2020 Spring DISIS Cluster Study

Phase 1 Report

10/16/2020

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1.0 Executive Summary

The 2020 Spring Definitive Interconnection System Impact Study Cluster (DISIS-2020-001) includes seven (7) Generation Interconnection Request (GIR)s – GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5, GI-2020-6, GI-2020-7, and GI-2020-10.

GI-2020-1 is a 199MW_{ac} net rated Solar Photovoltaic (PV) Generating Facility requesting Energy Resource Interconnection Service (ERIS). The Point of Interconnection (POI) is Mirasol 230kV substation.

GI-2020-3 is a 199MW_{ac} net rated Solar PV Generating Facility requesting ERIS. The POI is a tap on the Boone-Comanche 230kV line, at approximately 5 miles from the Boone Substation.

GI-2020-4 is a 100MW_{ac} net rated Solar PV Generating Facility requesting ERIS. The POI is at Mirasol 230kV substation.

GI-2020-5 is a 24MW (18MW in Summer) expansion of the Existing Fort Saint Vrain#4 generator requesting ERIS.

GI-2020-6 is a 199MW_{ac} net rated Solar Photovoltaic (PV) Generating Facility requesting Network Resource Interconnection Service (NRIS). The Point of Interconnection (POI) is a tap on the Pawnee - Missile 230kV line, at approximately 9.93 miles from the Missile Site Substation.

GI-2020-7 is a net 1000MW_{ac} hybrid (700MW Wind plus 300MW Solar) Generating Facility requesting ERIS. The Point of Interconnection (POI) is at Mirasol 345kV substation.

GI-2020-10 is a net 230MW_{ac} AC-coupled Solar PV and Battery Energy Storage (BES) Generating Facility requesting NRIS. The Point of Interconnection (POI) is a tap on the Comanche - Midway 230kV, at approximately 6 miles from the Comanche Substation.

The GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7 and GI-2020-10 GIRs are studied under the Southern Colorado study pocket analysis.

The GI-2020-5 is studied under the Northern Colorado study pocket and GI-2020-6 is studied under the Eastern Colorado study pocket analysis.

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

1.1 GI-2020-1 Results

The total estimated cost of the transmission system improvements for GI-2020-1: $15.5768 Million (Tables 24 and 30).

Energy Resource Interconnection Service of GI-2020-1 is: 199MW (after required transmission system improvements in Tables 24 and 30).

The construction of Mirasol 230kV Substation for GI-2020-1 interconnection will require a Certificate of Public Convenience & Necessity (CPCN) and the estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the Mirasol 230kV Substation is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the 12/1/2023 Commercial Operation Date (COD) of GI-2020-1.

1.2 GI-2020-3 Results

The total cost of the required Upgrades for GI-2020-3 to interconnect at the GI-2020-3 230kV Switching Station is $18.795 Million (Tables 25 and 31).

Energy Resource Interconnection Service of GI-2020-3 is: 199MW (after required transmission system improvements in Tables 25 and 31)

The construction of the GI-2020-3 Switching Station at the Boone – Comanche 230kV line for interconnecting GI-2020-3 will require a CPCN. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the GI-2020-3 Switching Station is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the 12/1/2023 COD of GI-2020-3.

1.3 GI-2020-4 Results

The total cost of the required Upgrades for GI-2020-4 to interconnect at the Mirasol 230kV Substation is $15.5767 Million (Tables 24 and 32).

Energy Resource Interconnection Service of GI-2020-4 is: 100MW (after required transmission system improvements in Tables 24 and 32).

Note: A CPCN is needed for the construction of the Mirasol 230kV Substation. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the Mirasol

230kV Substation is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the 12/1/2023 COD of GI-2020-4.

1.4 GI-2020-5 Results

The total estimated cost of the transmission system improvements for GI-2020-5 are: $0.05 Million (Tables 16 and 33).

Energy Resource Interconnection Service of GI-2020-5 is: 24MW (after required transmission system improvements in Tables 16 and 33).

1.5 GI-2020-6 Results

The total estimated cost of the transmission system improvements for GI-2020-6 are: $18.581 Million (Tables 26 and 34).

Network Resource Interconnection Service of GI-2020-6 is: 199MW (after required transmission system improvements in Tables 26 and 34).

Note: A CPCN will be required to build the GI-2020-6 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the GI-2020-6 230kV Switching Station is approximately 36 months after authorization to proceed has been obtained

1.6 GI-2020-7 Results

The total estimated cost of the transmission system improvements for GI-2020-7 are: $22.7867 Million (Tables 24, 29 and 35).

Energy Resource Interconnection Service of GI-2020-7 is: 1000MW (after required transmission system improvements in Tables 24, 29 and 35).

Note: A CPCN will be required to build the Mirasol 345kV Substation to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the Mirasol 345kV Substation is approximately 36 months after authorization to proceed has been obtained. The output of the hybrid Generating Facility will be limited to 1000MW 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

1.7 GI-2020-10 Results

The total estimated cost of the transmission system improvements for GI-2020-10 are: $14.424 Million (Tables 27, 28 and 36).

Network Resource Interconnection Service of GI-2020-10 is: 230MW (after required transmission system improvements in Tables 27, 28 and 36).

Note: The output of the hybrid Generating Facility will be limited to 230MW 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 construction of the GI-2014-9 230kV Switching Station will require a CPCN and the estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the GI-2014-9 230kV Switching Station is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-10.

Note – This results in this report may be revised during Phase 2 of DISIS-2020-001. The revisions in Phase 2 may also include re-evaluation of the Mirasol Substation configuration.

2.0 Introduction

Public Service Company of Colorado (PSCo) received eleven (11) GIRs in the DISIS-2020-001 out of which seven (7) GIRs moved forward to Phase 1 of the study. The total Interconnection Service requested in the DISIS-2020-001 cluster is 1951MW. The GIRs are identified by their queue numbers – GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5, GI-2020-6, GI-2020-7, and GI-2020-10. Out of the seven (7) GIRs, GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5 and GI-2020-7 requested ERIS[1] and, GI-2020-6 and GI-2020-10 requested NRIS[2]. A summary of the requests in the DISIS-2020-001 is given in

[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.

Table 1.

3.0 Description of the GIRs

3.1 Description of GI-2020-1

GI-2020-1 is a 199MW_{ac} net rated Solar Photovoltaic (PV) Generating Facility located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of sixty-eight (68) FS3350M 3.35MVA, ±0.90PF inverters, each with its own 0.66/34.5kV, 3.51MVA, wye-delta, Z=8.5% and X/R=10 pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 135/180/225MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R = 35 main step-up transformer which will connect to the PSCo transmission system via a 0.5 mile 230kV generation tie-line. The POI is Mirasol 230kV Substation which is a new Substation in Pueblo County, approximately 10 miles from the existing Comanche Substation.

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

Table 1 – Summary of GIRs in the DISIS

Status of PSCo's Interconnection Requests and Studies as of: 6/1/2020

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	Status of Request
DEFINITIVE INTERCONNECTION SYSTEM IMPACT STUDY CLUSTER # 1 - WINDOW OPENED FEBRUARY 1, 2020 - CLOSED MARCH 16, 2020 (DISIS-2020-001)											
GI-2020-01	DISIS-2020-001	3/9/2020	199	199	199	Pueblo County, CO	Mirasol 230 kV Substation	12/1/2023	ERIS	Solar	DISIS Studies In-Progress
GI-2020-02	DISIS-2020-001	3/9/2020	199	199	199	Kit Carson County, CO	Missile Site 345 kV Substation	12/1/2022	ERIS	Wind	Withdrawn 4/15/2020
GI-2020-03	DISIS-2020-001	3/9/2020	199	199	199	Pueblo County, CO	Boone-Comanche 230kV Line	12/1/2023	ERIS	Solar	DISIS Studies In-Progress
GI-2020-04	DISIS-2020-001	3/9/2020	100	100	100	Pueblo County, CO	Mirasol 230 kV Substation	12/1/2023	ERIS	Solar	DISIS Studies In-Progress
GI-2020-05	DISIS-2020-001	3/9/2020	24	18	24	Weld County, CO	Ft. St. Vrain	11/1/2020	ERIS	Combustion Turbine	DISIS Studies In-Progress
GI-2020-06	DISIS-2020-001	3/26/2020	199	199	199	Adams County, CO	Pawnee-Missile Site 230 kV Line	11/15/2022	NRIS	Solar	DISIS Studies In-Progress
GI-2020-07	DISIS-2020-001	3/26/2020	1000	1000	1000	Pueblo County, CO	Mirasol 345 kV Substation	12/1/2023	ERIS	Wind+Solar	DISIS Studies In-Progress
GI-2020-08	DISIS-2020-001	3/30/2020	199	199	199	Weld County, CO	Ft. Lupton - Pawnee 230kV Line	12/15/2022	NRIS	Battery+Solar	Withdrawn 5/29/2020
GI-2020-09	DISIS-2020-001	4/6/2020	230	230	230	Washington County, CO	Smoky Hill-Pawnee 345kV Line	11/1/2022	ERIS	Wind	Withdrawn 5/22/2020
GI-2020-10	DISIS-2020-001	4/7/2020	230	230	230	Pueblo County, CO	Comanche - Midway 230kV Line	12/1/2023	NRIS	Battery+Solar	DISIS Studies In-Progress
GI-2020-11	DISIS-2020-001	4/15/2020	1500	1500	1500	Baca County, CO	Mirasol 345 kV Substation	12/1/2023	ERIS	Wind+Solar	Withdrawn 5/22/2020

3.2 Description of GI-2020-3

GI-2020-3 is a 199MW$_{ac}$ net rated Solar PV Generating Facility that will be located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of sixty-eight (68) FS3350M 3.35MVA, ±0.90PF inverters, each with its own 0.66/34.5kV, wye-delta 3.51MVA, Z=8.5% and X/R=10.5 pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 135/180/225MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R=35 main step-up transformer which will connect to the

PSCo transmission system via a 0.5mile 230kV generation tie-line. The POI is a tap on PSCo's Boone – Comanche 230kV line at approximately 5.1 miles from the Boone Substation. The interconnection at the tap point will require building a new 230kV switching station which will be referred to as "GI-2020-3 Switching Station" in this report.

The proposed COD of GI-2020-3 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.3 Description of GI-2020-4

GI-2020-4 is a 100MW$_{ac}$ net rated Solar PV Generating Facility that will be located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of thirty-six (36) FS3350M 3.35MWA, ±0.90PF inverters, each with its own 0.66/34.5kV, 3.51MVA, Z=8.5% and X/R=10.5 pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 69/92/115MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R=35 main step-up transformer which will connect to the PSCo transmission system via a 0.5 mile, 230kV generation tie-line. The POI is Mirasol 230kV Substation which is a new Substation in Pueblo County, approximately 10 miles from the existing Comanche Substation.

The proposed COD of GI-2020-4 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.4 Description of GI-2020-5

GI-2020-5 is an 18MW (Summer)/24MW(Winter) incremental capacity in the output of the existing Fort Saint Vrain#4 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#4 after the Provisional Interconnection will be 167MW(Summer)/173MW(Winter).

The POI of the incremental capacity is the existing Fort Saint Vrain Substation where Fort Saint Vrain#4 currently interconnects.

The proposed Commercial Operation Date (COD) of the incremental capacity is November 1, 2020. Since the POI is existing and operational, a backfeed date is not applicable to GI-2020-5.

3.5 Description of GI-2020-6

GI-2020-6 is a 199MW$_{ac}$ net rated Solar PV Generating Facility that will be located in Adams County, Colorado. The Solar PV Generating Facility will consist of sixty-two (62) SMA SC-4000 UP-US 3.75MVA, ±0.80PF inverters, each with its own 0.6/34.5kV, 4.00MVA, wye-delta, Z=6% and X/R=15 pad-mounted step-up transformer. The 34.5kV collector system will connect to four (4) 48/64/80MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=9% and X/R=35 main step-up transformers which will connect to the PSCo transmission system via a 0.5 mile 230kV generation tie-line. The POI is a tap on the PSCo's Pawnee – Missile 230kV line at approximately 9.93 miles from the Missile Substation. The interconnection at the tap point will require building a new 230kV switching station which will be referred to as "GI-2020-6 Switching Station" in this report. The output of GI-2020-6 NRIS request is assumed to be serving PSCo native load.

The proposed COD of GI-2020-6 is November 15, 2022. For the study purpose, the back-feed date is assumed to be May 15, 2022, approximately six (6) months before the COD.

