.7	89.6%	128.3	160.4%	70.8%	MidwayPS – Fuller 230kV Breaker failure
MidwayPS – GI-2020-13 POI 230kV # 1	Line	PSCo	319	185.3	58.1%	535.8	168.0%	109.9%	Boone - Comanche 230kV Line #1 & Boone 230/115kV Xfmr #1
MidwayPS - MidwayBR 230kV # 1	Line	PSCo	756	476.5	63.0%	832.2	110.1%	47.1%	Tundra - Daniels Park 345kV Line #2 & Comanche 345/230kV Xfmr #4
MidwayPS - Fuller 230kV # 1	Line	PSCo	478	492.4	103.0%	795.0	166.3%	63.3%	Midway 230kV Bus tie
Palmer - Monument 115kV # 1	Line	PSCo	162	121.3	74.9%	207.7	128.2%	53.3%	Daniels Park - Fuller 230kV line #1 & Daniels Park - Waterton 230kV line
Desert Cove – West Station 115kV # 1	Line	BHE	222	243.4	109.6%	351.1	158.1%	48.5%	MidwayPS – Fuller 230kV Breaker failure
Waterton – Martin Tap 115kV # 1	Line	PSCo	189	164.8	87.2%	212.5	112.4%	25.3%	Soda Lake 230kV Substation
Waterton 345/230kV Xfmr	Xfmr	PSCo	756	599.0	79.2%	1449.4	191.7%	112.5%	MidwayPS – Fuller 230kV Breaker failure
Waterton – GI-2020-14 POI 345kV # 1	Line	PSCo	1183	628.4	53.1%	1618.0	136.8%	83.7%	MidwayPS – Fuller 230kV Breaker failure
West Canon – Hogback 115kV # 1	Line	BHE	153	139.2	91.0%	193.9	126.7%	35.8%	MidwayPS – Fuller 230kV Breaker failure
West Canon 230/115kV # 1	Line	BHE	100	98.2	98.2%	145.7	145.7%	47.5%	MidwayPS – Fuller 230kV Breaker failure
Daniels Park - Tundra 345kV # 2	Line	PSCo	1195	1042.2	87.2%	1332.6	111.5%	24.3%	Daniels Park 345/230kV Xfmr #4 & Daniels Park - Comanche 345kV Line #1
Daniels Park - Comanche 345kV # 1	Line	PSCo	1195	1031.6	86.3%	1320.0	110.5%	24.1%	Daniels Park 345/230kV Xfmr #4 & Tundra - Daniels Park 345kV Line #2
Vollmer Tap – Black Squirrel 115kV # 1	Line	TSGT	173	164.9	95.3%	233.1	134.7%	39.4%	Daniels Park - Fuller 230kV line #1 & Daniels Park - Waterton 230kV line

Vollmer Tap - Fuller 115kV # 1	Line	TSGT	193	173.7	90.0%	242.2	125.5%	35.5%	Daniels Park - Fuller 230kV line #1 & Daniels Park - Waterton 230kV line
MidwayBR- RD_NIXON 115kV # 1	Line	CSU	195	136.8	70.2%	213.8	109.6%	39.5%	MidwayPS – Fuller 230kV Breaker failure
Monument – Gresham 115kV # 1	Line	TSGT	145	119.4	82.4%	187.0	128.9%	46.6%	Daniels Park - Fuller 230kV line #1 & Daniels Park - Waterton 230kV line
Gresham – Black Forest Tap 115kV # 1	Line	TSGT	173	123.3	71.3%	190.9	110.3%	39.1%	Daniels Park - Fuller 230kV line #1 & Daniels Park - Waterton 230kV line
Black Forest Tap - Black Squirrel 115kV # 1	Line	TSGT	143	119.4	83.5%	185.4	129.7%	46.2%	Fuller - Daniels Park 230kV Line #1 &Fuller - MidwayPS 230kV Line #1
Fuller 230/115kV # 1	Xfmr	TSGT	100	80.8	80.8%	107.2	107.2%	26.4%	Daniels Park - Fuller 230kV line #1 & Daniels Park - Waterton 230kV line
Fuller 230/115kV # 2	Xfmr	TSGT	100	108.1	108.1%	136.3	136.3%	28.2%	Fuller 230/115kV Xfmr #1 & Falcon - Fuller 115kV Line #1

The multiple contingency analysis shows several new overloads and increases to existing overloads after the addition of the Southern Colorado Pocket Cluster ERIS GIRs. In addition, the multiple contingency of the Tundra – Daniels Park and Comanche – Daniels Park 345kV lines did not result in a convergence solution. Per TPL1-4, multiple contingency overloads are mitigated using system adjustments, including generation redispatch and/or operator actions. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the multiple contingencies that diverged. 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.

