



GENERATION INTERCONNECTION REQUEST # GI-2017-6

**FEASIBILITY STUDY REPORT
(DRAFT)**

**50 MW SOLAR FACILITY,
BARR LAKE 230KV SUBSTATION
ADAMS COUNTY, COLORADO**

XCEL ENERGY – PSCO TRANSMISSION PLANNING WEST
September 29, 2017



Executive Summary

The GI-2017-6 (“GI”) is a 50 MW solar generation facility that will be located in Adams County, Colorado. The GI facility will consist of several strings of Canadian Solar 340 W panels that will then be strung together and will land at a TMEIC Inverter PVH-L2700GR. The power will then go through a series of local transformers, which will then step up through a 34.5/230kV, 66.6 MVA transformer. The GI Customer designated the 230kV bus at PSCo’s Barr Lake Substation as the Point of Interconnection (POI) – no alternative POI was specified.

The proposed Commercial Operation Date (COD)¹ is December 31, 2019. Accordingly the backfeed date is assumed to be June 30, 2019, approximately six (6) months before the COD.

As requested by the Customer, this generation interconnection was studied for both Network Resource Interconnection Service (NRIS)² and Energy Resource Interconnection Service (ERIS)³. These investigations included steady-state (power flow) and short-circuit studies. The power flow analyses were performed using a 2022HS base case put together by Western Electricity Coordinating Council (WECC).

The 50 MW output of GI-2017-6 is assumed to be delivered to PSCo native load, so existing PSCo generation is used as its sink.

The study did not show any thermal or voltage limit violations attributable to the interconnection of GI-2017-6 that would need mitigation with network upgrades.

NRIS for GI-2017-6 = 50 MW

ERIS for GI-2017-6 = 50 MW

¹ **Commercial Operation Date** of a unit shall mean the date on which the Generating Facility commences Commercial Operation as agreed to by the Parties pursuant to Appendix E to the Standard Large Generator Interconnection Agreement.

² **Network Resource Interconnection Service (NRIS)** allows Interconnection Customer’s Large Generating Facility to be designated as a Network Resource, up to the Large Generating Facility’s full output, on the same basis as existing Network Resources interconnected to Transmission Provider’s Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur. (*section 3.2.2 of Attachment N in Xcel Energy OATT*)

³ **Energy Resource Interconnection Service (ERIS)** allows Interconnection Customer to connect the Large Generating Facility to the Transmission System and be eligible to deliver the Large Generating Facility’s output using the existing firm or non-firm capacity of the Transmission System on an “as available” basis. Energy Resource Interconnection Service does not in and of itself convey any right to deliver electricity to any specific customer or Point of Delivery. (*section 3.2.1 of Attachment N in Xcel Energy OATT*)



Tables 2, 3 and 4 provide the indicative cost estimates (with no implied accuracy) and associated timeframes for the system improvements needed to interconnect GI-2017-6. The total estimated cost of system improvements is approximately **\$5.740** million and includes:

- \$ 1.055 million for PSCo-Owned, Customer-Funded Transmission Provider Interconnection Facilities
- \$ 4.685 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- \$ 0.000 million for PSCo-Owned, PSCo-Funded Network Upgrades for Delivery

It is anticipated that completion of construction may take up to 18 months from the receipt of the Customer's Notice to Proceed (NTP).

