Feasibility Study Report
Generation Interconnection Request # GI-2016-13

200MW Solar Photovoltaic Facility
Tapping Comanche - Boone 230kV Substation
Pueblo County, Colorado

Transmission Planning West
Xcel Energy
October 18, 2016

Executive Summary

This report evaluates the feasibility of interconnecting GI-2016-13, a 200MW solar photovoltaic generation facility that will be located in Pueblo, Colorado. The GI-2016-13 solar photovoltaic generation facility will be comprised of GE-LVS-1520-SLR inverters which will connect to thirty (30) 0.55/34.5kV, 2MVA generator step-up transformers, the generator step up transformers will interface with one 34.5/230/13.8 kV, 135/180/225 MVA Main Step-up Transformer which will interconnect to the POI.

The Primary POI requested by the Interconnection Customer is a tap on the Boone – Comanche 230kV line, at approximately five (5) miles from the Boone Substation. The tap point will be a new Substation which will be referred to as "GI-2016-13 230kV Substation" in this report. The GI-2016-13 facility will interconnect to the Primary POI using a 2 mile 230kV tie-line that will be owned and constructed by the Interconnection Customer. The Interconnection Customer did not propose a secondary POI.

The Commercial Operation Date (COD) and backfeed date of GI-2016-13 are June 1, 2020, and December 1, 2019 respectively. The study request is for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS).

The scope of this report includes steady state (power flow) analysis and short circuit analysis. The studies were performed using a Western Electricity Coordinating Council (WECC) approved 2022HS1 heavy summer base case by simulating heavy south-north flow on the Comanche – Midway – Jackson Fuller – Daniels Park study area.

The GI-2016-13 interconnection request 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 any affected party's GIR queue, other than the interconnection requests that are considered to be planned resources for which Power Purchase Agreements have been signed.

The affected parties for this study are Colorado Springs Utilities (CSU), Black Hills Colorado Electric (BHCE) and Intermountain Rural Electric Association (IREA).

Steady State Contingency Analysis Results:

The benchmark case and study case did not have any system intact thermal violations or bus voltage violations.

The GI-2016-13 generation facility interconnection caused new thermal overloads on two (2) PSCo facilities. In addition, interconnection of GI-2016-13 contributed to an increase in the pre-existing benchmark case overload on PSCo's Waterton – Martin2 Tap 115kV (4%), CSU's Cottonwood N – KettleCreek S 115kV line and the Palmer Lake – Monument 115kV line (15.7%) jointly owned by PSCo and CSU.

The implementation of the Palmer Lake – Monument 115kV line operating procedure eliminates the overloads on the Palmer Lake – Monument 115kV line as well as the Cottonwood N – KettleCreek S 115kV line. PSCo has a planned project to increase the rating of the Waterton – Martin 2 Tap 115kV line rating in 2019. The PSCo planned rating increase will be sufficient to eliminate the thermal overload in the study case; therefore, this thermal violation is not attributable to GI-2016-13.

The following PSCo facility contingency overloads are attributable to the interconnection of GI-2016-13.

- Daniels Park – Prairie1 230kV line loading increased from 95.9% to 102.6%
- Greenwood – Monaco 230kV line loading increased from 97.1% to 104.1%

There were no voltage violations attributable to GI-2016-13 addition.

However, CSU and BHCE consider multiple contingencies as credible outages for planning purposes, so the Interconnection Customer will need to work with CSU and BHCE in order to identify mitigation measures to eliminate the following thermal violations.

The following CSU facility contingency overloads are attributable to the interconnection of GI-2016-13

- Monument - Gresham 115kV line loading increased from 105.6% to 108.8%
- Fountain S – RD_Nixon 115kV line loading increased from 115.6% to 118.1%

The following BHCE facility contingency overloads are attributable to the interconnection of GI-2016-13

- Burntmill – GreenHorn 115kV line loading increased from 94.9% to 102.5%
- Fountain Valley – DesertCove 115kV line loading increased from 141.7% to 161.3%
- Fountain Valley – MidwayBR 115kV line loading increased from 146.5% to 166.8%
- HydePark – Pueblo Plant 115kV line loading increased from 97.8% to 106.6%
- Pueblo Plant – Reader 115kV line loading increased from 100% to 107.9%

Short Circuit

The POI will be a new substation; therefore, the circuit breakers at the new substation will be adequately rated. The fault current levels and Thevenin impedance values for three phase and single line to ground faults at the POI are given in Table-2. The breaker duty study determined that no breaker replacements are needed in neighboring substations.

Conclusion

Energy Resource Interconnection Service (ERIS): GI-2016-13 output for ERIS is 0 MW for the studied generation dispatch scenario due to the benchmark case multiple contingency overloads in the CSU and BHCE facilities listed above. However, the ERIS output may vary from 0MW to 200MW depending on the dispatch levels of the prevailing generation resources located in the electrical vicinity of GI-2016-13 (Jackson Fuller, Comanche, Midway and Lamar areas, CSU system and BHCE system).

Network Resource Interconnection Service (NRIS): Implementing the Network Upgrades needed to mitigate the above mentioned thermal overload on the PSCo, CSU and BHCE facilities will allow GI-2016-13 to achieve full NRIS of 200MW. The Network Upgrades required to eliminate thermal violations on the PSCo lines include fixing terminal equipment to increase the line ratings. The cost for uprating the two PSCo lines is included in Table-5. The Interconnection Customer should work with CSU and BHCE in order to identify mitigation measures to eliminate the above mentioned CSU and BHCE facility overloads.

