

Generation Interconnection Feasibility Study Report

Request # GI-2008-25

50 MW Photovoltaic Facility, near San Luis Valley, Colorado

PSCo Transmission Planning
July 10, 2009

Executive Summary

On January 20, 2009, Public Service Company of Colorado (PSCo) and the Customer signed a Large Generation Interconnection Feasibility Study Agreement to evaluate the feasibility of interconnecting a 50 MW of DT solar powered generation facility at the San Luis Valley (SLV) substation. The Customer's solar facility consists of arrays of fixed tilt, thin-film, photovoltaic modules, interconnecting to a 34.5 kV collector bus with one (1) dedicated 34.5/69 kV step-up transformer. According to PSCo Interconnection Guidelines¹, the Customer's dedicated 34.5/69 kV step-up transformer will need to be a grounded wye-delta connection with the grounded wye being on the high side of the transformer, see figure 1. From the Customer's 69 kV bus, there will be a short, approximately 1000 feet of transmission line connecting with the SLV 69 kV yard. See figure 2 for the geographical location of the Customer's facility relative to the SLV substation.

The Customer requested the primary point of interconnection to be on the SLV 69 kV bus. The alternative point of interconnection is on the SLV 115 kV bus if the primary point is not feasible. The proposed commercial operation in-service date is July 1, 2012 with an assumed back feed date of January 1, 2012. Upon completion of the Feasibility Study, PSCo has determined that it is feasible to interconnect at SLV 69 kV substation and deliver the full 50 MW of power by the requested in-service date assuming the authorization to proceed will be granted to PSCo by June 1, 2010.

This request was studied both as Energy Resource (ER)², and Network Resource (NR)³. This investigation included steady-state power flow study and preliminary short circuit analysis. The request was studied as a stand-alone project, with no evaluations made of other potential new

¹ **Interconnection Guidelines** for Transmission Interconnected Producer-Owned Generation Greater than 20 MW, version 3.0 12/31/06.

² **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

³ **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.



generation requests that may exist in the LGIP queue, other than the generation projects that are already approved and planned to be in service by the summer of 2012.

Energy Resource

The ER portion of this study determined that the Customer could provide 0 MW without modifications to the substation. The SLV 69 kV yard will need to be expanded with an additional bay prior to the requested interconnection. Once the interconnection is made, non-firm transmission capability may be available depending on marketing activities, dispatch patterns, generation levels, demand levels, TOT levels, and the status of transmission facilities.

Network Resource

As an NR request, PSCo evaluated the network to determine the upgrades required to deliver the full 50 MW of the solar facility to PSCo native loads.

The cost for the transmission interconnection (in 2009 dollars)

The total estimated cost to interconnect the project is approximately **\$693,000** and includes:

- \$261,000 for PSCo-Owned, Customer-Funded interconnection facilities
- \$432,000 for PSCo-Owned, PSCo-Funded interconnection facilities

See cost and schedule for an approximate in service date in Table 3 and Table 4. There are no major network upgrades needed to the current transmission system to transfer full power to PSCo native loads.

PSCo Engineering and Siting & Land Rights conducted studies and determined that the time required to site, engineer, procure and construct the SLV 69 kV yard expansion would be approximately 18 months from the Authorization to Proceed to the completion of the project. A more detailed schedule will be available in the system impact study report.

Note: The schedule included in this study report is only an approximation. The San Luis Valley substation is a jointly owned substation between PSCo and Tri-State. All engineering and construction requests will need to be routed to Tri-State, as they are the responsible party for operation and maintenance of the SLV substation. During the scoping meeting, Tri-State had been notified the intent of the interconnection request. As the study progresses, Tri-State will become more involved and may be asked to do the engineering and construction work if agreed by all parties.

Any Interconnection Agreement (IA) requires that certain conditions be met, as follow:

1. The conditions of the Interconnection Guidelines¹ are met.
2. A single point of contact is given to Operations to manage the Transmission System reliably for all projects (GI-2008-25) as found in the Interconnection Guidelines.
3. Customer must show the ability to operate the solar generation within the required +/- 0.95 power factor range during all operating conditions (0 MW to 50 MW) as measured at the Point of Interconnection (POI).

