Interconnection Feasibility Study Report
Request # GI-2010-18

30 MW Solar Photovoltaic Generation
Pueblo County, Colorado

Public Service Company of Colorado
Transmission Planning
March 27, 2012

Executive Summary

Public Service Company of Colorado (PSCo) received an interconnection request (GI-2010-18) for a 30 MW solar photovoltaic generation facility. The solar facility will be located at the Northeast corner of the Lime road and St. Charles road, immediately east of the Comanche Power plant, in Pueblo, Colorado. The interconnection request was received on November 16, 2010. The solar generation facility will consist of sixty, 0.5MW Sunny Central SMA SC500HE-US inverters.

The Customer requested a primary Point of Interconnection (POI) on the Comanche 115 kV bus. The solar facility will be located 0.25 miles from the Comanche Substation and connected to the POI using a 115 kV Customer owned transmission line. An alternative POI has been requested tapping one of the Comanche-Midway 230 kV lines. The alternative POI will be evaluated only if the primary POI is not feasible. Both of the proposed POIs are shown in Figure 1 below. The Customer has initially proposed a November 2012 in-service date for this facility. In an email received on January 19, 2012, the Customer has revised the in-service date as fourth quarter 2013. Since the Customer has not provided a specific in-service date, it is assumed to be December 31, 2013 and the backfeed date is assumed to be June 1, 2013. Based on the construction schedule in Table 2, this Interconnection will not be able to meet the proposed back feed date of July 1, 2013.

This request was studied as an Energy Resource only. The studies were performed using 2013 heavy summer conditions. 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 Generator Interconnection Request queue, other than the generation projects that are already approved and planned to be in service by July 2013. 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 an additional 30 MW of generation is injected into the Comanche 115 kV substation or one of the Comanche-Midway 230 kV lines, and delivering the additional generation to native PSCo loads.

Energy Resource (ER)

For the primary point of Interconnection (Comanche 115 kV), there were no new overloads and none of the existing overloads increased by more than 1%. The largest increase in overload was 0.9% on the Reader 115/69 KV transformers for the loss of the other Reader 115/69 KV transformer. Since the increase in overload is close to 1%, the Customer will need to work with BHE to address this overload. Black Hills Power is pursuing a project to replace the two existing Reader 115/69 kV transformers with 80 MVA transformers in fourth quarter, 2013. The new transformers would mitigate the existing overload and since the increase in overload is less than 1%, the Energy Resource capability of the proposed generation is 30 MW

ER = 30 MW (at Comanche 115 kV POI)

Since the primary POI is feasible, the secondary POI was not studied

Short Circuit

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

Cost Estimates

Comanche 115 kV Primary POI

The cost for the transmission interconnection (in 2012 dollars):

Transmission Proposal
The total estimated cost of the recommended system improvements to interconnect the project is approximately **$1,397,000** and includes:

- $ 1.397 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 12 months following receipt of authorization to proceed. The December 2013 in service date is infeasible based on the construction schedule and needs to be reevaluated.

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.