6.2.4 Affected Systems

TSGT has ownership on the Boone – Midway 230kV line, So TSGT is an Affected System to GI-2020-13. There are no additional cost impacts expected for the Affected System facility. There are no other Affected Parties identified in the Southern Colorado study pocket analysis.

6.2.5 Summary of Southern Study Pocket Analysis

The maximum allowable ERIS before Network Upgrades is:

- **ERIS of GI-2020-12: 213.8MW**
- **ERIS of GI-2020-13: 303.0MW**
- **ERIS of GI-2020-14: 345.6MW**

The ERIS identified after Network Upgrades is:

- **ERIS of GI-2020-12: 400MW (after Network Upgrades in Tables 12 and 13)**
- **ERIS of GI-2020-13: 374MW (after Network Upgrades in Tables 12 and 13)**
- **ERIS of GI-2020-14: 700MW (after Network Upgrades in Tables 12, 13 and 14)**

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 16.

Table 16 – 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
JMSHAFR2 13.80	ST	1	45.6	50.7

Bus Name	ID	Status	PGen (MW)	PMax (MW)
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	58.1	65.5
KNUTSON2 13.80	G2	1	58.1	65.5
PAWNEE 22.00	C1	1	535	535
MANCHEF1 16.00	G1	0	0	140
MANCHEF2 16.00	G2	0	0	140
RMEC1 15.00	G1	1	143.1	159
RMEC2 15.00	G2	1	143.1	159
RMEC3 23.00	ST	1	284.4	316
SPNDLE1 18.00	G1	1	141.3	157
SPNDLE2 18.00	G2	1	141.3	157
SPRUCE1 18.000	G1	0	0	162
SPRUCE2 18.000	G2	0	0	162
ST.VRAIN 22.00	ST	1	279	310
ST.VR_2 18.00	G2	1	121.4	146
ST.VR_3 18.00	G3	1	133.2	148
ST.VR_4 18.00	G4	1	137.7	177
ST.VR_5 18.00	G5	1	164.7	183
ST.VR_6 18.00	G6	1	164	183
MTNBRZ_W1 34.50	W1	1	135.2	169

6.3.2 Study Case Modeling

An NRIS Study Case was created from the Benchmark Case by modeling GI-2020-16 at the Barr Lake 230kV Substation. The 199.5MW output from the generator was balanced by redispatching all PSCo and non-PSCo generation connected to the PSCo Transmission System outside the study pocket on a pro-rata basis.

6.3.3 Steady State Analysis Results

The results of 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 17.

An ERIS Study Case was created from the NRIS Study Case by modeling GI-2020-15 tapping the Fort Lupton – Pawnee 230kV line. The 250MW output from the generator was balanced by redispatching the PSCo resources 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 Study Case are given in Table 18.

Per TPL1-4, multiple contingency overloads are mitigated using system adjustments, including generation redispatch and/or operator actions.

6.3.4 Affected Systems

TSGT has been identified as an Affected System to GI-2020-16 as the interconnection may require upgrades to substation termination facilities at the Reunion Substation. The cost of these Network Upgrades are not included in this study report and are expected to be available in the Phase 2 report.

There are no other Affected System impacts identified in the Northern study pocket analysis.

6.3.5 Summary of Northern Study Pocket Analysis

Since the study did not identify any Network Upgrades, the GIRs were attributed full ERIS before Network Upgrades.

The maximum ERIS identified for GI-2020-15 is 250 MW.

The maximum NRIS identified for GI-2020-16 is 199.5 MW

Table 17 – 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		
California – Cherokee_S 115kV #1	Line	PSCo	151	156.9	103.9%	159.9	105.9%	1.9%	Cherokee – Sandown 115kV Line & Cherokee to Capitol Hill 115kV Line

Table 18 – 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		
California – Cherokee_S 115kV #1	Line	PSCo	151	159.8	105.9%	161.9	107.2%	1.4%	Cherokee – Sandown 115kV line & Cherokee to Capitol Hill 115kV line
Valmont 230/115kV #7	Xfmr	PSCo	318	314.6	98.9%	319.8	100.6%	1.6%	Valmont 230/115kV Xfmr #2 & Vamont – Plains End 230kV Line

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

The total costs of Network Upgrades assigned under Sections 4.2.4(a) and 4.2.4(b) are given below

7.1 Total Cost of Station Network Upgrades

The estimated total cost of Station Network Upgrades for each POI and the GIRs sharing the POI are given in Table 19.

