Interconnection Feasibility Study Report
Request # GI-2010-09

30 MW Solar Photovoltaic Generation
Pueblo County, Colorado

Public Service Company of Colorado
Transmission Planning
August 30, 2011

Executive Summary

Public Service Company of Colorado (PSCo) received an interconnection request (GI-2010-09) for a 30 MW solar photovoltaic generation facility in Pueblo County, Colorado. The interconnection request was received June 22, 2010. The solar generation facility will consist of 60 Advanced Energy Solaron 500 kW inverters connected to photovoltaic panels.

The Customer originally requested a primary Point of Interconnection (POI) on one of the Comanche-Midway 230 kV lines. These lines are a half mile from the solar facility. The original alternative POI requested by PSCo was the Boone 115 kV substation, which is 8.7 miles from the solar facility. However, in an email dated May 5, 2011, the Customer requested that the Boone 115 kV substation be considered as the primary POI. Both of the proposed POIs are shown in Figure 1 below. At both POIs, the proposed generation would be connected via a Customer owned radial 115 kV or 230 kV line. The requested in-service date is June 30, 2012. The assumed backfeed date is December 31, 2011.

This request was studied as a Network Resource and an Energy Resource. These investigations included steady-state power flow and short circuit analyses. The request was studied as a stand-alone project only, with no evaluations made of other potential new generation requests that may exist in the Large Generator Interconnection Request (LGIR) queue, other than the generation projects that are already approved and planned to be in service by June 2012. The main purpose of this Feasibility Study was to evaluate the potential impact on the PSCo transmission infrastructure as well as that of neighboring utilities when injecting the additional 30 MW of generation into the Comanche-Midway 230 kV line or the Boone 115 kV substation, and delivering the additional generation to native PSCo loads.

Network Resource (NR)

At the primary POI at the Boone 115 kV substation, the proposed generation caused a

2.0% increase in contingency overloading on Black Hills Energy's (BHE) Portland – West Station 115 kV circuit for the loss of the Midway BR to West Canon 230 kV line. Therefore, the Customer will need to work with BHE to address this overload. However, since there were no new overloads or overloads that increased by greater than 1% on the PSCo system, the Network Resource Capability of the proposed generation is as follows:

NR = 30 MW (at Boone 115 kV POI, without PSCo upgrades)

At the alternative POI on the Comanche-Midway 230 kV line, the proposed generation caused a 1.5% increase in contingency overloading on BHE's Portland – West Station 115 kV circuit for the loss of the Midway BR to West Canon 230 kV line. Therefore, the Customer will need to work with BHE to address this overload. However, since there were no new overloads or overloads that increased by greater than 1% on the PSCo system, the Network Resource Capability of the proposed generation is as follows:

NR = 30 MW (at Comanche-Midway 230 kV POI, without PSCo upgrades)

Energy Resource (ER)

For the Boone 115 kV POI, there were no new overloads, but there was an overload on the BHE system that increased by greater than 1%. Therefore, the Energy Resource Capability of the proposed generation is:

ER = 0 MW (at Boone 115 kV POI, without PSCo upgrades)

For the Comanche-Midway 230 kV POI, there were no new overloads, but there was an overload on the BHE system that increased by greater than 1%. Therefore, the Energy Resource Capability of the proposed generation is:

ER = 0 MW (at Comanche-Midway 230 kV POI, without PSCo upgrades)

Short Circuit

The short circuit study results showed no new circuit breakers overdutied due to the proposed solar generation facility.

Cost Estimates

Boone 115 kV Primary POI

The cost for the transmission interconnection (in 2011 dollars):

Transmission Proposal
The total estimated cost of the recommended system improvements to interconnect the project is approximately **$2,054,000** and includes:

- $ 2.054 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- $ 0.000 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- $ 0.000 million for PSCo Network Upgrades for Delivery to PSCo Loads

This work can be completed in 18 months following receipt of authorization to proceed. However, the backfeed date of December 31, 2011 cannot be met with this timeline.