3.6 Description of GI-2020-7

GI-2020-7 is a 1000MW$_{ac}$ net rated Solar PV and Wind hybrid Generating Facility that will be located in Pueblo County, Colorado. The wind Generating Facility will consist of three hundred fifty-four (354) GE 2.5MW, ±0.90PF wind turbines each with its own 0.69/34.5kV, 2.9MVA, Z=6.06% and X/R=7.5 wye-gnd/delta pad-mounted step-up transformer. The solar PV Generating Facility will consist of one-hundred-ten (110) FS3430M 3.43MVA, ±0.90PF inverters, each with its own 0.66/34.5kV, 3.51MVA, Z=8.5% and X/R=7.5 wye-gnd/delta pad-mounted step-up transformer. The 34.5kV collector system of the PV and the wind Generating Facilities will connect to three (3) 168/224/280MVA, 34.5/13.8/345kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R=40 main step-up transformers for Wind and one (1) 201/268/335MVA, Z=8.5% and X/R=40 main step-up transformer for Solar PV which will connect to the PSCo transmission system via a 150 mile 345kV generation tie-line. The POI is Mirasol 345kV Substation which is a new Substation in Pueblo County, approximately 10 miles from the existing Comanche Substation. The output of the hybrid Generating Facility will be limited to 1000MW at the POI using centralized power plant controller.

The proposed COD of GI-2020-7 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.7 Description of GI-2020-10

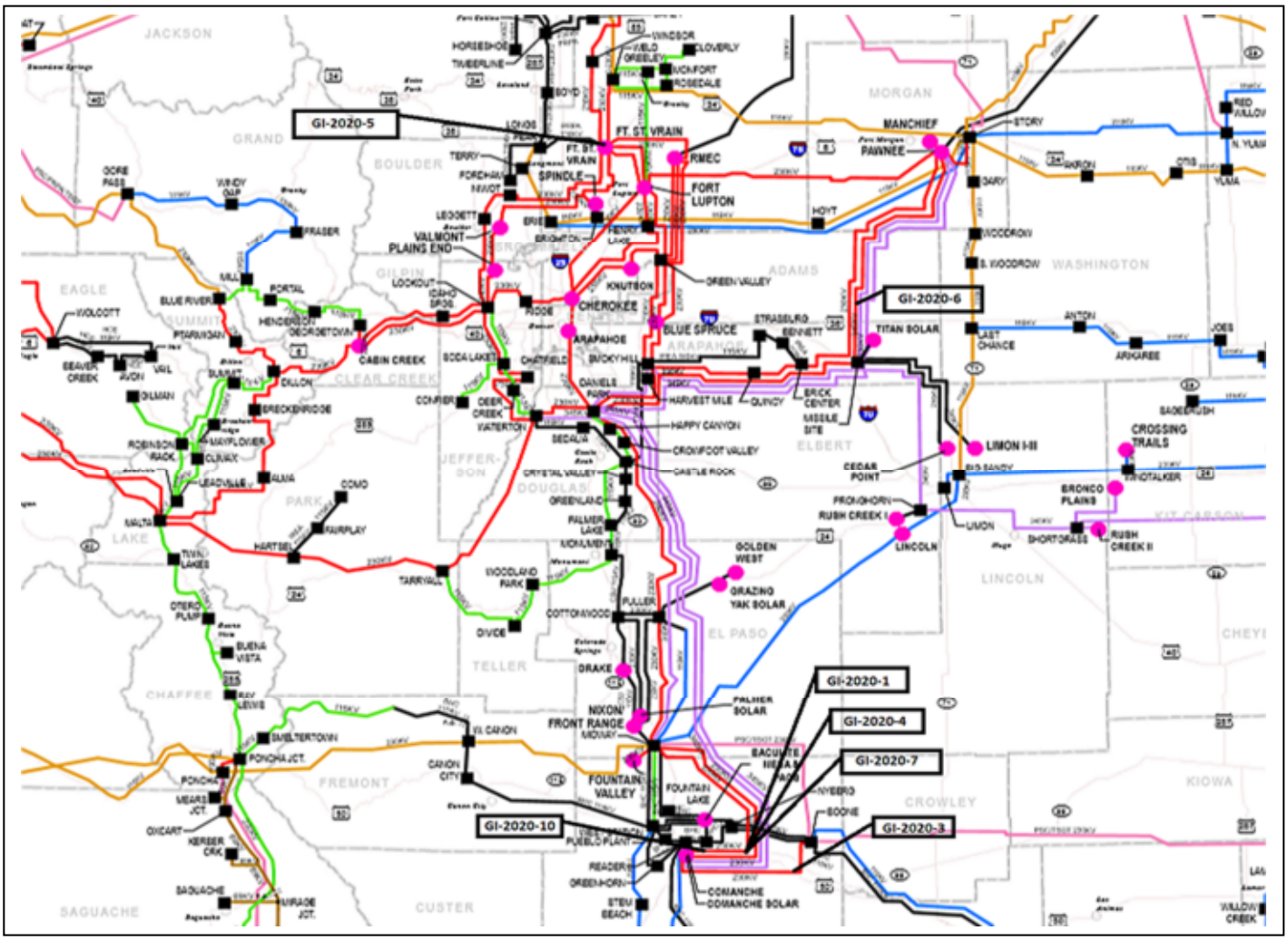
GI-2020-10 is a 230MW$_{ac}$ net rated AC-Coupled Solar PV plus BES hybrid Generating Facility that will be located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of seventy-three (73) HEM FS3350M 3.35MVA, ±0.90PF inverters and the BES Generating Facility will consist of seventy (70) HEM FS3350M 3.35MVA, ±0.985PF inverters. The inverters are medium voltage inverters with embedded padmount transformers. The 34.5kV collector system of the Solar PV and BES generating facilities will connect to one (1) 154/206/256MVA, 34.5/230kV wye-gnd/delta/wye-gnd, Z=7.5% and X/R=42.4 main step-up transformer which will connect to the PSCo transmission system via a 0.1 mile 230kV generation tie-line. The POI is a tap on the PSCo's Comanche – Midway 230kV line, at approximately 6 miles from the Comanche Substation. Since the tap position of the higher-queued request GI-2014-9 is at the same location, the study assumed GI-2020-10 interconnects at the same switching station as GI-2014-9 (GI-2014-9 230kV Switching Station).

The BES facility has a charge rate and discharge rate of 230MW for 4hrs. The output of the hybrid Generating Facility will be limited to 230MW at the POI using centralized power plant controller. The PV and BES generators will be operated together to meet the FERC 827 reactive power capability requirements. The BES generator is capable of a primary frequency response operating range of +/-0.036Hz. The BES generator will only charge from the PV.

The output of GI-2020-10 NRIS request is assumed to be serving PSCo native load.

The proposed COD of GI-2020-10 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

Figure 1 – Approximate Locations of the POIs of the GIRs in the DISIS-2020-001



4.0 Study Scope

The purpose of the study is to determine the system impact of interconnecting all seven GIRs in the DISIS-2020-001 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 indicative level cost estimates. The cost estimates provide total costs and each GIR cost responsibility for Transmission Provider Interconnection Facilities and Network Upgrade identified in the steady state analysis.

The steady state analysis identifies thermal and voltage violations in the PSCo system and the neighboring 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-2020-1, GI-2020-3, GI-2020-4, GI-2020-7, and GI-2020-10, are in Southern Colorado and fall under the "Southern Colorado" study pocket. GI-2020-5 falls under the "Northern Colorado" study pocket and GI-2020-6 falls under the "Eastern Colorado" study pocket. Each study pocket analysis modeled the cluster GIRs that fall under the study pocket.

4.2 Study Criteria

PSCo adheres to applicable NERC Reliability Standards and WECC Reliability Criteria, as well as its internal transmission planning criteria for studies. The following steady state analysis criteria is used for the reliability analysis of the PSCo system and neighboring utility systems for each study pocket analysis.

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 PSSE V33 and the ACCC tool. The generation redispatch for ERIS is identified using GE's OPF tool.

4.3.1 Steady State Assessment methodology

The thermal and voltage violations are identified by running the same set of contingencies on the Benchmark Case and the Study Case and comparing the results.

For PSCo facilities, thermal violations include any facilities without a pre-existing thermal violation that (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 2% or more to the benchmark case loading. Pre-existing thermal violations are identified if the overloads increased by 1% or more.

For non-PSCo facilities, thermal violations include all new facility overloads with thermal loading >100% and existing thermal overloads that increased by 1% or more from the benchmark case overload in the Study Case after the Study Pocket GIR Cluster addition.

The voltage violations include new voltage violations which resulted in a further variation of 0.1 per unit. The study pocket violations are attributed to individual NRIS GIRs in the study pocket by calculating their individual contributions using DFAX criteria.

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

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

When the Cluster 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 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 maximum allowed output without requiring additional Network Upgrades for the ERIS GIRs will be identified in subsequent phases of this study.

The OPF is run using the following generation dispatch assumptions:

1. All existing resources and external resources are considered.
2. The Pmin of wind and solar generator's is 0MW.
3. The Pmin of conventional generation is as provided in the WECC models.

4.3.2 Contingency Analysis

For each study pocket analysis, the transmission system on which steady state contingency analysis is run includes the WECC designated areas 70 and 73, and WECC designated zone 121.

4.4 Study Area(s) considered for the DISIS

The study area or monitored area is the electrical system consisting of PSCo's transmission system and the neighbouring utility's transmission systems that could be impacted by the interconnection of the Study Pocket GIR(s).

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 neighbouring utilities 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 neighbouring utilities included in the analysis include TSGT transmission system in the study area.

4.4.3 Eastern Colorado Study Area

The study area selected for the Eastern Colorado study pocket includes WECC designates zones 700, 703 and 706. The neighbouring utilities included in the analysis include TSGT, IREA and WAPA systems in the study area.

5.0 Base Case Modeling Assumptions

Except for GI-2020-5, all GIRs have a COD towards the end of 2022 or 2023. The 2023HS case developed for the 2019 Colorado Coordinated Planning Group TPL1-4 studies is selected as the

starting case to perform the Southern Colorado and Eastern Colorado study pocket analysis. The case was reviewed by PSCo and neighboring utilities within the Colorado Coordinated Planning Group (CCPG) footprint and updates are incorporated.

The GI-2020-5, Northern Colorado Study Pocket analysis is done by selecting the 2020HW WECC approved base case released on February 28, 2020, consistent with the COD of the GIR.

5.1 2023HS Base Case Modeling

The Base Case is created from the starting case by including the following un-built transmission projects. All transmission planned projects in PSCo's 10 year transmission plan that are expected to be in-service before July 2023, and have internal approval are modeled in the Base Case.
The PSCo planned projects are described at:
http://www.oasis.oati.com/woa/docs/PSCO/PSCOdocs/FERC_890_Q1_2020_Transmission_Plan_Presentation.pdf
The PSCo projects modeled in the Base Case include the following:

- 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
- High Point Substation –ISD 2022
- Titan Substation – ISD 2022
- 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

All transmission facilities are modeled per the latest FAC008-3 release. Also, the following planned rating upgrades are modeled in the Base Case:

- 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 Leetsdale – Monaco 230kV line to 560MVA – ISD 2021
- Upgrade Greenwood – Monaco 230kV line to 560MVA – ISD 2021

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

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

- Burnt Mill – Greenhorn 115kV Rebuild (1/21/2021)
- Desert Cove - Ftn Valley Rebuild (1/22/2021)
- Nyberg - Airport Memorial Rebuild (1/22/2021)
- Pueblo West substation (4/13/2021)
- Pueblo Reservoir – Burnt Mill 115kV Rebuild (8/31/2021)
- Boone - South Fowler 115kV Project (10/1/2021)
- North Penrose Substation (January 2022)
- West Station – Pueblo Res 115kV Rebuild (1/31/2022)

The following additional changes were made to the Colorado Springs Utilities (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 S 115/230kV transformer project tapping the Cottonwood – Fuller 230kV line – ISD 2023

The Base Case model includes the existing PSCo generation resources. In addition, the following higher-queued generation from PSCo's queue are modeled in the Base Case: GI-2014-6, GI-2014-8, GI-2014-9, GI-2014-13, Transitional Cluster (GI-2018-24 and GI-2019-6) and 1RSC-2020 (RSC-2020-1, RSC-2020-2 and RSC-2020-4). While the higher-queued NRIS requests are dispatched at 100% nameplate, the higher-queued ERIS requests are modeled offline. Since RSC-2020-4 represents the same project and replaces GI-2014-12 and the Interconnection Customer has committed to terminate the existing 2014-12 LGIA, GI-2014-12 is modeled offline in the Base Case.

5.1.1 Affected System Model

The following GIRs from the neighboring utility's current queues are modeled in the Base Case per neighboring Utility's request.