Table 19 – Total cost of Station Network Upgrades by POI

POI	Total Cost (Million)	GIRs Sharing the POI
GI-2020-12/GI-2020-14 345kV Switching Station	$35.544	GI-2020-12 and GI-2020-14
GI-2020-13 230kV Switching Station	$20.043	GI-2020-13
GI-2020-15 230kV Switching Station	$21.582	GI-2020-15
Barr Lake 230kV Substation	$10.872	GI-2020-16

The estimated total cost and details of the Station Network Upgrades required at the GI-2020-12/GI-2020-14 345kV Switching Station, tapping the Midway – Waterton 345kV line are shown in Table 19. These Station Network Upgrade costs are shared by GI-2020-12 and GI-2020-14 on a per-capita basis, as shown in Table 25 below. Construction of the GI-2020-12/GI-2020-14 345kV 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 for regulatory activities and, to site, design, procure and construct the switching station is expected to take up to 36 months.

Table 20 –Station Network Upgrades – GI-2020-12 /GI-2020-14 345kV Switching Station

Element	Description	Cost Est. (Millions)
New PSCo's GI-2020-12/GI-2020-14 345kV Switching Station	Install a new 345kV substation on the Waterton - Midway 345kV line. The new equipment includes: • (10) 345kV 3000A circuit breakers • (20) 345kV 3000A disconnect switches • (8) 345kV CCVTs • (12) 345kV Surge Arresters • (4) 345kV Deadends • (1) Electrical Equipment Enclosure • (8) Line Traps • Station controls and wiring • Associated foundations and structures	$26.043

New PSCo's GI-2020-12/GI-2020-14 345kV Switching Station	Install required communication in the EEE	$0.553
PSCO's Waterton -Midway 345kV Line	Reconfiguration of the 345kV and 230kV lines in the corridor to interconnect with the GI-2020-12/GI-2020-14 Switching Station	$7.380
PSCo's Midway Substation	Midway line termination equipment upgrade	$1.468
	Siting and Land Rights support for substation construction	$0.100
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$35.544**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost and details of the Station Network Upgrades required at the GI-2020-13 230kV Switching Station tapping the Boone – Midway 230kV line are shown in Table 21. These Station Network Upgrade costs are shared by GI-2020-13, as shown in Table 26 below. Construction of the GI-2020-13 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 for regulatory activities and, to site, design, procure and construct the switching station is expected to take up to 36 months.

Table 21 –Station Network Upgrades – GI-2020-13 230kV Switching Station

Element	Description	Cost Est. (Millions)
New PSCo's GI-2020-13 230kV Switching Station	Install a new 230kV substation on the Pawnee-Missile line.The new equipment includes: • (3) 230kV 3000A circuit breakers • (8) 230kV 3000A disconnect switches • (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	$15.868
New PSCo's GI-2020-13 230kV Switching Station	Install required communication in the EEE	$0.531
PSCO's Boone- Midway Line	Line reconfiguration to accommodate Interconnection Customer	$1.457
PSCo's Boone Substation	Boone line termination equipment upgrade	$1.136
PSCo;s Midway Substation	Midway line termination equipment upgrade	$0.951
	Siting and Land Rights support for substation construction	$0.100

	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$20.043**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost and details of the Station Network Upgrades required at the GI-2020-15 230kV Switching Station tapping the Fort Lupton – Pawnee 230kV line are shown in Table 22. These Station Network Upgrade costs are shared by GI-2020-15, as shown in Table 27 below. Construction of the GI-2020-15 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 22 –Station Network Upgrades – GI-2020-15 230kV Switching Station

Element	**Description**	**Cost Est. (Millions)**
PSCo's GI-2020-15 New 230kV Switchyard	Install a new 230kV substation on the Pawnee-Missile line. The new equipment includes: • (3) 230kV 3000A circuit breakers • (8) 230kV 3000A disconnect switches • (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	$16.001
PSCo's GI-2020-15 New 230kV Switchyard	Install required communication in the EEE	$0.597
PSCo's t. Lupton-Pawnee 5463 Line	Line reconfiguration to accommodate Interconnection Customer	$2.458
PSCo's Fort Lupton Substation	Fort Lupton line termination equipment upgrade	$1.213
PSCo;s Pawnee Substtion	Pawnee line termination equipment upgrade	$1.213
	Siting and Land Rights support for substation construction	$0.100
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$21.582**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost and details of the Station Network Upgrades required at the Barr Lake 230kV Substation are shown in Table 23. These Station Network Upgrade costs are shared by GI-2020-16, as shown in Table 28 below. Since the Barr Lake Substation will be expanded to

interconnect GI-2020-16, it is expected that the expansion work may require 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 for 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 – Barr Lake 230kV Substation*

