Provisional Interconnection Study Report
Provisional Interconnection Request for GI-2019-6 (PI-2019-6)

240 MW Solar Photovoltaic Generating Facility
Comanche 230kV Substation
Pueblo County, Colorado

Xcel Energy - Transmission Planning West
Xcel Energy
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Executive Summary

The PI-2019-6 is the Provisional Interconnection (PI) Service Request for the Energy Resource Interconnection Service (ERIS) request GI-2019-6 (GI). The Generating Facility is a 240MW$_{ac}$ rated Solar Photovoltaic (PV) Generating Facility that will be located in Pueblo County, Colorado. The original Point of Interconnection (POI) requested for this Generating Facility is a tap on Public Service Company of Colorado (PSCo)'s Evraz - Comanche 230kV line. On January 27, 2020, PSCo has received email communication from the Customer confirming Comanche 230kV Substation as the proposed POI.

The proposed Commercial Operation Date (COD) of the Generating Facility is June 1, 2021. Based on the construction schedules, the back-feed date is expected to be March 1, 2021.

PI-2019-6 was studied for Provisional Interconnection Service and the 240MW rated output of the PI was assumed to be delivered to Public Service Company of Colorado (PSCo) native load, so existing PSCo generation was used as its sink.

The power flow analysis included steady state analysis and the study identified one new overload on the PSCo system.

The transient stability analysis determined that all generating units are stable (remain in synchronism), display positive damping and the maximum transient voltage dips are within the acceptable dynamic performance criteria.

The short-circuit and breaker duty analysis determined that no breaker replacements are needed at the POI station and/or in neighboring PSCo stations.

The total estimated cost of the PSCo transmission system improvements required for PI-2019-6 to qualify for Provisional Interconnection Service is:

- **$3.130 Million (Tables 6 and 7)**

For PI-2019-6 interconnection:

- **Provisional Interconnection Service (after required transmission system improvements) = 240MW**

The Provisional Interconnection Service results above are contingent upon the transmission system improvements identified in Attachment 1.

Security: The GI-2019-6 request is ERIS. The estimated risk of the potential interconnection facilities and Network Upgrades that might be identified at the conclusion of the GI-2019-6 LGIP is $5 million. Security amount for PI-2019-6 is $5 million.

The Customer is required to design and build the Generating Facility to mitigate any potential inverter interactions with the neighboring inverter based Generating Facility(ies), interference with performance of the arc furnace load in the area and existing STATCOMs near the Comanche Substation

The Interconnection Customer assumes all risk and liabilities with respect to changes between the Provisional Large Generator Interconnection Agreement and the Large Generator Interconnection Agreement, including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.

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

Introduction

The PI-2019-6 is the Provisional Interconnection (PI) Service Request for the Energy Resource Interconnection Service (ERIS) request GI-2019-6 (GI). The Generating Facility is a 240MW net rated Solar Photovoltaic (PV) Generating Facility that will be located in Pueblo County, Colorado. The proposed PV Generating Facility consists of eighty-four (84) Sungrow 3.15MVA, +/- 0.8 power factor inverters arranged in two (2) groups. Each inverter will consist of 630V/34.5kV, 3.15MVA, Z=6% pad-mounted step-up transformer. The 34.5 KV collector systems of the two groups will interface with two (2) 80/106/133MVA, 34.5/230/13.8kV wye-wye-delta, Z=8% (based on 80MVA rating) main step-up transformers which will connect to the Public Service Company of Colorado (PSCo) transmission system at the Comanche 230kV Substation. The original Point of Interconnection (POI) requested for this Generating Facility is a tap on PSCo's Evraz - Comanche 230kV line. On January 27, 2020, PSCo has received email communication from the Customer confirming Comanche 230kV Substation as the proposed POI.