IREA:

- 80MW Pioneer Solar PV facility interconnecting on the Victory – Brick Center 115kV line – COD 12/31/2020
- 75MW Hunter Solar PV facility interconnecting at Brick Center 115kV Substaiton – COD 2/1/2022
- 54.5MW Kiowa Solar PV facility interconnecting at Victory 115kV Substation – COD 4/1/2023

TSGT:

- TI-17-0224, 104MW NRIS Wind, Big Sandy-Landsman Ck 230kV line (ISD is 2020)
- TI-18-0827, 145MW NRIS Wind, Redtail substation
- TI-18-0809, 100MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line
- TI-19-1016, 40MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line (schedule to NM)
- TI-19-0828, 200MW NRIS/ERIS Wind, North Yuma-Story 230kV line

None of the GIs in BHE queue are considered to impact PSCo.

5.2 2023HW Base Case Modeling

Consistent with the COD of the GI-2020-5, the 2020HW WECC base case released on February 28, 2020 is selected for the studies.

There are no future transmission planned projects in PSCo's 10 year transmission plan expected to be in-service between November 2020 and when these studies are being performed, so no additional projects are modeled.

The Base Case model includes the existing PSCo generation resources. In addition, the following higher-queued generation from PSCo's queue are modeled in the Base Case: GI-2014-6, GI-2014-8, GI-2014-9, GI-2014-13, Transitional Cluster (GI-2018-24 and GI-2019-6) and 1RSC-2020 (RSC-2020-1, RSC-2020-2 and RSC-2020-4). While the higher-queued NRIS requests are dispatched at 100% nameplate, the higher-queued ERIS requests are modeled offline. Since RSC-2020-4 represents the same project and replaces GI-2014-12 and the Interconnection Customer has committed to terminate the existing 2014-12 LGIA, GI-2014-12 is modeled offline in the Base Case.

5.2.1 Affected System Model

The following GIRs from the neighboring utility's current queues are modeled in the Base Case per neighboring Utility's request.

IREA:

- 80MW Pioneer Solar PV facility interconnecting on the Victory – Brick Center 115kV line – COD 12/31/2020
- 75MW Hunter Solar PV facility interconnecting at Brick Center 115kV SUbstaiton – COD 2/1/2022
- 54.5MW Kiowa Solar PV facility interconnecting at Victory 115kV Substation – COD 4/1/2023

TSGT:

- TI-17-0224, 104MW NRIS Wind, Big Sandy-Landsman Ck 230kV line (ISD is 2020)
- TI-18-0827, 145MW NRIS Wind, Redtail substation
- TI-18-0809, 100MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line
- TI-19-1016, 40MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line (schedule to NM)
- TI-19-0828, 200MW NRIS/ERIS Wind, North Yuma-Story 230kV line

None of the GIs in BHE queue are considered to impact PSCo.

6.0 Generation Interconnection Service Analysis

The GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7, and GI-2020-10 are studied in the Southern Colorado study pocket, the Interconnection Service for the five GIRs is determined using the Southern Colorado study pocket analysis results. Similarly, the Interconnection Service for GI-2020-5 is determined using the Northern Colorado study pocket analysis results and the Interconnection Service for GI-2020-6 is determined using the Eastern Colorado study pocket analysis.

6.1 Voltage and Reactive Power Capability Evaluation

All GIRs except GI-2020-5 are non-Synchronous generators. Accordingly, the following voltage regulation and reactive power capability requirements at the POI are applicable to the non-synchronous GIRs in DISIS-2020-001:

- 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 looks for the capability of the GIR to maintain ±0.95pf at the high side of the main step-up transformer and maintain normal steady state operating voltage range (0.95-1.05 p.u.) at the POI. All GIRs are required to design their interconnection to meet the POI voltage control requirements that will be specified by PSCo's Transmission Operations group.

For synchronous generators, Xcel Energy's OATT requires the Interconnection Customer design the Large Generating Facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging at the POI.

6.1.1 GI-2020-1 reactive capability evaluation

According to the modeling data provided by the Customer, GI-2020-1 generator model is as follows: Pmax=204MW, Pmin=0MW, Qmax=98Mvar, Qmin=-98Mvar. Additionally, the Generating Facility includes a 20Mvar shunt capacitor bank.

Since the analysis indicates GI-2020-1 is able to maintain 0.936 lag and 0.725 lead power factor, the GI is capable of meeting ±0.95pf at the high side of the main step-up transformer while maintaining at least 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels.

Table 2 - Reactive capability evaluation of GI-2020-1

Gen MW / Mvar	20 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
204MW / 98Mvar	on	1.175	1.056	199.4	75.2	0.936 (lag)	1.055	199.4	75.2	0.936 (lag)
204MW / -98Mvar	off	0.847	1.009	195.3	-185.6	0.725 (lead)	1.01	195.3	-186	0.724 (lead)
20.4MW / 6.5Mvar	off	1.052	1.042	20.3	6.6	0.951 (lag)	1.042	20.3	6.6	0.951 (lag)
20.4MW / -6.5Mvar	off	1.034	1.039	20.3	-6.6	0.951 (lead)	1.039	20.3	-6.6	0.951 (lead)

Gen MW / Mvar	20 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
0MW / -98Mvar	off	0.884	1.021	-1.5	-112.6	N/A	1.021	-1.5	-112.5	N/A

6.1.2 GI-2020-3 reactive capability evaluation

According to the modeling data provided by the Customer, GI-2020-3 generator model is as follows: Pmax=204MW, Pmin= 0MW, Qmax=99Mvar, Qmin=-99Mvar.

The reactive capability analysis indicates that GI-2020-3 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining at least 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels.

Table 3 – Reactive Capability Evaluation for GI-2020-3

Gen MW / Mvar	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
204MW / 99Mvar	1.108	1.037	199	71.6	0.941 (lag)	1.036	199	71.2	0.942 (lag)
204MW / -99Mvar	0.894	0.978	197.7	-143.9	0.809 (lead)	0.979	197.6	-144.2	0.808 (lead)
20.4MW / 3.1Mvar	1.022	1.018	18.3	6	0.950 (lag)	1.018	18.3	6.2	0.947 (lag)
20.4MW / -8.8Mvar	1.011	1.015	18.3	-6	0.950 (lead)	1.016	18.3	-5.8	0.953 (lead)
0MW / -62.7Mvar	0.952	1	-2.3	-62.9	N/A	1	-2.3	-62.7	N/A

6.1.3 GI-2020-4 reactive capability evaluation

According to the modeling data provided by the Customer, GI-2020-4 generator model is as follows: Pmax=100MW, Pmin=0MW, Qmax=52.2Mvar, Qmin=-52.2Mvar.

The reactive capability analysis indicates that GI-2020-4 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining atleast 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels.

Table 4 – Reactive Capability Evaluation of GI-2020-4

Gen MW / Mvar	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
100MW / 52.2Mvar	1.106	1.05	99.2	44	0.914 (lag)	1.049	99.2	44.2	0.913 (lag)
100MW / -52.2Mvar	0.974	0.974	99	-63.9	0.840 (lead)	1.031	99	-63.6	0.841 (lead)
10MW / 0.1Mvar	1.045	1.041	10	3.3	0.950 (lag)	1.041	10	3.6	0.941 (lag)
10MW / -6.4Mvar	1.036	1.04	10	-3.3	0.950 (lead)	1.04	10	3	0.958 (lead)
0MW / -5.8Mvar	1.036	1.032	-0.2	-52.2	N/A	1.032	-0.2	-51.9	N/A

6.1.4 GI-2020-5 reactive capability evaluation

The Fort Saint Vrain#4 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 generator is modeled by increasing the Qmax and Qmin values pro-rata for the 24MW increase in Fort Saint Vrain#4 capacity. The analysis indicates that the incremental output is capable of meeting +/-0.95 power factor at the POI.

Table 5 – Reactive Capability Evaluation of GI-2020-5

Gen MW / Mvar	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
177MW / 105.2Mvar	1.039	1.022	172.6	84.8	0.898 (lag)	1.022	172.6	84.8	0.898 (lag)
177MW / -55.9Mvar	0.961	1.016	172.6	-75.8	0.916 (lead)	1.016	172.6	-75.8	0.916 (lead)

6.1.5 GI-2020-6 reactive capability evaluation

According to the modeling data provided by the Customer, GI-2020-6 generator model is as follows: Pmax=202MW, Pmin= 0MW, Qmax=115Mvar, Qmin=-115Mvar.

The reactive capability analysis indicates that GI-2020-6 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining at least 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels.

Table 6 – Reactive Capability Evaluation of GI-2020-6

Gen MW / Mvar	Gen Voltage (p.u.) - (Gen1 / Gen2 / Gen3 / Gen4)	Main Step-up Transformer High Side				POI			
		Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
202MW / 115Mvar	1.146 / 1.146 / 1.146 / 1.146	1.06	199.8	78	0.932 (lag)	1.059	199.6	77.9	0.932 (lag)
202MW / -115Mvar	0.88 / 0.88 / 0.876 / 0.876	1.004	198.2	-176.6	0.747 (lead)	1.005	197.6	-177.2	0.744 (lead)
20.2MW / 6.4Mvar	1.048 / 1.048 / 1.048 / 1.048	1.042	20.2	6.6	0.951 (lag)	1.041	20.2	6.8	0.948 (lag)
20.2MW / -6.8Mvar	1.034 / 1.034 / 1.034 / 1.034	1.039	20.2	-6.6	0.951 (lead)	1.039	20.2	-6.4	0.953 (lead)
0MW / -83.2Mvar	0.943 / 0.943 / 0.941 / 0.941	1.02	-0.4	-89.4	N/A	1.021	-0.4	-89.3	N/A

6.1.6 GI-2020-7 reactive capability evaluation

According to the modeling data provided by the Customer, GI-2020-7 generator model is as follows: Pmax=1023MW, Pmin= 0MW, Qmax=542.674Mvar, Qmin=-542.67Mvar. In addition, 2x45 Mvar shunt capacitor bank was modelled at the 345kV bus.

The reactive capability analysis indicates that GI-2020-7 is capable of maintaining ±0.95pf at the high side of the main step-up transformer, however there is significant Mvar absorption on the generation tie-line. The Interconnection Customer is required to compensate the losses on the generation tie-line by installing static and/or dynamic reactive devices. The reactive power flow analysis will be studied in detail under Phase 2.

Table 7 – Reactive Capability Evaluation of GI-2020-7

Gen MW / Mvar	Gen Voltage (p.u.) (Gen1 / Gen2 / Gen3 / Gen4)	Main Step-up Transformer High Side				POI			
		Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
1023.4MW / 542.7Mvar	1.147 / 1.135 / 1.147 / 1.147	1.059	1009.7	388.8	0.933 lag	1.014	999.1	294.3	0.959 lag
1023.4MW / -105.3Mvar	0.786 / 0.866 / 0.786 / 0.786	0.86	1000.6	-394.6	0.930 lead	0.897	983.8	-561	0.869 lead
102.34MW / 9Mvar	1.018 / 1.005 / 1.018 / 1.018	1.01	102.2	33.6	0.950 lag	1.005	102.1	48.8	0.902 lag
100MW / -57Mvar	0.989 / 0.991 / 0.989 / 0.989	0.997	102.2	-33.6	0.950 lead	0.998	102	-18.6	0.984 lead
0MW / -43.8Mvar	0.994 / 0.994 / 0.994 / 0.994	1	0	-17.9	N/A	1.001	0	-1.7	N/A

6.1.7 GI-2020-10 reactive capability evaluation

According to the modeling data provided by the Customer, GI-2020-10 generator model is as follows: Pmax=239MW, Pmin= 0MW, Qmax=124.7Mvar, Qmin=-124.7Mvar. The PV and BES generators are controlled together to maintain the reactive power requirements.

The reactive capability analysis indicates that GI-2020-10 is capable of maintaining ±0.95pf at the high side of the main step-up transformer while maintaining at least 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels.

Table 8 – Reactive Capability Evaluation of GI-2020-10

Gen MW(PV/BESS) / Mvar (PV/BESS)	Gen Voltage (p.u.) (PV/BESS)	Main Step-up Transformer High Side				POI			
		Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
239MW / 124.7Mvar	1.125 / 1.082	1.059	230.5	83.3	0.940 (lag)	1.058	230.5	83.1	0.941 (lag)
239MW / -124.7Mvar	0.888 / 0.885	0.997	226.1	-193.1	0.760 (lead)	0.998	226.5	-193.3	0.761 (lead)
23.9MW / 7.2Mvar	1.022 / 1.019	1.04	22	7.2	0.950 (lag)	1.04	22	7.2	0.950 (lag)
23.9MW / -7.2Mvar	1.010 / 1.008	1.037	22	-7.2	0.950 (lead)	1.037	22	-7.2	0.950 (lead)
0MW / -124.7MVar	0.889 / 0.914	1.008	-3.1	-136.3	N/A	1.008	-3.1	-136.3	N/A

6.2 Southern Colorado Study Pocket Analysis

6.2.1 Benchmark Case Modeling

The Benchmark Case for evaluating the Southern Colorado Study Pocket GIRs is developed from the Base Case described in Section 5.1 of this report 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 given in Table 9. The stressed dispatch from the respective generator is balanced by decreasing the respective owner's generation outside the study pocket on a pro-rata basis. The generation dispatch of the neighboring systems was provided by the neighboring utilities.