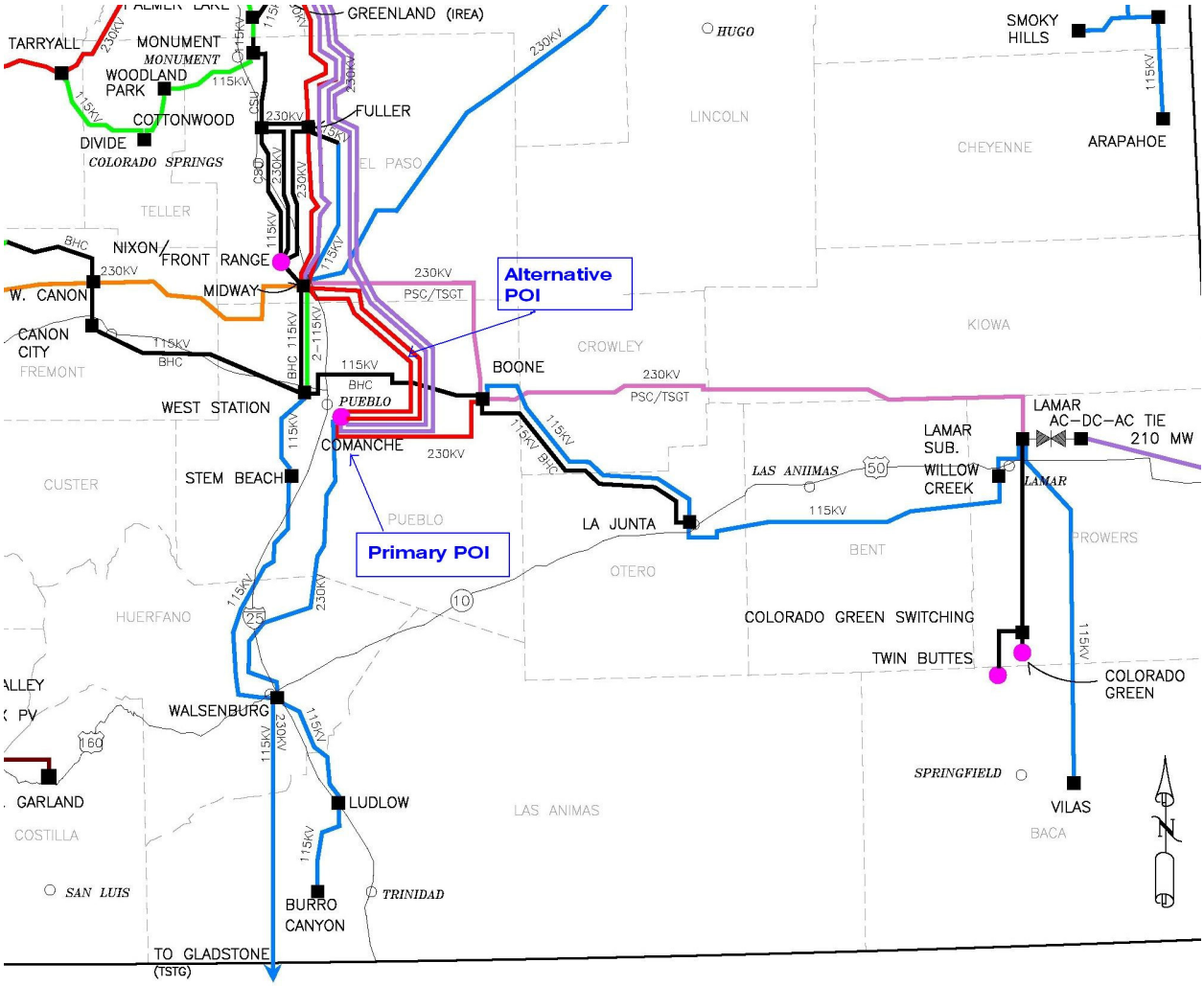

Figure 1 Comanche, Midway, Boone and Surrounding Transmission System

Introduction

Public Service Company of Colorado (PSCo) received an interconnection request (GI-2010-18) for a 30 MW solar photovoltaic generation facility in Pueblo County, Colorado. The solar facility will be located at the Northeast corner of the Lime road and St. Charles road, immediately east of the Comanche Power plant. The interconnection request was received on November 16, 2010. The solar generation facility will consist of sixty 0.5MW Sunny Central SMA SC500HE-US inverters.

The Customer requested a primary Point of Interconnection (POI) on the Comanche 115kV bus. The solar facility will be located 0.25 miles from the Comanche Substation and connected to the POI using a 115 kV Customer owned transmission line. An alternative POI has been requested tapping one of the Comanche-Midway 230 KV lines. . The alternative POI will be evaluated only if the primary POI is not feasible. Both of the proposed POIs are shown in Figure 1 above. The Customer has initially proposed a November 2012 in-service date in the Interconnection Request letter. In an email received on January 19, 2012, the Customer has revised the in-service date to be fourth quarter 2013. Since a specific date is not given, the in-service date is assumed to be December 31. 2013 and the backfeed date is assumed to be July 1, 2013. Based on the construction schedule in Table 2, the Interconnection will not be able to meet the proposed back feed date of July 2013.