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

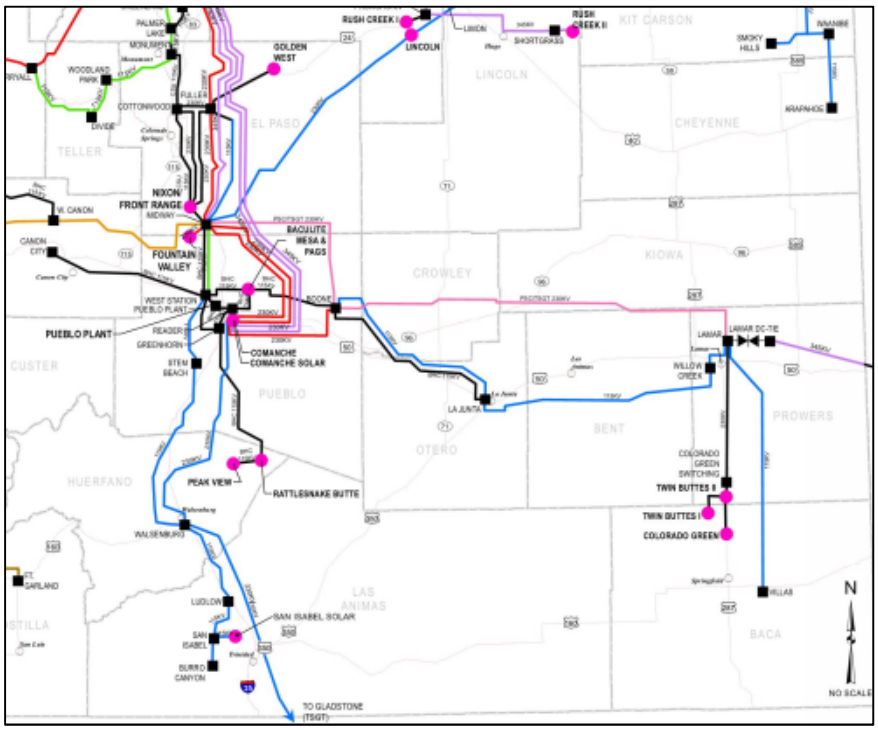

Figure 1 - PI-2019-6 Study Area

The proposed Commercial Operation Date (COD) of the GI is June 1, 2021. Accordingly, based on the typical construction timeframes for similar projects, the back-feed date is assumed to be December 1, 2020, approximately six (6) months before the COD.

The main purpose of this study is to determine the system impact of interconnecting 240MW of PV generation at the Comanche 230kV Substation. Per the Provisional Interconnection Study Request, PI-2019-6 is studied for Provisional Interconnection Service[1] only. As stated in the PI-2019-6 study agreement, GI-2019-6 selected Energy Resource Interconnection Service (ERIS)[2]. For this evaluation, the 240 MW rated output of the generating facility is assumed to be delivered to PSCo native load, so existing PSCo generation is used to sink the PI output.

Study Scope and Analysis Criteria

The scope of this report includes steady state (power flow) analysis, transient stability analysis, short circuit analysis, and appropriation level cost estimates (+/- 20% accuracy). The report also identifies the estimated Security[3] for the PI. The power flow analysis identifies thermal and voltage violations in the PSCo system and the neighboring systems as a result of the interconnection of the GI for Provisional Interconnection. Several single contingencies are studied.

The transient stability analysis verifies that all generating units within the PSCo transmission system and the neighboring systems remain stable (in synchronism), have positive damping, and satisfy acceptable dynamic performance criteria.

The short circuit analysis determines the maximum available fault current at the POI and identifies if any circuit breaker(s) within the PSCo station(s) exceed their breaker duty ratings and need to be replaced.

The system impact analysis criteria are as follows:

PSCo adheres to applicable NERC Reliability Standards and WECC Reliability Criteria, as well as its internal transmission planning criteria for studies. The steady state analysis criteria are as follows:

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

[1] **Provisional Interconnection Service** shall mean an Interconnection Service provided by Transmission Provider associated with interconnecting the Interconnection Customer's Generating Facility to Transmission Provider's Transmission System and enabling that Transmission System to receive electric energy and capacity from the Generating Facility at the Point of Interconnection, pursuant to the terms of the Provisional Large Generator Interconnection Agreement and, if applicable, the Tariff.

[2] **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.

[3] **Security** estimates the risk associated with the Network Upgrades and Interconnection Facilities that could be identified in the corresponding LGIA.

Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=8% of pre-contingency voltage

The same list of contingencies was run on the benchmark case and the study case, and the results were compared.

For PSCo facilities, thermal violations attributable to the PI include any facilities without a pre-existing thermal violation that (i) resulted in a new thermal loading >100% post the GI addition (ii) contributed to an incremental loading increase of 1% or more to the benchmark case loading. For non-PSCo facilities, thermal violations attributed to the GI include all new facility overloads with a thermal loading of >100% and existing thermal overloads that increased by 1% or more from the benchmark case overload post the GI addition.