Table 9 – Generation Dispatch Used to Stress the Southern Study Pocket Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
COGENTRIX_PV34.500	S3	1	19.5	30	PSCo

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
COMAN_1 24.000	C1	1	360	360	PSCo
COMAN_2 24.000	C2	1	365	365	PSCo
COMAN_3 27.000	C3	1	869	869	PSCo
COMAN_PV 34.500	S1	1	104.1	122.5	PSCo
CO_GRN_E 34.500	W1	1	17	81	PSCo
CO_GRN_W 34.500	W2	1	17	81	PSCo
FTNVL1&2 13.800	G1	1	36	40	PSCo
FTNVL1&2 13.800	G2	1	36	40	PSCo
FTNVL3&4 13.800	G3	1	36	40	PSCo
FTNVL3&4 13.800	G4	1	36	40	PSCo
FTNVL5&6 13.800	G5	1	36	40	PSCo
FTNVL5&6 13.800	G6	1	36	40	PSCo
GSANDHIL_PV 34.500	S1	1	12.4	19	PSCo
JKFULGEN 0.6900	W1	1	199.5	250	PSCo
LAMAR_DC 230.00	DC	0	0	210	PSCo
SOLAR_GE 34.500	S2	1	19.5	30	PSCo
TWNBUTTE 34.500	W1	1	15.8	75	PSCo
SUNPOWER 34.500	S1	1	33.8	52	PSCo
SI_GEN 0.6000	1	1	25.5	30	TSGT
TBII_GEN 0.6900	W	1	16	76	TSGT
TI-18-0809 0.6300	PV	1	85	100	TSGT
TI-19-1016 0.6300	PV	1	34	40	TSGT
APT_DSLF 4.1600	G1	0	0	10	BHE
BAC_MSA GEN113.800	G1	1	90	90	BHE
BAC_MSA GEN213.800	G1	1	90	90	BHE
BAC_MSA GEN413.800	G1	1	35	40	BHE
BAC_MSA GEN413.800	G2	1	35	40	BHE
BAC_MSA GEN413.800	S1	1	20	24.8	BHE
BAC_MSA GEN513.800	G1	1	20	40	BHE
BAC_MSA GEN513.800	G2	1	30	40	BHE
BAC_MSA GEN513.800	S1	1	14	24.8	BHE
BAC_MSA GEN613.800	G1	0	0	40	BHE
BUSCHRNCH_LO0.7000	W1	1	30	59.4	BHE
BUSCHRWTG1 0.7000	G1	1	14	28.8	BHE

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
PEAKVIEWLO 0.7000	G1	1	22	60	BHE
PUB_DSLS 4.1600	G1	0	0	8	BHE
R.F.DSLS 4.1600	G1	0	10	10	BHE
GI-2014-13 34.5	S1	0	53	53	N/A
GI-2014-6 34.5	S1	1	100	100	PSCo
GI-2014-8 34.5	S1	1	60	60	PSCo
GI-2014-9 34.5	WS	1	70	70	PSCo
GI-2014-12 34.5	S1	0	0	53	N/A
GI-2018-24 34.5	S1	1	250	250	PSCo
GI-2019-6 34.5kV	S1	0	0	240	N/A
RSC-2020-2	1	0	0	75	N/A
RSC-2020-4	1	0	0	53	N/A

6.2.2 Study Case Modeling

6.2.2.1 Mirasol Substation Configuration

The Southern Colorado study pocket has 3 GIRs requesting POI at the Mirasol Substation – GI-2020-1, GI-2020-4 and GI-2020-7.

Mirasol is a new 230/345kV Substation with 230kV and 345kV voltages and expected to be located approximately 10 miles east of the existing Comanche Substation. The facilities required to configure the Mirasol Substation are:

- Tap the Comanche – Midway 230kV line # 1
- Tap Comanche – GI-2014-9 – Midway 230kV line # 2
- Tap the Comanche – Tundra – Daniels Park 345kV line
- Install one 230/345kV, 560MVA transformer

This configuration did not result in any overloads.

The cost of the upgrades is assigned as follows:

Mirasol Station Network Upgrades - required to tap the two 230kV kV lines and one 345kV line. Cost allocated to GI-2020-1, GI-2020-4 and GI-2020-7 on a per capita basis.

Other Southern Colorado Study Pocket Network Upgrades –Mirasol 230/345kV, 560MVA transformer is shared based on the proportional impact of each GIR on the Network Upgrade.

The NRIS Study Case is created from the Benchmark Case by modeling all Southern Pocket GIRs. The GI-2020-10 NRIS request was modeled at the same POI as GI-2014-9 and dispatched at its full requested amount of 230MW. The output of GI-2020-10 was balanced by redispatching the PSCo generation outside the study area on a pro-rata basis. The ERIS GIRs are modeled offline.

The ERIS Study case was created from the NRIS Study case by (1) modeling the NRIS upgrades, (2) increasing the output of (a) GI-2020-1, GI-2020-4 and GI-2020-7 at Mirasol 230/345 kV Substation, and (b) GI-2020-3 on the Boone – Comanche 230kV line. The total 1697MW of ERIS generation is balanced by redispatching the PSCo and non-PSCo resources outside the study pocket on a pro-rata basis.

6.2.3 Steady State Analysis

The results of the single contingency analysis (P1 and P2-1) for the NRIS Study case are given in Table 10 below.

Table 10 Southern Colorado Study Pocket NRIS Study 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		
Daniels Park – Prairie 230kV #1	Line	PSCo	576	559.3	97.1%	596.2	103.5%	6.3%	Daniels Park – Prairie 230kV #2
Daniels Park – Prairie 230kV #2	Line	PSCo	576	553.5	96.1%	590.4	102.0%	6.3%	Daniels Park – Prairie 230kV #1

The addition of GI-2020-10 resulted in two new overloads in the PSCo system. The overloads on the Daniels Park – prairie 230kV # 1 and Daniels Park – Prairie 230kV 230kV # 2 lines can be mitigated by replacing the conductor with 756MVA capable conductor. Since GI-2020-10 is the only GIR dispatched above zero in the NRIS Study Case, the total cost of the two upgrades is 100% allocated to GI-2020-10.

The results of the multiple contingency analysis for the NRIS Study Case are given in Table 11 below. The multiple contingency analysis shows several new overloads after the addition of GI-2020-10. Per TPL1-4, multiple contingency overloads can be mitigated using system adjustments, including generation redispatch (existing and GIRs under study) and/or operator actions. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the PSCo multiple contingencies studies in Table 11 below. 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.

Table 101 – Southern Colorado Study Pocket NRIS Study Results – Overloads identified in Multiple Contingencies

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in NRIS Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Boone – Comanche 230kV #1	Line	PSCo	318.7	316.3	99.3	341.3	107.1%	7.8%	Comanche – Daniels Park 345kV #1 & Daniels Park – Tundra 345kV #1
Boone – MidwayPS 230kV # 1	Line	PSCo	318.7	307.9	96.6%	352.2	110.0%	13.4%	Daniels Park - Comanche 345kV # 1 & 2
Comanche – Mirasol 230kV #1	Line	PSCo	478	454.1	95.0%	505.7	105.80%	10.8%	Daniels Park - Comanche 345kV # 1 & Mirasol - Comanche 345kV # 1
Fountain Valley - MidwayBR	Line	PSCo	171.0	150.5	88.0%	171.5	100.3%	12.3%	Daniels Park - Comanche 345kV # 1 & 2
HydePark – PuebloInt 115kV # 1	Line	PSCo	160.0	150.7	94.2%	171.5	107.2%	13.0%	Daniels Park - Comanche 345kV # 1 & 2
MidwayPS – Midway BR 230kV # 1	Line	PSCo	576	533.4	92.6%	627.3	108.9%	16.3%	Mirasol - Tundra 345kV # 1 & Comanche – Daniel Park 345kV #1

Following the evaluation of NRIS GIR, the Daniels Park – Prairie 1 230kV line # 1 and Daniels Park – Prairie2 230kV line #2 Network Upgrades are modeled in the Study Case and ERIS GIR(s) in the study pocket are modeled at 100%. The results of the single contingency analysis (P1 and P2-1) for the ERIS Study case are given in Table 12 below.

Table 12 Southern Colorado Study Pocket ERIS study results – Overloads identified in Single Contingency Analysis

Overloaded Facility	Type	Owner	Facility Normal Rating (MVA)	Facility Loading in NRIS Study Case		Facility Loading in ERIS 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	478	322	67.4%	533.3	111.6%	44.2%	System Intact	Beyond POI Sub	Yes
MidwayPS 115/230kV # 1	Xfmr	PSCo	150	112.9	75.3%	158.01	105.3%	30.1%	System Intact	Beyond POI Sub	Yes
Palmer Lake – Monument 115kV #1	Line	PSCo /CSU	108	63.6	58.9%	112.83	104.5%	45.6%	System Intact	Beyond POI Sub	Yes
Boone – GI-2020-3 Switching Station 230kV #1	Line	PSCo	318.7	174	54.6%	386.97	121.4%	66.8%	Daniels Park – Tundra 345kV Line # 1	Connected to POI Sub	Yes
Midway – Mirasol 230kV # 1	Line	PSCo	478	299.5	62.6%	590.38	123.5%	60.9%	Daniels Park – Tundra 345kV Line # 1	Connected to POI Sub	Yes
Midway – Mirasol 230kV # 2	Line	PSCo	478	299.5	62.6%	590.38	123.5%	60.9%	Daniels Park - Tundra 345kV Line # 1	Connected to POI Sub	Yes
Tundra – Mirasol 345kV # 1	Line	PSCo	1195	698.6	58.5%	1431.2	119.8%	61.3%	Daniels Park – Comanche 345kV Line# 1	Connected to POI Sub	Yes

Black Forest Tap – Black Squirrel MV 115kV # 1	Line	TSGT	143	125	87.4%	194.9	136.3%	48.9%	Daniels Park – Fuller 115kV Line # 1	Beyond POI Sub	Yes
Boone – MidwayPS 230kV # 1	Line	PSCo	319	206.1	64.7%	405.9	127.4%	62.7%	Daniels Park – Tundra 345kV Line # 1	Beyond POI Sub	Yes
Daniels Park – Prairie1 230kV # 1	Line	PSCo	756	596.5	78.9%	819.9	108.5%	29.6%	Daniels Park – Prairie3 230kV # 2	Beyond POI Sub	Yes
Daniels Park – Prairie1 230kV # 2	Line	PSCo	756	587.4	77.7%	814.5	107.7%	30.0%	Daniels Park – Prairie1 230kV # 1	Beyond POI Sub	Yes
Daniels Park 345/230kV # 4	Xfmr	PSCo	560	493.2	88.1%	626.8	111.9%	23.9%	Daniels Park 345/230kV # 3 or 5	Beyond POI Sub	Yes
Daniels Park 345/230kV # 5	Xfmr	PSCo	560	493.2	88.1%	626.8	111.9%	23.9%	Daniels Park 345/230kV # 3 or 4	Beyond POI Sub	Yes
Daniels Park 345/230kV # 3	Xfmr	PSCo	560	493.2	88.1%	626.8	111.9%	23.9%	Daniels Park 345/230kV # 4 or 5	Beyond POI Sub	Yes
Daniels Park – Comanche 345kV # 1	Line	PSCo	1195	915.3	76.6%	1680.7	140.6%	64.0%	Daniels Park – Tundra 345kV Line # 1	Beyond POI Sub	Yes
Daniels Park – Tundra 345kV Line # 1	Line	PSCo	1195	916.2	76.7%	1686.1	141.1%	64.4%	Daniels Park – Comanche 345kV # 1	Connected to POI Sub	Yes
Daniels Park – Fuller 230kV # 1	Line	PSCo	478	356.2	74.5%	592.3	123.9%	49.4%	West Canyon – PonchaBR 230kV Line # 1	Beyond POI Sub	Yes
Fountain Valley – MidwayBR 115kV # 1	Line	BHE	171	101.1	59.1%	186.3	108.9%	49.8%	Daniels Park – Tundra 345kV Line # 1	Beyond POI Sub	Yes
Fuller 230/115kV # 1	Xfmr	TSGT	100	76.5	76.5%	101.9	101.9%	25.4%	Daniels Park – Fuller 115kV # 1	Beyond POI Sub	Yes
Fuller 230/115kV # 2	Xfmr	TSGT	100	76.5	76.5%	101.9	101.9%	25.4%	Daniels Park – Fuller 115kV Line # 1	Beyond POI Sub	Yes
Greenwood – Monaco 230kV # 1	Line	PSCo	560	468.4	83.6%	560.7	100.1%	16.5%	Buckley – Smokyhill 230kV Line # 1	Beyond POI Sub	Yes