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 1.02-1.03 per unit at regulating (generation) buses and 1.0-1.03 per unit at transmission load buses in the Southeast Colorado area. Following a single contingency, transmission system steady state bus voltages must remain within 0.90-1.05 per unit at all the buses, and power flows within 100% of the facilities' continuous thermal ratings. Also, voltage deviations should not exceed 5%.

The proposed facility was studied as an Energy Resource only. 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 and Black Hills Energy (BHE).

Power Flow Study Models

The proposed solar facility interconnection was studied using 2013 heavy summer loading conditions. The 2013HS case was built using the WECC approved 2012HS3SA base case. PSCo loads in the case were adjusted to reflect the most recent (September 2011) PSCo load forecast for 2013. The topology was updated to reflect current project plans and rating changes for 2013, updates were included for CSU, TSGT, BHE, WAPA and zone 121 of New Mexico systems per their submittals. PSCo updates included the addition of 40 Mvar reactors at Comanche 345 kV and Daniels Park 345 kV, corrected impedance of the Missile Site-Daniels Park and Missile Site-Pawnee 230kV circuits, modeled Missile Site 345 kV Substation and associated wind generation, Corrected impedance of the Daniels park-Comanche 345 kV lines, Boone-Lamar 230 kV and Boone-Midway 230 kV lines. Also, Poncha 230/115 kV auto transformer, Chambers 230/115 kV #2 transformer were modeled. GSU tap settings of Comanche units were corrected, Tap settings of Midway 230/345 kV xfmr, Waterton 230/345 kV xfmr, Comanche 230/345 kV xfmrs and Daniesl Park 230/345 kV xfmrs were corrected. BHP's updates include upgrades to the existing Portland-West Station 115 kV line, a second Portland–West Station 115 kV line, ArequeGulch-PP mine xfmr voltage settings corrected and upgrades to the Reader-Greenhorn 115 kV line were modeled. .

Two main power flow generation dispatch scenarios were evaluated. One was created as a reference scenario and the other was created with the proposed generation. To assess the impact of the proposed 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 1,2 & 3, BHP's Baculite Mesa units and wind generation at Rattlesnake. The Colorado Green wind farms, Twin Buttes wind farm and Lamar DC tie were dispatched such that flow on Boone-Lamar 230 KV line is at PSCo's maximum contract capability. Generation at Fort Saint Vrain Units 5 & 6, Plains End NUG and Brush NUG was used as sink for the dispatch changes. PSCo control area (Area 70) wind generation facilities except for Colorado Green and Twin Butte were dispatched to 21%.

The PSSE raw equivalent model submitted by the Customer was used for modeling the Solar facility. The following changes were made to the model for the study purpose:

- Qmax and Qmin set to zero so that the machine is modeled at unity power factor.
- The lumped unit is modeled at the 115 kV bus at the Customers end
- the 0.7 kV model is removed from the representation.

The 115 kV transmission tie line was modeled using the 115 kV line parameters provided by the Customer.. The power factor of the proposed generation was set to unity for the thermal analysis. The new generation was offset by reducing generation at Spindle unit 1.

Power Flow Study Process

Contingency power flow studies were completed on the reference power flow case and the power flow case with the proposed new generation using PTI's PSSE Ver. 32.1.0 program. Results from each of the two cases were compared and new overloads or existing overloads that increased by at least 1% in the case with the new generation were noted. Any new voltage deviations or increase in the voltage deviations of 5% or more are noted. PSSE's ACCC activity was used to perform the load flow contingency analysis. Areas 70 and 73, and zone 121 were used for the contingency files (single branches and tie lines). Monitored elements included branches and ties in zones 700, 704, 705, 709, 712, 757, 790, 791 and 121.

Power Flow Results

Comanche 115 kV POI

The results of the contingency analyses for the Primary POI (Comanche 115 kV bus) can be found in Table 5. The proposed 30 MW solar interconnection has not caused any new thermal violations and none of the existing thermal overloads found in the reference case increased by greater than 1%. The largest increase in overload was 0.9% on the Reader 115/69 kV transformers for the loss of the other Reader 115/69 kV transformer. The benchmark case overload on Reader 115/69 kV #T1 transformer was 136.7% of its 42 MVA rating and the overload in the case with the new generation was 137.6% of its 42 MVA. The benchmark case overload on Reader 115/69 kV #T2 transformer was 137.9% of its 42 MVA rating and the overload in the case with the new generation was 138.8% of its 42 MVA. Black Hills Power is pursuing a project to replace the two existing Reader 115/69 kV transformers with 80 MVA transformers. The project is scheduled to be completed by fourth quarter 2013. The new transformers would mitigate the existing overload and since the increase in overload is less than 1%, the Energy Resource capability of the proposed generation is 30 MW. The proposed solar

facility has caused no new voltage violations. The highest increase in existing voltage violations was 0.3%. Since the increase in overload is close to 1%, the Customer will need to work with BHE to address this overload.