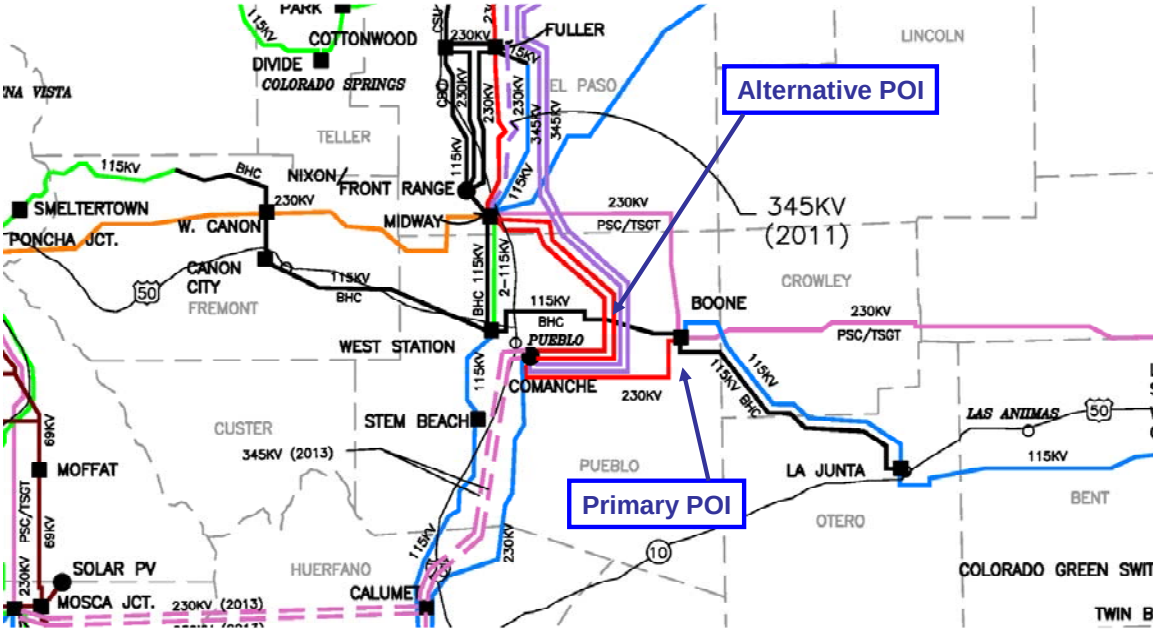
The Interconnection Agreement (IA) requires that certain conditions be met, as follows:

1 The conditions of the Large Generator Interconnection Guidelines (LGIG) are met.

2 PSCO will require testing of the full range of 0 MW to 30 MW operational capability of the facility to verify that the facility can safely and reliably operate within required power factor and voltage ranges.

3 A single point of contact needs to be provided to PSCo Operations to facilitate reliable management of the transmission system.

Figure 1 Comanche, Midway, Boone and Surrounding Transmission System



Introduction

Public Service Company of Colorado (PSCo) received an interconnection request (GI-2010-09) for a 30 MW solar photovoltaic generation facility in Pueblo County, Colorado. The interconnection request was received June 22, 2010. The solar generation facility will consist of 60 Advanced Energy Solaron 500 kW inverters connected to photovoltaic panels.

The Customer originally requested a primary Point of Interconnection (POI) on one of the Comanche-Midway 230 kV lines. These lines are a half mile from the solar facility. The original alternative POI requested by PSCo was the Boone 115 kV substation, which is 8.7 miles from the solar facility. However, in an email dated May 5, 2011, the Customer requested that the Boone 115 kV substation be considered as the primary POI. Both of the proposed POIs are shown in Figure 1 above. At both POIs, the proposed generation would be connected via a Customer owned radial 115 kV or 230 kV line. The requested in-service date is June 30, 2012. The assumed backfeed date is December 31, 2011.

Study Scope and Analysis

The Feasibility Study evaluated the transmission impacts associated with the proposed solar generation facility. It consisted of power flow and short circuit analyses. The power flow analysis identified any thermal or voltage limit violations resulting from the installation of the proposed generation and an identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified any new circuit breakers overdutied due to the proposed generation and the short circuit levels at the primary POI.