Cost Estimates (in 2016 dollars)

The total estimated cost of the recommended system improvements to interconnect the project is approximately $8.347 million and includes:

- $ 0.860 million for PSCo-Owned, Customer-Funded Transmission Provider Interconnection Facilities
- $ 6.794 million for PSCo-Owned, PSCo-Funded Network Facilities for Interconnection
- $ 0.693 million for PSCo Network Upgrades for Delivery to PSCo Loads

The estimated time to design, procure and construct the interconnection facilities is approximately 18 months after authorization to proceed has been obtained. A CPCN will likely be required for the GI-2016-13 230kV Substation construction. The time to secure the CPCN would be approximately 18 months before any procurement and construction can be done. The total estimated time for design procurement and construction will be 36 months from the time the necessary authorization to proceed has been obtained.

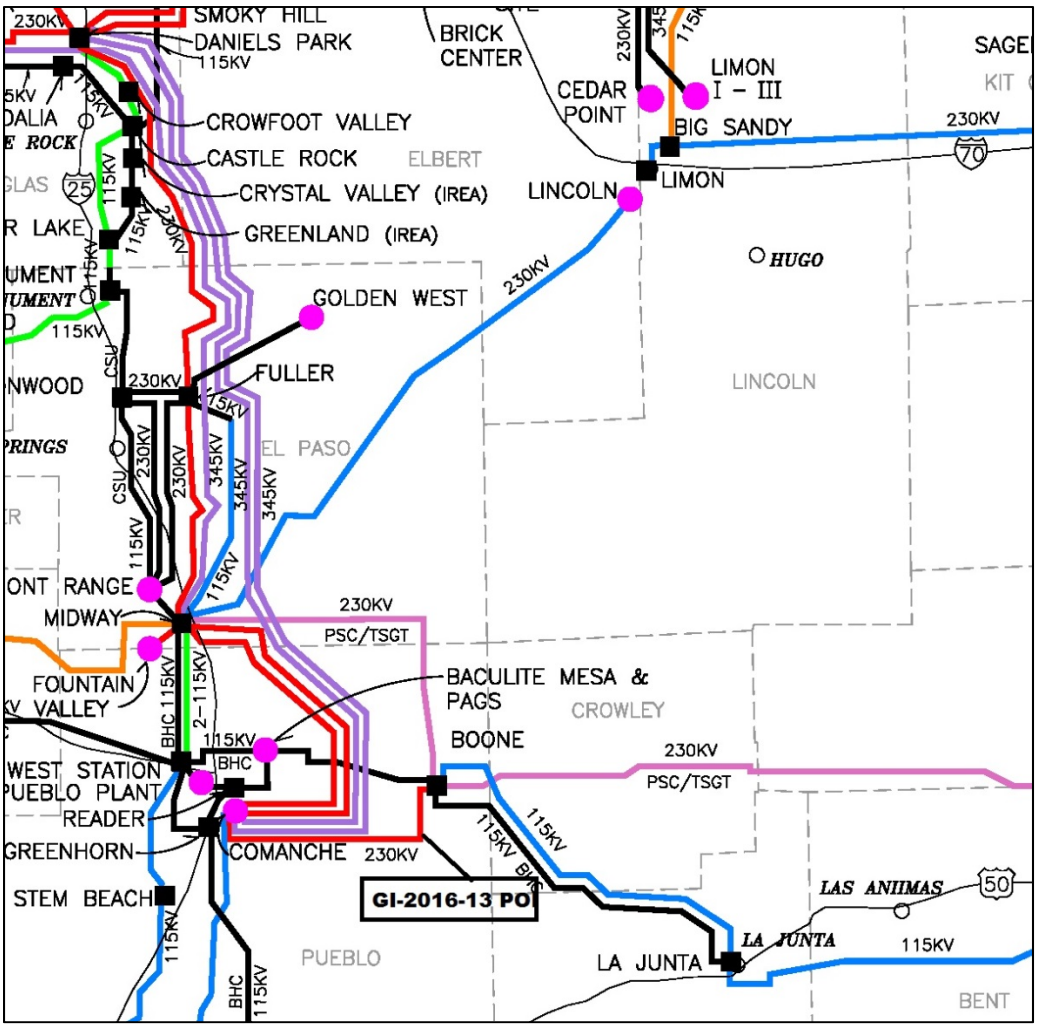

Figure 1 - GI-2016-13 Point of Interconnection on the Boone – Comanche 230kV line and Study Area

Introduction

Public Service Company of Colorado (PSCo) received a generation interconnection study request for a new 200MW solar photovoltaic generation facility ("GI-2016-13") on June 16, 2016. The GI-2016-13 solar photovoltaic generation facility will be comprised of GE-LVS-1520-SLR inverters which will connect to 0.55/34.5kV, 2MVA generator step up transformers. The generator step up transformers will interface with one 34.5/230/13.8 kV, 135/180/225 MVA Main Step-up Transformer which will interconnect to the POI.

The Primary POI requested by the Interconnection Customer is a tap on the Boone – Comanche 230kV line, at approximately five (5) miles from the Boone Substation. The tap point will be a new Substation which will be referred to in this report as "GI-2016-13 230kV Substation". The GI-2016-13 will interconnect to the Primary POI using a 2 mile 230kV tie-line that will be owned and constructed by the Interconnection Customer. The GI-2016-13 generation facility will be located in the town of Boone in Pueblo County, Colorado.