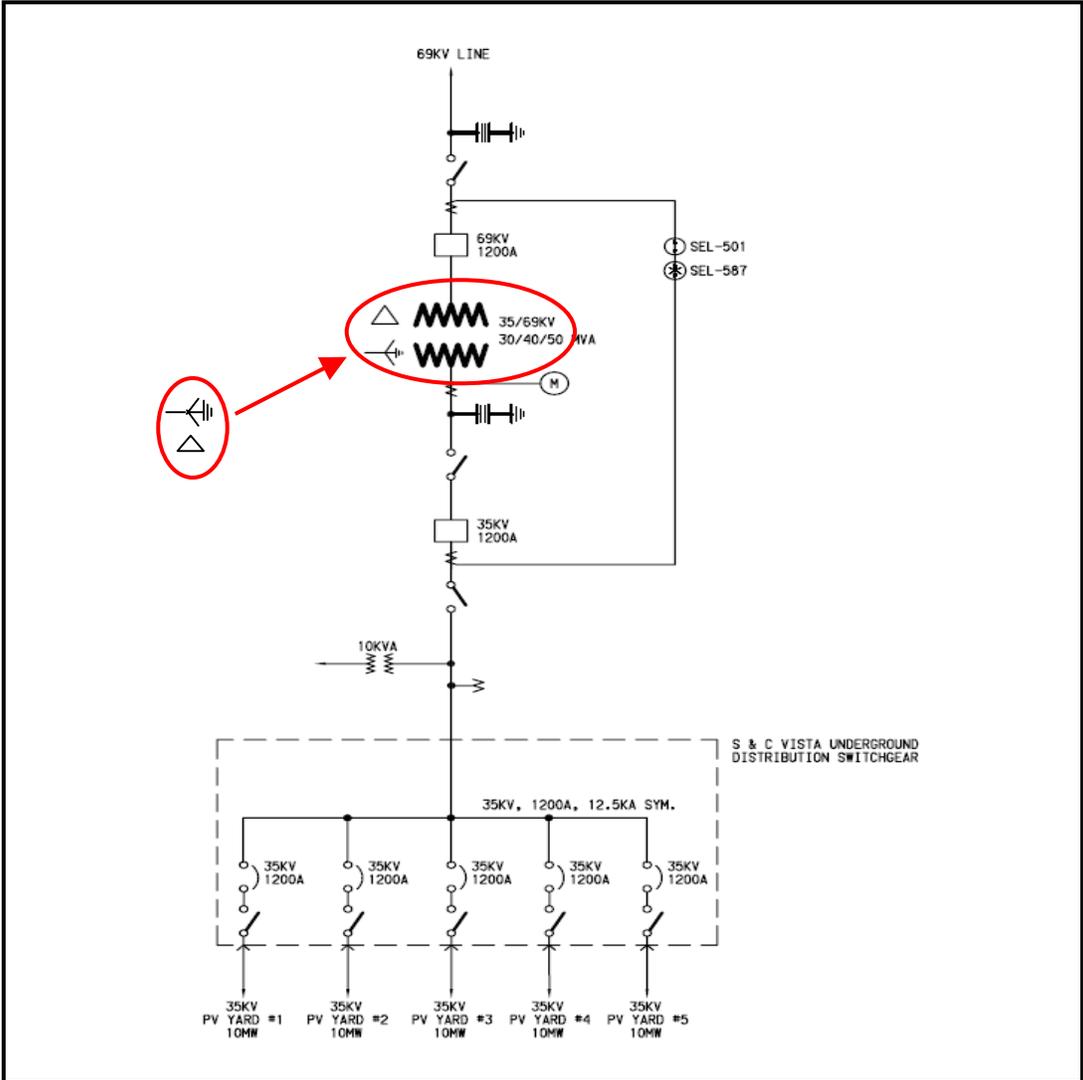


Figure 1: One-line diagram of the Customer’s solar generation facility