PSCo adheres to NERC & WECC Reliability Criteria, as well as internal Company criteria for planning studies. During system intact conditions, criteria are to maintain transmission system bus voltages between 0.95 and 1.05 per unit of nominal, and steady-state power flows below the thermal ratings of all facilities. Operationally, PSCo tries 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. Following a single contingency, transmission system steady state bus voltages must remain within 0.90 per unit to 1.10 per unit, and power flows within 100% of the facilities' continuous thermal ratings. Also, voltage deviations should not exceed 5%.

This project was studied as a Network Resource. 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 project's Energy Resource Capability was also evaluated. 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

For this project, potential affected parties include Tri-State Generation & Transmission (TSG&T) and Black Hills Energy (BHE).

Power Flow Study Models

The power flow studies for 2012 summer were based on the WECC approved 10HS3BP case. PSCo loads in the case were adjusted to reflect the most recent (April 2010) PSCo load forecast for 2012. IREA load was also adjusted to reflect IREA's latest 2010 load forecast for 2012. The topology was also updated to reflect current project plans. Updates were included for the PSCo, CSU, TSG&T, WAPA, and BHE systems. The PSCo updates included the addition of the Midway-Waterton 345 kV circuit, upgrade of the Comanche 230/115 kV T1 transformer, addition of the Comanche and Daniels Park 345 kV 40 Mvar reactors, correction of the Comanche-Reader 115 kV circuit 1 & 2 ratings, and correction of the Comanche Unit 1 & 2 GSU transformer primary rated voltages. The updates also included the Missile Site 230 kV substation and associated wind plant, the Chambers Project, and the new Waterton 230/115 kV transformers.

Two main power flow generation dispatch scenarios were evaluated. One was created as a reference scenario and the other was created with the additional generation. To assess the impact of the additional generation on the transmission system, the power flow models were modified to simulate higher flows from southern Colorado to the north. To accomplish this, generation in south-central Colorado was dispatched to maximum output to increase flows to the north. Generation increases were implemented at Comanche Units 1-3 and the Colorado Green & Twin Butte wind farms. The new 400 MW BHE generation at Airport Tap was also included. Generation at Cameo Units 1 & 2, Ft. Lupton Units 1 & 2, Manchief Units 1 & 2, Fort St Vrain Units 1-6, Valmont Units 6-8, Arapahoe Units 5-7, Brush Units 1, 3, & 4, Spruce Units 1-2, Fountain Valley Units 1-6,, and the Plains End Plant was used as a sink for the dispatch changes. PSCo control area (Area 70) wind generation facilities except for Colorado Green and Twin Butte were dispatched to 12.5%.

In the cases with the proposed generation, the 30 MW of new solar generation was added using modeling information provided by the customer. The power factor of the proposed generation was set to unity for the thermal analysis.

Given that it was originally PSCo that preferred the Boone 115 kV POI, the impedance of the 8.7 mile 115 kV line for the primary POI was provided by PSCo. The impedance of the Ft. Lupton-Hudson 115 kV transmission line with 1 – 477 kcmil ACSR 26/7 conductor was used as a surrogate, adjusted for distance. The new generation was offset by reducing generation at Spindle Units 1 & 2.

Power Flow Study Process

Contingency power flow studies were completed on the reference models and the models with the proposed new generation using PTI's PSSE Ver. 30.3.2 program. Results from each of the two cases were compared and new overloads or overloads that increased significantly in the new generation case were noted. Voltage criteria violations were also recorded. PSSE's ACCC activity was used to perform the load flow contingency analysis. Siemens PTI's MUST program FCITC analysis was used to determine the Energy Resource capability. Areas 70 and 73 were used for the contingency files (single branches and tielines). Monitored elements included branches and ties in zones 700, 704, 705, 709, 712, 757, 790, 791, and 121.