Greenwood – Prairie 1 230kV # 2	Line	PSCo	576	522.8	90.8%	748.1	129.9%	39.1%	Daniels Park – Prairie3 230kV Line # 2	Beyond POI Sub	Yes
Greenwood – Prairie 3 230kV # 1	Line	PSCo	576	536.4	93.1%	760.6	132.0%	38.9%	Daniels Park – Prairie3 230kV Line # 1	Beyond POI Sub	Yes
Gresham – BlakForest Tap 115kV # 1	Line	TSGT	173	119.8	69.2%	189.5	109.6%	40.3%	Daniels Park – Fuller 115kV Line # 1	Beyond POI Sub	Yes
Hyde Park – Pueblo Plant 115kV # 1	Line	BHE	160	103.2	64.5%	182.3	114.0%	49.4%	Daniels Park – Tundra 345kV Line # 1	Beyond POI Sub	Yes
Kelker E – Templeton 115kV # 1	Line	CSU	131	114.1	87.1%	135.9	103.7%	16.6%	Kelker W – Rock Island 115kV Line # 1	Beyond POI Sub	Yes
Midway – Fuller 230kV # 1	Line	PSCo	382	325.8	85.2%	520.6	136.1%	51.0%	Daniels Park – Tundra 345kV # 1	Beyond POI Sub	Yes
MidwayPS 345/230kV # 3	Xfmr	PSCo	560	450.1	80.4%	703	125.5%	45.2%	Daniels Park – Tundra 345kV # 1	Beyond POI Sub	Yes
MidwayPS 115/230kV # 1	Xfmr	PSCo	150	135.8	90.5%	197.5	131.7%	41.1%	Daniels Park – Comanche 345kV Line # 1	Beyond POI Sub	Yes
Monument – Gresham 115kV # 1	Line	TSGT	145	116.1	80.1%	185.8	128.1%	48.0%	Daniels Park – Fuller 115kV Line # 1	Beyond POI Sub	Yes
Palmer Lake – Monument 115kV # 1	Line	PSCo	108	105.9	98.0%	188	174.1%	76.1%	Daniels Park – Fuller 115kV # 1	Beyond POI Sub	Yes
Portland – Skala 115kV # 1	Line	BHE	120	86.4	72.0%	120.7	100.6%	28.6%	MidwayBR – West Canyon # 1	Beyond POI Sub	Yes
Pueblo Plant – Reader 115kV # 1	Line	BHE	160	120.7	75.4%	200.7	125.4%	50.0%	Daniels Park – Tundra 345kV # 1	Beyond POI Sub	Yes
Vollmer – Black Squirrel 115kV # 1	Line	TSGT	173	153.6	88.8%	224	129.5%	40.7%	Daniels Park – Fuller 115kV # 1	Beyond POI Sub	Yes
Vollmer – Fuller 115kV # 1	Line	TSGT	173	153.7	88.8%	224.1	129.5%	40.7%	Daniels Park – Fuller 115kV # 1	Beyond POI Sub	Yes
West Canyon – Hogback 115kV # 1	Line	BHE	120	101.7	84.7%	157.6	131.3%	46.6%	MidwayBR – West Canyon # 1	Beyond POI Sub	Yes

West Canyon 230/115kV # 1	Line	BHE	100	75.6	75.6%	128.8	128.8%	53.2%	MidwayBR – West Canyon # 1	Beyond POI Sub	Yes
Waterton 345/230kV # 3	Xfmr	PSCo	560	443.3	79.2%	702.5	125.4%	46.3%	Daniels Park – Tundra 345kV # 1	Beyond POI Sub	Yes

Table 12 shows the ERIS overloads for stressed generation dispatch in the Southern Colorado region. The OPF identified redispatch scenarios for each of the overloads. Since all ERIS overloads were mitigated using redispatch, no new Network Upgrades are identified and the full ERIS can be accommodated for all the GIRs as described below:

- ERIS of GI-2020-1 is 199MW
- ERIS of GI-2020-3 is 199MW
- ERIS of GI-2020-4 is 100MW
- ERIS of GI-2020-7 is 1000MW

The results of the multiple contingency analysis for the ERIS Study case are given in Table 13 below.

Table 113 – Power Flow Analysis Results of Southern Colorado Study Pocket ERIS GIRs – Overloads identified in Multiple Contingencies

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in NRIS Study Case		Facility Loading in ERIS Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Black Forest Tap - Black Squirrel 115kV # 1	Line	TSGT	143.0	173.3	121.2%	290.4	203.1%	81.8%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
Boone – MidwayPS 230kV # 1	Line	PSCo	318.7	259.9	81.6%	502.0	157.5%	76.0%	Mirasol – MidwayPS 230kV Line # 1 & 2

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in NRIS Study Case		Facility Loading in ERIS Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Bradley S – Fountain N 115kV # 1	Line	CSU	212.0	200.2	94.4%	231.1	109.0%	14.6%	Kelker North – South 230kV bus tie
Claremont – Fuller 230kV # 1	Line	CSU	376.0	297.4	79.1%	458.6	122.0%	42.9%	Midway – Waterton 345kV # 1 & Midway – Fuller 230kV # 1
Daniels Park – Fuller 230kV # 1	Line	PSCo	478.0	396.8	83.0%	789.3	165.1%	82.1%	Comanche – Tundra 345kV Line #1 & COMANCHE 230/345kV Xfmr # 4
Daniels Park – Tundra 345kV # 1	Line	PSCo	1195.0	902.3	75.5%	1700.6	142.3%	66.8%	Comanche – Daniels Park 345kV # 1 & Daniels Park 345/230kV # 4
DesertCove – West Station 115kV # 1	Line	BHE	222.0	183.2	82.5%	324.8	146.3%	63.8%	MidwayPS – Fuller 230kV Breaker failure
Fountain S – RD_Nixon 115kV # 1	Line	CSU	212.0	260.3	122.8%	293.0	138.2%	15.5%	Kelker North – South 230kV bus tie
Fountain Valley – Desertcove 115kV # 1	Line	BHE	222.0	180.2	81.2%	321.7	144.9%	63.7%	MidwayPS – Fuller 230kV Breaker failure
Fountain Valley – MidwayBR 115kV # 1	Line	BHE	171.0	178.9	104.6%	320.3	187.3%	82.7%	MidwayPS – Fuller 230kV Breaker failure
Fuller 230/115kV # 1	Xfmr	TSGT	100.0	96.8	96.8%	140.3	140.3%	43.6%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
Fuller 230/115kV # 1	Xfmr	TSGT	100.0	96.8	96.8%	140.3	140.3%	43.6%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in NRIS Study Case		Facility Loading in ERIS Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Greenwood – Prairie 1 230kV # 1	Line	PSCo	576.0	414.9	72.0%	617.7	107.2%	35.2%	Greenwood – Leetsdale 230kV # 1 & Greenwood – Daniels Park 230kV # 1
Greenwood – Prairie 3 230kV # 1	Line	PSCo	576.0	488.7	84.8%	732.5	127.2%	42.3%	Daniels Park – Greenwood 230kV# 1 & Daniels Park – Missile 230kV # 1
Gresham – Black Forest Tap 115kV # 1	Line	TSGT	173.0	168.1	97.1%	284.6	164.5%	67.4%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
Hydepark – Pueblo plant 115kV # 1	Line	BHE	160.0	120.8	75.5%	215.6	134.7%	59.2%	Mirasol – MidwayPS 230kV # 1 & 2
Kelker E – Templeton 115kV # 1	Line	CSU	146.0	137.6	94.3%	160.2	109.7%	15.5%	Kelker West 115kV Bus
Kelker W – Rock Island 115kV # 1	Line	CSU	180.0	177.0	98.3%	187.9	104.4%	6.1%	Cottonwood S – Steston 230kV # 1 & Cottonwood N - Fuller 230kV # 1
MidwayBR – Rancho 115kV # 1	Line	TSGT	145.0	106.2	73.3%	149.4	103.0%	29.7%	Midway – Waterton 345kV #1 & MidwayPS – Fuller 230kV # 1
MidwayBR – RD_Nixon 230kV # 1	Line	CSU	531.0	410.6	77.3%	681.1	128.3%	50.9%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
Midway 230/115kV # 1	Xfmr	PSCo	115.0	125.2	83.5%	187.3	124.8%	41.4%	BOONE – MIDWAYPS 230kV Line, BOONE – LAMAR 230kV Line
MidwayPS – Fuller 230kV # 1	Line	PSCo	382.4	400.6	104.8%	654.7	171.2%	66.5%	Midway 230kV Bus tie

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in NRIS Study Case		Facility Loading in ERIS Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
MidwayPS – MidwayBR 230kV # 1	Line	PSCo/ WAPA	576.0	682.1	118.4%	1150.0	199.7%	81.2%	Midway – Waterton 345kV #1 & Midway – Fuller 230kV # 1
Monument – Gresham 115kV # 1	Line	TSGT	145.0	164.3	113.3%	280.6	193.5%	80.2%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
Palmer Lake – Monument 115kV # 1	Line	PSCo/ CSU	108.0	161.6	149.6%	297.9	275.8%	126.2%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
Portland – Skala 115kV # 1	Line	BHE	120.0	90.9	75.8%	133.5	111.3%	35.5%	Midway – Waterton 345kV #1 & Midway – Fuller 230kV # 1
Pueblo Plant – Reader 115kV # 1	Line	BHE	160.0	138.2	86.4%	233.3	145.8%	59.4%	MIRASOL – MIDWAYPS 230kV Line # 1 & # 2
Rancho – LorsonRanch 115kV # 1	Line	TSGT	145.0	103.0	71.0%	145.9	100.6%	29.6%	Midway – Waterton 345kV #1 & Midway – Fuller 230kV # 1
Vollmer Tap – Black Squirrel 115kV # 1	Line	TSGT	173.0	202.1	116.8%	320.5	185.3%	68.4%	Midway – Waterton 345kV #1 & Daniels Park – Fuller 230kV # 1
West Canyon – Hogback 115kV # 1	Line	BHE	120.0	109.0	90.8%	177.7	148.1%	57.3%	MidwayPS – Fuller 230kV Breaker failure
West Canyon 230/115kV # 1	Xfmr	BHE	100.0	82.4	82.4%	144.7	144.7%	62.3%	MidwayPS – Fuller 230kV Breaker failure
Waterton 345/230kV # 3	Xfmr	PSCo	756.0	518.9	68.6%	812.5	107.5%	38.8%	MidwayPS – 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. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the PSCo multiple contingencies studies in Table 13 above. 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

There are no impacts to Affected System identified in the Southern Colorado study pocket analysis.

The multiple contingency overloads are mitigated using system adjustments, including generation redispatch and/or operator actions.

6.2.5 Summary of Southern Study Pocket Analysis

The maximum ERIS identified for GI-2020-1 is 199MW.
The maximum ERIS identified for GI-2020-3 is 199MW.
The maximum ERIS identified for GI-2020-4 is 100MW.
The maximum ERIS identified for GI-2020-7 is 1000MW.
The NRIS identified for GI-2020-10 is 230MW (after upgrading Daniels Park – Prairie 230kV # 1 and Daniels Park – Prairie 230kV # 2 lines to 756MVA)

6.3 Eastern Study Pocket Analysis

6.3.1 Benchmark Case Modeling

The Benchmark Case for evaluating the Eastern Colorado Study Pocket GIR (GI-2020-6) is developed from the Base Case described in Section 5.1 of this report by stressing the Study Pocket generation dispatch as given in Table 14 for the Eastern Colorado Study Pocket. The generation dispatch of the neighbouring systems was provided by the neighbouring utilities.