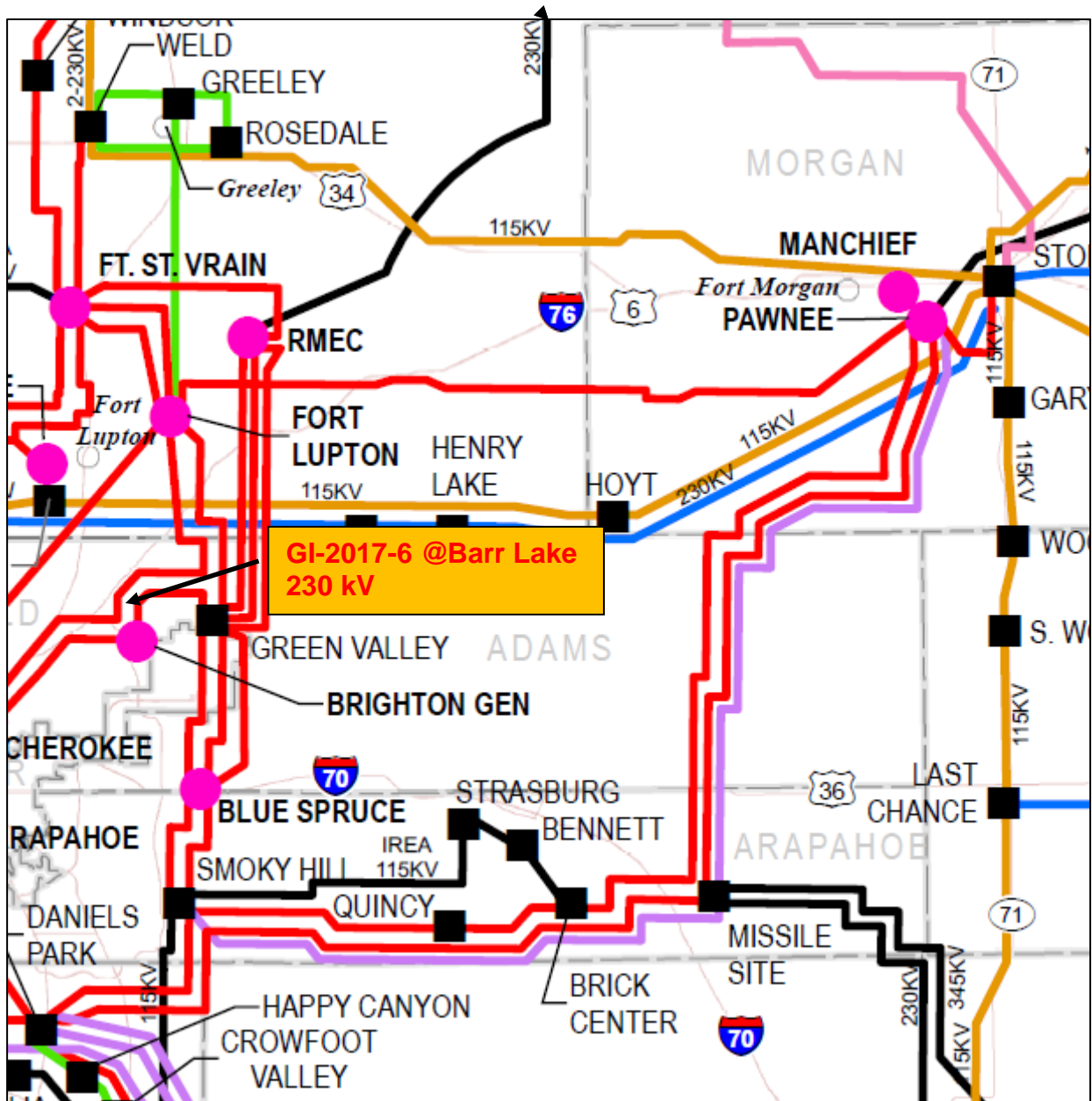


Figure 1: Point of Interconnection and Study Area for GI-2017-6



A. Introduction

The GI-2017-6 (“GI”) is a 50 MW solar generation facility that will be located in Adams County, Colorado. The GI facility will consist of several strings of Canadian Solar 340 W panels that will then be strung together and will land at a TMEIC Inverter PVH-L2700GR. The power will then go through a series of local transformers, which will then step up through a 34.5/230kV, 66.6 MVA transformer. Public Service Company of Colorado (PSCo) received the feasibility study request for the GI on February 10, 2017, and a scoping meeting was held on March 13, 2017. The GI Customer designated the 230kV bus at PSCo’s Barr Lake Substation as the Point of Interconnection (POI) – no alternative POI was specified.