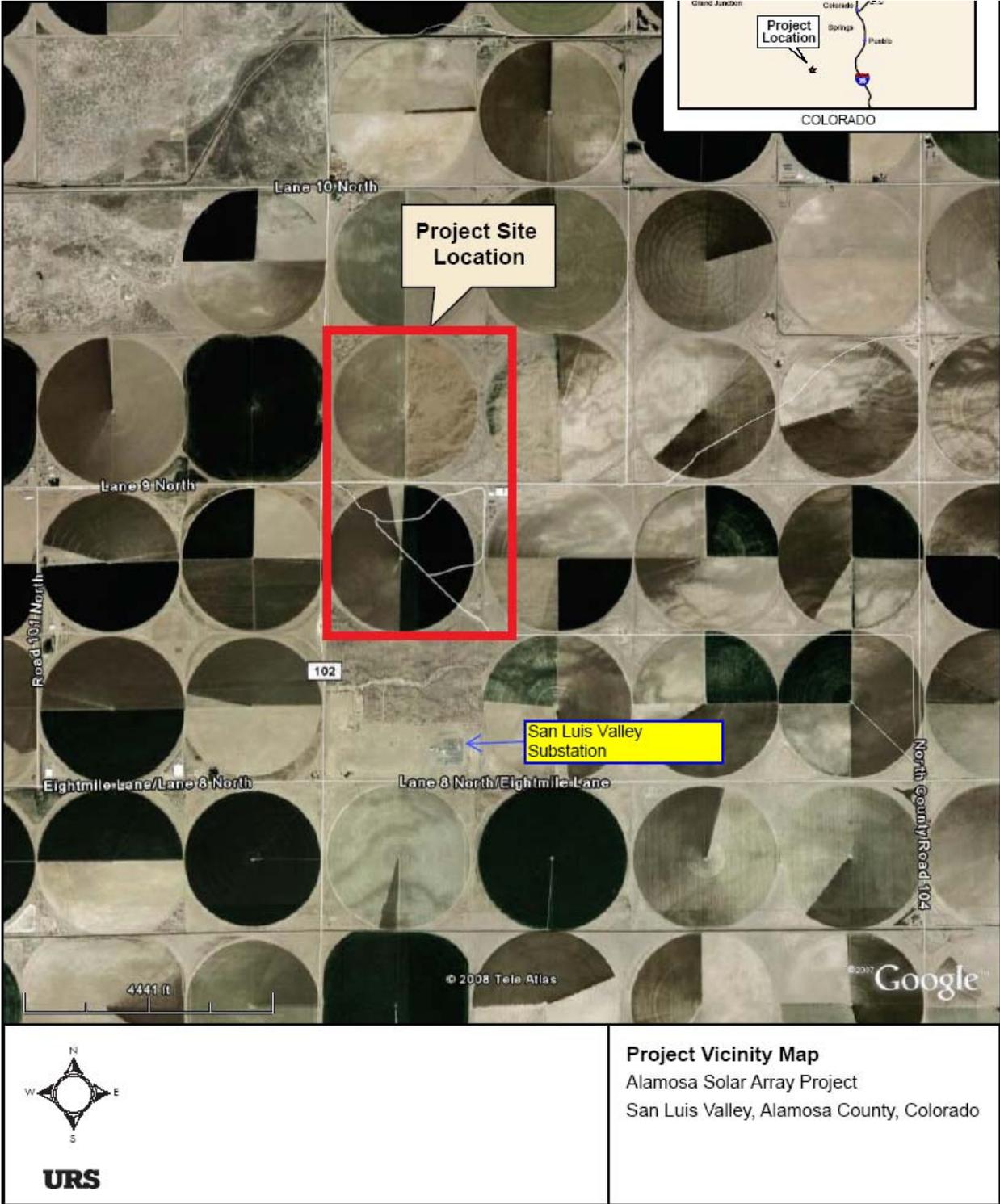


Figure 2: Geographical map of the Customer’s solar generation facility.