Table 14 – Generation Dispatch Used to Stress the Eastern Study Pocket Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
ARAP5&6 13.800	G5	1	35	39	PSCo

ARAP5&6 13.800	G6	1	35	39.5	PSCo
ARAP7 13.800	ST	1	45	47	PSCo
CHEROK2 15.500	SC	1	0	0	PSCo
CHEROK4 22.000	G4	1	350	350	PSCo
CHEROK5 18.000	G5	1	170	202.8	PSCo
CHEROK6 18.000	G6	1	170	194	PSCo
CHEROK7 18.000	ST	1	220	255	PSCo
SPRUCE1 18.000	G1	0	0	162	PSCo
SPRUCE2 18.000	G2	0	0	162	PSCo
MANCHEF1 16.000	G1	1	136.1	151.3	PSCo
MANCHEF2 16.000	G2	1	136.1	151.3	PSCo
PAWNEE 22.000	C1	1	536	536	PSCo
PTZLOGN1 34.500	W1	1	160.8	201	PSCo
PTZLOGN2 34.500	W2	1	96	120	PSCo
PTZLOGN3 34.500	W3	1	63.6	79.5	PSCo
PTZLOGN4 34.500	W4	1	140	175	PSCo
CEDARPOINT 34.500	W1	1	200	250	PSCo
TITAN-PV 34.500	S1	1	42.5	50	PSCo
CHEYRGE_W1 0.6900	W1	1	99.2	124	PSCo
CHEYRGE_W2 0.6900	W2	1	100.8	126	PSCo
CHEYRGW_W1 0.6900	W1	1	99.2	124	PSCo
CHEYRGW_W2 0.6900	W2	1	100.8	126	PSCo
LIMON1_W 34.500	W1	1	160.8	201	PSCo
LIMON2_W 34.500	W2	1	160.8	201	PSCo
LIMON3_W 34.500	W3	1	160.8	201	PSCo
BRONCO_W1 0.6900	W1	1	240	300	PSCo
RUSHCK_W1 34.500	W1	1	304	380	PSCo
RUSHCK_W2 34.500	W2	1	176	220	PSCo
KNUTSON1 13.800	G1	1	64.5	64.5	TSGT
KNUTSON2 13.800	G2	1	64.5	64.5	TSGT
CEDAR2_W1 0.6600	W1	1	31.5	125	PSCo
CEDAR2_W2 0.6900	W2	1	5.25	100.8	PSCo
CEDAR2_W3 0.6600	W3	1	25	25	PSCo
CEDARCK_1A 34.500	W1	1	46.2	220	PSCo
CEDARCK_1B 34.500	W2	1	16.8	80	PSCo

6.3.2 Study Case Modeling

A NRIS Study case was created from the Benchmark Case by modelling GI-2020-6 interconnected at a tap on PSCo's Pawnee – Missile Site 230kV line using the GIR modelling data provided by the Interconnection Customer. The 199MW output of GI-2020-6 was sunk to Fort Saint Vrain and Rocky Mountain Energy Center generation.

6.3.3 Steady State Analysis

The single (P1 and P2-1) and multiple contingency analysis did not identify any overloads attributable to GI-2020-6.

6.3.4 Affected Systems

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

6.3.5 Summary of Eastern Study Pocket Analysis

The maximum NRIS identified for GI-2020-6 is 199MW.

6.4 Northern Study Pocket Analysis

6.4.1 Benchmark Case Modeling

The Benchmark Case for evaluating the Northern Colorado Study Pocket GIR -GI-2020-5 is developed from the Base Case described in Section 5.2 of this report by stressing the Study Pocket generation dispatch as given in Table 15 for the Northern Colorado Study Pocket. The generation dispatch of the neighboring systems was provided by the neighboring utilities.

Table 15 – Generation Dispatch Used to Stress the Northern Study Pocket Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
CEDAR2_W1 0.66	W1	1	100	125	PSCO
CEDAR2_W2 0.69	W2	1	80.6	100.8	PSCO
CEDAR2_W3 0.66	W3	1	20	25	PSCO
CEDARCK_1A 34.50	W1	1	176	220	PSCO
CEDARCK_1B 34.50	W2	1	64	80	PSCO
CHEROK4 22.00	G4	0	0	383	PSCO
FTLUP1-2 13.80	G1	1	45	50	PSCO
FTLUP1-2 13.80	G2	1	45	50	PSCO

JMSHAFR1	13.80	G1	1	32.2	35.8	TSGT
JMSHAFR1	13.80	G2	1	31.5	35	TSGT
JMSHAFR2	13.80	ST	1	45.6	50.7	TSGT
JMSHAFR3	13.80	G3	1	32.5	36.1	TSGT
JMSHAFR3	13.80	ST	1	45	50	TSGT
JMSHAFR4	13.80	G4	1	31.3	34.8	TSGT
JMSHAFR4	13.80	G5	1	29.7	33	TSGT
KNUTSON1	13.80	G1	1	65.3	72.5	TSGT
KNUTSON2	13.80	G2	1	65.3	72.5	TSGT
PAWNEE	22.00	C1	1	535	535	PSCO
MANCHEF1	16.00	G1	0	0	140	PSCO
MANCHEF1	16.00	IA	0	0	11	PSCO
MANCHEF2	16.00	G2	0	0	140	PSCO
MANCHEF2	16.00	IA	0	0	10	PSCO
PLNENDG1_1	13.80	G0	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G1	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G2	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G3	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G4	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G5	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G6	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G7	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G8	1	4.9	5.4	PSCO
PLNENDG1_1	13.80	G9	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G0	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G1	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G2	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G3	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G4	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G5	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G6	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G7	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G8	1	4.9	5.4	PSCO
PLNENDG1_2	13.80	G9	1	4.9	5.4	PSCO
PLNENDG2_1	13.80	G1	1	7.3	8.1	PSCO

PLNENDG2_1	13.80	G2	1	7.3	8.1	PSCO
PLNENDG2_1	13.80	G3	1	7.3	8.1	PSCO
PLNENDG2_1	13.80	G4	1	7.3	8.1	PSCO
PLNENDG2_1	13.80	G5	1	7.3	8.1	PSCO
PLNENDG2_1	13.80	G6	1	7.3	8.1	PSCO
PLNENDG2_1	13.80	G7	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G1	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G2	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G3	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G4	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G5	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G6	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G7	1	7.3	8.1	PSCO
PLNENDG2_2	13.80	G1	1	7.3	8.1	PSCO
RMEC1	15.00	G1	1	128	142.2	PSCO
RMEC1	15.00	IA	1	11.5	12.8	PSCO
RMEC2	15.00	G2	1	135.5	150.5	PSCO
RMEC2	15.00	IA	1	4.1	4.5	PSCO
RMEC3	23.00	ST	1	281.7	313	PSCO
RMEC3	23.00	IA	1	9.9	11	PSCO
SPNDLE1	18.00	G1	1	128.8	143.1	PSCO
SPNDLE1	18.00	IA	1	12.5	13.9	PSCO
SPNDLE2	18.00	G2	1	126.5	140.6	PSCO
SPNDLE2	18.00	IA	1	14.8	16.4	PSCO
ST.VRAIN	22.00	ST	1	279	310	PSCO
ST.VR_2	18.00	G2	1	120.5	133.9	PSCO
ST.VR_2	18.00	IA	1	10.89	12.1	PSCO
ST.VR_3	18.00	G3	1	111.9	124.3	PSCO
ST.VR_3	18.00	IA	1	21.3	23.7	PSCO
ST.VR_4	18.00	G4	1	145.4	145.4	PSCO
ST.VR_4	18.00	IA	1	7.6	7.6	PSCO
ST.VR_5	18.00	G5	1	141.7	157.4	PSCO
ST.VR_5	18.00	IA	1	23	25.6	PSCO
ST.VR_6	18.00	G6	1	141.7	157.4	PSCO
ST.VR_6	18.00	IA	1	23	25.6	PSCO

VALMONT6	13.80	G6	0	0	53	PSCO
VALMNT7	13.80	G7	0	0	41.7	PSCO
VALMNT7	13.80	IA	0	0	2.6	PSCO
VALMNT8	13.80	G8	0	0	41.7	PSCO
VALMNT8	13.80	IA	0	0	2.6	PSCO
MTNBRZ_W1	34.50	W1	1	135.2	169	PSCO

6.4.2 Study Case Modeling

A study case was created from the Benchmark Case by increasing Fort Saint Vrain # 4 by 24MW. The additional 24MW output from GI-2020-5 was sunk to Comanche 3.

6.4.3 Steady State Analysis

The Steady State analysis did not identify any violations for either single or multiple contingency analysis.

6.4.4 Affected Systems

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

6.4.5 Summary of Northern Study Pocket Analysis

The maximum ERIS identified for GI-2020-5 is 24MW.

7.0 Generation Interconnection Service 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 Costs of Network Upgrades

The estimated total cost of the station equipment Network Upgrades for Interconnection, by each POI are shown in Table 16.

Table 16 – Total cost of Station Network Upgrades by POI

POI	Total Cost	GIRs Sharing the POI
Mirasol 230/345kV Substation	$42.848 Million	GI-2020-1, GI-2020-4 and GI-2020-7
GI-2020-3 230kV Switching Station	$17.182 Million	GI-2020-3
GI-2020-6 230kV Switching Station	$16.977 Million	GI-2020-6
Existing Fort Saint Vrain4	0	GI-2020-5
Breaker addition at GI-2014-9 230kV Switching Station	$2.229 Million	GI-2020-10

The estimated total cost and details of the station Network Upgrades required at the Mirasol 230/345kV Substation POI are shown in Table 17. These Station Network Upgrade costs are shared by GI-2020-1, GI-2020-4 and GI-2020-7 on a per-capita basis, as shown in Table 24 below.

Table 17 –Station Network Upgrades - Mirasol 230/345kV Substation

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 230/345kV Substation	Install a new 345-230kV substation on the 345 kV Comanche – Tundra line and the (2) 230kV Comanche – Midway lines. (4) Position ring bus on the 345kV side and (7) Position breaker and a half configuration on the 230kV side. The new equipment includes: • (5) 345kV 3000A circuit breakers • (11) 230kV 3000A circuit breakers • (13) 345kV 3000A disconnect switches • (24) 230kV 3000A disconnect switches • (7) 345kV CCVTs • (15) 230kV CCVTs • (9) 345kV Surge Arresters • (15) 230kV Surge Arresters • (3) 345kV Deadends • (6) 230kV Deadends • (2) Electrical Equipment Enclosure • (4) Line Traps • Station controls and wiring • Associated foundations and structures	$33.790
PSCo's Mirasol 230kV Substation	Install required communication in the EEE at the Mirasol switching station	$0.965
PSCo's Mirasol 230kV Substation	Tap lines 5411, 5413, 7015, 7017; Raise 5415 in place to accommodate 230kV taps to Mirasol sub	$5.743

PSCo's Midway 230kV Bus	Update primary and secondary line relaying and associated breaker fail on two 230kV lines to Mirasol	$0.939
PSCo's Comanche 230kV Bus	Update primary and secondary line relaying and associated breaker fail on two 230kV lines at Comanche	$1.011
Mirasol 230kV Substation	Reterminate the transmission line into the new switching station	$0.225
Mirasol 230kV Substation	Sighting & Land Rights support for substation construction	$0.175
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$42.848**
Time Frame	**Site, design, procure and construct**	**36 Months***

*Construction of the Mirasol 230/345kV Substation requires a CPCN from the Colorado Public Utilities Commission. 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 to site, design, procure and construct the Mirasol 230/345kV Substation is expected to take up to 36 months, shown in Table 25 below.

The estimated total cost and details of the station Network Upgrades required at the GI-2020-3 230kV Switching Station are shown in Table 18. These Station Network Upgrade costs are shared by GI-2020-3 on a per-capita basis.

Table 18 –Station Network Upgrades – GI-2020-3 230kV Switching Station

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-3 New 230kV Substation	Install a new 230kV substation on the Boone-Comanche 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	$14.860
PSCo's GI-2020-3 New 230kV Substation	Install required communication in the EEE	$0.451
PSC0's Boone Substation	Boone-230kV 5413 Line Terminal Upgrade	$1.011
PSCo's Comanche Substation	Comanche-230kV 5413 Line Terminal Upgrade	$0.860
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$17.182**

Time Frame	**Site, design, procure and construct**	**36 Months****

**Construction of the GI-2020-3 230kV Switching Station requires a CPCN from the Colorado Public Utilities Commission. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following CPCN approval is estimated to be 18 months, so the total time required to site, design, procure and construct the GI-2020-3 230kV Switching Station is expected to take up to 36 months

The estimated total cost and details of the station Network Upgrades required at the GI-2020-6 230kV Switching Station are shown in Table 19. These Station Network Upgrade costs are shared by GI-2020-6 on a per-capita basis, shown in Table 26 below.

Table 19 –Station Network Upgrades – GI-2020-6 230kV Switching Station

Element	**Description**	**Cost Est. (Millions)**
PSCo's GI-2020-6 New 230kV Substation	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	$14.965
PSCo's GI-2020-6 New 230kV Substation	Install required communication in the EEE	$0.450
PSC0's Pawnee Substation	Pawnee-230kV 5457 Line Terminal Upgrade	$0.779
PSCo's Missile Substation	Missile-230kV 5457 Line Terminal Upgrade	$0.783
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$16.977**
Time Frame	**Site, design, procure and construct**	**36 Months*****

***Construction of the GI-2020-6 230kV Switching Station requires a CPCN from the Colorado Public Utilities Commission. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following CPCN approval is estimated to be 18 months, so the total time required to site, design, procure and construct the GI-2020-6 230kV Switching Station is expected to take up to 36 months.