Element	Description	Cost Est. (Millions)
PSCo's Barr Lake 230kV Switchyard	Barr Lake 230kV substation expansion to accomodate Interconnection Customer. The new equipment includes: • (4) 230kV 3000A circuit breakers • (8) 230kV 3000A disconnect switches • (8) 230kV CCVTs • (6) 230kV Surge Arresters • (4) 230kV Deadends • (1) Electrical Equipment Enclosure • (2) Line Traps • Station controls and wiring • Associated foundations and structures	$8.160
PSCo's Barr Lake 230kV Switchyard	Install required communication in the EEE	$0.553
PSCo's Reunion-Barr Lake Line	Line reconfiguration to accommodate Interconnection Customer	$0.871
PSCo'sGreen Valley Substation	Green Valley line termination upgrade	$1.188
	Siting and Land Rights support for substation construction	$0.100
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$10.872**
Time Frame	**Site, design, procure and construct**	**36 Months**

Note – TSGT's Reunion Substation may require line terminal upgrades. These costs will be included in the Phase 2 report.

7.2 Total Cost of Other Network Upgrades

The estimated total cost and details of the other Network Upgrades identified in the Southern Colorado study pocket analysis are shown in Table 24. These Network Upgrade costs are shared by all GIRs in the corresponding Study Pockets based on their proportional impact shown in Tables 12, 13 and 14 above. The Northern Colorado study pocket did not identify any other Network Upgrades.

Table 24 – Other Southern Colorado Study Pocket Network Upgrades

Element	Description	Cost Est. (Millions)	GI-2020-12 Impact	GI-2020-13 Impact	GI-2020-14 Impact
Comanche – Daniels Park 345kV line	Terminal Upgrades at Comanche and Daniels Park substations to allow looping of the Comanche – Daniels Park 345kV line into GI-2020-12/GI-2020-14 345kV Switching Station	$2.936	32.5%	15.4%	52.1%
PSCo's Waterton Substation	Add second Waterton 345/230kV, 560MVA xfmr	$19.598	32.0%	16.8%	51.2%
Boone – GI-2020-13 230kV line	Uprate Boone – GI-2020-13 230kV line to 394MVA	$1.457	0	100%	0

7.3 Cost of Station and other Network Upgrades by GIR

Table 95 – Allocation of GI-2020-12/GI-2020-14 345kV Switching Station Cost by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 19)
GI-2020-12	400	36.37%	$12.927 Million
GI-2020-14	700	63.63%	$22.617 Million

Table 106 – Allocation of GI-2020-13 230kV Switching Station Cost by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 20)
GI-2020-13	374	100%	$20.043 Million

Table 117 – Allocation of GI-2020-15 230kV Switching Station Cost by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 21)
GI-2020-15	250	100%	$21.582 Million

Table 128 – Allocation of Barr Lake 230kV Substation POI Cost by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 22)
GI-2020-16	199.5	100%	$10.872 Million

Table 29 – Allocation of Cost of other Network Upgrades

Network Upgrade	GIR	GIR MW	% Share per Section 4.2.4(b) of Attachment N	Costs allocated to GIR (% share x total costs from Table 23)
Comanche and Daniels Park line terminiation Upgrades	GI-2020-12	400	32.5%	$0.954 Million
	GI-2020-13	374	15.4%	$0.452 Million
	GI-2020-14	700	52.1%	$1.53 Million
Add second Waterton 345/230kV, 560MVA xfmr	GI-2020-12	400	32.0%	$6.271 Million
	GI-2020-13	374	16.8%	$3.292 Million
	GI-2020-14	700	51.2%	$10.034 Million
Uprate Boone – GI-2020-13 230kV line to 394MVA	GI-2020-12	400	0	0
	GI-2020-13	374	100%	$1.457 Million
	GI-2020-14	700	0	0

7.4 Summary of Transmission Provider's Interconnection Facilities and Network Upgrade Costs allocates to GI-2020-12

The total cost of the required Upgrades for GI-2020-12 to interconnect on the Midway – Waterton 345kV line is **$22.386 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $2.234 Million (Table 30)**
- **The cost of Station Network Upgrades is $12.927 Million (Table 25)**
- **The cost of other Network Upgrades is $7.225 Million (Table 29)**

Figure 2 is a conceptual one-line of the GI-2020-12 POI at the GI-2020-12/GI-2020-14 345kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-12 are given in Tables 25, 29 and 30. A CPCN will be required to build the GI-2020-12/GI-2020-14 345kV 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.