Power Flow Results

Boone 115 kV POI

The results of the contingency analyses for the primary POI at the Boone 115 kV POI can be found in Table 5 in the Appendix. These results showed one increase in a previously existing overload that was greater than 1%. That overload was on BHE's Portland – West Station 115 kV circuit for the loss of the Midway BR to West Canon 230 kV line. The benchmark case overload was 137.4% of its 80 MVA rating and the overload in the case with the new generation was 139.4% of its rating for an increase of 2.0%. The Customer will need to work with BHE to develop an appropriate mitigation strategy for this overload.

Comanche-Midway 230 kV POI

The results of the contingency analyses for the alternative POI on the Comanche-Midway 230 kV line can be found in Table 6 in the Appendix. These results showed one increase in a previously existing overload that was greater than 1%. That overload was on BHE's Portland – West Station 115 kV circuit for the loss of the Midway BR to West Canon 230 kV line. The benchmark case overload was 137.4% of its 80 MVA rating and the overload in the case with the new generation was 138.9% of its rating for

an increase of 1.5%. The Customer will need to work with BHE to develop an appropriate mitigation strategy for this overload.

Network Resource (NR)

At the primary POI at the Boone 115 kV substation, the proposed generation caused a 2.0% increase in contingency overloading on BHE's Portland – West Station 115 kV circuit for the loss of the Midway BR to West Canon 230 kV line. Therefore, the Customer will need to work with BHE to address this overload. However, since there were no new overloads or overloads that increased by greater than 1% on the PSCo system, the Network Resource Capability of the proposed generation is as follows:

NR = 30 MW (at Boone 115 kV POI, without PSCo upgrades)

At the alternative POI on the Comanche-Midway 230 kV line, the proposed generation caused a 1.5% increase in contingency overloading on BHE's Portland – West Station 115 kV circuit for the loss of the Midway BR to West Canon 230 kV line. Therefore, the Customer will need to work with BHE to address this overload. However, since there were no new overloads or overloads that increased by greater than 1% on the PSCo system, the Network Resource Capability of the proposed generation is as follows:

NR = 30 MW (at Comanche-Midway 230 kV POI, without PSCo upgrades)

Energy Resource (ER)

For the Boone 115 kV POI, there were no new overloads, but there was an overload on the BHE system that increased by greater than 1%. Therefore, the Energy Resource Capability of the proposed generation is:

ER = 0 MW (at Boone 115 kV POI, without PSCo upgrades)

For the Comanche-Midway 230 kV POI, there were no new overloads, but there was an overload on the BHE system that increased by greater than 1%. Therefore, the Energy Resource Capability of the proposed generation is:

ER = 0 MW (at Comanche-Midway 230 kV POI, without PSCo upgrades)

Short Circuit

For the Customer proposed interconnection at the Boone 115 kV primary POI, no new circuit breakers are expected to exceed their capabilities following installation of the new

generation. The calculated short circuit parameters for the POI at the Boone 115 kV substation are shown in Table 1 below.

Table 1 – Short Circuit Parameters at the Boone 115 kV POI

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance (R +j X) (ohms)
All Facilities in Service	8589.9	8423.5	Z1(pos)= 0.69621 +j 7.69803 Z2(neg)= 0.69658 +j 7.69777 Z0(zero)= 0.85678 +j 8.14340

Costs Estimates and Assumptions
GI-2010-9 (Feasibility Study Report)
July 18, 2011

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 2011 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 **$2,054,000.** Figure 2 below represents a conceptual one-line of the proposed interconnection at the Boone 115kV Substation. These estimates do not include costs for any other Customer owned equipment and associated design and engineering. The following tables list the improvements required to accommodate the interconnection and the delivery of the Armadillo Flats 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.