The Commercial Operation Date (COD) and backfeed date of GI-2016-13 are June 1, 2020 and December 1, 2019, respectively.

The Interconnection Customer did not propose a secondary POI.

The GI-2016-13 generation interconnection study request is for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS).

PSCo load is assumed to be the sink for GI-2016-13 generation.

Study Scope and Analysis Criteria

The scope of this report includes steady state (power flow) analysis and short circuit analysis. The power flow analysis identifies thermal and voltage violations in the PSCo system and the affected party's system as a result of the interconnection of GI-2016-13. Several single and multiple contingencies are studied. Short circuit analysis determines the maximum available fault current at the POI. The breaker duty study determines if breaker replacements are needed in neighboring substations due to the interconnection of GI-2016-13.

PSCo adheres to applicable NERC Reliability Standards & WECC Reliability Criteria, as well as internal criteria for planning studies. For the steady state analysis the 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 – Single Contingencies:
Thermal Loading: <=100% Normal facility rating
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

P3-P7– Multiple Contingencies:

Thermal Loading: <=100% Emergency facility rating
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

The thermal and voltage analysis criteria for BHCE facilities are the same as above.

The thermal and voltage analysis criteria for CSU facilities are the same as above, except that the thermal analysis for single contingencies is calculated based on the emergency rating of the facility.

GI-2016-13 was studied for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS).

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.

Network Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission system (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

The affected parties for this GI study are Colorado Springs Utilities (CSU), Black Hills Colorado Electric (BHCE) and Intermountain Rural Electric Association (IREA).

Power Flow Study Models

The study was performed using the Western Electricity Coordinating Council (WECC) 2022HS1 power flow case released on 09/1/2016. The 2022HS1 case was selected for the Power Flow analysis in order to include the effect of Tri-State Generation and Transmission Inc.'s Lamar – Burlington 230kV line project which provides a new transmission path for flows out of the Lamar Substation.

The 2022HS1 WECC case was updated to include the 75MW Twin Buttes generation expansion (in-service date 12/2018), 30MW San Isabel Solar generator interconnected on the Ludlo tap – Pinon Canyon 115kV line (in-service date 2016) and replacement of Lamar 230/115kV #T1 with the 150MVA unit (expected in-service date 12/2018).

The generation dispatch in the WECC base case was adjusted to create 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 below. PSCo's generation in zones 700, 704, 709, 710 and 712 was dispatched such that wind generation is at

85% name plate capacity, solar generation is at 80% nameplate capacity, conventional non-coal generation is at 90% name plate capacity and, coal generation is dispatched at 100% nameplate capacity.

The output from GI-2016-13 mainly flows to Boone Substation and then to Midway Substation, since the generation from Jackson Fuller wind effects the facility loadings on the transmission system connected to the Midway Substation, Jackson Fuller wind units were dispatched at 100% nameplate capacity.

The Lamar DC tie, the Colorado Green and Twin Buttes wind generators are dispatched such that the total combined injection at Lamar 230kV bus was 350MW.

For BHCE generation dispatch, Baculite Mesa units were dispatched at 100% nameplate rating and the remaining generation slack is dispatched at Rattlesnake Wind.

The generation dispatch for CSU loads was provided by CSU.

The GI-2016-13 interconnection request 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 GIRs 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-2016-13 – the benchmark case and the study case. The benchmark case modeled the system without the -GI-2016-13 interconnection, whereas the study case included GI-2016-13 interconnection. The GI was modeled in the study case using the PSSE modeling data provided by the Interconnection Customer. The 200MW generation from GI-2016-13 is sunk at Fort Saint Vrain Unit #1.

Power Flow Study Process

The steady state analysis was performed using PTI's PSSE Ver. 33.6.0 program and the ACCC contingency analysis tool. Contingencies were performed in accordance with the NERC Standard TPL-001-4. These are described below.

The analysis was performed for P0, P1, P2, P4 and P7 contingencies. The P3, P5 and P6 contingencies were not run; Instead, the P4, P7 contingencies were run which are worst case.

- The P0 analysis was done on all of area 70.
- The P1 single contingencies were run on zones 121, 700, 703, 704, 705, 709, 710, 712, 752 and 757.
- The P2 single contingencies were run on all of area 70, area 73 and zone 121.
- The P4 and P7 contingencies were run on zones 121, 700, 703, 704, 705, 709, 710, 712, 752 and 757.

The power flow study process described above is summarized in the table below.

Table 01 – TPL-001-4 Transmission Planning Performance Requirements Simulated

Category	Description	Initial Condition	Event	Interruption of Firm Transmission Service Allowed?	Non-consequential Load Loss Allowed?	Areas Analyzed	Zones Analyzed
P0	No Contingency	Normal System	None	No	No	70	
P1	Single Contingency	Normal System	Loss of generator, branch, transformer, shunt device	No	No		121, 700, 703, 704, 709, 710, 712, 752, 757
P2	Single Contingency	Normal System	Open line section w/o fault, bus section fault, internal breaker faults	Conditional	Conditional	70, 73	121
P3	Multiple Contingency	Loss of Gen followed by system adjustment	Loss of generator, branch, transformer, shunt device	No	No		
P4	Multiple Contingency (Fault + stuck breaker	Normal System	Loss of multiple elements from stuck breaker clearing a fault	Conditional	Conditional		121, 700, 703, 704, 709, 710, 712, 752, 757
P5	Multiple Contingency (Fault + relay failure)	Normal System	Delayed fault clearing due to failure of non-redundant relay protecting a faulted element	Conditional	Conditional		121, 700, 703, 704, 709, 710, 712, 752, 757
P6	Multiple Contingency (Two overlapping singles)	Loss of branch, transformer, shunt device followed by system adjustment	Loss of branch, transformer, shunt device	Yes	Yes		
P7	Multiple Contingency (Common structure)	Normal System	Loss of any two adjacent (vertically or horizontally) circuits on a common structure	Yes	Yes		121, 700, 703, 704, 709, 710, 712, 752, 757