The proposed Commercial Operation Date (COD)¹ is December 31, 2019. Accordingly, the backfeed date is assumed to be June 30, 2019, approximately six (6) months before the COD.

The 50 MW output of GI-2017-6 is assumed to be delivered to PSCo native load, so existing PSCo generation is used as the sink.

B. Study Scope and Analysis

The scope of this report includes steady state (power flow) analysis, short circuit analysis and indicative level cost estimates. The power flow analysis identified thermal and voltage violations in the PSCo system and the affected party’s system as a result of the interconnection of the GI. Several single contingencies were studied. Short circuit analysis determines the maximum available fault current at the POI. In addition, the breaker duty study determines if any breakers in the neighboring substations exceed their breaker duty ratings and need to be replaced.

PSCo adheres to applicable NERC Reliability Standards & Western Electricity Coordinating Council (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: $\leq 100\%$ of the normal facility rating

Voltage range: 0.95 to 1.05 per unit

P1-P2 – Single Contingencies:

Thermal Loading: $\leq 100\%$ Normal facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: $\leq 5\%$ of pre-contingency voltage



P3-P7– Multiple Contingencies:

Thermal Loading: $\leq 100\%$ Emergency facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: $\leq 5\%$ of pre-contingency voltage

The GI was studied for both Network Resource Interconnection Service (NRIS)² and Energy Resource Interconnection Service (ERIS)³.

C. Power Flow Study Models

The power flow case used for the study was the WECC 2022HS case released on 8/31/2016, which was reviewed and finalized for the 2017 Colorado Coordinated Planning Group studies. The Pawnee – Daniels Park 345kV project (expected to be in-service in 2019) and the Rush Creek Generation (expected to be in-service in 2018) are modeled in-service in the case.

The generation dispatch in the WECC base case was adjusted to create a reasonably stressed flow in the study area which comprises WECC designated zones 700 and 706. This was accomplished by adopting the generation dispatch given in Table-6&7 (Appendix B). Figure-1 shows the system map of the study area and the POI.

The GI-2017-6 interconnection was studied as a stand-alone project. That is, the study did not include any other Generator Interconnection Requests (GIR) existing in PSCo's or an affected party's GIR queue, other than the GIR's that are considered to be planned resources for which Power Purchase Agreements have been signed.

Two power flow cases were created for evaluating the feasibility of GI-2017-6 interconnection – the benchmark case and the study case. The benchmark case modeled the system without GI-2017-6, whereas the study case included GI-2017-6.

The GI was studied using the following generator modeling data:

$P_{max} = 50$ MW, $P_{min} = 0$ MW, $Q_{max} = 16$ MVAR (@0.95pf lag) and $Q_{min} = -16$ MVAR (@0.95pf lead).

PSCo's Comanche #1 unit was used as the sink for the 50 MW generation injection from GI-2017-6.

D. Power Flow Study Process



The study area is the electrical system consisting of PSCo's transmission system and the affected party's transmission system that is impacted or that will impact interconnection of the GI. The study area for GI-2017-6 includes WECC designated zones 700 and 706. Figure-1 shows the general study area and the POI.

The steady state analysis was performed using PTI's PSSE Ver. 33.6.0 program and the ACCC contingency analysis tool. The analysis was performed for P0, P1, P2 contingencies of North American Reliability Council standard TPL-001-4.

- The P0 analysis was run on all of area 70 and 73
- The P1 single contingencies were run all of area 70 and 73
- The P2 single contingencies were run on all of area 70 and 73

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

The thermal violations on PSCo facilities attributed to the GI interconnection included any facility without a pre-existing thermal violation but resulted in a thermal loading >100% post GI interconnection and contributed to a 2% increase in the facility loading compared to the benchmark case loading.

Also, pre-existing thermal violations in the benchmark case are attributable to the GI interconnection if the planned PSCo upgrade is insufficient to mitigate the (increased) thermal violation in the study case. In such case, only the additional facility rating increase (beyond the PSCo planned uprate) required to accommodate the full NRIS capacity will be attributed to GI.