The voltage violations assigned to the PI include new voltage violations or existing voltage violations which resulted in a further variation of 0.1 per unit.

Transient stability criteria require that all generating machines remain in synchronism and all power swings should be well damped following a contingency event. Also, transient voltage performance should meet the following WECC Disturbance-Performance criteria:

- Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds for all contingencies
- For all contingencies, following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.
- For contingencies without a fault, voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.

The study area is the electrical system consisting of PSCo's transmission system and the neighboring transmission systems that are impacted by or that will impact interconnection of the PI. The study area for PI-2019-6 includes WECC designated zones 121, 700, 703, 704, 705, 709, 710, 712, 752 and 757.

System Impact Study Power Flow Case Creation

The Base Case used for the power flow analysis originated from the 2023HS case built for the 2018 TPL1 Work Group of the Colorado Coordinated Planning Group (CCPG). As part of the case build efforts for the TPL1 work group, the case was reviewed by PSCo and neighboring utilities within the CCPG foot print.

All transmission planned projects in PSCo's 10 year transmission plan that are expected to be in-service before July 2023 are modeled in the Base Case, consistent with the case season and

year. These projects are described at:
(http://www.oasis.oati.com/woa/docs/PSCO/PSCOdocs/Q1_2019_Transmission_Plan.pdf)

The PSCo projects added to the Base Case include the following:

- Shortgrass 345kV Switching Station – ISD 2020
- Shortgrass – Cheyenne Ridge 345kV line – ISD 2020
- Graham Creek 115kV Substation – ISD 2021
- Husky 230/115kV Substation – ISD 2021
- Cloverly 115kV Substation – ISD 2021
- Ault – Husky 230kV line – ISD 2021
- Husky – Graham Creek – Cloverly 115kV line – ISD 2021
- Monument – Flying Horse 115kV Series Reactor – ISD 2021
- 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
- Increase Waterton – Martin1 tap 115kV line to 159MVA – ISD 2022

The following additional changes were made to the Tri-State Generation and Transmission (TSGT) model in the Base Case per further review and comment from TSGT:

- 30MW San Isabel Solar tapping Ludlo Tap – Pinon Canyon 115kV line
- 80MW TSGT_0809 solar facility tapping Gladstone – Walsenburg 230kV line
- Fuller – Vollmer – Black Squirrel 115 kV line modeled at 173 MVA
- Fuller 230/115kV, 100MVA #2 transformer

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

- Fountain Valley – DesertCove 115kV line was modeled at 222MVA. Planned upgrade project in 1/2021
- Fountain Valley – MidwayBR 115kV line was modeled at 222MVA. Planned upgrade project in 1/2021
- Pueblo West Substation – ISD 1/2021
- Skyline Ranch Substation – ISD 10/2021
- West Station – Greenhorn 115kV line Rebuild – ISD 9/2022

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
- Grazing Yak Solar – ISD 2020
- Cottonwood 230/115kV auto-transformer replacement – ISD 2019
- Nixon – Kelker 230kV line upgrade – ISD 2019

The Base Case model includes the existing PSCo generation resources. The other Provisional Interconnection requests modeled in the Base Case are GI-2018-24, GI-2018-25, GI-2019-3 and GI-2019-4. There were no other generators in the Provisional Interconnection queue with POI in the same generation pocket and no higher-queued generation in the Generation Interconnection queue which have a Power Purchase Agreement or have received the state approval in the Electric Resource Plan which qualified for inclusion in the Base Case.

The Benchmark Case for evaluating the system impact of PI-2019-6 generation output was created from the Base Case by changing the 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 1 below. The generation dispatch of the neighboring systems was provided by the neighboring utilities.