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

Table 30 – GI-2020-12 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)

PSCo's GI-2020-12/14 New 345kV Switching Station	Interconnection GI-2020-12 at the new Switching station tapping the Waterton - Midway 345kV line. 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.	$2.034
	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	**$2.234**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.5 Summary of Transmission Provider's Interconnection Facilities and Network Upgrade Costs allocates to GI-2020-13

The total cost of the required Upgrades for GI-2020-13 to interconnect on the Boone - Midway – 230kV line is **$27.065 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.821 Million (Table 31)**
- **The cost of Station Network Upgrades is $20.043 Million (Table 26)**
- **The cost of other Network Upgrades is $5.201 Million (Table 29)**

Figure 3 is a conceptual one-line of the GI-2020-13 POI switching station tapping the Boone – Midway 230kV line.

The list of improvements required to accommodate the interconnection of GI-2020-13 are given in Tables 26, 29 and 31. A CPCN will be required to build the GI-2020-13 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.

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

Table 30 – GI-2020-13 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-13 New 230kV Switchyard	Interconnection Customer to tap at the Boone - Midway 230kV line. The new equipment includes: • (1) 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.	$1.621
	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	**$1.821**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.6 Summary of Transmission Provider's Interconnection Facilities and Network Upgrade Costs allocates to GI-2020-14

The total cost of the required Upgrades for GI-2020-14 to interconnect on the Midway – Waterton 345kV line is **$36.415 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $2.234 Million (Table 32)**
- **The cost of Station Network Upgrades is $22.617 Million (Table 25)**
- **The cost of other Network Upgrades is $11.564 Million (Table 29)**

Figure 2 is a conceptual one-line of the GI-2020-14 POI at the GI-2020-12/GI-2020-14 345kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-14 are given in Tables 25, 29 and 32. A CPCN will be required to build the GI-2020-12/GI-2020-14 345kV 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 32 – GI-2020-14 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-12/14 New 345kV Switching Station	Interconnection GI-2020-12 at the new Switching station tapping the Waterton - Midway 345kV line. 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.	$2.034
	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	**$2.234**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.7 Summary of Transmission Provider's Interconnection Facilities and Network Upgrade Costs allocates to GI-2020-15

The total cost of the required Upgrades for GI-2020-15 to interconnect on the Fort Lupton – Pawnee 230kV line is **$23.403 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.821 Million (Table 33)**
- **The cost of Station Network Upgrades is $21.582 Million (Table 27)**
- **The cost of other Network Upgrades is 0**

Figure 4 is a conceptual one-line of the GI-2020-15 POI switching station tapping the Fort Lupton – Pawnee 230kV line.

The list of improvements required to accommodate the interconnection of GI-2020-15 are given in Tables 27 and 33. A CPCN will be required to build the GI-2020-15 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 33 – GI-2020-15 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-15 New 230kV Switchyard	Interconnection Customer to tap at the Fort Lupton-Pawnee 230kV line. The new equipment includes: • (1) 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.	$1.621
	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	**$1.821**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.8 Summary of Transmission Provider's Interconnection Facilities and Network Upgrade Costs allocates to GI-2020-16

The total cost of the required Upgrades for GI-2020-16 to interconnect at the Barr Lake 230kV Substation is **$12.397 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.525 Million (Table 34)**
- **The cost of Station Network Upgrades is $10.872 Million (Table 28)**
- **The cost of other Network Upgrades is 0**

Figure 5 is a conceptual one-line of the GI-2020-16 POI at the Barr Lake 230kV Substation.

The list of improvements required to accommodate the interconnection of GI-2020-16 are given in Tables 28 and 34. A CPCN will be required to expand the Barr Lake 230kV Substation for the

interconnection of GI-2020-16. 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 34 – GI-2020-16 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Barr Lake 230kV Substtion	Interconnection Customer to tap at the Barr Lake 230kV line. The new equipment includes: • (2) 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.	$1.325
	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	**$1.525**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.9 Cost Estimate Assumptions

PSCo Engineering has developed Cost Estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the DISIS-2020-002 Cluster GIRs on the PSCo transmission system. 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

- A CPCN will be required for the interconnection facilities for all the GIRs
- 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
- The Customer Generating Facilities 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 DISIS-2020-002 and Interconnection Service in and itself does not convey transmission service.

8.1 GI-2020-12

The total cost of the required Upgrades for GI-2020-12 to interconnect on the Midway – Waterton 345kV line is **$22.386 Million** (Tables 25, 29 and 30).

Energy Resource Interconnection of GI-202012 before Network Upgrades is: 213.8MW

Energy Resource Interconnection Service of GI-2020-12 is: 400MW (after required transmission system improvements in Tables 25, 29 and 30).

A CPCN is needed for the construction of the GI-2020-12/GI-2020-14 345kV 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-2020-12.

8.1 GI-2020-13

The total cost of the required Upgrades for GI-2020-13 to interconnect on the Boone - Midway – 230kV line is **$27.065 Million** (Tables 26, 29 and 31).