For affected party facilities, all new thermal violations with loading >100% are attributable to the GI interconnection. For pre-existing thermal violations, only the incremental loading increase is attributed to the GI interconnection.

The voltage violations attributed to GI included any new voltage range and voltage deviation violations. Increments in the existing voltage violations are attributed to the GI if the increase is fairly significant.

Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect its Large Generating Facility with Public Service of Colorado's (PSCo) 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>).

In addition, solar generating plant interconnections must also fulfill the performance requirements specified in FERC Order 661-A. 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 (GI) 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 (34.5 kV or 115 kV 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 1.02 – 1.03 per unit voltage range standards at the POI. Further, for solar generating plants to meet the LVRT (Low Voltage Ride Through) performance requirements specified in FERC Order 661-A, an appropriately sized and located dynamic reactive power device (DVAR, SVC, etc.) may also need to be installed within the generating plant. 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).

E. Power Flow Results

Single Contingency Analysis:



The results of single contingency analysis are provided in Table 5 in Appendix A. Several pre-existing thermal violations (without GI-2017-6) exist. But since these thermal violations show no (zero) incremental change with the addition of GI-2017-6, none of them can be attributed to GI-2017-6. The single contingency analysis did not show any voltage limit violations due to the addition of the GI-2017-6.

F. Short Circuit Analysis

The short circuit study results show that no circuit breakers in the Barr Lake Substation (or in PSCo’s system) will be over-dutied by interconnecting the proposed GI-2017-6 solar generation facility. The base case scenario before GI-2017-6 included preliminary models for all expected transmission system improvements projected through the end of 2019. It is assumed that the impedance of the generator tie line is negligible. The main power transformer is assumed to be 230/34.5/13.8kV wye-wye-delta with an impedance of 10% on the base rating of 33MVA.

Table 1. Short Circuit Analysis Results

GI-2017-6 Impact on Short Circuit Levels at Barr Lake 230kV POI

System Condition	Three-Phase (3-Ph) Fault Level (Amps)	Single-Line-to-Ground (SLG) Fault Level (Amps)	Thevenin System Equivalent Impedance (R + jX) (Ohms)
Before GI-2017-6 Y2019	17,629	15,591	Z1(pos)= 0.735+j7.497 Z2(neg)= 0.760+j7.476 Z0(zero)= 1.608+j10.390
After GI-2017-6 Y2019	17,863	16,505	Z1(pos)= 0.735+j7.497 Z2(neg)= 0.760+j7.476 Z0(zero)= 1.437+j9.766

G. Conclusion

Since the study did not find any thermal and voltage limit violations attributable to the addition of GI-2017-6, pending breaker duty analysis,

NRIS for GI-2017-6 = 50 MW

ERIS for GI-2017-6 = 50 MW

H. Cost Estimates and Assumptions



Indicative level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery have been developed by PSCo Engineering. The cost estimates are in 2017 dollars with escalation and contingencies applied and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new PSCo facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering. The estimated total interconnection cost and network upgrades for delivery for GI-2017-6 is **\$5.740 million**.

The following tables list the improvements required to accommodate the interconnection and the delivery of the Project generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon a more detailed and refined design.

Figure 2 shows a conceptual one-line of the proposed interconnection at the Barr Lake 230kV Substation.

