Feasibility Study Report
Generation Interconnection Request # GI-2016-7

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

Transmission Planning West
Xcel Energy
September 26, 2016

Executive Summary

This report evaluates the feasibility of interconnecting GI-2016-7, a 240MW solar photovoltaic generation facility at the Boone 230kV bus. The generation facility will consist of one hundred and twenty (120) SMA Sunny Central 2200-US inverters equally distributed over three groups; each group will consist of forty (40) inverters and twenty (20) 4MVA generation step-up transformers. The three groups will connect to a 240MVA Main Step-up Transformer which will interconnect to the Boone 230kV Point of Interconnection (POI) using a Customer owned 230kV tie-line. The Interconnection Customer did not propose a secondary POI. The generation facility is targeted to have a Commercial Operation Date (COD) of December 1, 2018, so the backfeed date is assumed to be June 1, 2018; approximately six months before the COD. 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 2018 heavy summer base case by simulating heavy south-north flow on the Comanche – Midway – Jackson Fuller – Daniels Park transmission path.

The GI-2016-7 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 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), Tri-State Generation and Transmission Inc. (TSGT), Western Area Power Administration (WAPA) and Intermountain Rural Electric Association (IREA).

Steady State contingency analysis results: The 240 MW injection from GI-2016-7 caused thermal violations on facilities in PSCo, BHCE and CSU systems. In addition, one facility jointly owned by PSCo and WAPA had thermal loading exceeding 100% of the facility rating.

Implementing the Palmer Lake – Monument 115kV line operating procedure was effective in mitigating all the thermal violations on CSU facilities caused by GI-2016-7. However, implementing the operating procedure caused one new overload on the Happy Canyon –

Daniels Park 115kV line and marginal loading on the Daniels Park – Prairie1 230kV line. Any thermal violation in the benchmark case is not attributable to the GI-2016-7 interconnection unless the higher facility rating resulting from PSCo's planned upgrade is insufficient to mitigate the (increased) thermal violation in the study case. PSCo will plan a project to fix the terminal equipment on the Happy Canyon – Daniels Park 115kV line, the new line rating targeted by PSCo would be sufficient to mitigate the study case overload. The Midway 230kV bus tie overload is marginal (100%) in the study case, so a mitigation measure is not identified

The following thermal violations on PSCo transmission facilities are attributable to the interconnection of GI-2016-7:

- Daniels Park – Prairie1 230kV line loading increased from 100.0% to 112.5% (limited by terminal equipment)
- Greenwood – Prairie3 230kV line loading increased from 88.4% to 100.8% (limited by terminal equipment)
- Greenwood – Monaco12 230kV line loading increased from 92.2% to 100.7% (limited by terminal equipment)
- Waterton – Martin2tap 115kV line loading increased from 95.9% to 101.6% (limited by terminal equipment)

PSCo has a planned project to fix terminal equipment on the Waterton – Martin2tap 115kV line loading, so the cost of implementing the network upgrades on this line is not included in the cost estimates.

In addition, the following BHCE transmission facility overload is attributable to GI-2016-7 interconnection.

- Portland – Skala 115kV line loading increased from 96.7% to 106.2%

There were no voltage violations attributable to GI-2016-7 interconnection.

Short Circuit

The GI-2016-7 is a solar photovoltaic facility, so the fault current contribution from the inverters is minimal and not long enough to cause breaker duty to exceed. No breaker duty violations are attributable to GI-2016-7 interconnection.

Energy Resource Interconnection Service (ERIS): GI-2016-7 output for ERIS is 0 MW for the studied generation dispatch scenario due to the marginal loading on the Daniels Park – Priaire1 230kV line in the benchmark case. However, 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 GI-2016-7 (Jackson Fuller, Comanche, Midway and Lamar areas).

Network Resource Interconnection Service (NRIS): Implementing the Network Upgrades needed to mitigate the above mentioned thermal overloads on PSCo and BHCE systems will allow GI-2016-7 to achieve full NRIS of 240MW.

All network upgrades on the PSCo system consist of upgrading terminal equipment limiters on the overloaded facilities.

The Interconnection Customer has to work with BHCE in order to find network upgrades to mitigate the identified thermal violations on the BHCE lines.

Cost Estimates

The cost for the transmission interconnection (in 2016 dollars):

The total estimated cost of the recommended system improvements to interconnect the project is approximately **$2.591 Million** and includes:

- $ 0.978 Million for PSCo-Owned, Customer-Funded Interconnection Facilities
- $ 1.127 Million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- $ 0.486 Million for PSCo Network Upgrades for Delivery to PSCo Loads

This work can be completed in 18 months following receipt of authorization to proceed.