The estimated total cost and details of the station Network Upgrades required at the GI-2014-9 230kV Switching Station are shown in Table 20. These Station Network Upgrade costs are shared by GI-2020-10 on a per-capita basis, shown in Table 27 below.

Table 20 –Station Network Upgrades – Expansion of GI-2014-9 Switching Station

Element	Description	Cost Est. (Millions)
PSCo's GI-2014-9 New 230kV Substation	Interconnect Customer to tap the new GI-2014-9 230kV Transmission Substation. The new equipment includes: •One 230kV circuit breaker •Two 230kV gang switches •Associated communications, supervisory and SCADA equipment •Associated line relaying, station controls and testing •Associated bus, miscellaneous electrical equipment, cabling and wiring •Associated foundations and structures •Associated road and site development, fencing and grounding	$2.016
PSCo's GI-2014-9 New 230kV Substation	Install required communication in the EEE	$0.213
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$2.229**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost and details of the other Southern Colorado study pocket Network Upgrades are shown in Table 21. These Network Upgrade costs are shared by all GIRs in the Southern Colorado Study Pocket (GI-2020-1, GI-2020-3, GI-2020-7 and GI-2020-10) based on their proportional impact, shown in Table 23 and 29 below.

Table 21 – Other Southern Colorado Study Pocket Network Upgrades

Element	Description	Cost Est. (Millions)
PSCo's Mirasol Substation	Install a new 345-230kV substation on the 345 kV Comanche – Tundra line and the 230kV Comanche – Midway lines. New equipment includes; (1) 345-230kV 560MVA Transformer	$7.210
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$7.210**
Time Frame	**Site, design, procure and construct**	**18 Months**

The estimated total cost and details of the Daniels Park – Prairie 230kV # 1 & 2 Network Upgrades are shown in Table 22. These Network Upgrade costs are shared by all NRIS GIRs in the Southern Colorado Study Pocket (GI-2020-10) based on their proportional impact, shown in Table 23 and 28 below.

Table 22 – Daniels Park – Prairie 230kV # 1 and # 2 Network Upgrades

Element	Description	Cost Est. (Millions)
Daniels Park – Prarie 1 230kV line 5111	Upgrade line 5111 to 756MVA	$7.850
Daniels Park – Prarie 3 230kV line 5707	Upgrade line 5707 to 756MVA	$2.670
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$10.520**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost of the Network Upgrades and the impacting GIRs are shown in Table 23.

Table 23 – Total cost of Network Upgrades

Network Upgrade	Total Cost	GIRs Sharing the Network Upgrade Cost
Daniels Park – Prairie 230kV # 1	$7.850 Million	GI-2020-10
Daniels Park – Prairie 230kV # 2	$2.670 Million	GI-2020-10
Mirasol Network Upgrades – Mirasol 230/345kV, 560MVA transformer	$7.210 Million	GI-2020-1, GI-2020-3, GI-2020-7 and GI-2020-10

7.2 Cost Estimates of Station and Other Network Upgrades by GIR

Table 124 – Allocation of Mirasol 230/345kV Substation Costs 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 17)
GI-2020-1	199MW	33.33%	$14.2827 Million
GI-2020-4	100MW	33.33%	$14.2827 Million
GI-2020-7	1000MW	33.33%	$14.2827 Million

Table 135 – Allocation of GI-2020-3 230kV Switching Station Costs 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 18)
GI-2020-3	199MW	100%	$17.182 Million

Table 146 – Allocation of GI-2020-6 230kV Switching Station Costs 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-2020-6	199MW	100%	$16.977 Million

Table 157 – Allocation of GI-2020-10 breaker addition Costs 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-2020-10	230MW	100%	$2.229 Million

Table 28 – Allocation of Cost of Daniels Park – Prairie 230kV # 1 & 2 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 21)
Daniels Park – Prairie 230kV # 1	GI-2020-10	230MW	100%	$7.850 Million
Daniels Park – Prairie 230kV # 2	GI-2020-10	230MW	100%	$2.670 Million

Table 29 – Allocation of Cost of Other Southern Colorado Study Pocket Network Upgrades

Network Upgrade	GIR	GIR MW	DFAX	MW Impact	% Share per Section 4.2.4(b) of Attachment N	Costs allocated to GIR (% share x total costs from Table 21)
Mirasol 230/345kV, 560MVA transformer	GI-2020-7	1000	0.2719	278.1537	100%	$7.210 Million

7.2.1 Summary of Transmission Provider's Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-1

The total cost of the required Upgrades for GI-2020-1 to interconnect at the Mirasol 230/345kV Substation is **$15.5768 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.294 Million (Table 30)**
- **The cost of Station Network Upgrades is $14.2827 Million (Table 24)**

Figure 2 is a conceptual one-line of the GI-2020-1 POI at the Mirasol 230/345kV Substation.

The list of improvements required to accommodate the interconnection of GI-2020-1, the Customer's 199MW Solar PV Generating Facility are given in Tables 24 and 30. A CPCN will be required to build the Mirasol 230/345kV Substation to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) 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 30 – GI-2020-1 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 230kV Substation	Interconnection Customer at the Mirasol Substation 230kV bus. 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.	$1.219
PSCo's Mirasol 230kV Substation	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 230kV Substation	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.294**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.2 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-3

The total cost of the required Upgrades for GI-2020-3 to interconnect at the GI-2020-3 230kV Switching Station is **$18.795 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.613 Million (Table 31)**
- **The cost of Station Network Upgrades is $17.182 Million (Table 25)**

Figure 3 is a conceptual one-line of the GI-2020-3 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-3, the Customer's 199MW Solar PV Generating Facility are given in Tables 25 and 31. A CPCN will be required to build the GI-2020-3 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) 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-2020-3 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-3 230kV Switching Station	Interconnection Customer to tap at the Boone-Comanche 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.	$1.538
PSCo's GI-2020-3 230kV Switching Station	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's GI-2020-3 230kV Switching Station	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.613**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.3 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-4

The total cost of the required Upgrades for GI-2020-4 to interconnect at the Mirasol 230/345kV Substation is **$15.5767 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.294 Million (See Table 32)**
- **The cost of Station Network Upgrades is $14.2827 Million (Table 24)**

Figure 2 is a conceptual one-line of the GI-2020-4 POI at the Mirasol 230/345kV Substation.

The list of improvements required to accommodate the interconnection of GI-2020-4, the Customer's 100MW Solar PV Generating Facility are given in Tables 24 and 32. A CPCN will be required to build the Mirasol 230/345kV Substation to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) 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-2020-4 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 230kV Substation	Interconnection Customer to tap at the Mirasol Substation 230kV bus. 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.	$1.219
PSCo's Mirasol 230kV Substation	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 230kV Substation	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.294**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.4 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-5

The total cost of the required Upgrades to accommodate the GI-2020-5 expansion of the Fort Saint Vrain # 4 generation at the Fort Sait Vrain Substation is **$50,000.**

- **The cost of Transmission Provider's Interconnection Facilities is $50,000 (Table 33)**
- **The cost of Station Network Upgrades is 0 (Table 16)**

The list of improvements required to accommodate the GI-2020-5, the Customer's 24MW incremental output at Fort Saint Vrain#4 are given in Tables 16 and 29.

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

Table 33 - GI-2020-05 Transmission Provider's Interconnection Facilitie

Element	Description	Cost Est. (Millions)
PSCo's FSV Unit #4	Confirmation testing of incremental increase in generation output due to an plant equipment upgrade	$0.050
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$0.050**
Time Frame	**Site, design, procure and construct**	**12 Months**

7.2.5 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-6

The total cost of the required Upgrades for GI-2020-6 to interconnect at the GI-2020-6 230kV switching station tapping the Pawnee – Missile 230kV line is **$18.581 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.604 Million (Table 34)**
- **The cost of Station Network Upgrades is $16.977 Million (Table 26)**

Figure 4 is a conceptual one-line of the GI-2020-6 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-6, the Customer's 199MW Solar PV Generating Facility are given in Tables 26 and 34. A CPCN will be required to build the GI-2020-6 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) 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-2020-6 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-6 New 230kV Switchyard	Interconnection Customer to tap at the Pawnee-Missile 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.	$1.529
PSCo's Mirasol 230kV Substation	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 230kV Substation	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.604**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.6 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-7

The total cost of the required Upgrades for GI-2020-7 to interconnect at the Mirasol 230/345kV Substation is **$22.7867 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.294 Million (Table 35)**
- **The cost of Station Network Upgrades is $14.2827 Million (Table 24)**
- **The cost of Mirasol 230/345kV, 560MVA transformer Network Upgrade is $7.210 Million (Table 29)**

The list of improvements required to accommodate the interconnection of GI-2020-7, the Customer's 1000MW Wind plus Solar PV hybrid Generating Facility are given in Tables 24, 29 and 35. A CPCN will be required to build the Mirasol 230/345kV Substation to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) 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 35 – GI-2020-7 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 345kV Substation	Interconnection Customer to tap at the Mirasol Substation 345kV bus. 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.	$1.219
PSCo's Mirasol 345kV Substation	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 345kV Substation	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.294**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.7 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-10

The total cost of the required Upgrades for GI-2020-10 to interconnect at the GI-2014-9 230kV Switching Station is **$14.424 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.675 Million (Table 36)**
- **The cost of Station Network Upgrades is $2.229 Million (Table 27)**
- **The cost of Daniels Park – Prairie 230kV # 1 uprate to 756MVA is $7.850 Million (Table 28)**
- **The cost of Daniels Park – Prairie 230kV # 2 uprate to 756MVA is $2.670 Million (Table 28)**

The list of improvements required to accommodate the interconnection of GI-2020-10, the Customer's 230MW Solar PV and BES Hybrid Generating Facility are given in Tables 27, 28 and 36.

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

Table 36 – GI-2020-10 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-10 New 230kV Switchyard	Interconnection Customer to tap at the Comanche-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.	$1.600
PSCo's Mirasol 230kV Substation	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 230kV Substation	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.675**
Time Frame	**Site, design, procure and construct**	**36 Months**

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-2020-001 and Interconnection Service in and itself does not convey transmission service.

8.1 Cost Estimate Assumptions

The PSCo Engineering has developed indicative level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the DISIS-2020-001 Cluster. The cost estimates are in 2020 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 Customer owned equipment and associated design and engineering.

A level of accuracy is not specified for indicative level estimates.

- Labour is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- Except for GI-2020-05, it is assumed that a CPCN will be required for the interconnection facilities.
- The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.
- Except for GI-2020-05, 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.

8.2 GI-2020-1

The total estimated cost of the transmission system improvements for GI-2020-1: $15.5768 Million (Tables 24 and 30).

Energy Resource Interconnection Service of GI-2020-1 is: 199MW (after required transmission system improvements in Tables 24 and 30).

Note: A CPCN is needed for the construction of the Mirasol 230/345kV Substation. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-1.

8.3 GI-2020-3

The total cost of the required Upgrades for GI-2020-3 to interconnect at the GI-2020-3 230kV Switching Station is **$18.795 Million** (Tables 25 and 31).

Energy Resource Interconnection Service of GI-2020-3 is: 199MW (after required transmission system improvements in Tables 25 and 31).

Note: A CPCN is needed for the construction of the GI-2020-3 230kV Switching Station. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-3.

8.4 GI-2020-4

The total cost of the required Upgrades for GI-2020-4 to interconnect at the Mirasol 230/345kV Substation is **$15.5767 Million** (Tables 24 and 32).

Energy Resource Interconnection Service of GI-2020-4 is: 100MW (after required transmission system improvements in Tables 24 and 32).

Note: A CPCN is needed for the construction of the Mirasol 230/345kV Substation. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the

interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-4.

8.5 GI-2020-5

The total estimated cost of the transmission system improvements for GI-2020-5 are: $0.05 Million (Tables 16 and 33).

Energy Resource Interconnection Service of GI-2020-5 is: 24MW (after required transmission system improvements in Tables 16 and 33).

8.6 GI-2020-6

The total estimated cost of the transmission system improvements for GI-2020-6 are: $18.581 Million (Tables 26 and 34).

Network Resource Interconnection Service of GI-2020-6 is: 199MW (after required transmission system improvements in Tables 26 and 34).

Note: A CPCN will be required to build the GI-2020-6 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

8.7 GI-2020-7

The total estimated cost of the transmission system improvements for GI-2020-7 are: $22.7867 Million (Tables 24, 29 and 35).

Energy Resource Interconnection Service of GI-2020-7 is: 1000MW (after required transmission system improvements in Tables 24, 29 and 35).