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

The thermal violations attributed to the GI-2016-13 interconnection included any facilities without a pre-existing thermal violation but resulted in a thermal loading >100% post GI-2016-13 interconnection and contributed to a 2% increase in the facility loading compared to the benchmark case loading.

Pre-existing thermal violations in the benchmark case are attributable to the GI-2016-13 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 NRIS will be attributed to GI-2016-13.

The voltage violations attributed to GI-2016-13 included any new voltage range and voltage deviation violations.

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 GI-2016-13. The study area for GI-2016-13 includes WECC designated zones 121, 700, 703, 704, 705, 709, 710, 712, 752 and 757.

Power Flow Results

Single Contingency Analysis:

The benchmark case and study case did not have any system intact (P0) thermal or voltage violations.

The results of single contingency analysis (P1 and P2) are given in Table-6. The results show that the interconnection of GI-2016-13 caused new thermal overloads on two (2) PSCo facilities. In addition, interconnection of GI-2016-13 contributed to an increase in the pre-existing benchmark case overload on PSCo's Waterton – Martin2 Tap 115kV (4%), CSU's Cottonwood N – KettleCreek S 115kV line and the Palmer Lake – Monument 115kV line (15.7%) jointly owned by PSCo and CSU.

The implementation of the Palmer Lake – Monument 115kV line operating procedure eliminates the overloads on the Palmer Lake – Monument 115kV line as well as the Cottonwood N – KettleCreek S 115kV line. This operating procedure involves opening the Palmer Lake-Monument 115kV branch for certain overloads on CSU system. PSCo has a planned project to increase the rating of the Waterton – Martin 2 Tap 115kV line rating in 2019. The PSCo planned rating increase will be sufficient to eliminate the thermal overload in the study case; therefore, this thermal violation is not attributable to GI-2016-13.

The following PSCo facility contingency overloads are attributable to the interconnection of GI-2016-13.

- Daniels Park – Prairie1 230kV line loading increased from 95.9% to 102.6%
- Greenwood – Monaco 230kV line loading increased from 97.1% to 104.1%

Addition of GI-2016-13 did not cause any new voltage violations and increases in the existing voltage violations are small as to not require monitoring. There were no voltage violations attributable to GI-2016-13 addition.

The results of the multiple contingency analysis are given in Table-8 and Table-9. The study modeled a heavy South – North dispatch in the case, so the mitigation measures for multiple contingency analysis for PSCo will be developed on a discretionary basis if a need is identified. However, CSU and BHCE consider multiple contingencies as credible outages for planning purposes, so the Interconnection Customer will need to work with CSU and BHCE in order to identify mitigation measures to eliminate the following thermal violations.

The following CSU facility contingency overloads are attributable to the interconnection of GI-2016-13

- Monument - Gresham 115kV line loading increased from 105.6% to 108.8%
- Fountain S – RD_Nixon 115kV line loading increased from 115.6% to 118.1%

The following BHCE facility contingency overloads are attributable to the interconnection of GI-2016-13

- Burntmill – GreenHorn 115kV line loading increased from 94.9% to 102.5%
- Fountain Valley – DesertCove 115kV line loading increased from 141.7% to 161.3%
- Fountain Valley – MidwayBR 115kV line loading increased from 146.5% to 166.8%
- HydePark – Pueblo Plant 115kV line loading increased from 97.8% to 106.6%
- Pueblo Plant – Reader 115kV line loading increased from 100% to 107.9%

Short Circuit

The POI is a new substation; therefore, the circuit breakers at the new substation will be adequately rated. The calculated short circuit levels and Thevenin system equivalent impedances at the GI-2016-13 230kV Switching Station POI are tabulated below.

Table 2 – Short Circuit Parameters at th GI-2016-13 230kV Switching Station POI

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	SLG X/R	3 Phase X/R
Without GI-2016-13	9318	7970	6.6488	9.4733
With GI-2016-13	9459	8071	6.5656	9.2929

The breaker duty study determined that no breaker replacements are needed in neighboring substations.

Conclusion

Energy Resource Interconnection Service (ERIS): GI-2016-13 output for ERIS is 0 MW for the studied generation dispatch scenario. The limiting element is CSU's Monument – Gresham 115kV line which has a benchmark case loading of 105.6% for the Cottonwood 115kV tie breaker failure. However, the ERIS output may vary from 0MW to 200MW depending on the dispatch levels of the prevailing generation resources located in the electrical vicinity of GI-2016-13 (Jackson Fuller, Comanche, Midway and Lamar areas, and the CSU system).