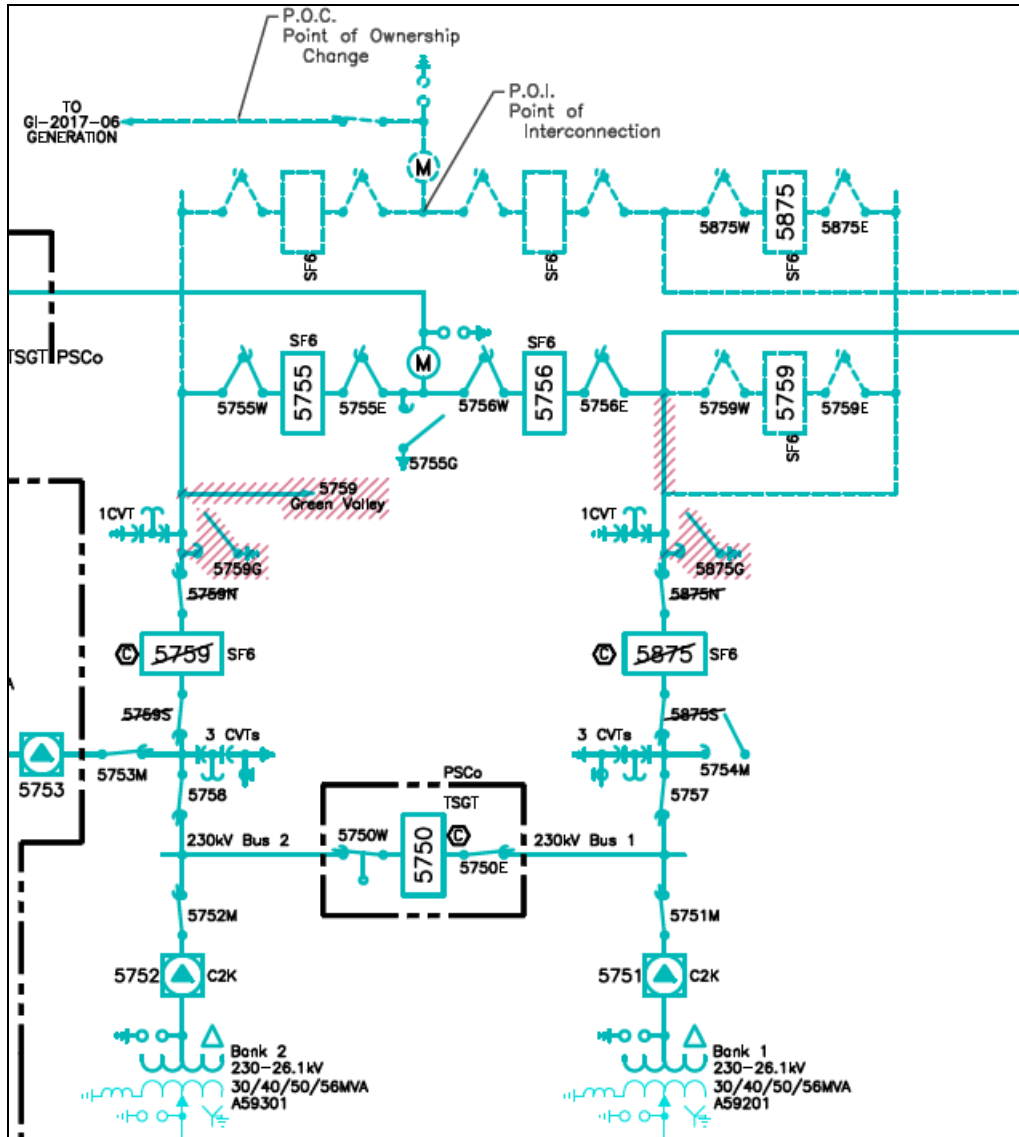


Figure 2. Preliminary One-Line Diagram for GI-2017-6 Interconnection at Barr Lake 230kV Substation.

Table 2. PSCo Owned, Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Barr Lake 230kV Transmission Sub Station	Interconnect Customer to the Barr Lake Sub 230kV bus. The new equipment includes; <ul style="list-style-type: none"> • One (1) motor operated 230kV disconnect switch • Three (3) 230kV combination CT/PT metering units • One (1) 230kV CCVT • Power Quality Metering (230kV line from Customer) • Three (3) surge arresters • Two (2) relay panels • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing 	\$1.000
	Transmission line tap into substation. Conductor, hardware, and installation labor.	\$0.055
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$1.055
Time Frame	Design, procure and construct	18 Months