Energy Resource Interconnection of GI-202012 before Network Upgrades is: 303MW

Energy Resource Interconnection Service of GI-2020-13 is: 374MW (after required transmission system improvements in Tables 26, 29 and 31).

A CPCN is needed for the construction of the GI-2020-13 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-2020-13.

The output of the GI-2020-13 hybrid Generating Facility will be limited to 374MW 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.

8.2 GI-2020-14

The total cost of the required Upgrades for GI-2020-14 to interconnect on the Midway – Waterton 345kV line is **$36.415 Million** (Tables 25, 29 and 32).

Energy Resource Interconnection of GI-202012 before Network Upgrades is: 345.6MW

Energy Resource Interconnection Service of GI-2020-14 is: 700MW (after required transmission system improvements in Tables 25, 29 and 32).

A CPCN is needed for the construction of the GI-2020-12/GI-2020-14 345kV 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-2020-14.

8.1 GI-2020-15

The total cost of the required Upgrades for GI-2020-15 to interconnect on the Fort Lupton – Pawnee 230kV line is **$23.403 Million** (Tables 27 and 33).

Energy Resource Interconnection of GI-2020-15 before Network Upgrades is: 250MW

Energy Resource Interconnection Service of GI-2020-15 is: 250MW (after required transmission system improvements in Tables 27 and 33).

A CPCN is needed for the construction of the GI-2020-15 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-2020-15.

8.1 GI-2020-16

The total cost of the required Upgrades for GI-2020-16 to interconnect at the Barr Lake 230kV Substation is **$12.397 Million** (Tables 28 and 34).

Energy Resource Interconnection of GI-2020-16 before Network Upgrades is: 199.5MW

Energy Resource Interconnection Service of GI-2020-16 is: 199.5MW (after required transmission system improvements in Tables 28 and 34).

A CPCN is needed for the expansion of the Barr Lake 230kV Substation to interconnect GI-2020-16. 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-2020-16.

Figure 2 – Preliminary One-line of the GI-2020-12/GI-2020-14 345kV Switching Station

