



## Generation Interconnection Feasibility Study Report Request # GI-2008-27

100 MW Solar Thermal Generation, San Luis Valley, Colorado

PSCo Transmission Planning  
April 6, 2010

### A. Executive Summary

On February 11, 2009 Public Service Company of Colorado (PSCo) Transmission Planning received a generation interconnection request to evaluate the feasibility of interconnecting a 250-MW solar thermal generation facility to PSCo system by tapping the Poncha – San Luis Valley (SLV) 230 kV transmission line. On June 2009, the Customer notified PSCo to reduce the plant capacity to 100 MW, interconnecting at the same location.

The new 100 MW of steam-turbine generator will utilize the collected solar energy and pass it through a heat-exchanger to produce steam for the prime mover. The generator will be connected through a dedicated generator step-up transformer with the terminal voltage of 13.8 kV. The steam turbine is rated at 137 MVA with a power factor of 0.85 lead/lag.

Since the Customer's generation facility is located adjacent to the transmission line, the Point of Interconnection (POI) will be a new three breaker ring-bus substation tapping the Poncha – SLV 230 kV line at approximately 10 miles north of the SLV substation per PSCo Large Generator Interconnection Guidelines (LGIG), see figure 1. The Poncha – SLV 230 kV line is jointly owned by PSCo and TSG&T and operated by TSG&T. During the Facility study process, PSCo and TSG&T will discuss the ownership and operation breakdown of the new substation.

According to the study agreement between the Customer and PSCo, the Customer has requested this generation interconnection to be studied only as a Network Resource (NR)<sup>1</sup> with the generation delivered to PSCo's native loads. The Customer's has proposed commercial in-service date of January 1, 2014 with an assumed back-feed date of June 1, 2013. Upon completion of the Feasibility Study, PSCo has determined that it is feasible to interconnect to PSCo system by tapping the Poncha – SLV 230 kV

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<sup>1</sup> **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.

line via a three breaker ring-bus substation. The results of this study indicate that 100 MW of GI-2008-27 generation project delivered to the PSCo native loads does not result in the overloading of facilities in the PSCo regional transmission system. However, the voltage levels at several buses violate criteria for certain single line contingencies. TSG&T has an Under Voltage Load Shedding (UVLS) scheme established for the San Luis Valley region in case the voltages dip below 0.93 p.u. in order to avoid voltage collapse. In addition to the UVLS, the region will need additional capacitor banks to maintain the voltage within criteria under N-1 contingencies. The additional capacitor banks at the Alamosa Terminal will be evaluated in the PSCo annual budget study. This solution will not alleviate the current UVLS scheme that may operate under certain N-1 contingencies. Under these conditions, the 100 MW of Network Resource requested would not require any major Transmission Network Upgrades. Installing the SB-100 project (San Luis Valley – Calumet – Comanche transmission project) would eliminate the need for the UVLS scheme.

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 the summer of 2014. The main purpose of this study was to evaluate the potential impact of GI-2008-27 on the PSCo transmission infrastructure as well as neighboring entities, when injecting a total of 100 MW of generation, and delivering that additional generation to native PSCo loads. The costs to interconnect the project with the transmission system at San Luis Valley Substation have been evaluated by PSCo Engineering. This study considered facilities that are part of the PSCo transmission system as well as monitoring other nearby entities' regional transmission systems.

### Stand Alone Results

The stand-alone analysis consisted of a comparative study of the system behavior with the addition of the Customer's 100 MW project to the PSCo system compared with that associated with the existing PSCo system. The power flow model used in this study is a 2014 budget model with summer load and moderately stressed south-to-north power flows. Using the 2014 summer case, two scenarios were developed and studied: with the SB-100<sup>2</sup> project (San Luis Valley – Calumet – Comanche transmission project), and without the SB-100 project. A 2014 spring case was also used, recognizing that the transmission capability in this region could be more constrained during light load conditions than summer peak periods. The same scenarios and studies were run for the 2014 spring case. All scenarios were run with an assumption that the Alamosa

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<sup>2</sup> **Senate Bill 100 Project** includes the following:

Install the San Luis valley (SLV) –Calumet-Comanche transmission project. This consists of two 230 kV lines from SLV to a new Calumet Substation and two 345 kV lines from Calumet to Comanche. The existing Comanche –Walsenburg 230 kV circuit will also be looped into Calumet and a second 230 kV line will be installed from Calumet to Walsenburg.