Table 3. PSCo Owned, PSCo Funded Network Upgrades for Interconnection

Element	Description	Cost Estimate (Millions)
PSCo's Barr Lake 230kV Transmission Sub Station	Interconnect Customer to the Barr Lake Sub 230kV bus. The new equipment includes; <ul style="list-style-type: none"> • One (1) 230kV circuit breaker • Two (2) 230kV gang switches • Associated communications, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, miscellaneous electrical equipment, cabling and wiring • Associated foundations and structures • Associated road and site development, fencing and grounding 	\$4.600
	Siting and Land Rights support for substation land acquisition and construction.	\$0.085
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	\$4.685
Time Frame	Site, design, procure and construct	18 Months



Table 4. PSCo Owned, PSCo Funded Network Upgrades for Delivery

Element	Description	Cost Estimate (Millions)
NA	None identified	NA
	Total Cost Estimate for PSCo Network Upgrades for Delivery	\$0
Duration	Design, procure, permit and construct	NA
	Total Project Estimate	\$5.740

Cost Estimate Assumptions

- Indicative level project cost estimates (IE) for Interconnection Facilities were developed by PSCo Engineering. No level of accuracy is specified for IE’s.
- Estimates are based on 2017 dollars (appropriate contingency and escalation applied).
- Allowance for Funds Used During Construction (AFUDC) has been excluded.
- Labor is estimated for straight time only with no overtime included.
- Lead times for materials were considered for the schedule.
- PSCo (or it’s Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- A CPCN will not be required for the interconnection facilities construction.
- The estimated time to design, procure and construct the interconnection facilities is approximately 18 months.
- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date due.
- This project is completely independent of other queued projects and their respective ISD’s.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- 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.
- Power Quality Metering (PQM) will be required on the Customer’s 230 kV line terminating into Barr Lake Substation.
- The Customer’s Generation Facility is not in PSCo’s retail service territory. Therefore, no costs for retail load metering are included in these estimates.



Appendix A – Power Flow Contingency Analysis Results

Notes –

1. No new thermal violations occurred with GI-2017-6.
2. Thermal overloads are calculated using the normal rating of the facility.
3. Below are samples of pre-existing thermal violations (that is, without GI-2017-6). The comprehensive list of pre-existing thermal violations is available upon request.

Table 5 – Summary of Thermal Violations from Single Contingency Analysis

				Facility Loading Without GI-2017-6		Facility Loading With GI-2017-6			
Monitored Facility (Line or Transformer)	Type	Owner	Branch Rating MVA (Norm/Emer)	N-1 Flow MVA	N-1 Flow % of Rating (Norm/Emer)	N-1 Flow MVA	N-1 Flow % of Rating (Norm/Emer)	% Change	NERC Single Contingency
Allison – Soda Lake 115kV	Line	PSCo	153/174	159	105%/92%	159	105%/92%	0.0%	Bancroft – Kendrick 115kV
Bancroft – Kendrick 115kV	Line	PSCo	158/174	159	102%/92%	159	102%/92%	0.0%	Allison – Soda Lake 115kV
Cherokee_S – Mapleton2 115kV	Line	PSCo	159/175	165	104%/94%	165	104%/94%	0.0%	Cherokee_S – North 115kV
Lafayette-Valmont 115kV	Line	PSCo	120/146	140	117%/96%	140	117%/96%	0.0%	Coorsrec-Fultonts 115kV