Xcel Energy

Figure 2: Proposed Boone Station One-line with Project Interconnection

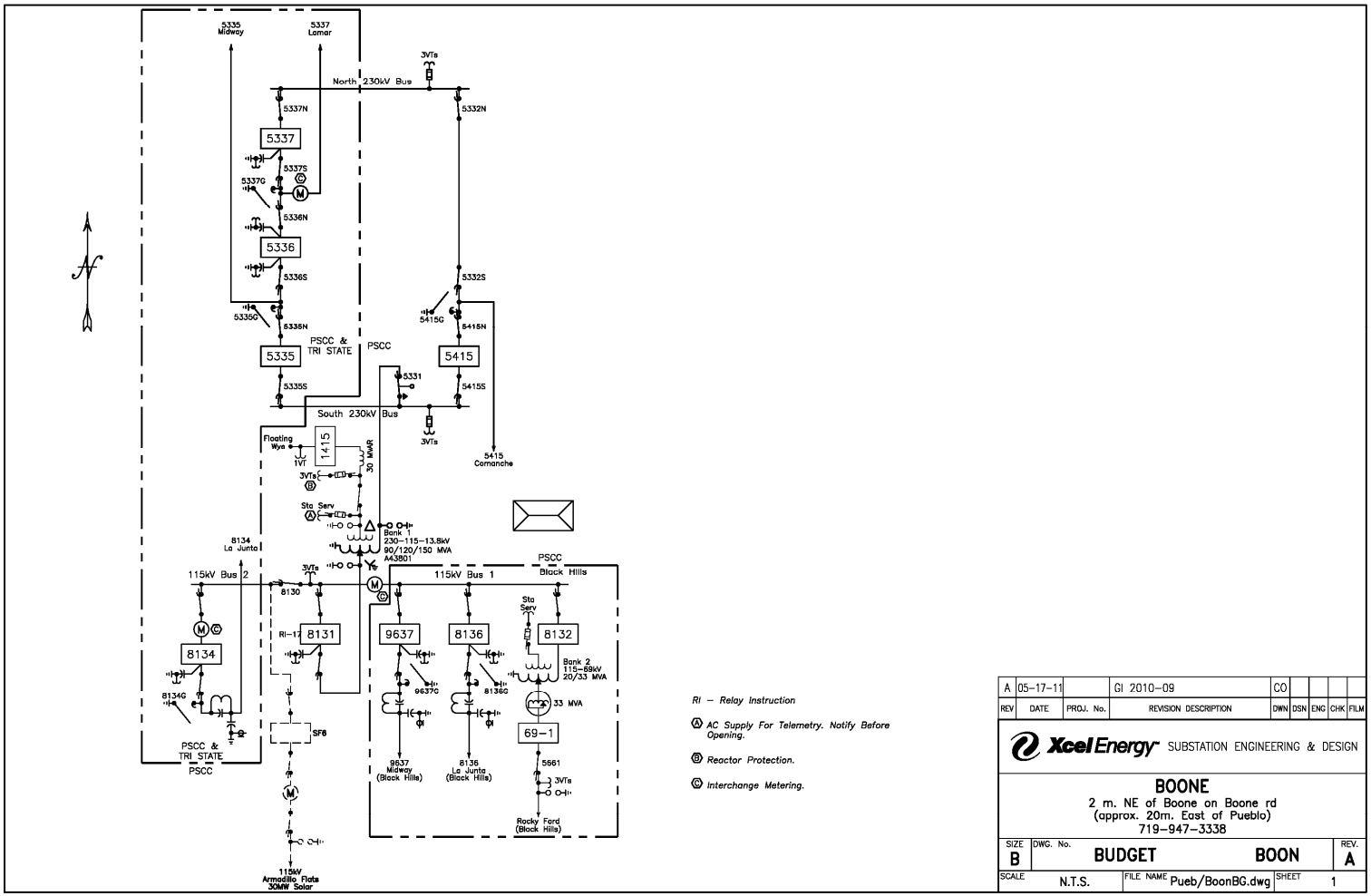


Table 2 – PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Boone 115kV Transmission Substation	Interconnect Customer to the 115kV bus at the Boone 115kV Substation. The new equipment includes: • Three 115kV gang switches • One 115kV circuit breaker • Two 115V combination CT/PT metering units • Power Quality Metering (115kV line from Customer) • Three 115kV lightning arresters • One relay panel (transformer breaker panel) • Associated communications, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$1.891**
Element Power's Armadillo flats 115kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment.	**$0.163**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$2.054**
Time Frame	**Design, procure and construct**	**18 Months**