Network Resource Interconnection Service (NRIS): Implementing the Network Upgrades needed to mitigate the above mentioned thermal overload on the PSCo, CSU and BHCE facilities will allow GI-2016-13 to achieve full NRIS of 200MW. The Network Upgrades required to eliminate thermal violations on the PSCo lines include fixing terminal equipment to increase the line ratings. The cost for uprating the two PSCo lines is included in Table-5. The Interconnection Customer should work with CSU and BHCE in order to identify mitigation measures to eliminate the above mentioned CSU and BHCE facility overloads

Costs Estimates and Assumptions

Scoping level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering. The cost estimates are in 2016 dollars with escalation and contingencies applied (AFUDC is not included) 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 cost for the required upgrades is **$8,347,000.**

Figure 2 below is a conceptual one-line of the proposed interconnection. The Point of Interconnection (POI) will be a tap on the Boone - Comanche 230kV Transmission Line approximately five (5) miles from the Boone substation, called “GI-2016-13 230kV Substation”.

The following Tables 3 and 4 list the improvements required to accommodate the interconnection and the delivery of the customer’s 200MW solar 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.

- 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 it’s 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 18 months after authorization to proceed has been obtained. A CPCN will likely be required for the GI-2016-13 230kV Substation construction. The time to secure the CPCN would be approximately 18 months before any procurement and construction can be done. The total estimated time for design procurement and construction will be 36 months from the time the necessary authorization to proceed has been obtained.
- This project is completely independent of other queued projects and their respective ISD’s.
- The Customer will string OPGW fiber into the substation as part of the transmission line construction scope.
- The 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 the requested back feed due date.
- Power Quality Metering (PQM) will be required on the Customer’s 230 kV line terminating into the Proposed Switching Station.
- Network Upgrade costs in Table-5 only include cost estimates for PSCo facilities.

Table 3 – PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Estimated Cost (Millions)
PSCo's GI-2016-13 230kV Switching Station	Interconnect Customer to the 230kV bus at the Proposed Switching Station. The new equipment includes: • One (1) motor operated 230kV disconnect switch • Three (3) 230kV combination CT/PT metering units • 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	**$0.810**
	Boone – Comanche 230kV line tap into substation. Conductor, hardware, and installation labor.	**$0.050**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$0.860**
Time Frame	**Design, procure and construct**	**18 Months**

Table 4: PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Estimated Cost (Millions)
PSCo's GI-2016-13 230kV Switching Station	Interconnect Customer to the 230kV bus at the Proposed 230kV Substation. The new equipment includes: • Three (3) 230kV circuit breakers • Eight (8) 230kV gang switches • One (1) 230kV CCVT • 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	**$6.386**
	In/Out Tap on the 5415 Comanche – Boone 230kV Line the Proposed Switching Station.	**$0.323**
	Siting and Land Rights support for substation land acquisition and construction.	**$0.085**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$6.794**
Time Frame	**Design, procure and construct**	**18 Months**

Table 5 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
PSCo's Comanche 230kV Substation	Relay panel replacement.	**$0.205**
PSCo's Greenwood 230kV Sub.	Replace under-rated elements on the Greenwood-Monaco 230kV transmission line.	**$0.212**
PSCo's Monaco 230kv Sub.	Replace under-rated elements on the Greenwood-Monaco 230kV transmission line.	**$0.037**
PSCo's Daniels Park 230kv Sub.	Replace under-rated elements on the Daniels Park-Prairie 230kV transmission line.	**$0.192**
PSCo's Prairie 230kv Sub.	Replace under-rated elements on the Daniels Park-Prairie 230kV transmission line.	**$0.047**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0.693**
	Design, procure and construct	**18 Months**
	Time Required for CPCN	**18 Months**
	Total Time to obtain CPCN, Design, Procure and Construct	**36 Months**
	Total Project Estimate	**$8.347**

A. Power Flow Contingency Analysis Results

Notes –

1. All thermal loadings are highlighted in yellow and violations are identified in red.
2. For Single Contingency Analysis, thermal overloads on:
   - PSCo facilities are calculated using the applicable Normal Rating.
   - CSU facilities are calculated using the applicable Emergency Rating.
3. For Multiple Contingency Analysis, thermal overloads on all facilities are calculated using applicable Emergency Rating of the facility

Table 6 – Summary of thermal violations from Single Contingency Analysis Without the Palmer Lake– Monument 115kV Line Operating Procedure

				Facility Loading Without GI-2016-13		Facility Loading With GI-2016-13			
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**
Waterton – Martin2tap 115kV	Line	PSCo	127/140	135.0	106.3%/96.4%	140.6	110.7%/100.4%	4.4%	Sodalakes 230/115kV # T1
Daniels Park – Prairie1 230kV	Line	PSCo	478/478	451.7	94.5%/94.5%	482.8	101%/101%	6.5%	Daniels Park – Prairie3 230kV
Greenwood – Monaco 230kV	Line	PSCo	405/481	393.3	97.1%/81.7%	421.2	104.0%/87.6%	6.9%	Buckley – SmokyHill 230kV
Palmer Lake – Monument 115kV	Line	PSCo/ CSU	142/157	156.3	110.1%/99.6%	178.6	125.8%/113.8%	14.2%	Daniels Park – Jackson Fuller 230kV
Cottonwood N - KettleCreek S 115kV	Line	CSU	162/180	186.8	115.3%/103.8%	199.3	123.0%/110.7%	6.9%	Brairgate S – Cottonwood S 115kV