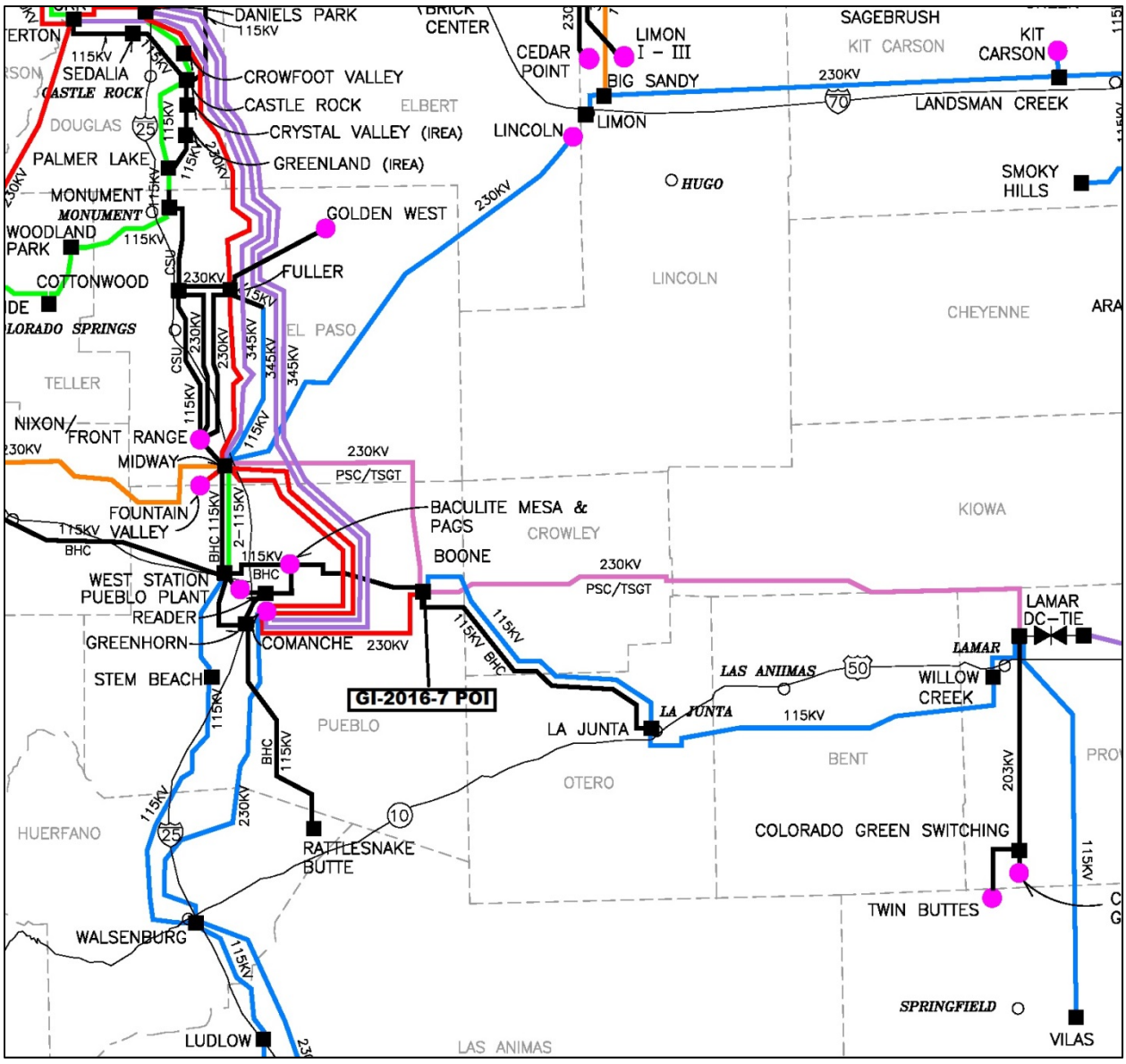

Figure 1 - GI-2016-7 Boone Point of Interconnection and Study Area

Introduction

Public Service Company of Colorado (PSCo) received a 240MW solar Photovoltaic generation facility study request ("GI-2016-7") on May 3, 2016. The Generation facility will be made up of one hundred and twenty (120) SMA Sunny Central 2200-US inverters connected in three groups. Each group will consist of forty (40) inverters and twenty (20) 4 MVA step-up transformers. The three groups will in turn connect to a 240MVA Main Step-up Transformer which will connect to the Point of Interconnection (POI) using a 230kV Customer owned tie-line. The GI facility will be located in Pueblo County, Colorado.