Therefore, the Energy Resource Capability of the proposed generation at the Comanche 115 kV bus is:

ER = 30 MW (at Comanche 115 kV)

Since the primary POI is feasible, the secondary POI was not evaluated

Short Circuit

For the Customer proposed interconnection at the Comanche 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 Comanche 115 kV substation are shown in Table 1 below.

Table 1 – Short Circuit Parameters at the Comanche 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	27300	30100	Z1(pos)= 0.19684+j2.42021 Z2(neg)= 0.21447+j2.42072 Z0(zero)= 0.12213+j1.74469

Costs Estimates and Assumptions
GI-2010-18 (Feasibility Study Report)

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 2012 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 **$1,397,000.** Figure 2 below represents a conceptual one-line of the proposed interconnection at the Comanche 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 Customer's 30MW solar generation output. The cost responsibilities associated with these facilities shall be handled per current FERC guidelines. System improvements are subject to change upon completion of the Facility Study.

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

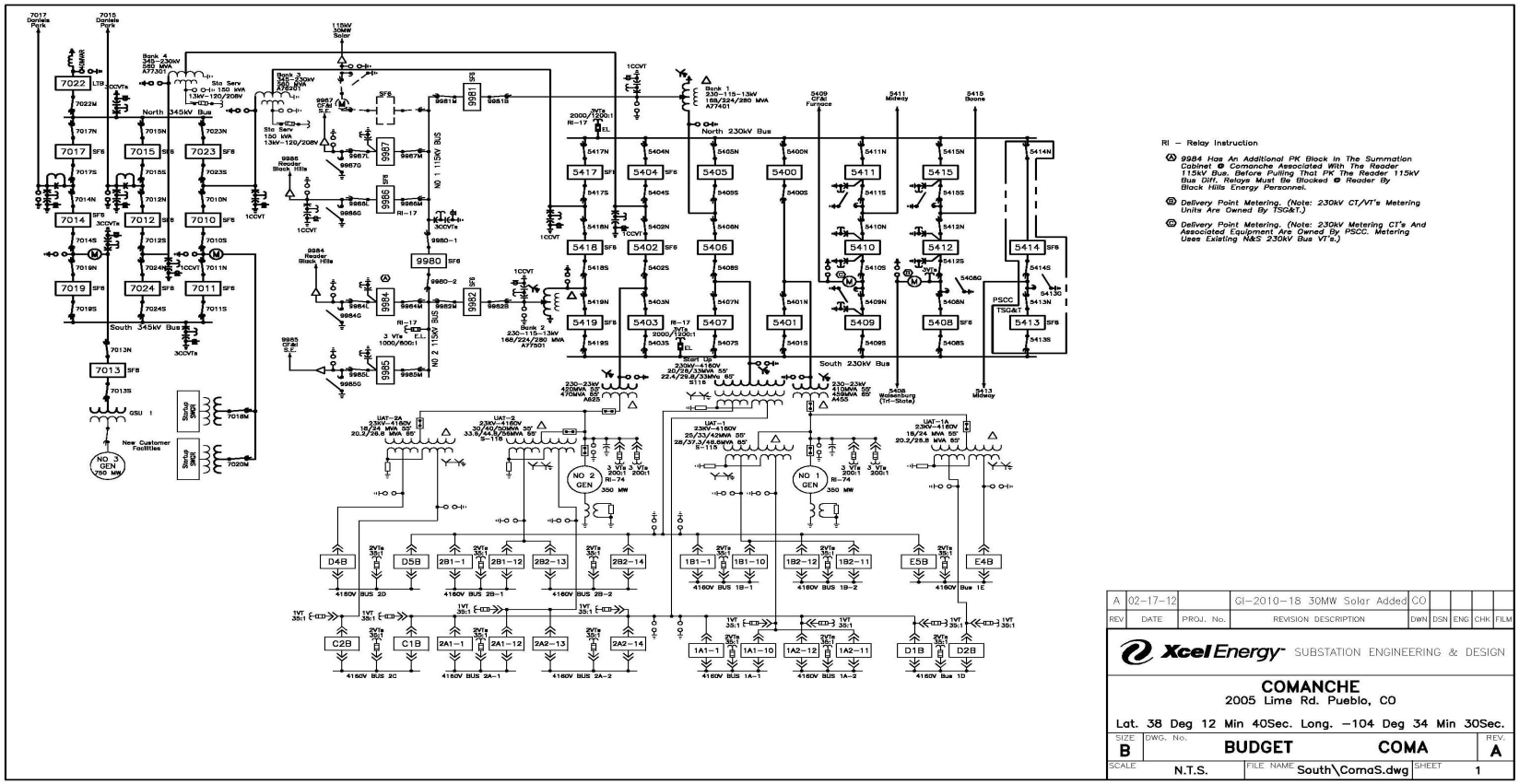

Table 2 – PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Comanche 115kV Transmission Substation	Interconnect Customer to the 115kV bus at the Comanche 115kV Substation. The new equipment includes: • Three 115kV gang switches • One 115kV circuit breaker • Power Quality Metering (115kV line from Customer) • Three 115kV lightning arresters • One relay panel (transformer breaker panel) • One new underground transmission line transition structure • 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	**$1.169**
Customer's 115kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment. Install a new relay panel at the customer generation site. Connect SCADA from the site to the Lookout Control Center.	**$0.228**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$1.397**
Time Frame	**Design, procure and construct**	**12 Months**