Notes –

1. All thermal loadings are highlighted in yellow and violations are identified in red.
2. For Single Contingency Analysis, thermal overloads on:
   - PSCo facilities are calculated using the applicable Normal Rating.
   - CSU facilities are calculated using the applicable Emergency Rating.
3. For Multiple Contingency Analysis, thermal overloads on all facilities are calculated using applicable Emergency Rating of the facility

Table 7 – Summary of thermal violations from Single Contingency Analysis With the Palmer Lake – Monument 115kV Line Operating Procedure

				Facility Loading Without GI-2016-13		Facility Loading With GI-2016-13			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**N-1 Flow MVA**	**N-1 Flow % of Ratin (Norm/Emer)**	**N-1 Flow MVA**	**N-1 Flow % of Rating (Norm/Emer)**	**% Change**	**NERC Single Contingency**
Waterton – Martin2tap 115kV	Line	PSCo	127/140	130.9	103.1%/93.5%	135.9	107.0%/97.1%	3.9%	Sodalakes 230/115kV # T1
Daniels Park – Prairie1 230kV	Line	PSCo	478/478	458.4	95.9%/95.9%	490.4	102.6%/102.6%	6.7%	Daniels Park – Prairie3 230kV
Greenwood – Monaco 230kV	Line	PSCo	405/481	393.3	97.1%/81.8%	421.6	104.1%/87.7%	7.0%	Buckley – SmokyHill 230kV
Palmer Lake – Monument 115kV	Line	PSCo/ CSU	142/157	N/A	N/A	N/A	N/A	N/A	Daniels Park – Jackson Fuller 230kV
Cottonwood N - KettleCreek S 115kV	Line	CSU	162/180	133.9	82.7%/74.4%	138.2	85.3%/76.8%	2.4%	Brairgate S – Cottonwood S 115kV

Notes –

1. For Multiple Contingency Analysis, thermal overloads on all facilities are calculated using applicable Emergency Rating of the facility
2. The multiple contingency analysis results are for monitoring purpose, mitigation measures will be developed on a discretionary basis if a need is identified.

Table 8 – Summary of thermal violations from Multiple Contingency Analysis
Without the Palmer Lake– Monument 115kV Line Operating Procedure

				Facility Loading Without GI-2016-13		Facility Loading With GI-2016-13			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**% Change**	**NERC Multiple Contingency**
Daniels Park – Fuller 230kV	Line	PSCo	478/478	538.3	112.6%/112.6%	602.3	126.0%/126.0%	13.4%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Burntmill – GreenHorn 115kV	Line	BHCE	119/119	112.9	94.9%/94.9%	121.9	102.5%/102.5%	7.6%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Fountain Valley – DesertCove 115kV	Line	BHCE	119/119	168.6	141.7%/141.7%	191.9	161.3%/161.3%	19.6%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Fountain Valley – MidwayBR 115kV	Line	BHCE	115/115	168.5	146.5%/146.5%	191.9	166.8%/166.8%	20.3%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
HydePark – Pueblo Plant 115kV	Line	BHCE	160/160	156.5	97.8%/97.8%	170.6	106.6%/106.6%	8.8%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Pueblo Plant – Reader 115kV	Line	BHCE	182/182	182	100.0%/100.0%	196.4	107.9%/107.9%	7.9%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Castlerock – Crystal Valley 115kV	Line	IREA	162/178.2	170.4	105.2%/95.6%	196.0	121.0%/110%	14.4%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Palmer Lake – Greenland 115kV	Line	IREA	162/178.2	189.6%	117.0%/106.3%	214.9	132.7%/120.6%	14.3%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Palmer Lake – Monument 115kV	Line	PSCo/ CSU	142/157	233.4	164.4%/148.7%	265.1	186.7%/168.9%	20.2%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Greenland – Crystal Valley 115kV	Line	IREA	162/178.2	183.7	113.4%/103.1%	209.3	129.2%/117.4%	14.3%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Monument – Flyhorse N 115kV	Line	CSU	142/157	207.3	146.0%/132.0%	235.9	166.1%/150.2%	18.2%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Flyhorse S – KettleCreek N 115kV	Line	CSU	162/180	221.8	136.9%/123.2%	250.3	154.5%/139.0%	15.8%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV

Table 8 – Summary of thermal violations from Multiple Contingency Analysis Without the Palmer Lake– Monument 115kV Line Operating Procedure									
				Facility Loading Without GI-2016-13		Facility Loading With GI-2016-13			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**% Change**	**NERC Multiple Contingency**
Flyhorse S – Flyhorse N 115kV	Line	CSU	239/239	221.3	92.6%/92.6%	250	104.6%/104.6%	12%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Cottonwood N – KettleCreek S 115kV	Line	CSU	162/180	191.5	118.2%/106.4%	211.1	130.3%/117.3%	10.9%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Midway 230 bus tie	Line	PSCo/ WAPA	430/478	469.1	109.1%/98.1%	539.7	125.5%/112.9%	14.8%	Double Ckt: Midway – Waterton 345kV & Midway – Jackson Fuller 230kV
DanielsPark – SantaFe 230kV	Line	PSCo	319/319	312.3	97.9%/97.9%	335.6	105.2%/105.2%	7.3%	Breaker Failure: Greenwood 230kV
Monument – Gresham 115kV	Line	CSU	145/145	150.8	97.7%/97.7%	160.1	104.2%/104.2%	6.5%	Breaker Failure: Cottonwood 115kV Tie
Brairgate S – Cottonwood S 115kV	Line	CSU	150/192	188.1	125.4%/97.9%	198.8	132.5%/103.5%	5.6%	Breaker Failure: Cottonwood N 115kV Bus
Fountain S – RD_Nixon 115kV	Line	CSU	195/212	252.9	129.7%/119.3%	259.9	133.3%/122.6%	3.3%	Double Ckt: Kelker S – Front Range 230kV & Kelker N – RD_Nixon 230kV

Notes –

1. For Multiple Contingency Analysis, thermal overloads on all facilities are calculated using applicable Emergency Rating of the facility
2. The multiple contingency analysis results are for monitoring purpose, mitigation measures will be developed on a discretionary basis if a need is identified.