The Primary POI requested by the Interconnection Customer is the Boone 230kV Substation in Pueblo County, Colorado. The Commercial Operation Date (COD) requested by the Customer is December 31, 2018. The Interconnection Customer did not specify a backfeed for GI-2016-7, so it was assumed to be June 31, 2018; six months before the COD.

The Interconnection Customer did not propose a secondary POI.

The Generation interconnection study request is for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS).

Study Scope and Analysis

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 addition of GI-2016-7; several single and double contingencies are studied. The short circuit analysis identifies any overdutied circuit breakers at the Boone Substation and surrounding substations due to the addition of GI-2016-7.

PSCo adheres to applicable NERC Reliability Standards & WECC Reliability Criteria, as well as internal criteria for planning studies. For PSCo facilities, the steady state analysis criteria is as follows:

P0 - system intact conditions: Thermal Loading <=100% 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 for <=300kV
Voltage range – 0.90 to 1.05 Per Unit for >300kV
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 for <=300kV
Voltage range – 0.90 to 1.05 Per Unit for >300kV
Voltage deviation - <=5% of pre-contingency voltage

The steady state analysis criteria is for CSU facilities – Thermal Loading <= 100% emergency rating of facilities for both single and multiple contingencies.

The voltage range criteria for all non-PSCo facilities is 0.9-1.1 P.U. for both single and multiple contingencies

Operationally, PSCo attempts to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulating (generation) buses to 1.0 per unit or higher at transmission load buses.

GI-2016-7 is 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), Tri-State Generation and Transmission Inc. (TSGT) and Intermountain Rural Electric Association (IREA).

Power Flow Study Models

The study was performed using the Western Electricity Coordinating Council (WECC) 2018HS3 power flow case released on 02/02/2016. The case was updated to include the 75MW Twin Buttes generation expansion, 30MW San Isabel Solar generator interconnected on the Ludlotap – Pinoncanyon 115kV line, replacement of Lamar 230/115kV #T1 with 150MVA unit and Drake#5 generator retirement.

The generation dispatch in the WECC base case was adjusted to create a heavy south to north flow on the Comanche – Midway - Jackson Fuller – Daniels Park transmission path. This was accomplished by adopting the generation dispatch given in Table-9 below. PSCo's generation in zones 700, 704, 709, 710 and 712 is dispatched such that wind generation is at 85% name plate capacity, solar generation is at 80% name plate capacity, conventional non-coal generation is at 90% name plate capacity and, coal generation is dispatched at 100% name plate capacity. For BHCE, Baculite Mesa units are dispatched at 100% name plate rating and the remaining generation is dispatched at Rattlesnake Wind (recommended by BHCE because of the Boone POI).

The generation dispatch for CSU loads is provided by CSU.

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

The GI-2016-7 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 interconnection requests 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-2016-7 – the benchmark case and the study case. The benchmark case modeled the system without GI-2016-7, whereas the study case included GI-2016-7. The GI was modeled using the PSSE modeling data provided by the Interconnection Customer. PSCo's Fort Saint Vrain #3 and #4 units are used as the sink for the 240 MW generation injection of GI-2016-7. The GI-2016-7 model provided by the customer resulted in a total injection of 235MW at the Boone 230kV bus after losses on the GI-2016-7 interconnection facilities, so the Pmax of the generator model is increased such that the total injection at Boone 230kV is 240MW, consistent with the study request.

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 NERC Standard TPL-001-4. These are described below.

The analysis was performed for P0, P1, P2, P4, P5 and P7 contingencies. The P3, and P6 contingencies were not run; Instead, the P5 and P7 contingencies were run which are worse 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, P5 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	Sometimes	Sometimes	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	Sometimes	Sometimes		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	Sometimes	Sometimes		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 GI-2016-12 interconnection included any facilities without a pre-existing thermal violation but resulted in a thermal loading >100% and contributed to a 2% increase in the facility loading in the study case.

Pre-existing thermal violations in the benchmark case are attributable to the GI-2016-12 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 GI capacity will be attributed to GI-2016-12.

The voltage violations attributed to GI-2016-12 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-2016-12. The study area for GI-2016-12 at the Boone POI include 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 and voltage violations.
The results of single contingency analysis (P1 and P2) are given in Table-6. The results show that the addition of GI-2016-7 caused new thermal overloads on various PSCo, BHCE and CSU facilities. In addition, one facility jointly owned by PSCo and WAPA has a thermal violation.