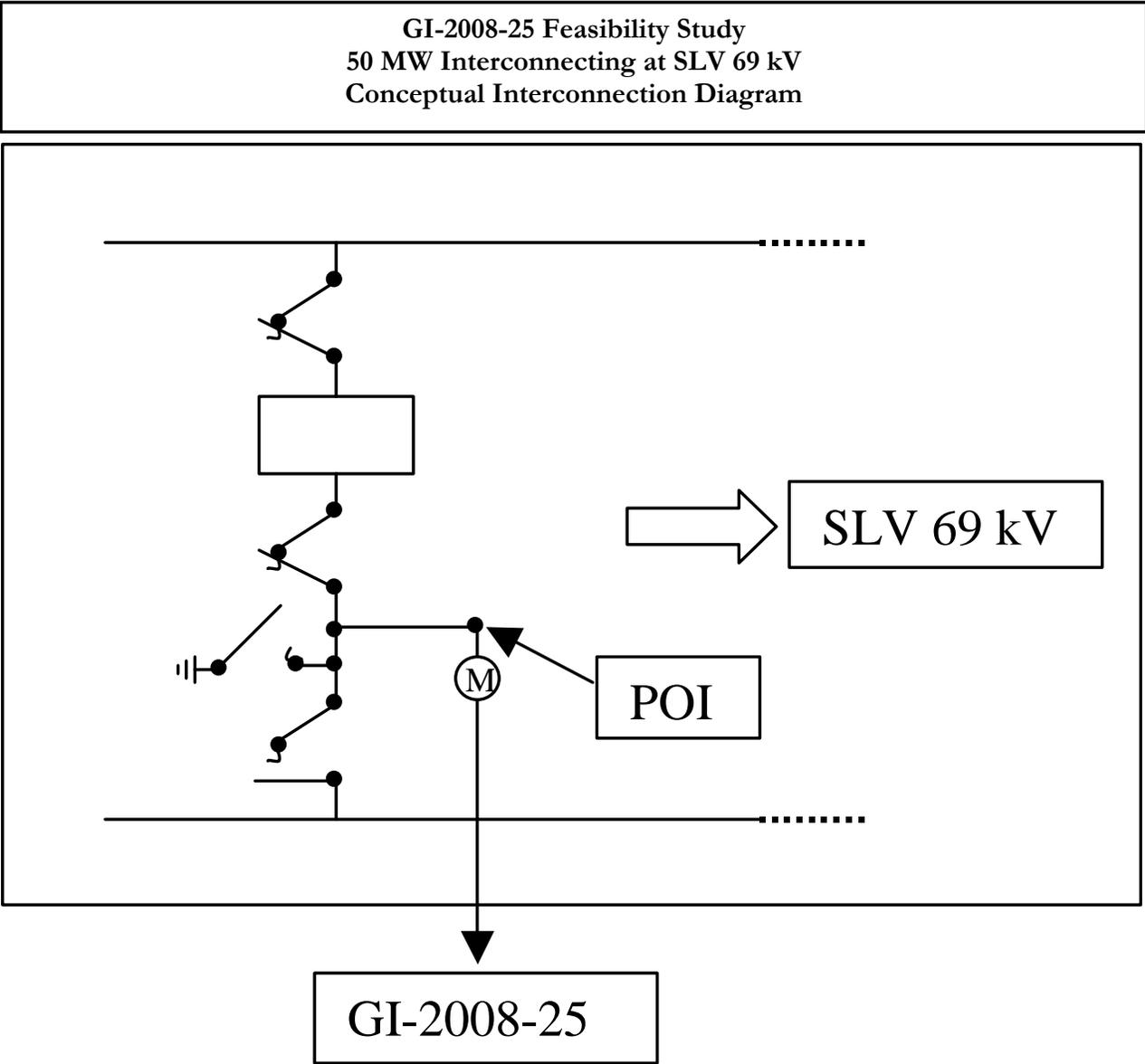


Figure 3: GI-2008-25 interconnection portion of the Feasibility Study.

Introduction

PSCo Transmission received a large generator interconnection request (GI-2008-25) to interconnect 50 MW solar facility consists of arrays of fixed tilt, thin-film, photovoltaic modules, with a commercial operation date of July 1, 2012 and a back feed date of January 1, 2012. The proposed solar facility will be located in Alamosa County, Colorado and will be interconnected into the PSCo transmission system via a 1000 feet radial 69 kV line. The Customer has requested that this Project be evaluated as a Network Resource (NR) and an Energy Resource (ER) with the energy going to PSCo native loads.