Table 1 – Generation Dispatch Used to Stress the Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
APT_DSLS 4.1600	G1	0	0	10	BHE
BAC_MSA GEN1 13.800	G1	1	59.4	90	BHE
BAC_MSA GEN2 13.800	G1	1	59.4	90	BHE
BAC_MSA GEN4 13.800	G1	1	26.4	40	BHE
BAC_MSA GEN4 13.800	G2	1	26.4	40	BHE
BAC_MSA GEN4 13.800	S1	1	16.4	24.8	BHE
BAC_MSA GEN5 13.800	G1	1	26.4	40	BHE
BAC_MSA GEN5 13.800	G2	1	26.4	40	BHE
BAC_MSA GEN5 13.800	S1	1	16.4	24.8	BHE
BAC_MSA GEN6 13.800	G1	1	26.4	40	BHE
BUSCHRNCH_LO0.7000	1	1	35.2	60	BHE
BUSCHRWTG1 0.7000	G1	1	16.9	28.8	BHE
E_CANON 69.000	G1	0	0	8	BHE
PP_MINE 69.000	G1	0	0	3	BHE
PUB_DSLS 4.1600	G1	0	0	10	BHE
R.F.DSLS 4.1600	G1	0	0	10	BHE
RTLSNKWNDLO 0.7000	G1	1	35.2	60	BHE
ALMSACT1 13.800	G1	0	0	17	PSCo
ALMSACT2 13.800	G2	0	0	14	PSCO
COGENTRIX_PV 34.500	S3	1	19.5	30	PSCO
COMAN_1 24.000	C1	1	360	360	PSCO
COMAN_2 24.000	C2	1	365	365	PSCO
COMAN_3 27.000	C3	1	788	788	PSCO
COMAN_PV 34.500	S1	1	102	120	PSCO
CO_GRN_E 34.500	W1	1	64.8	81	PSCo

CO_GRN_W 34.500	W2	1	64.8	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	249.4	PSCO
LAMAR_DC 230.00	DC	0	0	210	PSCO
SOLAR_GE 34.500	S2	1	19.5	30	PSCO
SUNPOWER 34.500	S1	1	33.8	52	PSCO
TWNBUTTE 34.500	W1	1	60	75	PSCO
SI_GEN 0.6000	1	1	24	30	TSGT
TBII_GEN 0.6900	W	1	60	76	TSGT
TSGT_0809 0.6200	PV	1	80	100	TSGT
GI-2018-24	PV+BES	0	250	0	---
GI-2018-25	PV+BES	0	200	0	---
GI-2019-3	PV+BES	0	75	0	---
GI-2019-4	PV+BES	0	50	0	---

A Study Case was created from the Benchmark Case by adding the PI-2019-6 Generating Facility at the proposed POI. The 240MW output from PI-2019-6 was sunk pro-rata to the PSCo units outside the study area.

The PI-2019-6 Generating Facility was modeled using the power flow modeling data provided by the Generation Interconnection Customer. The results of the Benchmark Case vs Study Case, was compared to determine the impacts due to addition of PI-2019-6, and the Provisional Interconnection Service capacity of PI-2019-6.
The "kig" parameter in the dynamic model was changed from 10.0 to 1.0 to achieve satisfactory performance in pgen recovery post fault clearing. Refer to the transient stability results for additional information.

The steady state analysis was performed using PTI's PSSE Ver. 33.12.0 program and the ACCC contingency analysis tool.

The transient stability analysis was performed using General Electric's PSLF Ver.21.0_07 program. Three phase faults were simulated for selected single and multiple contingencies using standard clearing times. The voltage and frequency of transmission busses in the study area, and the relative rotor angle of generators in the study area were recorded and analyzed. PSLF's DYTOOLS EPCL program was used to simulate the disturbances.

Power Flow Analysis Results

The results of the single contingency analysis (P1 and P2-1) are given in Table 2 below.

Table 2 Power Flow Analysis Results

Note – Thermal overloads for single contingencies are calculated using the normal rating of the facility. All overloads are in red.

Table 2: Differential Impact of PI-2019-6 on Facility Loadings									
Summary of Power Flows from Single Contingency Analysis									
				Facility Loading Without PI-2019-6		Facility Loading With PI-2019-6			
Monitored Facility (Line or Transformer)	Type	Owner	Branch Rating MVA (Norm)	Flow MVA	Flow % of Rating (Norm)	Flow MVA	Flow % of Rating (Norm)	% Change	NERC Single Contingency
BRIARGATE S - CTTNWD S 115 kV line 1	Line	CSU	150.0	147.9	98.6%	152.3	101.5%	2.9%	CTTNWD N - KETTLECK S 115 kV Line

The results of the single contingency analysis (P1 and P2-1) are given in Table 2. The addition of PI-2019-6 caused one new overload on the CSU system. The facility overloads impacted by the addition of PI-2019-6 are as follows:

- Briargate – Cottonwood 115 KV line loading increased from 98.6% to 101.5% (CSU facility)

Based on the stressed generation dispatch modeled in the study, the output of PI-2019-6 is limited; however, in the operating world, higher output may become feasible on an as-available basis depending on the prevailing dispatch of existing generation resources located in the electrical vicinity of PI-2019-6 (Jackson Fuller, Comanche, Midway and Lamar areas) and available firm and/or non-firm transmission capacity available on the system.