Note: A CPCN will be required to build the Mirasol 230/345kV Substation to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. The output of the hybrid Generating Facility will be limited to 1000MW 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.

8.8 GI-2020-10

The total estimated cost of the transmission system improvements for GI-2020-10 are: $14.424 Million (Tables 27, 28 and 36).

Network Resource Interconnection Service of GI-2020-10 is: 230MW (after required transmission system improvements in Tables 27, 28 and 36).

Note: The output of the hybrid Generating Facility will be limited to 230MW 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 construction of the GI-2014-9 230kV Switching Station will require a CPCN and the estimated time frame for regulatory activities (CPCN) 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-2020-10.

Note – This results in this report may be revised during Phase 2 of DISIS-2020-001. The revisions in Phase 2 may also include re-evaluation of the Mirasol Substation configuration.

Figure 2 – Preliminary One-line of the Mirasol 230/345kV Substation showing POIs of GI-2020-1, GI-2020-4 and GI-2020-7

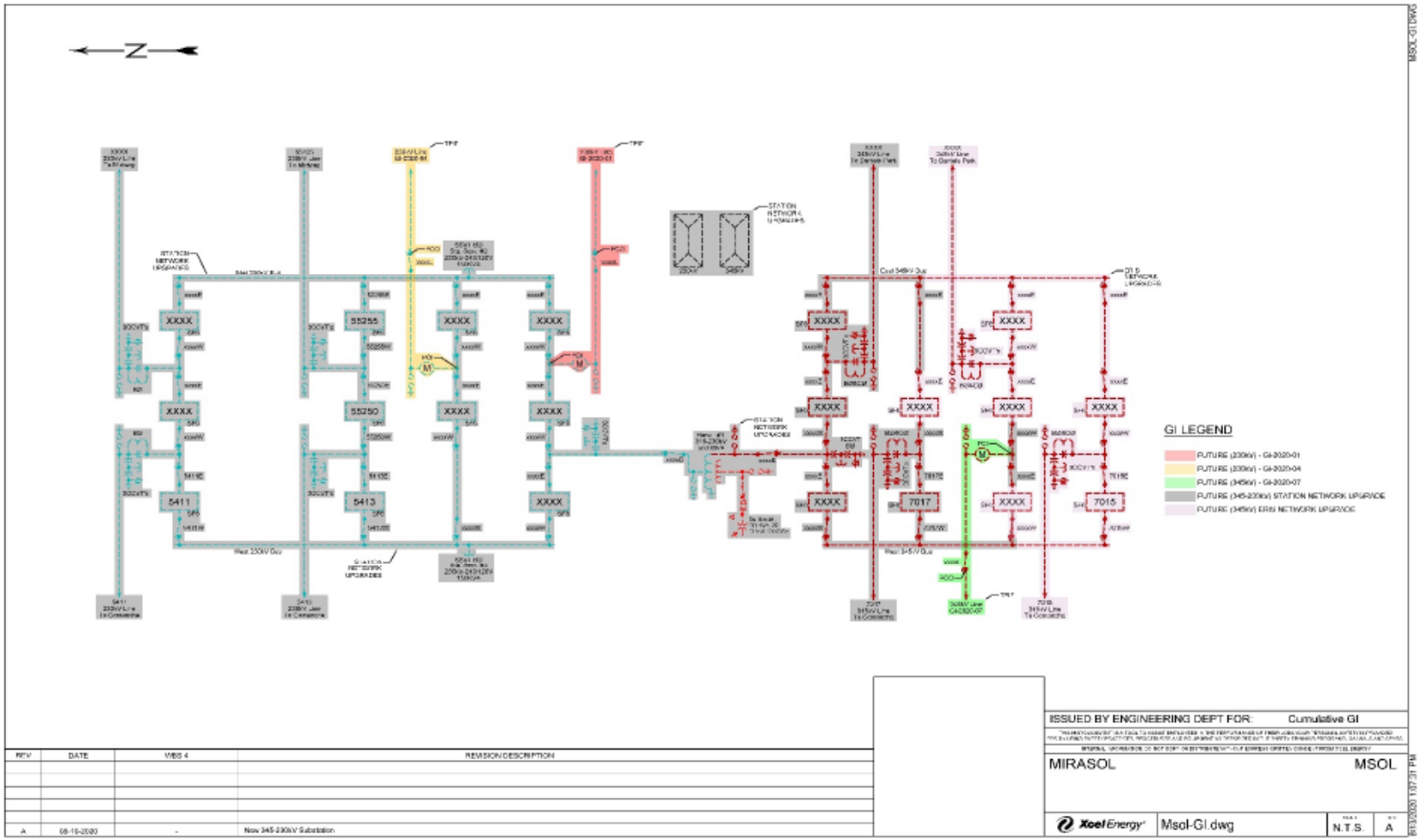


Figure 3 – Preliminary One-line of the GI-2020-3 230kV Switching Station showing GI-2020-3 POI

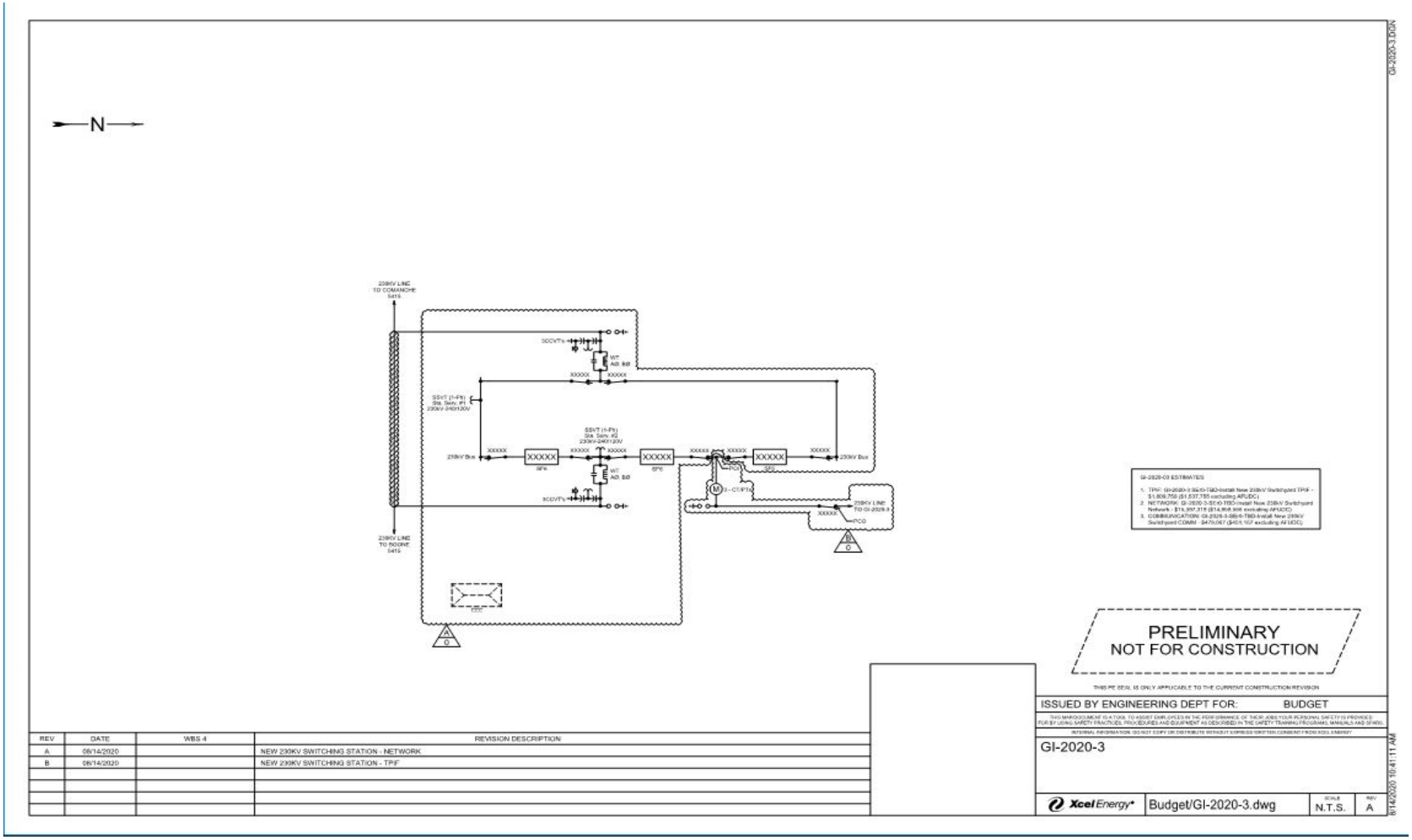


Figure 4 – Preliminary One-line of the GI-2020-6 230kV Switching Station showing GI-2020-6 POI

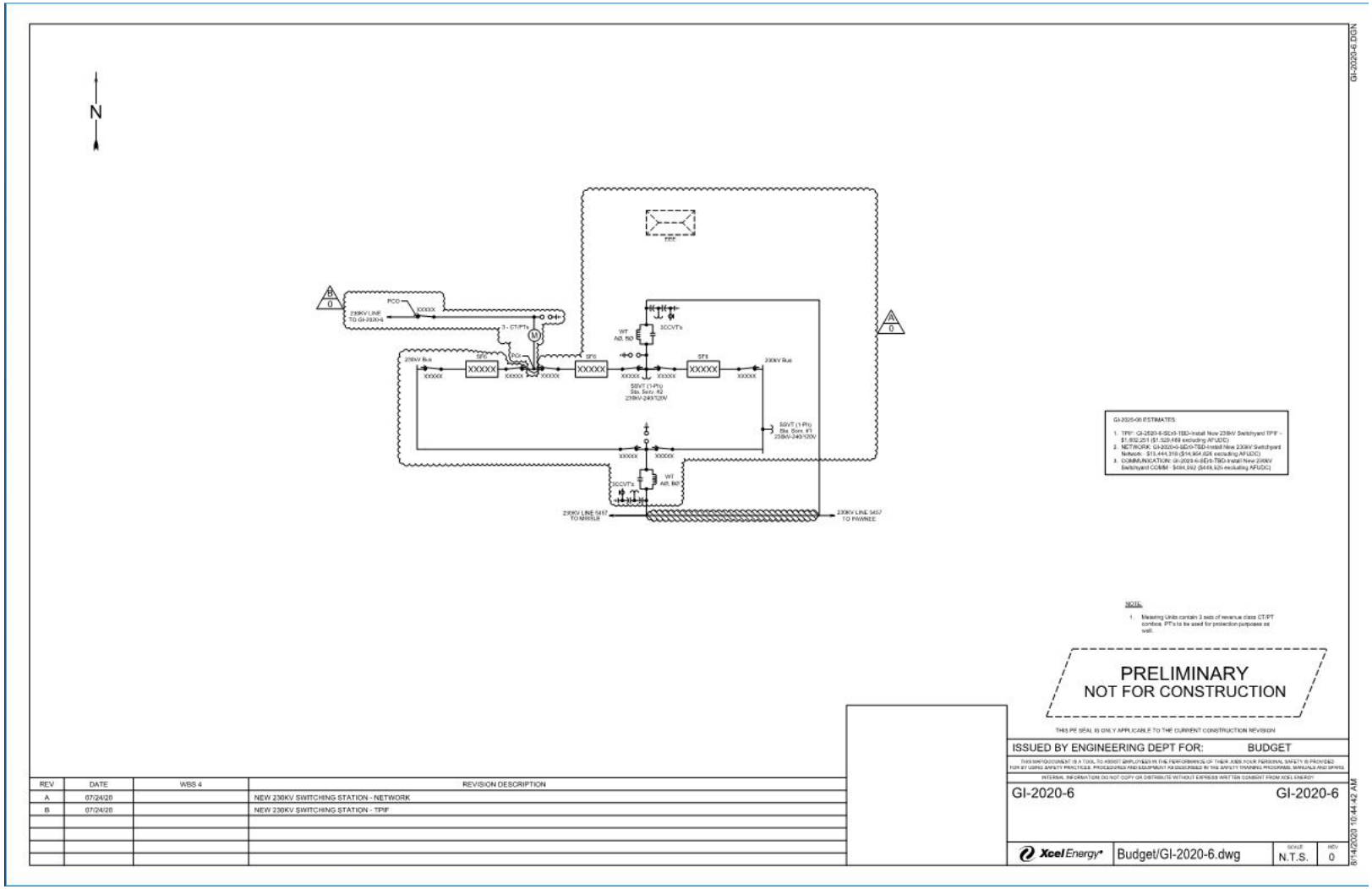


Figure 5 – Preliminary One-line of the GI-2014-9 230kV Switching Station showing GI-2020-10 POI