Study Scope and Analysis

The Interconnection Feasibility Study evaluated the transmission requirements associated with the proposed interconnection to the PSCo Transmission System. It consisted of power flow and short circuit analyses. The power flow analysis provided a preliminary identification of any thermal or voltage limit violations resulting for the interconnection, and for a NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo native loads. The short circuit analysis identified any circuit breaker short circuit capability limits exceeded as a result of the Interconnection and for a NR request, the delivery of the proposed generation to PSCo native loads.

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 system nominal / normal conditions, and steady state power flows within 1.0 per-unit of all elements' thermal (continuous current or MVA) ratings. Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per-unit or higher at generation buses, to 1.0 per-unit or higher at transmission load buses. Following a single contingency element outage, transmission system steady state bus voltages must remain within 0.90 per-unit to 1.10 per-unit, and power flows within 1.0 per-unit of the elements continuous thermal ratings.

For this project, affected party is Tri-State Generation and Transmission (TSGT). PSCo will notify and work with the affected party during the system impact study (SIS) phase.

Power Flow Study Models

The power flow studies were based on PSCo 2012 heavy summer budget case, which was derived from the Western Electricity Coordinating Council (WECC) approved 2013 heavy summer base case. Generation was dispatched for relatively high south-to-north stressing, with further regional stressing created by modeling the Comanche 3 close to full output (700 MW), Comanche 1 and Comanche 2 near full output (620 MW), and the Lamar DC Tie at the contractual output (101 MW importing from East to West). All wind farm generation facilities were modeled at 12.5% output level, consistent with other study procedures.

The Customer's 50 MW solar facility was modeled as one (1) lumped equivalent on the 34.5 kV bus using the conventional generator model assuming unity power factor (without any additional VAR support). The default operating mode for the inverters within the plant is fixed unity power factor. In this operating mode, the reactive power dispatch (Qgen) and associated limits (Qmax and Qmin)



were all set equal to zero. The inverters themselves have the capability to operate over a range of power factors from 0.95 lagging to 0.95 leading. The generator was tied to a dedicated 34.5/69 kV, 50 MVA main step-up transformers, with a 1000 feet, 69 kV Customer transmission line connecting the generating facility to the POI. For dispatching to the PSCo native loads, the Customer's generation was scheduled (re-dispatched) to offset other PSCo generation in the northern PSCo system by reducing generation in that area.

Table 1: Pertinent modeling adjustments:

Base Case	Generation Resources	Net Output (MW)
2012 HS	Alamosa CT	OFF
	Alamosa Solar	8 (net)
	Comanche 1 and 2	620
	Comanche 3	700
	Lamar DC Tie	101 (East -> West)
	GI-2008-25	50

The Point of Interconnection (POI) between the Customer and PSCo is assumed to be the point at which the Customer's 1000 feet, 69 kV transmission line connects to the SLV substation. Since the 1000 feet of 69 kV transmission line has negligible impedance, it was not modeled in the power flow cases.

Power Flow Study Results and Conclusions

Two study cases using proper generation dispatch to stress the power flows as mentioned above were evaluated under system intact and outage conditions. The first case was used as a benchmark with no additions made to the budget case. The second case includes the proposed 50 MW solar generation facility and associated interconnection facilities. Automated contingency power flow simulations (ACCC) were completed on these cases, switching out single elements one at a time for all of the elements (lines and transformers) in the study area (zone 710) in the San Luis Valley.

The studies were then compared to each other, identifying criteria violations in the study area that were direct results of the addition of the 50 MW solar generation facility connected to the SLV substation and delivering power to PSCo native load customers. The studies indicated no new violations due to the new generation interconnection. There was one thermal violation listed in Table 5 under N-1 contingency, but that was a benchmark violation. The same rationale could be made about the voltage violation. There was no new voltage limit violation due to the new generation interconnection.