The thermal overloads in the CSU system were eliminated when the Palmer Lake- Monument 115kV line operating procedure is implemented. The results of the steady state analysis after implementing the Palmer Lake – Monument 115kV line operating procedure are given in Table-7. From the results in Table-7, it is evident that the operating procedure caused one new overload on the Happy Canyon – Daniels Park 115kV line and marginal loading on the Daniels Park – Prairie1 230kV line. Any thermal violation in the benchmark case is not attributable to the GI-2016-7 interconnection unless the higher facility rating resulting from PSCo's planned upgrade is insufficient to mitigate the (increased) thermal violation in the study case. PSCo will plan a project to fix the terminal equipment on the Happy Canyon – Daniels Park 115kV line, the new line rating targeted by PSCo would be sufficient to mitigate the study case overload. The Midway 230kV bus tie overload is marginal (100%) in the study case, so a mitigation measure is not identified.

The following thermal violations on PSCo facilities are attributable to the GI-2016-7 addition:

- Daniels Park – Prairie1 230kV line loading increased from 100.0% to 112.5% (limited by terminal equipment)
- Greenwood – Prairie3 230kV line loading increased from 88.4% to 100.8% (limited by terminal equipment)
- Greenwood – Monaco12 230kV line loading increased from 92.2% to 100.7% (limited by terminal equipment)
- Waterton – Martin2tap 115kV line loading increased from 95.9% to 101.6% (limited by terminal equipment)

PSCo has a planned project to fix terminal equipment on the Waterton – Martin2tap 115kV line loading, so the cost of implementing the network upgrades on this line is not included in the cost estimates.

In addition, the following BHCE facility overload is attributable to the interconnection of GI-2016-7.

- Portland – Skala 115kV line loading increased from 96.7% to 106.2%

Addition of GI-2016-7 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-2016-7 addition.

The results of the multiple contingency analysis are given in Table-8. The multiple contingency analysis results are provided for monitoring purpose, and mitigation measures will be developed on a discretionary basis if a need is identified.

Short Circuit

The GI-2016-7 is a solar photovoltaic facility, so the fault current contribution from the inverters is minimal and not long enough to cause breaker duty to exceed. No breaker duty violations are attributable to GI-2016-7 addition.

The calculated short circuit levels and Thevenin system equivalent impedances at the Boone 230kV POI are tabulated below.

Table 2 – Short Circuit Parameters at the Boone 230 kV POI

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	SLG X/R	3 Phase X/R
System Intact	10282.7	10211.0	10.297	9.7942

Conclusion

Energy Resource Interconnection Service (ERIS): GI-2016-7 output for ERIS is 0 MW for the studied generation dispatch scenario due to the marginal loading on the Daniels Park – Priaire1 230kV line in the benchmark case. However, 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 GI-2016-7 (Jackson Fuller, Comanche, Midway and Lamar areas).

Network Resource Interconnection Service (NRIS): Implementing the Network Upgrades needed to mitigate the above mentioned thermal overloads on PSCo and BHCE systems will allow GI-2016-7 to achieve full NRIS of 240MW.
All network upgrades on the PSCo system consist of upgrading terminal equipment limiters on the overloaded facilities.

The Interconnection Customer has to work with BHCE in order to find network upgrades to mitigate the identified thermal violations on the BHCE lines.

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 **$2,401,000.**

Figure 2 below is a conceptual one-line of the proposed interconnection. The Point of Interconnection will be the Boone 230kV Transmission substation.

The following (Tables 3, 4 and 5) list the improvements required to accommodate the interconnection and the delivery of the customer's 240 MW 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.

- Estimates are based on 2016 dollars (appropriate contingency and escalation applied).
- 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 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.
- This project is completely independent of other queued projects and their respective ISD's.
- A CPCN will not be required for the interconnection facilities construction.
- 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 230 kV line terminating into Boone Substation.