Table 9 – Summary of thermal violations from Multiple Contingency Analysis With the Palmer Lake– Monument 115kV Line Operating Procedure

				Facility Loading Without GI-2016-13		Facility Loading With GI-2016-13			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**% Change**	**NERC Multiple Contingency**
Daniels Park – Fuller 230kV	Line	PSCo	478/478	628.1	131.4%/131.4%	704.6	147.4%/147.4%	16%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Burntmill – GreenHorn 115kV	Line	BHCE	119/119	112.5	94.5%/94.5%	121.5	102.1%/102.1%	7.6%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Fountain Valley – DesertCove 115kV	Line	BHCE	119/119	160.5	134.9%/134.9%	183.0	153.8%/153.8%	18.9%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Fountain Valley – MidwayBR 115kV	Line	BHCE	115/115	160.4	139.5%/139.5%	182.9	159.0%/159.0%	19.5%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
HydePark – Pueblo Plant 115kV	Line	BHCE	160/160	155.5	97.2%/97.2%	169.8	106.1%/106.1%	8.9%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Pueblo Plant – Reader 115kV	Line	BHCE	182/182	181.3	99.6%/99.6%	195.8	107.6%/107.6%	8.0%	Double Ckt: Daniels Park – Comanche 345 kV 1&2
Castlerock – Crystal Valley 115kV	Line	IREA	162/178.2	18.8	11.6%/10.5%	18.9	11.7%/10.6%	0.1%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Palmer Lake – Greenland 115kV	Line	IREA	162/178.2	3.1	1.9%/1.7%	3.1	1.9%/1.7%	0%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Palmer Lake – Monument 115kV	Line	PSCo/ CSU	142/157	N/A	N/A	N/A	N/a	N/A	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Greenland – Crystal Valley 115kV	Line	IREA	162/178.2	7.3	4.5%/4.1%	7.3	4.5%/4.1%	0%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Monument – Flyhorse N 115kV	Line	CSU	142/157	77.4	54.5%/49.3%	88.5	62.3%/56.3%	7.0%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Flyhorse S – KettleCreek N 115kV	Line	CSU	162/180	91.9	56.7%/51.0%	103.2	63.7%/57.3%	6.3%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV

Table 9 – Summary of thermal violations from Multiple Contingency Analysis With the Palmer Lake– Monument 115kV Line Operating Procedure									
				Facility Loading Without GI-2016-13		Facility Loading With GI-2016-13			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**Flow MVA**	**Flow % of Rating (Norm/Emer)**	**% Change**	**NERC Multiple Contingency**
Flyhorse S – Flyhorse N 115kV	Line	CSU	239/239	91.5	38.3%/38.3%	103.0	43.1%/43.1%	4.8%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Cottonwood N – KettleCreek S 115kV	Line	CSU	162/180	104.5	64.5%/58.0%	112.3	69.3%/62.4%	4.4%	Double Ckt: Midway – Waterton 345kV & Daniels Park – Jackson Fuller 230kV
Midway 230 bus tie	Line	PSCo/ WAPA	430/478	209.8	48.8%/43.9%	250.3	58.2%/52.4%	8.5%	Double Ckt: Midway – Waterton 345kV & Midway – Jackson Fuller 230kV
DanielsPark – SantaFe 230kV	Line	PSCo	319/319	314.8	98.7%/98.7%	338.8	106.2%/106.2%	7.5%	Breaker Failure: Greenwood 230kV
Monument – Gresham 115kV	Line	CSU	145/145	150.8	105.6%/105.6%	157.8	108.8%/108.8%	3.2%	Breaker Failure: Cottonwood 115kV Tie
Brairgate S – Cottonwood S 115kV	Line	CSU	150/192	150.8	100.5%/78.5%	154.8	103.2%/80.6%	2.1%	Breaker Failure: Cottonwood N 115kV Bus
Fountain S – RD_Nixon 115kV	Line	CSU	195/212	245.1	125.7%/115.6%	250.4	128.4%/118.1%	2.5%	Double Ckt: Kelker S – Front Range 230kV & Kelker N – RD_Nixon 230kV

Table 9 – Generation Dispatch in the Study area (MW is Gross Capacity)

PSCo:

Bus	LF ID	MW
Comanche PV	S1	102
Comanche	C1	357
Comanche	C2	365
Comanche	C3	795
Lamar DC Tie	DC	100
Fountain Valley	G1	36
Fountain Valley	G2	36
Fountain Valley	G3	36
Fountain Valley	G4	36
Fountain Valley	G5	36
Fountain Valley	G6	36
Colorado Green	W1	64.8
Colorado Green	W2	64.8
Twin Butte	W1	60
Twin Butte-II	W1	60
Jackson Fuller	W1&W2	250
Alamosa CT	G1	15.3
Alamosa CT	G2	12.6
Cogentrix	S3	25.5
Greater Sandhill	S1	16.1
Blanca Peak	S1	19.5
SLV Solar	S1	44.2