Energy Resource (ER) Study Results

The ER portion of this study determined that the Customer could provide 0 MW without modifications to the substation. The SLV 69 kV yard will need to be expanded with an additional bay prior to the requested interconnection. Once the interconnection is made, non-firm transmission capability may be available depending on marketing activities, dispatch patterns, generation levels, demand levels, TOT levels, and the status of transmission facilities.



Network Resource (NR) Study Results

As an NR request, PSCo evaluated the network to determine the upgrades required to deliver the full 50 MW of the solar facility to PSCo native loads. There are no major network upgrades needed to the current transmission system to transfer the full power output to PSCo native loads.

Voltage Control at the Point of Interconnection

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 complete include the following:

1. A solar 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 System Impact Study will investigate pertinent demand, dispatch, and outage scenarios based on the defined study area that includes the proposed POI. The study will conform to the NERC Transmission System Planning Performance Requirements (TPL standards).
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, and the locations of those facilities that may be needed for acceptable performance during the commissioning testing.

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 the line near the POI (if any) will need to be controlled according to the interconnection guidelines.



Short Circuit Study Results

A short circuit study was conducted to determine the fault currents (single-line-to-ground or three-phase) at the San Luis Valley substation (SLV) 69 kV bus. Table 2 summarizes the approximate fault currents at the SLV 69 kV bus with the addition of the 50 MW solar facility.

Table 2: Short-Circuit Study Results

System Condition	3Φ (A)	S-L-G (A)	Thevenin Equivalent (R & X) (Ω)
System Intact	I1=4430 I2=I0=0 IA=IB=IC=4430	I1=I2=1897 3I0=5690 IA=5690 IB=IC=0	Z1 (pos.)= 1.43, 8.88 Z2 (neg.)= 1.43, 8.88 Z0 (zero)=0.26, 3.01

PSCo Substation Engineering indicated that the addition of the 50 MW solar facility is not expected to necessitate the replacement of circuit breakers, switches or other substation equipment due to the increased fault current levels at the SLV 69 kV substation.



Costs Estimates and Assumptions

The estimated total cost for the required upgrades is **\$693,000**.

The estimated costs shown are (+/-30%) estimates in 2009 dollars and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, procurement and construction of these new PSCo facilities. This estimate did not include the cost for any other Developer owned equipment and associated design and engineering.

The following tables list the improvements required to accommodate the interconnection and the delivery of the Project. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon more detailed analysis.

Table 3: PSCo-Owned, Customer-Funded Interconnection Facilities

Element	Description	Cost Est. (Millions)
SLV 69 kV Substation	Interconnect customer to the 69 kV bus at San Luis Valley Substation <ul style="list-style-type: none"> • 69 kV bidirectional metering • Three 69 kV combination CT/PT instrument transformers • Dead-end structure to terminate customer's line • Associated foundations and structures • Associated line relaying and testing 	\$0.238
	Customer Load Frequency and Generator Witness Testing. (Customer generation telemetry equipment, and witnessing the Customer generator commissioning testing).	\$0.013
	Customer Generator Communication to Lookout.	\$0.010
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$0.261

Table 4: PSCo-Owned, PSCo-Funded Interconnection Facilities

Element	Description	Cost Est. (Millions)
SLV 69 kV Substation	Interconnect Customer's to line at PSCo's SLV 69 kV Substation. The new equipment includes: <ul style="list-style-type: none"> • One (1) 69 kV, 40 kA, Circuit Breaker • Three (3) 69 kV, 2000 A, Gang Operated Switches • Transmission Line Relaying • Associated Structures and Foundations 	\$0.432
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	\$0.432
Time Frame	Site, engineer, procure and construct	18 months

*Assumptions*

- 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.
- The estimated time for PSCo to site, engineer, procure and construction the scope of work identified in Table 3 and Table 4 is **18 months** after authorization to proceed has been obtained. This is completely independent of other queued projects and their respective in-service dates.
- San Luis Valley is a jointly owned substation between PSCo and Tri-State.

Table 5: Steady-state N-1 contingency table

Branch Overloads

From	To	Voltage (kV)	Ckt.	Rating (MVA)	Bench	Adding 50 MW @ SLV 69 kV	Contingency
Lagarita	Plaza	115	1	25	109%	109%	Loss of Hooper Tap - SLV 69 kV