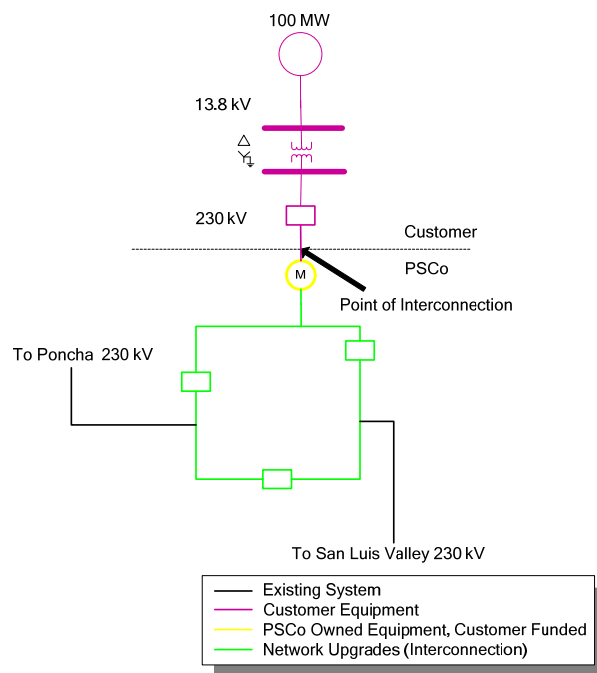
Terminal combustion turbines were offline. The results of the studies without the SB-100 project indicated low voltages under single contingency in the SLV region and a need for additional VAR support. The results of the studies with the SB-100 project indicated no low voltage and no thermal violations in the area. Furthermore, the SLV region will need reactor support to reduce the voltages at some buses once the SB-100 project lines are energized.

### Network Resource (NR)

Network Resource Interconnection Service is an Interconnection Service that allows the Interconnection Customer to integrate their Large Generating Facility with the Transmission Provider's Transmission System in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers. A Network Resource is any designated generating resource owned, purchased, or leased by a Network Customer under the Network Integration Transmission Service Tariff. Network Resources do not include any resource, or any portion thereof, that is committed for sale to third parties or otherwise cannot be called upon to meet the Network Customer's Network Load on a non-interruptible basis. Network Resource Interconnection Service in and of itself does not convey transmission service.

As a network request, contingency analysis was performed to determine the upgrades that would be required to deliver the entire output of the GI-2008-27 solar thermal facility as provided at the POI to PSCo native loads. Under that condition, the total estimated cost of the recommended system upgrades to accommodate the project is approximately **\$4.34 million** and includes:

- \$0.406 million for PSCo-Owned, Customer-Funded Interconnection Facilities.
- \$3.934 million for PSCo-Owned, PSCo-Funded Interconnection Facilities.



**Figure 1. Preliminary One-Line of the Proposed 100 MW Generating Facility**

## **B. Introduction**

Public Service Company of Colorado formally received a large generator interconnection request (GI-2008-27) to interconnect a solar thermal generating station, with a nameplate capacity of 100 MW and a commercial operation date of January 1, 2014. The GI-2008-27 project would be connected to a three breaker ring-bus tapping the Poncha – SLV 230 kV line, 10 miles north of the SLV substation. The Poncha – SLV 230 kV line is jointly owned by PSCo and TSG&T and operated by TSG&T. During the Facility study process, PSCo and TSG&T will discuss the ownership and operation of the new substation. It is assumed that the Customer has procured the land adjacent to the transmission line and PSCo will purchase the piece of land underneath the line from the Customer to build the substation.

This request was evaluated as a stand alone project with no other higher queued projects modeled. The Customer has requested that this project be evaluated as a Network Resource (NR), with the energy delivered to PSCo customers. In June, 2009, the Customer requested a reduction to 100 MW of generation capability to be studied.

The new 100 MW of steam-turbine generator will utilize the collected solar energy and pass it through a heat-exchanger to produce steam for the prime mover. The generator will be connected through a dedicated generator step-up transformer with the terminal voltage of 13.8 kV. The steam turbine is rated at 137 MVA with a power factor of 0.85 lead/lag.

### **C. Study Scope and Analysis**

This feasibility study evaluates the feasibility of providing 100 MW of power from the GI-2008-27 project to PSCo native loads. This request was studied as a Network Resource (NR) only. This feasibility study consisted of both steady state power flow analysis and short circuit analysis. The power flow analysis provides a preliminary identification of any thermal or voltage limit violations resulting from the interconnection, and for an NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identifies any circuit breakers with short circuit capability limits exceeded as a result of the interconnection and for a NR request, the delivery of the proposed generation to PSCo loads.