Table 3: PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Boone 115kV Transmission Substation	N/A	**$0.0**
		$0.0
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$0.0**
Time Frame	**Site, design, procure and construct**	**N/A**

Table 4 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
	Not Applicable	
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0.0**
	Design, procure and construct	**N/A**
	Total Project Estimate	**$2.054**

Cost Estimate Assumptions

- Scoping level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering.
- Estimates are based on 2011 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 authorized during the construction period to meet backfeed. Could potentially be problematic and extend requested backfeed date due to summer construction window.
- Power Quality Metering (PQM) will be required on the Customer's 115 kV line terminating into Boone Substation.

GI-2010-09

A. Load Flow Thermal Results

Table 5 – Summary Listing of Differentially Overloaded Facilities (Primary 115 kV POI)[1]

				Branch N-1 Loading Without GI-2010-09		Branch N-1 Loading With GI-2010-09			
Monitored Facility (Line or Transformer)	Type	Line Owner	Branch Rating MVA	N-1 Flow in MVA	N-1 Flow in % of Rating	N-1 Flow in MVA	N-1 Flow in % of Rating	% Change	N-1 Contingency Outage
Portland – West Station 115 kV	LN	BHE	80	109.2	137.4	110.8	139.4	2.0	Midway BR – West Canon 230 kV

[1] **Newly overloaded elements, or delta overloads > 1.0% of rating, due to proposed 30 MW generation increase at POI.**

Table 6 – Summary Listing of Differentially Overloaded Facilities (Alternative 230 kV POI)[2]

				Branch N-1 Loading Without GI-2010-09		Branch N-1 Loading With GI-2010-09			
Monitored Facility (Line or Transformer)	**Type**	**Line Owner**	**Branch Rating MVA**	**N-1 Flow in MVA**	**N-1 Flow in % of Rating**	**N-1 Flow in MVA**	**N-1 Flow in % of Rating**	**% Change**	**N-1 Contingency Outage**
Portland – West Station 115 kV	LN	BHE	80	109.2	137.4	110.3	138.9	1.5	Midway BR – West Canon 230 kV

[2] **Newly overloaded elements, or delta overloads > 1.0% of rating, due to proposed 30 MW generation increase at POI.**

B. Generation Dispatch

Dispatch of Major Generating Units in the Vicinity of GI-2010-09:

PSCo:

Bus	LF ID	MW
Comanche	C1	360.0
Comanche	C2	365.0
Comanche	C3	804.0
Lamar DC Tie	DC	101.0 Import
Fountain Valley	G1	0.0
Fountain Valley	G2	0.0
Fountain Valley	G3	0.0
Fountain Valley	G4	0.0
Fountain Valley	G5	0.0
Fountain Valley	G6	0.0
Colorado Green	1	81.0
Colorado Green	1	81.0
Twin Butte	1	75.0

BHE:

Bus	LF ID	MW
City of Lamar	G1	25.0
E Canon	G1	0.0
PP_MINE	G1	0.0
Pueblo Diesels	G1	0.0
Pueblo Plant	G1	0.0
Pueblo Plant	G2	0.0
R.F. Diesels	G1	0.0
Airport Diesels	G1	0.0
Baculite 1	G1	100.0
Baculite 2	G1	100.0
Baculite 3	G1	40.0
Baculite 3	G2	40.0
Baculite 3	S1	20.0
Baculite 4	G1	40.0
Baculite 4	G2	40.0
Baculite 4	S1	20.0

CSU:

Bus	LF ID	MW
Birdsale 1	1	0.0
Birdsale 2	1	0.0
Birdsale 3	1	0.0
Nixon	1	224.8
Tesla	1	28.0
Drake 5	1	49.0
Drake 6	1	82.3
Drake 7	1	139.1
Nixon CT 1	1	0.0
Nixon CT 2	1	0.0
Front Range CC 1	1	76.0
Front Range CC 2	1	77.0
Front Range CC 3	1	116.0