Table 3: PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Comanche 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	**$1.397**

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 2012 dollars (appropriate contingency and escalation applied).
- AFUDC has been excluded.
- The estimate assumes the Customer connection will be an underground 115 kV transmission line (No overhead line provision are included in the estimates)
- 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 12 months after authorization to proceed has been obtained.
- This project is completely independent of other queued projects and their respective ISD's.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- 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 Comanche Substation.

A. Load Flow Thermal Results

Table 5 – Summary Listing of New thermal Overloads and Increase in Existing Thermal Overloads of 1% or more (Comanche 115 kV Substation POI)[1]

				Branch N-1 Loading Without GI-2010-189		Branch N-1 Loading With GI-2010-18			
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
Reader 115/69 kV #T1	XFMR	BHE	42	57.4	136.7	57.8	137.6	0.9	Reader 115/69 kV #T2
Reader 115/69 kV #T2	XFMR	BHE	42	57.9	137.9	58.3	138.8	0.9	Reader 115/69 kV #T1

[1] **Detailed thermal violations due to the proposed 30 MW generation increase at Comanche 115 kV Substation.**

B. Generation Dispatch

Dispatch of Major Generating Units in the Vicinity of GI-2010-18:

PSCo:

Bus	LF ID	MW
Comanche	C1	353
Comanche	C2	362
Comanche	C3	809.0
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	48

ARPA:

Bus	LF ID	MW
City of Lamar	G1	24.8
City of Lamar	G2	16.9

BHE:

Bus	LF ID	MW
BUSCHWRTG1	G1	28.8
BUSCHWRTG2	G2	28.8
E Canon	G1	0.0
PP_MINE	G1	0.0
Pueblo Diesels	G1	0.0
Pueblo Plant	G1	20
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	90.6
Baculite 2	G1	90.6
Baculite 3	G1	40.0
Baculite 3	G2	40.0
Baculite 3	S1	24.8

Baculite 4	G1	40.0
Baculite 4	G2	40.0
Baculite 4	S1	24.8

CSU:

Bus	LF ID	MW
Birdsale 1	1	0.0
Birdsale 2	1	0.0
Birdsale 3	1	0.0
Nixon	1	230
Tesla	1	28.0
Drake 5	1	55.2
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	88
Front Range CC 2	1	88
Front Range CC 3	1	99.5