PSCo adheres to NERC/WECC criteria as well as internal company criteria for planning studies. The following criteria were used for this study:

- For system intact conditions, transmission system bus voltages must be maintained between 0.95 and 1.05 p.u. of system nominal / normal conditions, and steady-state power flows must be maintained within 1.00 p.u. of all elements' thermal (continuous current or MVA) ratings.
- PSCo tries to maintain a transmission system voltage profile ranging from 1.02 p.u. or higher at regulating buses, and 1.00 p.u. or higher at transmission load buses.
- The ideal voltage range for the 230 kV bus at the San Luis Valley substation is between 1.01 p.u. to 1.04 p.u.
- Following a single contingency element outage, transmission system steady state bus voltages must remain within 0.90 p.u. to 1.10 p.u. and power flows within 1.00 p.u. of the elements' continuous thermal ratings.

For this project, Tri-State Generation and Transmission association (TSG&T) is an affected party. PSCo will provide TSG&T with a copy of this feasibility study report and will work with TSG&T during the system impact study phase.

### **D. Power Flow Study Models**

Western Electricity Coordinating Council (WECC) coordinates the preparation of regional power flow cases for transmission planning purposes. PSCo Transmission developed a base case for the 2014 summer peak load as a part of their annual five-year project identification process, from WECC approved models and modified for PSCo-approved projects and topology changes.

In the 2014 summer peak case, the following generators in Area 70 (PSCo Transmission) and Area 73 (WAPA R.M) were re-dispatched to simulate high south-to-north stressed system conditions.

- The Lamar DC tie was set to import 210 MW. This increase in supply capability was accommodated by backing down generation at Ft. St. Vrain.
- A 16 MW solar photovoltaic was connected at the 69 kV Mosca Junction bus, since it is an approved future project that will be in operation before 2014.
- The two existing gas turbines at Alamosa Terminal in the power flow model were turned off.
- The generation at Comanche, RD Nixon and Front Range were dispatched close to maximum capacity.

TOT5 is the transmission interface between western and eastern Colorado. The power flow models were modified to simulate high TOT5 flows at a level of 805 MVA by redispatch of generation.

Using the modified 2014 summer load base case as the starting point, two sets of power flow models were developed to reflect the project with two potential transmission scenarios. One model reflected the transmission reinforcements proposed to address the renewable energy zone transmission requirements for the SB-100 project and the other model represented the transmission system without those upgrades. The following modifications were made to Area 70 in the 2014 base case to develop one of the power flow models, see figure 2:

1. A new substation would be built at Calumet (between Walsenburg and Comanche) with both a 230 kV and a 345 kV bus. The 230 kV bus at Calumet would tap the existing 230 kV circuit from Comanche to Walsenburg.
2. A 230 kV line would be built from Calumet to Walsenburg. Calumet would also be connected to Comanche through two new 345 kV lines.
3. The plan also includes two new 230 kV lines from San Luis Valley to Calumet.

In setting up the power flow models, Cherokee Unit 3 was designated as the slack bus for Area 70.

Recognizing that transmission capability in the San Luis Valley is constrained and impacted by load and generation levels in the region, this interconnection was also studied with the 2014 spring case. PSCo developed this case from WECC approved models, modifying loads and generation to reflect spring conditions. This case was also stressed from south-to-north and flows across TOT5 were increased in a manner similar to the summer case. The flow across TOT5 in the spring benchmark case is 923 MVA. Again, two sets of power flow models were developed from the base case to reflect the project with two potential transmission scenarios – with the transmission reinforcements

to address the renewable energy zones referenced in the SB-100 project and without the upgrades.

The proposed solar thermal generation facility consists of one 100 MW steam-turbine generator. The steam for the prime mover is created by utilizing collected solar energy, through a heat-exchanger. The generator has a terminal voltage of 13.8 kV. This facility will be interconnected to the PSCo system through a 112 MVA 230-13.8 kV step-up transformer, at a tap on the Poncha – SLV 230 kV line. This line will be tapped 10 miles north of the San Luis Valley Substation.