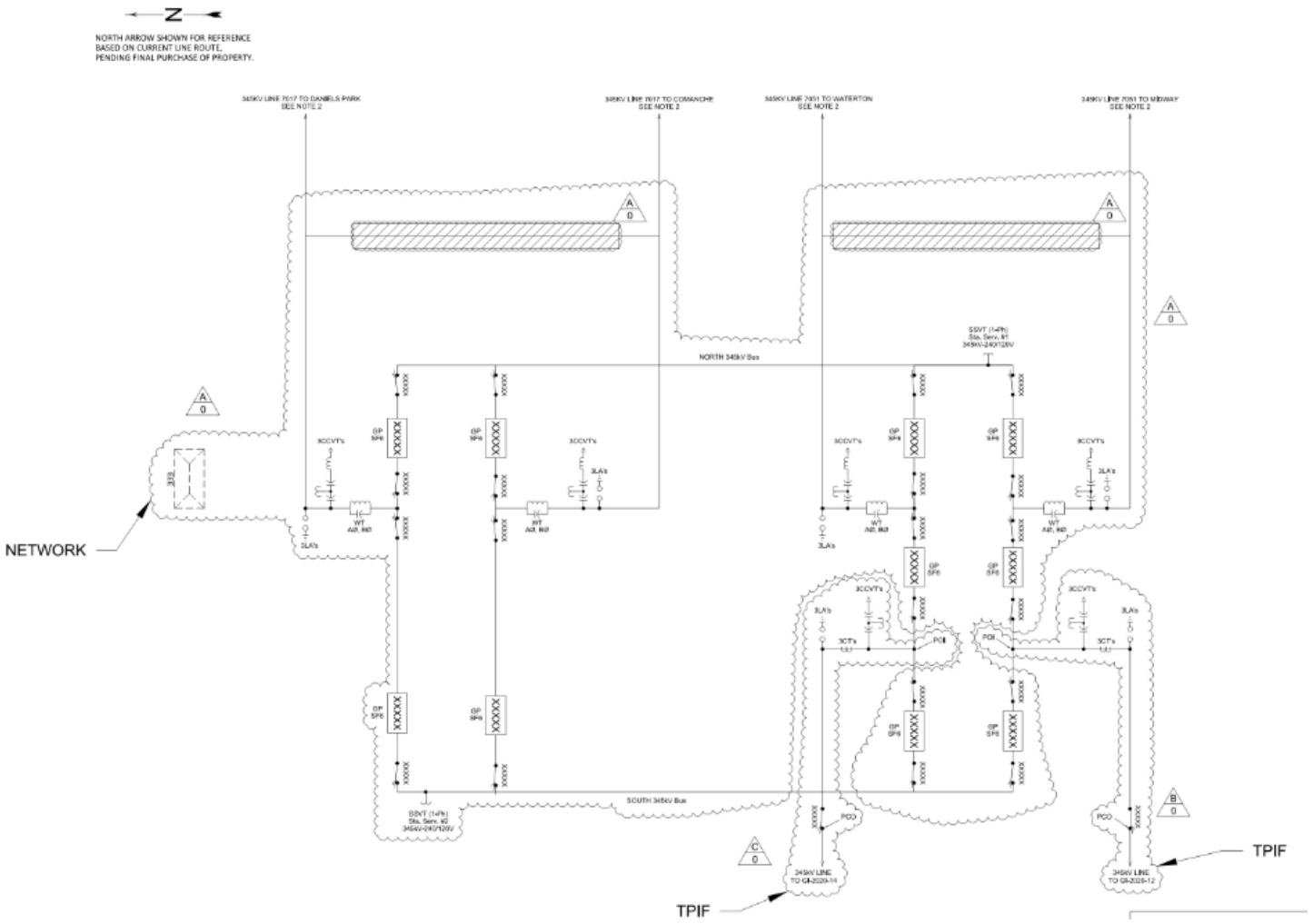

Figure 3 – Preliminary One-line of GI-2020-13 POI tapping the Boone – Midway 230kV Line