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

Element	Description	Cost Est. (Millions)
PSCo's Boone 230kV Transmission Substation	Interconnect Customer to the 230kV bus at the Boone Substation. 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	**$0.928**

	Transmission line tap into substation. Conductor, hardware, and installation labor.	**$0.050**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$0.978**
Time Frame	**Design, procure and construct**	**18 Months**

Table 4: PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Est. (Millions)
PSCo's Boone 230kV Transmission Substation	Interconnect Customer to the 230kV bus at the Boone 115kV Substation. The new equipment includes: • One (1) 230kV circuit breaker • Two (2) 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	**$1.127**
	Siting and Land Rights support for substation land acquisition and construction.	**$0.000**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$1.127**
Time Frame	**Site, design, procure and construct**	**18 Months**

Table 5 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
Daniels Park Substation	Uprated Jumpers and Associated Equipment	$0.190
Greenwood Substation	Uprated Jumpers and Associated Equipment	$0.212
Monaco Substation	Uprated Jumpers and Associated Equipment	$0.037
Prairie Substation	Uprated Jumpers and Associated Equipment	$0.047
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0.486**
	Design, procure and construct	**18 Months**
	Total Project Estimate	**$2.591**

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 Palmer Lake– Monument 115kV Line Operating Procedure

				Facility Loading Without GI-2016-7		Facility Loading With GI-2016-7			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**% Change**	**NERC Single Contingency**
Daniels Park – Prairie1 230kV	Line	PSCo	478/478	473.7	99.1%/99.1%	532.0	111.3%/111.3%	12.2%	Daniels Park – Prairie3 230kV Line
Greenwood – Prairie3 230kV	Line	PSCo	478/478	416.3	87.1%/87.1%	476.1	99.6%/99.6%	12.5%	Daniels Park – Prairie1 230kV Line
Greenwood – Monaco12 230kV	Line	PSCo	405/481	373.4	92.2%/77.6%	408.6	100.9%/84.9%	8.7%	Buckley- SmokyHill 230kV Line
Midway 230kV Bus tie	Line	PSCo/ WAPA	430/478	383.6	89.2%/80.2%	454.9	105.8%/95.2%	16.6%	MidwayPS – Jackson Fuller 230kV
Palmer Lake – Monument 115kV	Line	PSCo/ CSU	142/157	118.1	83.2%/75.2%	140.8	99.2%/89.7%	16%	Daniels Park – Jackson Fuller 230kV
Portland – Skala 115kV	Line	BHCE	111/111	105.5	95%/95%	115.6	104.1%/104.1%	9.1%	MidwayBR – West Canyon 230kV
Waterton – Martin2Tap 115kV	Line	PSCo	127/140	121.8	95.9%/87%	129.0	101.6%/92.2%	5.7%	Sodalake 230/115kV #T2
Cottonwood N - KettleCreek S 115kV	Line	CSU	162/180	189.6	117.0%/105.3%	204.1	126.0%/113.4%	8.1%	Brairgate S – Cottonwood S 115kV
Kelker N 230/115kV	Xfmr	CSU	280/319	303	108.2%/95.0%	311.1	111.1%/97.5%	2.5%	Kelker S 230/115kV
Kelker S 230/115kV	Xfmr	CSU	280/322	299.0	106.8%/92.9%	307.2	109.7%/95.4%	2.5%	Kelker N 230/115kV
Monument – Flyhorse N 115kV	Line	CSU	142/157	138.6	97.6%/88.3%	161.2	113.5%/102.7%	14.4%	Daniels Park – Jackson Fuller 230kV
BLKFORTP – BLK SQMV	Line	CSU	81/81	83.8	103.4%/103.4%	90.4	116.3%/116.3%	12.9%	Flyhorse S – Kettlecreek N 115kV

Table 6 – Summary of thermal violations from Single Contingency Analysis Without Palmer Lake– Monument 115kV Line Operating Procedure									
				Facility Loading Without GI-2016-7		Facility Loading With GI-2016-7			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**% Change**	**NERC Single Contingency**
115kV									
Fuller 230/115kV	Xfmr	CSU	100/100	99.6	99.6%/99.6%	102.6	102.6%/102.6%	3%	MidwayBR – Rancho 115kV
Flyhorse S – Kettle Creek N 115kV	Line	CSU	162/180	149.5	92.3%/83.1%	172.4	106.4%/95.8%	12.7%	Daniels Park – Jackson Fuller 230kV

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 Double 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 Palmer Lake – Monument 115kV Line Operating Procedure