The Customer is required to design and build the Generating Facility to mitigate any potential inverter interactions with the neighboring inverter based Generating Facility(ies), interference with performance of the arc furnace load in the area and existing STATCOMs near the Comanche Substation.

Voltage Regulation and Reactive Power Capability

The Interconnection Customer is required to interconnect its Large Generating Facility with PSCo's Transmission System in accordance with the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW* (available at: http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Interconnection/Interconnections-POL-TransmissionInterconnectionGuidelineGreat20MW.pdf).

Accordingly, the following voltage regulation and reactive power capability requirements at the POI are applicable to this interconnection request:

- To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system are expected to adhere to the *Rocky Mountain Area Voltage Coordination Guidelines (RMAVCG)*. Accordingly, since the POI for this interconnection request is located within Southeast Colorado - Region 4 defined in the *RMAVCG*; the applicable ideal transmission system voltage profile range is 1.02 – 1.03 per unit at regulated buses and 1.0 – 1.03 per unit at non-regulated buses.
- Xcel Energy's OATT (Attachment N effective 10/14/2016) 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 as long as the Generating Facility does not have to operate outside its 0.95 lag – 0.95 lead dynamic power factor range capability.
- 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 (34.5kV or 230kV bus) 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 and the 1.0 – 1.03 per unit voltage range standards at the POI. 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 Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and voltage ranges (noted above).

According to the modeling data provided by the Customer, PI-2019-6 generator has the following modeling parameters:

- Solar PV: Pmax =240MW, Pmin =0, Qmax = 104.6Mvar, Qmin = -104.6Mvar

Table 3 - Reactive Capability Evaluation

Gen MW/Mvar	shunt status (20 Mvar)	Gen Voltage (p.u.) - (PV1and PV2)	High Side Main Station Transformer Voltage (p.u.)	High Side MW	High Side Mvar	High Side Power Factor	POI Voltage (p.u.)	Lead/lag	POI MW	POI MVar	POI power Factor
240 MW/-74Mvar	off	1.007	1.032	238.8	-78.4	0.95	1.032	Lead	238.8	-78.4	0.95
240 MW/92.4Mvar	on	1.128	1.047	239	78.2	0.95	1.047	Lag	239	78.2	0.95
24.3 MW/ -12.2Mvar	off	1.034	1.039	24.3	-8	0.95	1.039	Lead	24.3	-8	0.95
24.3 MW/3.8 Mvar	off	1.047	1.040	24.3	8	0.95	1.040	Lag	24.3	8	0.95
240 MW/-104.6Mvar	of	0.938	1.024	237.3	-161.5	0.827	1.024	Lead	237.3	-161.5	0.827
240 MW/104.6Mvar	on	1.137	1.048	239	89.7	0.936	1.048	Lag	239	89.7	0.936
0 MW/-104.6 Mvar	off	0.946	1.029	-0.9	-109.6	N/A	1.029	N/A	-0.9	-109.6	N/A

From the analysis in Table 3, the Generating Facility is capable of meeting 0.95 PF at the high side of the main step-up transformer for the 240MW output and can achieve at least 1.0 per unit voltage at the POI.

Transient Stability Study Results

Table 4 Transient Stability Analysis Results

Stability Scenarios						
#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Boone 230kV	3ph	Boone 230/115kV Transformer	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
2	Boone 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
3	Boone 230kV	3ph	Boone – Comanche 230kV	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
4	Boone 230kV	3ph	Boone – Midway 230kV	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
5	Comanche 345 kV	3ph	Comanche#3 generator	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
6	Lamar 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
7	MidwayPS 230kV	3ph	All Fountain Valley gas units	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
8	MidwayPS 345kV	3ph	MidwayPS – Waterton 345kV line & Midway 230/345kV xfmr	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
9	Comanche 345kV	3ph	Comanche – Daniels Park 345kV line #1 and #2	4.0	Maximum transient voltage dips within criteria	Stable with positive damping

The results of the transient stability analysis are given in Table 4. The following results were obtained for the disturbances analyzed:

- ✓ No machines lost synchronism with the system
- ✓ No transient voltage drop violations were observed
- ✓ Machine rotor angles displayed positive damping

Transient stability plots showing surrounding bus voltages, bus frequencies, generator terminal voltages, generator relative angles, generator speeds, and generator power output for each of the disturbances runs for each study scenario have been created and documented in Appendix B. Furthermore, it is the responsibility of the Interconnection Customer to ensure that its generating
facility is capable of meeting the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in the NERC Reliability Standard PRC-024.