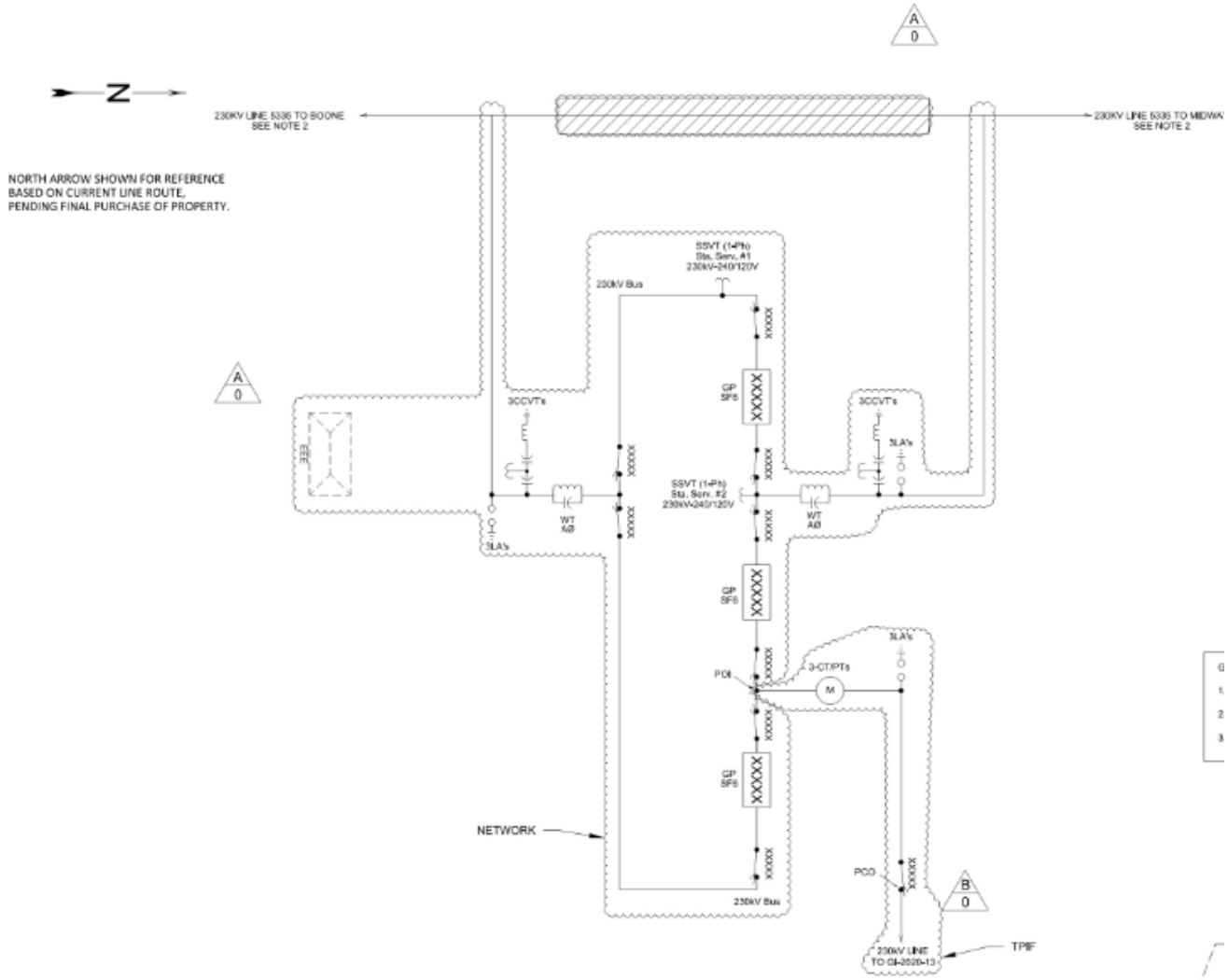

Figure 4 – Preliminary One-line of the GI-2020-15 230kV Switching Station tapping the Fort Lupton – Pawnee 230kV Line

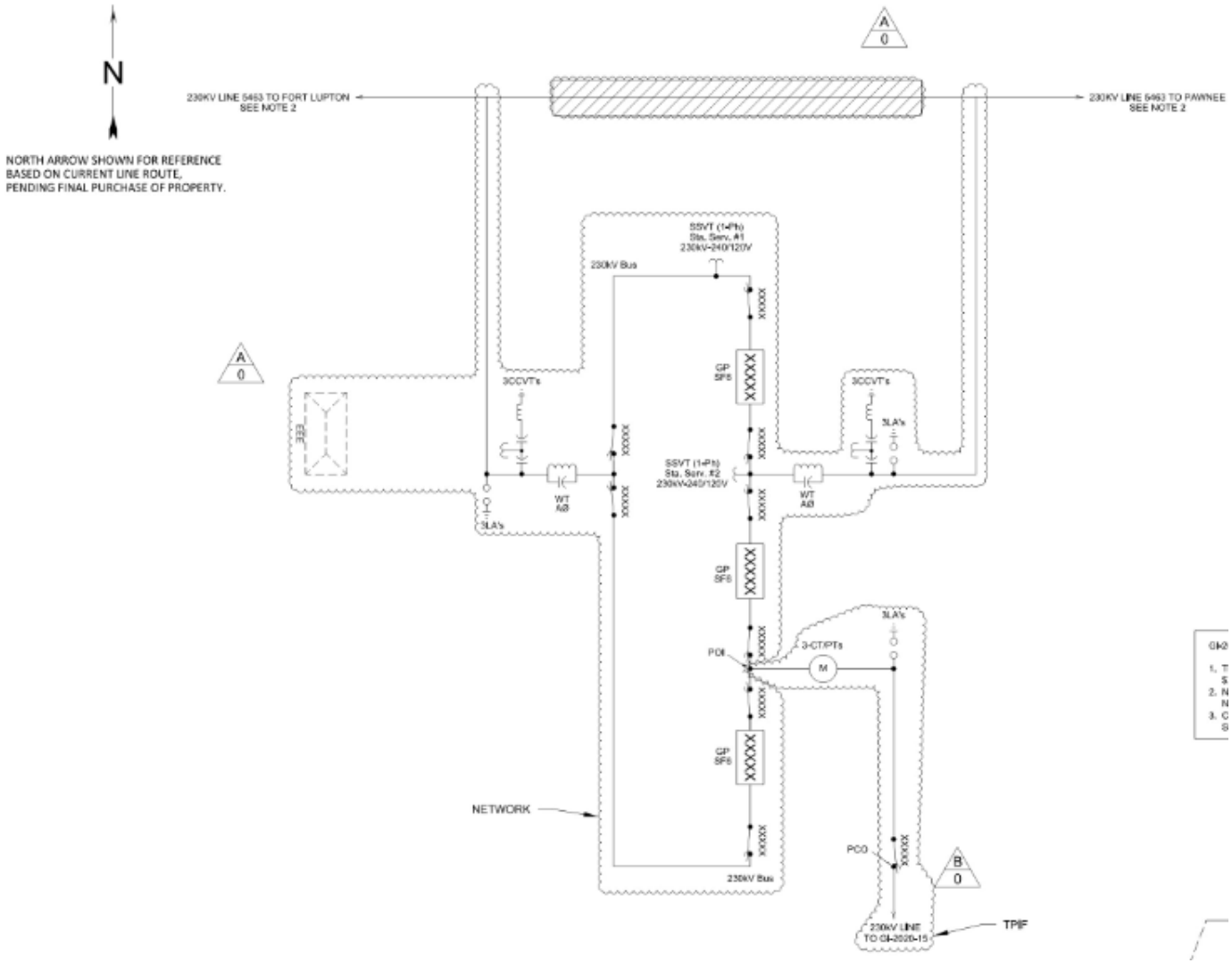

Figure 5 – Preliminary One-line of the GI-2020-16 at the Barr Lake 230kV Substation