				Facility Loading Without GI-2016-7		Facility Loading With GI-2016-7			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**% Change**	**NERC Single Contingency**
Happy Canyon – Daniels Park 115kV	Line	PSCo	120/120	127.6	106.3%/106.3%	128.9	107.4%/107.4%	1.1%	Parker – Bayou 115kV
Daniels Park – Prairie1 230kV	Line	PSCo	478/478	478	100%/100%	537.8	112.5%/112.5%	12.5%	Daniels Park – Prairie3 230kV Line
Greenwood – Prairie3 230kV	Line	PSCo	478/478	422.6	88.4%/88.4%	481.8	100.8%/100.8%	12.4%	Daniels Park – Prairie1 230kV Line
Greenwood – Monaco12 230kV	Line	PSCo	404/480	372.5	92.2%/77.6%	406.8	100.7%/84.8%	8.5%	Buckley- SmokyHill 230kV Line
Midway 230kV Bus tie	Line	PSCo/ WAPA	430/478	362.9	84.4%/75.9%	430	100.0%/89.9%	15.6%	MidwayPS – Jackson Fuller 230kV
Palmer Lake – Monument 115kV	Line	PSCo/ CSU	132/153	N/A	N/A		N/A	N/A	Daniels Park – Jackson Fuller 230kV
Portland – Skala 115kV	Line	BHCE	111/111	107.3	96.7%/96.7%	117.9	106.2%/106.2%	9.5%	MidwayBR – West Canyon 230kV
Waterton – Martin2Tap 115kV	Line	PSCo	125/138	118	94.4%/85.5%	124.8	99.8%/90.4%	5.4%	Sodalake 230/115kV #T2
Cottonwood N - KettleCreek S 115kV	Line	CSU	162/180	146.8	90.6%/81.5%	152.8	94.3%/84.9%	3.4%	Brairgate S – Cottonwood S 115kV
Kelker N 230/115kV	Xfmr	CSU	280/319	291.5	104.1%/91.4%	297.4	106.2%/93.2%	1.8%	Kelker S 230/115kV
Kelker S 230/115kV	Xfmr	CSU	280/322	287.6	102.7%/89.3%	293.7	104.9%/91.2%	1.9%	Kelker N 230/115kV
Monument – Flyhorse N 115kV	Line	CSU	142/157	65.5	46.1%/41.7%	74.1	52.2%/47.2%	5.5%	Daniels Park – Jackson Fuller 230kV

Table 7 – Summary of thermal violations from Single Contingency Analysis With Palmer Lake – Monument 115kV Line Operating Procedure										
				Facility Loading Without GI-2016-7		Facility Loading With GI-2016-7				
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**N-1 Flow MVA**	**N-1 Flow % of Rating**	**% Change**	**NERC Single Contingency**	
BLKFORTP – BLK SQMV 115kV	Line	CSU	81/81	68.3	84.3%/84.3%	74.0	91.4%/91.4%	7.1%	Flyhorse S – Kettlecreek N 115kV	
Fuller 230/115kV	Xfmr	CSU	100/100	86.9	86.9%/86.9%	87.4	87.4%/87.4%	0.5%	MidwayBR – Rancho 115kV	
Flyhorse S – Kettle Creek N 115kV	Line	CSU	162/180	51.4	31.7%/28.5%	85.2	52.6%/47.3%	18.8%	Daniels Park – Jackson Fuller 230kV	