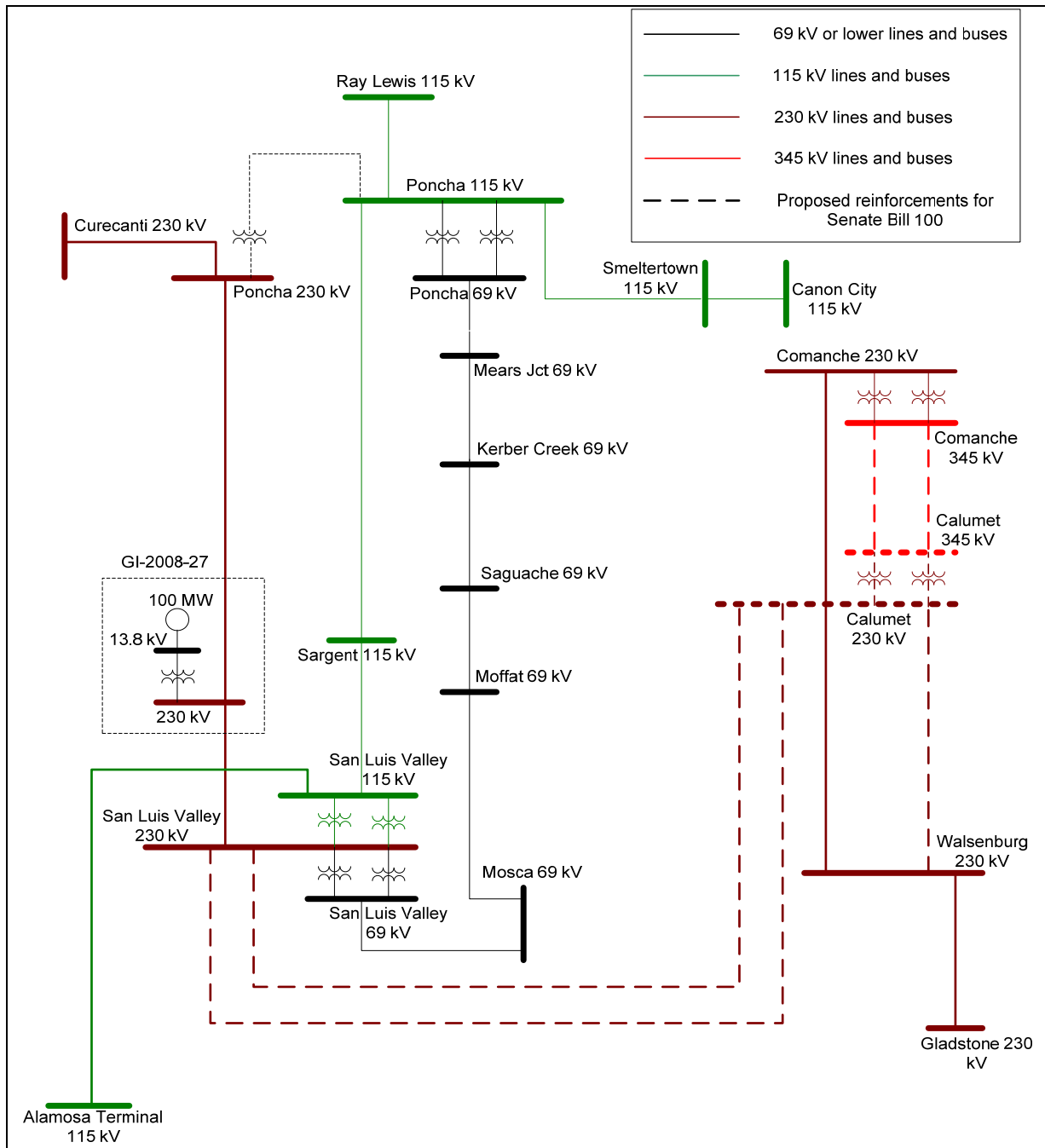


Figure 2. GI-2008-27 with the proposed SB-100 project for the SLV region



## **E. Power Flow Study Process**

Automated contingency power flow studies were completed on all power flow models using the PSS<sup>®</sup>MUST program, switching out single elements one at a time for all of the elements (lines and transformers) in control areas 70 (PSCo) and 73 (WAPA RM). Upon switching each element out, the program re-solves the power flow model with all transformer taps and switched shunt devices locked, and control area interchange adjustments disabled.

## **F. Power Flow Results**

### ***Thermal Overloads***

#### **Summer and Spring Cases (with and without SB-100 project)**

Connecting the generation facility to the 230 kV bus near San Luis Valley with and without the transmission lines proposed for the SB-100 project, does not cause any overloads on the lines close to the POI.