BHE:

Bus	LF ID	MW
BUSCHWRTG1	G1	23.0
BUSCHWRTG2	G2	23.0
BUSCHWRTG2	G3	23.0
E Canon	G1	0
PP_MINE	G1	0
PuebloDiesels	G1	0
Pueblo Plant	G1	0
Pueblo Plant	G2	0.0
R.F. Diesels	G1	0.0
Airport Diesels	G1	0.0
Canyon City	C1	0
Canyon City	C1	0
Baculite 1	G1	90
Baculite 2	G1	90
Baculite 3	G1	40.0
Baculite 3	G2	40.0
Baculite 3	S1	21
Baculite 4	G1	40.0

Baculite 4	G2	0.0
Baculite 4	S1	21
Baculite 5	G1	0

CSU:

Bus	**LF ID**	**MW**
Birdsale1	1	0.0
Birdsale 2	1	0.0
Birdsale 3	1	0.0
RD_Nixon	1	220.47
Tesla	1	13.2
Drake 5	1	0.0
Drake 6	1	80.6
Drake 7	1	137.1
Nixon CT 1	1	0.0
Nixon CT 2	1	0.0
Front Range CC 1	1	137.3
Front Range CC 2	1	136.9
Front Range CC 3	1	161.25

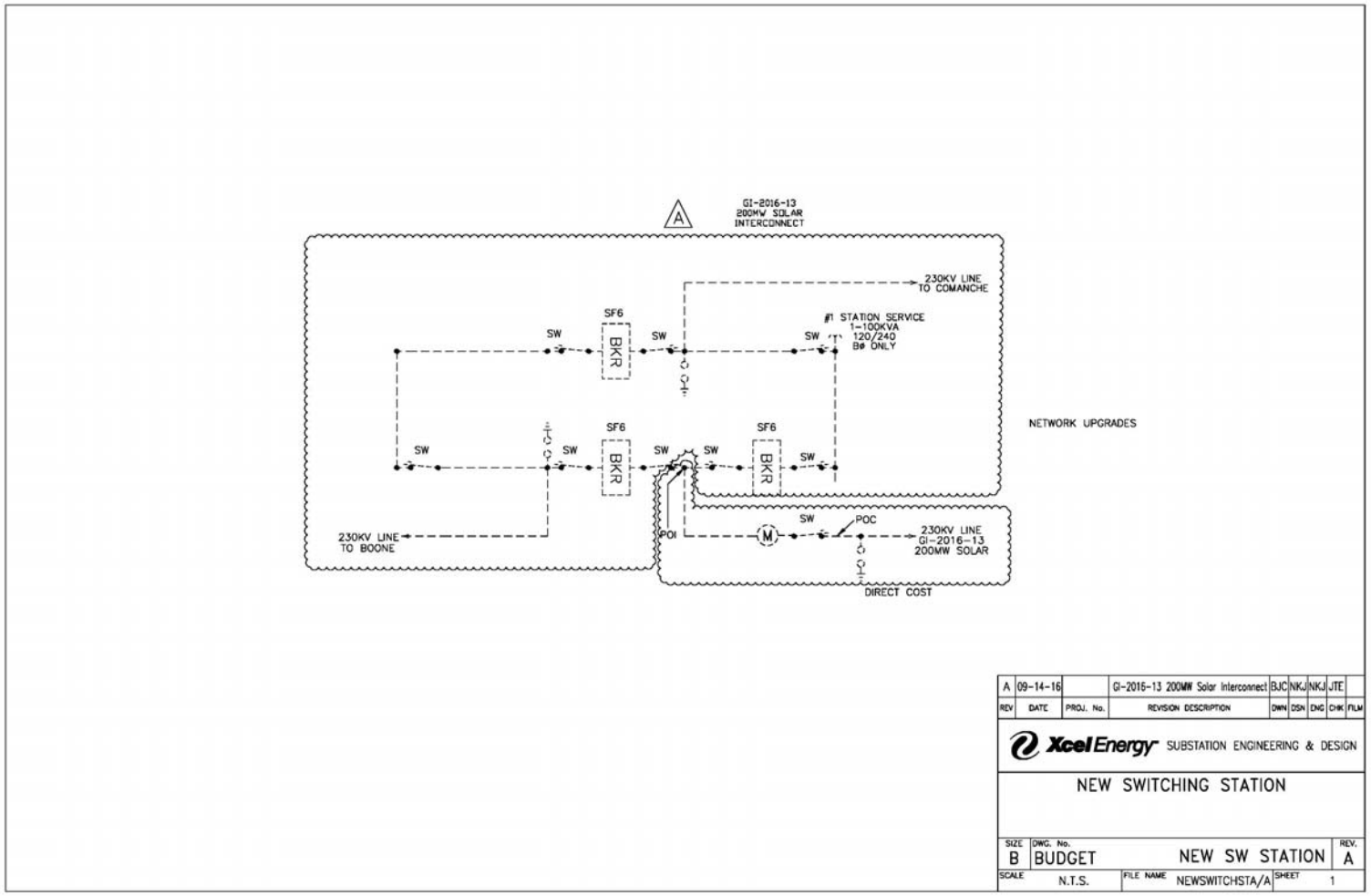

Figure 2 –Conceptual One-Line Diagram of the GI-2016-13 230kV Substation POI