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Table 8 – Summary of thermal violations from Multiple Contingency Analysis Without Palmer Lake– Monument 115kV Line Operating Procedure									
				Facility Loading Without GI-2016-7		Facility Loading With GI-2016-7			
Monitored Facility (Line or Transformer)	Type	Owner	Branch Rating MVA (Norm/Emer)	Flow MVA	Flow % of Rating	Flow MVA	Flow % of Rating	% Change	NERC Multiple Contingency
Arapahoe – SantaFe 230kV	Line	PSCo	300/319	293.1	97.7%/91.9%	332.4	110.8%/104.2%	12.3%	Double Ckt: Daniels Park – Prairie – Greenwood 230kV 1&2
Daniels Park – SantaFe 230kV	Line	PSCo	319/319	329.8	103.4%/103.4%	369.4	115.8%/115.8%	12.4%	Double Ckt: Daniels Park – Prairie – Greenwood 230kV 1&2
Canyon City – Skala 115kV	Line	BHCE	119/119	105.9	89.9%/89.9%	119	100.1%/100.1%	10.2%	Breaker Failure: MidwayBR 230kV Sub & MidwayPS – J.Fuller 230kV
Fountain Valley – DesertCove 115kV	Line	BHCE	119/119	149.6	125.7%/125.7%	176.5	148.3%/148.3%	22.6%	Breaker Failure: MidwayBR 230kV Sub & MidwayPS – J.Fuller 230kV
Fountain Valley – MidwayBR 115kV	Line	BHCE	119/119	148.5	124.8%/124.8%	175.3	147.3%/147.3%	22.5%	Breaker Failure: MidwayBR 230kV Sub & MidwayPS – J.Fuller 230kV
Portland – Skala 115kV	Line	BHCE	111/111	112	100.9%/100.9%	124.6	112.3%/112.3%	11.4%	Breaker Failure: MidwayBR 230kV Sub & MidwayPS – J.Fuller 230kV
DesertCove – West Station 115kV	Line	BHCE	119/119	170.8	143.6%/143.6%	197.9	166.3%/166.3%	22.7%	Breaker Failure: MidwayBR 230kV Sub & MidwayPS – J.Fuller 230kV
Midway 230kV Bus tie	Line	PSCo/ WAPA	430/478	556.4	129.4%116.4%	657.0	152.8%137.4%	21%	Double Ckt: MidwayPS – Waterton 345kV & MidwayPS – J. Fuller 230kV
Waterton – Martin1 Tap 115kV	Line	PSCo	138/142	139.2	100.9%/98.0%	146.8	106.4%/103.4%	5.4%	Double Ckt: Sodalake – Waterton 230kV & Sodalake – Waterton 115kV
Waterton – Martin2 Tap 115kV	Line	PSCo	127/140	131.6	103.6%/93.9%	141.5	111.4%/101.0%	7.1%	Breaker Failure: Sodalakes 230kV
Palmer Lake – Monument 115kV	Line	PSCo/C SU	142/157	181.8	128.0%/115.8%	214.6	151.1%/136.7%	20.9%	Double Ckt: MidwayPS – Waterton 345kV & Daniels Park – J. Fuller 230kV
Cottonwood N – Kettle Creek S 115kV	Line	CSU	162/180	183.2	113.1%101.8%	206.1	127.2%/114.5%	12.7%	Double Ckt: MidwayPS – Waterton 345kV & Daniels Park – Fuller 230kV
Monument – Flyhorse N 115kV	Line	CSU	142/157	204.2	143.8%/130.0%	238	167.6%/151.6%	21.6%	Double Ckt: MidwayPS – Waterton 345kV & Daniels Park – Fuller 230kV
Flyhorse S – Kettle Creek N 115kV	Line	CSU	162/180	215.6	133.1%/119.8%	249.5	154.0%/138.6%	18.8%	Double Ckt: MidwayPS – Waterton 345kV & Daniels Park – Fuller 230kV
Flyhorse S – Flyhorse N 115kV	Line	CSU	239/239	215.3	90.1%/90.1%	249.3	104.3%/104.3%	14.2%	Double Ckt: MidwayPS – Waterton 345kV & Daniels Park – Fuller 230kV

Table 8 – Summary of thermal violations from Multiple Contingency Analysis Without Palmer Lake– Monument 115kV Line Operating Procedure									
				Facility Loading Without GI-2016-7		Facility Loading With GI-2016-7			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow MVA**	**Flow % of Rating**	**Flow MVA**	**Flow % of Rating**	**% Change**	**NERC Multiple Contingency**
BLKFORTP – BLK SQMV 115kV	Line	CSU	81/81	128.5	158.7%/158.7%	139.1	171.7%/171.7%	13%	Breaker Failure: Cottonwood 115kV Tie
BLK SQMV – Fuller 115kV	Line	CSU	143/143	149.7	104.7%/104.7%	160.4	112.2%/112.2%	7.5%	Breaker Failure: Cottonwood 115kV Tie
Fuller 230/115 kV	Line	CSU	100/100	127.6	127.6%/127.6%	131.4	131.4%/131.4%	3.8%	Breaker Failure: Cottonwood 115kV Tie
Bradley S – Fountain N 115kV	Line	CSU	195/212	203.8	104.5%/96.1%	211.8	108.6%/99.9%	3.8%	Breaker Failure: Kelker 230kV Tie
Fountain S – RD_Nixon 115 kV	Line	CSU	195/212	261.9	134.3%/123.5%	270.1	138.5%/127.4%	3.9%	Breaker Failure: Kelker 230kV Tie
Brairgate S – Cottonwood S 115kV	Line	CSU	150/192	178.4	118.9%/92.9%	191.4	127.6%/99.7%	6.8%	Cottonwood N 115 kV bus
West Canyon 230/115 kV # T1	Line	BHCE	100/100	103.2	103.2%/103.2%	105	105.0%/105%	1.8%	Double Ckt: Portland – West Station 115kV #1 & 2
NCanon_W – Victor 69kV	Line	BHCE	24/24	24.2	100.7%/100.7%	27.7	115.5%/115.5%	14.8%	Breaker Failure: West Canyon 230/115kV # T1 & West Canyon – Canyon City 115kV

Note – Double circuit Daniels Park – Comanche 345 kV outage caused divergence of the power flow case