It should be noted that for contingency #9, a reduction in PI-2019-6 "pgen" output was observed for this contingency following a power swing after fault clearing. The "pgen" output never recovered to its pre-fault value. To correct the issue, "kig" parameter in the plant controller was changed from 10.0 to 1.0. The Interconnection Customer is requested to re-evaluate the dynamic model parameters.

Short Circuit and Breaker Duty Analysis

The calculated short circuit levels and Thevenin system equivalent impedances at the PI-2019-6 230kV Switching Station POI are shown in Table 5.

Table 5 – Short Circuit Parameters at the PI-2019-6 230kV Switching Station POI

	Before PI-2019-6 Interconnection	After PI-2019-6 Interconnection
Three Phase Current	24445A	24766A
Single Line to Ground Current	28560A	29033A
Positive Sequence Impedance	0.333+j5.492 ohms	0.333+j5.492 ohms
Negative Sequence Impedance	0.349+j5.512 ohms	0.349+j5.512 ohms
Zero Sequence Impedance	0.162+j3.023 ohms	0.155+j2.919 ohms

A preliminary breaker duty study did not identify any circuit breakers that became over-dutied"[2] as a result of adding this generation.

Costs Estimates and Assumptions

PSCo Engineering has developed Appropriation level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the Interconnection Customer's proposed generation facility. The cost estimates are in 2020 dollars with escalation and contingencies applied. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of these new

[2] "Over-dutied" circuit breaker: A circuit breaker whose short circuit current (SCC) rating is less than the available SCC at the bus.

PSCo facilities. This estimate does not include the cost for any Customer owned equipment and associated design and engineering.

The estimated total cost for the required upgrades is **$3,130,000.**

Figure 2 below is a conceptual one-line of the Comanche 230kV Substation Point of Interconnection, which will be at a new bay position in the Comanche Substation.

The Tables 6 and 7 list the improvements required to accommodate the interconnection and the delivery of the customer's 240MW PV generation facility generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to revision as a more detailed and refined design is produced.

The Transmission Provider has specified and estimated the cost of the equipment, engineering, procurement and construction work needed to interconnect PI-2019-6. The results of the engineering analysis for facilities owned by the Transmission Provider are appropriation level estimates and are summarized in Tables 6 and 7.

Table 6: "Transmission Provider's Interconnection Facilities" includes the nature and estimated cost of the Transmission Provider's Interconnection Facilities and an estimate of the time required to complete the construction and installation of such facilities.

Table 7: "Network Upgrades Required for Interconnection includes the nature and estimated cost of the Transmission Provider's Network Upgrades necessary to accomplish the interconnection and an estimate of the time required to complete the installation of such facilities.

Upgrades identified in Tables 6 and 7 are illustrated in Figure 2 in the Appendix which shows the physical and electrical connection of the Interconnection Customer's Generating Facility to the Transmission Provider's Transmission System. The one-line diagram also identifies the electrical switching configuration of the interconnection equipment, including, without limitation: the transformer, switchgear, meters, and other station equipment.

Conclusion:

The total estimated cost of the PSCo transmission system improvements required for PI-2019-6 to qualify for Provisional Interconnection Service is:

- **$3.130 Million (Tables 6 and 7)**

For PI-2019-6 interconnection:

Provisional Interconnection Service (after required transmission system improvements) = 240MW

The Provisional Interconnection Service results above are contingent upon the transmission system improvements identified in Attachment 1.

Security: The GI-2019-6 request is ERIS. The estimated risk of the potential interconnection facilities and Network Upgrades that might be identified at the conclusion of the GI-2019-6 LGIP is $5 million. Security amount for PI-2019-6 is $5 million.

The Customer is required to design and build the Generating Facility to mitigate any potential inverter interactions with the neighboring inverter based Generating Facility(ies), interference with performance of the arc furnace load in the area and existing STATCOMs near the Comanche Substation.

The Interconnection Customer assumes all risk and liabilities with respect to changes between the Provisional Large Generator Interconnection Agreement and the Large Generator Interconnection Agreement, including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.
Note: Provisional Interconnection Service in and of itself, does not convey transmission service.