Appendix B – Generation Dispatch

Table 6. Generation Dispatch for Wind in the Study Area

Bus Numl	Bus Name	Id	Ar	Area	Zonl	In Service	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mv)	QMax (Mv)	QMin (Mv)	PSCo	VER	delta	% renewable
70622	MISSILE_W1	34.500	W1	70	PSCo	700	1	200	250	0	0	0	200	0	0	wind at 80%
70629	RUSHCK_W1	34.500	W1	70	PSCo	700	1	320	400	0	0.8315	105.1789	-105.179	320	0	wind at 80%
70635	LIMON1_W	34.500	W1	70	PSCo	700	1	160.8	201	0	21.4561	65.7	-65.7	160.8	0	wind at 80%
70661	JKFUL1	34.500	W1	70	PSCo	757	1	26.06	124.1	0	-1.8299	40.88	-40.88	49.64	23.58	wind at 40%
70701	CO_GRN_E	34.500	W1	70	PSCo	712	1	17	81	10.8	-15.2891	26	-39.2	32.4	15.4	wind at 40%
70703	TWNBUTTE	34.500	W1	70	PSCo	712	1	15.8	75	0	-10.8608	25	-25	30	14.2	wind at 40%
70710	PTZLOGN1	34.500	W1	70	PSCo	706	1	80.4	201	0	-8.4023	65.7	-65.7	80.4	0	wind at 40%
70721	SPRNGCAN	34.500	W1	70	PSCo	706	1	12.6	60	0	-6.9906	20	-20	24	11.4	wind at 40%
70723	RDGCREST	34.500	W1	70	PSCo	752	1	6.3	29.7	0	0	0	11.88	5.58	wind at 40%	
70823	CEDARCK_1A	34.500	W1	70	PSCo	706	1	46.2	220	0	3.8879	49	-73	88	41.8	wind at 40%
70825	CEDARCK_2A	34.500	W1	70	PSCo	706	1	31.5	150	0	-7.517	49	-73	60	28.5	wind at 40%
70631	RUSHCK_W2	34.500	W2	70	PSCo	700	1	160	200	0	-12.2178	52.5895	-52.5895	160	0	wind at 80%
70636	LIMON2_W	34.500	W2	70	PSCo	700	1	160.8	201	0	14.8987	65.7	-65.7	160.8	0	wind at 80%
70662	JKFUL2	34.500	W2	70	PSCo	757	1	26.42	125.8	0	-1.8267	41.44	-41.44	50.32	23.9	wind at 40%
70702	CO_GRN_W	34.500	W2	70	PSCo	712	1	17	81	10.8	-1.7376	26	-39.2	32.4	15.4	wind at 40%
70712	PTZLOGN2	34.500	W2	70	PSCo	706	1	48	120	0	-5.6429	39.2	-39.2	48	0	wind at 40%
70824	CEDARCK_1B	34.500	W2	70	PSCo	706	1	16.8	80	0	3.8851	65.7	-65.7	32	15.2	wind at 40%
70826	CEDARCK_2B	34.500	W2	70	PSCo	706	1	21.5	100	0	-7.7698	32.67	-48.67	40	18.5	wind at 40%
70637	LIMON3_W	34.500	W3	70	PSCo	700	1	160.8	201	0	14.8764	65.7	-65.7	160.8	0	wind at 80%
70713	PTZLOGN3	34.500	W3	70	PSCo	706	1	31.8	79.5	0	-0.9555	26	-26	31.8	0	wind at 40%
70714	PTZLOGN4	34.500	W4	70	PSCo	706	1	70	175	0	10.5167	49	-73	70	0	wind at 40%



Table 7. Generation Dispatch for Solar in the Study Area

Bus Num	Bus Name	Id	Ar	Area	Zon	In Service	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mv)	QMax (Mv)	QMin (Mv)	PSCo	VER	delta	% renewable
70931	SLVSOLAR	34.500	S1	70	PSCO	710	1	12.4	19	0	0	0	10.45	-1.95	solar at 55%	
70934	COMAN_PV	34.500	S1	70	PSCO	704	1	78	120	0	0	0	66	-12	solar at 55%	
70935	SUNPOWER	34.500	S1	70	PSCO	710	1	28.6	52	0	0	0	28.6	0	solar at 55%	
71003	BAC_MSA GEN4	13.80	S1	70	PSCO	712	1	21	24.8	0	0.2034	15.6	13.64	-7.36	solar at 55%	
71004	BAC_MSA GEN5	13.80	S1	70	PSCO	712	1	21	24.8	0	0.1965	15.6	13.64	-7.36	solar at 55%	
70932	SOLAR_GE	34.500	S2	70	PSCO	710	1	19.5	30	0	0	0	16.5	-3	solar at 55%	
70933	SOLAR_GE	34.500	S3	70	PSCO	710	1	19.5	30	0	0	0	16.5	-3	solar at 55%	