### ***Voltage Criteria Violations***

Interconnecting to the PSCo bulk transmission system involves the Customer adhering to certain interconnection requirements. These requirements are contained in the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW (Guidelines). In addition, PSCo System Operations conducts commissioning tests prior to the commercial in-service date for a Customer's facilities. Some of the requirements that the Customer must comply include the following:

1. A generating plant shall maintain a power factor within the range of 0.95 leading to 0.95 lagging, measured at the POI, if the Transmission Provider's System Impact Study shows that such a requirement is necessary to ensure safety or reliability.
2. The results of the System Impact Study will not absolve the Customer from their responsibility to demonstrate to the satisfaction of PSCo System Operations prior to the commercial in-service date that it can safely operate within the required power factor and voltage ranges.
3. Reactive Power Control at the POI is the responsibility of the Customer. Additional Customer studies should be conducted by Customer to ensure that the facilities can meet the power factor control test and the voltage controller test when the facility is undergoing commissioning testing.
4. PSCo System Operations will require the Customer to perform operational tests prior to commercial operation that would verify that the equipment installed by the Customer meets operational requirements.

5. It is the responsibility of the Customer to determine what type of equipment (DVAR, added switched capacitors, SVC, reactors, etc.), the ratings (MVAR, voltage--13.8 kV or 230 kV), and the locations of those facilities that may be needed for acceptable performance during the commissioning testing.
6. PSCo requires the Customer to provide a single point of contact to coordinate compliance with the power factor and voltage regulation at the POI. The reactive flow at the end of 230 kV line near the POI will need to be controlled according to the Interconnection Guidelines.

According to WECC/NERC criteria, it is necessary to maintain voltages at all buses in the system between 0.95 p.u. to 1.05 p.u. under operating conditions. In the Rocky Mountain Voltage Coordination Guidelines that were developed by the Voltage Coordination Guideline Subcommittee of the Colorado Coordinated Planning Group, the ideal voltage range for the 230 kV bus voltage at San Luis Valley is 1.01 p.u. – 1.04 p.u.

#### Summer Case (without SB-100 project)

In the 2014 summer power flow cases which do not contain the network reinforcements suggested for the SB-100 project, no voltage violations were observed under N–0 conditions for both the benchmark case and the case with GI-2008-27. However, for the loss of the Poncha – SLV 230 kV line in the benchmark case, the voltages at almost all buses in the San Luis Valley area fall below 0.90 p.u. In the case with GI-2008-27, similar results were observed for the loss of the 230 kV line from SLV to the proposed generating facility.

At the present time TSG&T has an Under Voltage Load Shedding Scheme (UVLS) in place in the San Luis Valley. The breakers on the 115 kV lines from San Luis Valley to Stanley and San Luis Valley to Waverly and the 69 kV line from San Luis Valley to Hooper Tap are opened, shedding approximately 51.5 MVA of TSG&T load in the San Luis Valley in summer. This resolves the issue of low voltages observed for the loss of the Poncha – SLV 230 kV line, without causing any other thermal overloads or voltage violations. This UVLS scheme was also applied when GI-2008-27 is interconnected to the PSCo system. In this configuration, the UVLS may be implemented for the loss of the 230 kV circuit between San Luis Valley substation and the generator's POI.

Voltage collapse could occur for the loss of the Poncha – SLV 230 kV line during summer peak load periods in the benchmark case and for the loss of the 230-kV line from San Luis Valley to GI-2008-27 in the case with the proposed generation. Immediate use of the UVLS scheme would prevent voltage collapse.

During summer peak periods, a total of 24 MVAR of switched shunt capacitors at Alamosa need to be on, to be able to provide support for the sudden loss of the critical 230 kV circuit.

### Summer Case (with SB-100 project)

When the transmission reinforcements proposed for the SB-100 project are considered, high voltages were observed at several buses in South-Central Colorado in the benchmark case and with the proposed generation facility. The voltages at these buses in the benchmark case are listed in Table 1. In the Summer scenario case, there will be a need for a 20 MVAR reactor connected at the San Luis Valley 230 kV bus in order to maintain the voltage at that bus below 1.04 p.u. while keeping the voltage at all other buses in the system below 1.05 p.u.