Table 6 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
Comanche Sub 230kV Bus	Interconnect the 240MW PI-2019-6 Generating Facility: The new equipment includes: • One 230kV gang switch • Three 230kV arresters • One 230kV Deadend • Fiber Communication • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$0.358
	Transmission line tap into substation:	$0.045
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.025
	Total Cost Estimate for Transmission Providers Interconnection Facilities	**$0.428**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 7 - Network Upgrades for Interconnection (ERIS)

Element	Description	Cost Est. (Millions)
Comanche Sub 230kV Bus	Install a new bay position at the Comanche 230kV Substation to interconnect the 240MW Generating Facility. The new equipment includes: • Five 230kV gang switches • Two 230kV Gas Circuit Breakers • Three 230kV Metering CT/PT Combo Units • One 230kV Deadend • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • 230kV Bus Relaying	$2.692
	Siting and Land Rights support for substation construction	$0.010
	Total Cost Estimate for Network Upgrades for Interconnection	**$2.702**
Time Frame	**Site, design, procure and construct**	**12 Months**

Cost Estimate Assumptions

- Appropriation level project cost estimates (AE) for Interconnection Facilities were developed by PSCo Engineering. A level of accuracy of ±20% is specified for AE's.
- Estimates are based on 2020 dollars (appropriate contingency and escalation applied).
- "Allowance for Funds Used during Construction" (AFUDC) has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Solar Generation Facility is not in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates.
- PSCo (or its Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- The estimated time to design, procure and construct the interconnection facilities is approximately 12 months after authorization to proceed has been obtained.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date due.
- Power Quality Metering (PQM) will be required on the Customer's 230kV line generation tie-line terminating into Comanche 230kV Substation.
- 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.