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	1	64.8
Colorado Green	2	64.8
Twin Butte	1	60
Twin Butte-II	W1	60
Jackson Fuller	W1&W2	199.9
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
Pueblo Diesels	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	40.0

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	220.9
Tesla	1	13.2
Drake 5	1	0.0
Drake 6	1	81.6
Drake 7	1	138.2
Nixon CT 1	1	0.0
Nixon CT 2	1	0.0
Front Range CC 1	1	142.6
Front Range CC 2	1	142.6
Front Range CC 3	1	141.9

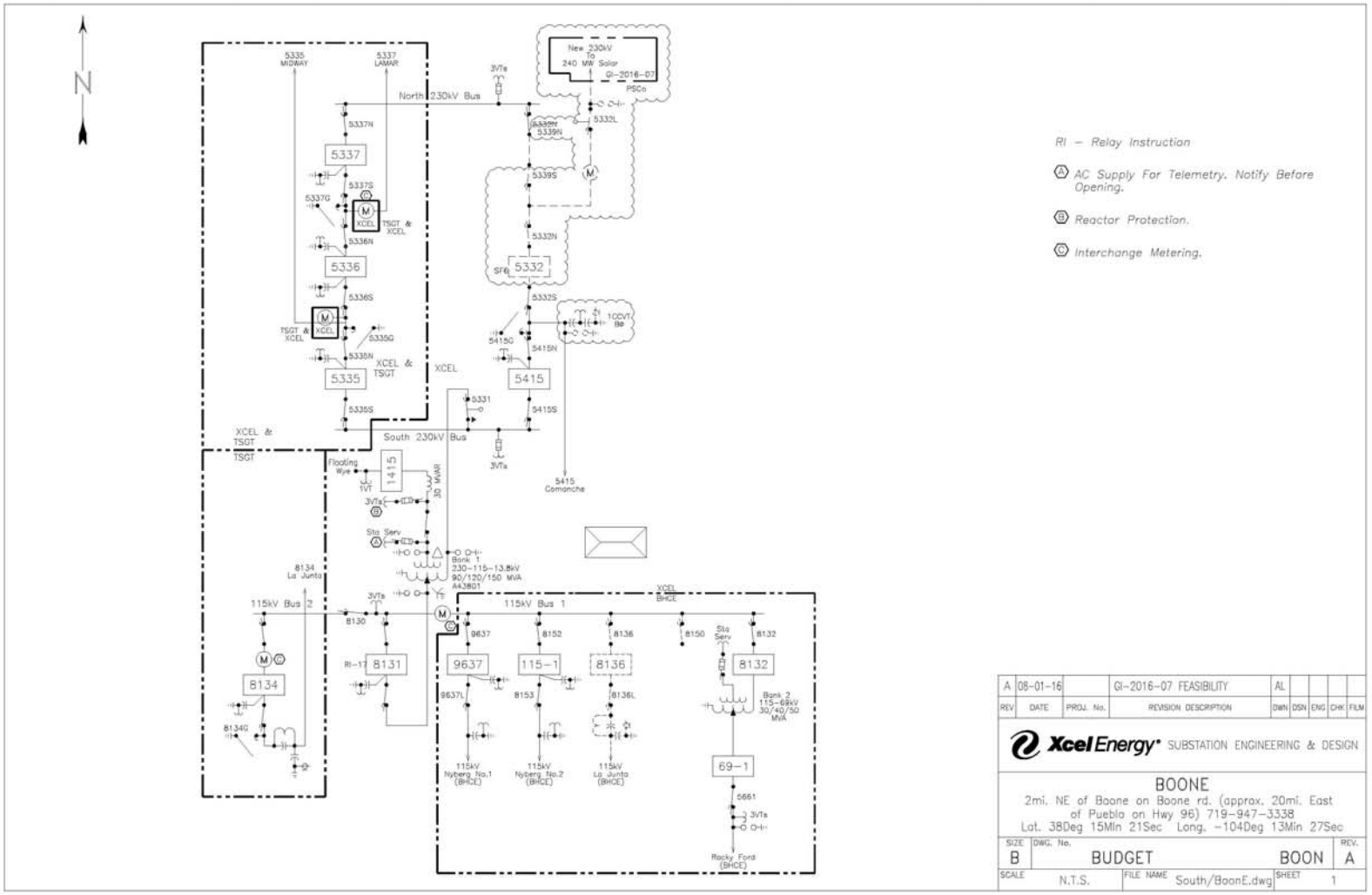

Figure 2 – GI-2016-7 Conceptual One-Line Diagram of the POI