**Table 1 – Voltages at selected buses in the case with SB-100 project**

Bus Number	Bus Name	Voltages-Summer Case		Voltages-Spring Case	
		Without Reactor (pu)	With Reactor (pu)	Without Reactor (pu)	With Reactor (pu)
70375	SANLSVLY 230.00	1.040	1.035	1.043	1.036
79054	POCHABR 230.00	1.040	1.042	1.048	1.044
70459	WALSENBG 230.00	1.046	1.044	1.050	1.046
70961	CALUMET 230.00	1.046	1.044	1.04	1.047
70960	CALUMET 345.00	1.048	1.046	1.050	1.047

**Note:** A 20 MVAR reactor at SLV 230 kV bus keeps the voltage within the acceptable range in summer, and a 35 MVAR reactor keeps the voltage within the acceptable range in spring.

### Spring Case (without SB-100 project)

In the 2014 spring power flow case without the reinforcements proposed for the SB-100 project, the voltage at most buses in the San Luis Valley falls below 0.90 p.u. for the loss of the Poncha to SLV 230 kV line. This can be prevented by implementing the UVLS scheme discussed earlier.

### Spring Case (with SB-100 project)

With the transmission reinforcements proposed for the SB-100 project, the voltage at several buses in South-Central Colorado violates criteria. In the Spring scenario case, there will be a need for a 30 MVAR reactor connected to the San Luis Valley 230 kV in order to maintain the voltages within acceptable voltage range, as shown in Table 1. No voltage violations were observed for any of the other contingencies.

### Network Resource (NR):

The results of this study indicate that the 100 MW of GI-2008-27 generation project delivered to the San Luis Valley POI does not result in the overloading of facilities in the PSCo regional transmission system. However, the voltage levels at several buses violate criteria for certain single line contingencies. These would be alleviated by the use of the existing UVLS. The 100 MW of GI-2008-27 requested would not require any Transmission Network Upgrades.

## G. Short-circuit Analysis

A short circuit study was conducted to determine the fault currents (three phase and single-line to ground) at the San Luis Valley substation. The approximate fault currents at San Luis Valley with the addition of the GI-2008-27 100 MW solar thermal facility are summarized in Table 3.

**Table 3 – Summary of fault results at San Luis Valley substation for 2014 ISD of GI-2008-27**

San Luis Valley SS (kV)	Three Phase Fault (Amps)	Single-Line-Ground Fault (Amps)
230	5523	5761
115	7788	9033
69	7021	7900

## H. Cost Estimates and Assumptions

**Table 4 – PSCo Owned; Customer Funded Interconnection Facilities**

Element	Description	Cost Est. (Millions)
<b>New Substation on San Luis Valley – Poncha Jct. Line</b>	Interconnect customer to the 230 kV bus at the New Substation <ul style="list-style-type: none"> <li>• 230 kV bidirectional metering</li> <li>• Three 230 kV combination CT/PT instrument transformers</li> <li>• Associated foundations and structures</li> <li>• Associated line relaying and testing</li> <li>• One 230 kV, 3000 A, Gang Operated Switch</li> <li>• Deadend structure to terminate customer's line</li> </ul>	<b>\$0.251</b>
	Customer Load Frequency and Generator Witness Testing. (Customer generation telemetry equipment, and witnessing the Customer generator commissioning testing).	<b>\$0.145</b>
	Customer Generator Communication to Lookout.	<b>\$0.010</b>
	<b>Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities</b>	<b>\$0.406</b>

**Table 5 – PSCo Owned; PSCo Funded Interconnection Facilities**

Element	Description	Cost Estimate (Millions)
<b>New Substation on San Luis Valley – Poncha Jct. Line</b>	Interconnect Customer's to line at New Substation 230 kV. The new equipment includes: <ul style="list-style-type: none"> <li>• Three 230 kV, 40 kA, Circuit Breakers</li> <li>• Twelve 230 kV, 3000 A, Gang Operated Switches</li> <li>• Transmission Line Relaying</li> <li>• Associated Structures and Foundations</li> </ul>	<b>\$3.600</b>
	Cost to Tap 230kV San Luis Valley – Poncha Jct. Line	<b>\$0.164</b>
	Land Acquisition	<b>\$0.170</b>
	<b>Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities</b>	<b>\$3.934</b>

**Assumptions for Alternatives**

- The cost estimates provided are “scoping estimates” with an accuracy of +/- 30%.
- Estimates are based on 2009 dollars (no escalation applied).
- There is no contingency or AFUDC included in the estimates.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- PSCo (or it's Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The estimated time for PSCo to site, engineer, procure and construction the scope of work identified in Table 5 is **18 months** after authorization to proceed has been obtained. This is completely independent of other queued projects and their respective in-service dates.