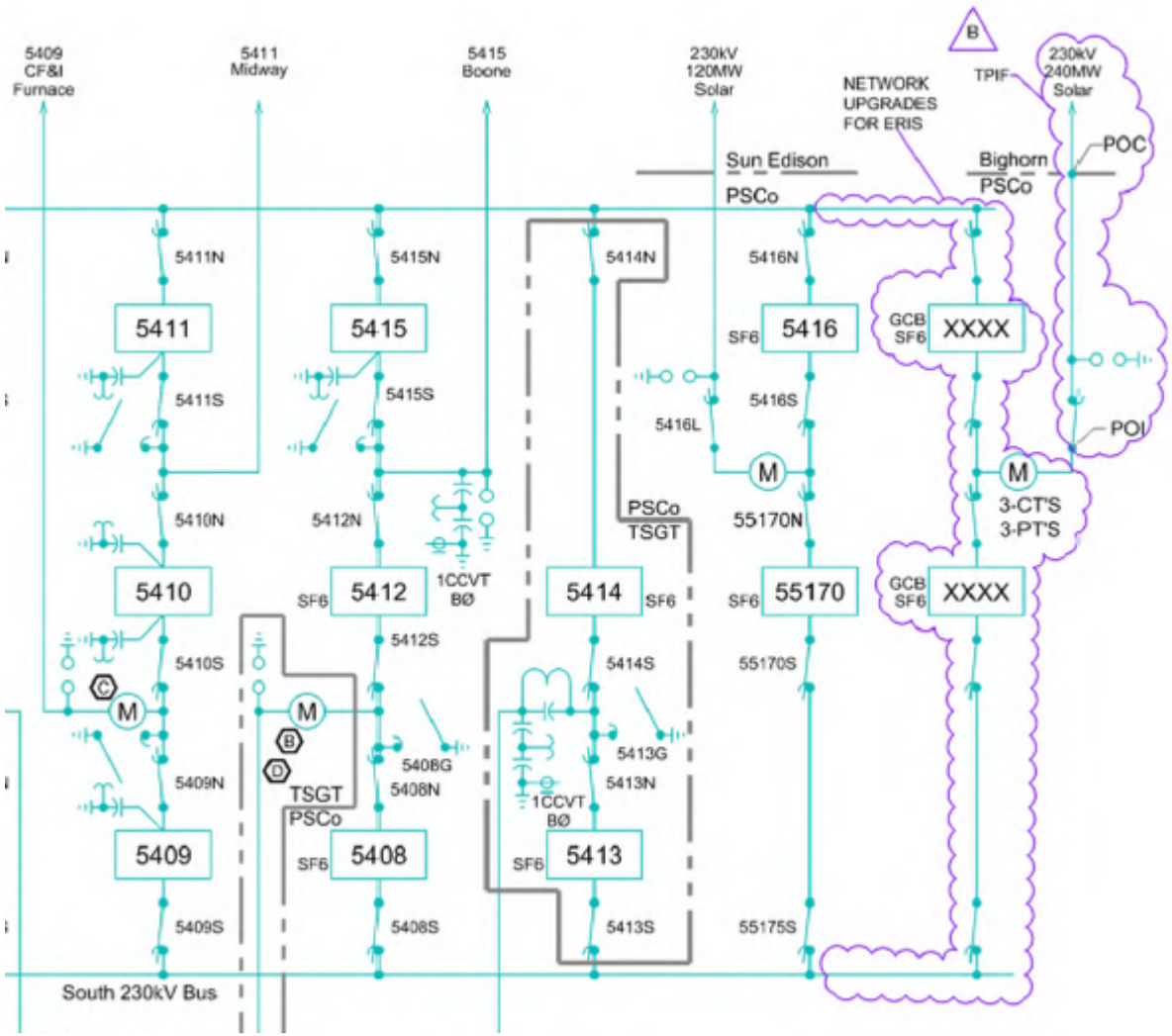

Figure 2 – Preliminary one-line of PI-2019-6 Comanche 230kV POI

Attachment 1 – Contingent Facilities Assigned to PI-2019-6

The following is the list of the unbuilt Interconnection Facilities and Network Upgrades upon which the PI-2019-6 request's costs, timing, and study findings are dependent, and if delayed or not built, could cause a need for re-studies of the Interconnection Request or a reassessment of the Interconnection Facilities and/or Network Upgrades and/or costs and timing. PI-2919-6's maximum allowable output may be effected if these Contingent Facilities are not in-service.

1. The following unbuilt transmission projects modeled in the Base Case
    - PSCo's Monument – Flying Horse 115kV Series Reactor project
    - PSCo's project to upgrade Waterton – Martin1 tap 115kV line
    - PSCo's project to upgrade Villa Grove – Poncha 69kV Line
    - PSCo's project to upgrade Poncha – San Luis Valley 115kV line
    - PSCo's terminal upgrade project to uprate the Waterton – Martin2 tap 115kV line to 189MVA
    - PSCo's terminal upgrade project to uprate the Malta – Twin Lakes 115kV line to 143MVA
    - PSCo's terminal upgrade project to uprate the Twin Lakes – Otero 115kV line to 143MVA
    - PSCo's terminal upgrade project to uprate the Otero – Buena Vista 115kV line to 150MVA
    - PSCo's terminal upgrade project to uprate the Buena Vista – Ray Lewis 115kV line to 136MVA
    - PSCo's terminal upgrade project to uprate the Ray Lewis – Poncha 115kV line to 164MVA
    - PSCo's terminal upgrade project to uprate the Arapahoe – SantaFe – Daniels Park 230kV to 560MVA
    - PSCo's terminal upgrade project to uprate the Daniels Park – Prairie1 230kV line to 576MVA
    - PSCo's terminal upgrade project to uprate the Greenwood – Monaco 230kV line to 503MVA
    - PSCo's terminal upgrade project to uprate the Leetsdale – Monaco 230kV line to 470MVA
    - PSCo's terminal upgrade project to uprate the Poncha – Smelter town 115kV line to 114MVA
    - PSCo's terminal upgrade project to uprate the San Luis Valley – Sargent 115kV line to 120MVA
    - TSGT's planned project to uprate the Fuller – Vollmer – Black Squirrel 115 kV line to 173 MVA
    - BHE's planed project to uprate the Fountain Valley – DesertCove 115kV line to 171MVA

- BHE's planned project to uprate the Fountain Valley – MidwayBR 115kV line to 171MVA
- BHE's Pueblo West Substation
- BHE's Skyline Ranch Substation
- BHE's West Station – Greenhorn 115kV line Rebuild project
- CSU's project to close Tesla - Cottonwood 34.5kV line and open the Kettle Creek – Tesla 34.5kV line
- CSU's new Cottonwood 230/115kV auto-transformer replacement
- CSU's Nixon – Kelker 230kV line uprate project

2. Network Upgrades for Interconnection assigned to PI-2019-6 (refer to Table 6 and 7 of this report)