Request # GI-2009-5 and GI-2009-6
Combined Generation Interconnection Feasibility/System Impact Study Report

30 MW Photovoltaic Facility, near San Luis Valley, Colorado

PSCo Transmission Planning
February 4, 2010

Executive Summary

On April 15, 2009, Public Service Company of Colorado (PSCo) and the Customer signed a combined Generation Interconnection Feasibility/System Impact Study Agreement to evaluate the feasibility of interconnecting 30 MW of solar photovoltaic (15 MW under GI-2009-5 and additional 15 MW under GI-2009-6) 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 34.5/115 kV step-up transformer, see figure 1. From the Customer's 115 kV bus, there will be a short transmission line connecting with the SLV 115 kV yard. Figure 2 shows the conceptual one-line of the interconnection at the SLV 115 kV yard.

The Customer requested the primary point of interconnection to be on the SLV 115 kV bus. The alternative point of interconnection is on the Mosca 69 kV bus if the primary point is not feasible. The proposed commercial operation in-service date is December 1, 2011 with an assumed back feed date of June 1, 2011. During the course of the study, PSCo has determined that it is feasible to interconnect at SLV 115 kV substation with no major network upgrades, but the proposed in-service date may not be achievable.

This request was studied both as Energy Resource (ER)[1], and Network Resource (NR)[2]. 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 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 2011.

[1] **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

[2] **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.

Energy Resource

The ER portion of this study determined that the Customer could provide 30 MW without modifications to the substation. The existing SLV 115 kV yard has enough room for an additional bay. 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 30 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 **$685,000** and includes:

- $230,000 for PSCo-Owned, Customer-Funded interconnection facilities
- $455,000 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 115 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 Guidelines[1] are met.

2. A single point of contact is given to Operations to manage the Transmission System reliably for all projects 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 30 MW) as measured at the Point of Interconnection (POI). The MVAR output shall be proportional with the output of the plant.

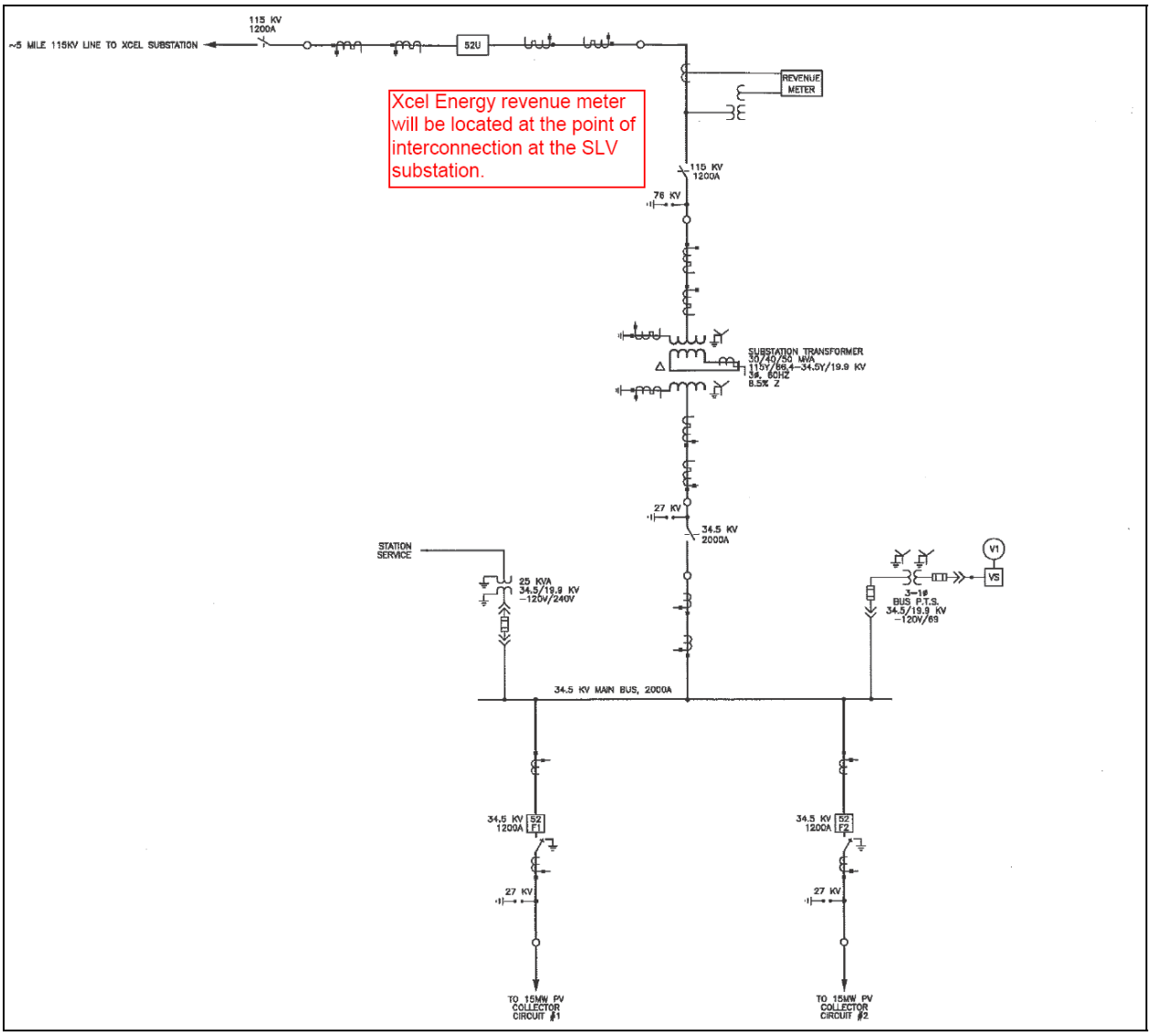

Figure 1: One-line diagram of the Customer's solar generation facility

30 MW Interconnecting at SLV 115 kV
Conceptual Interconnection Diagram

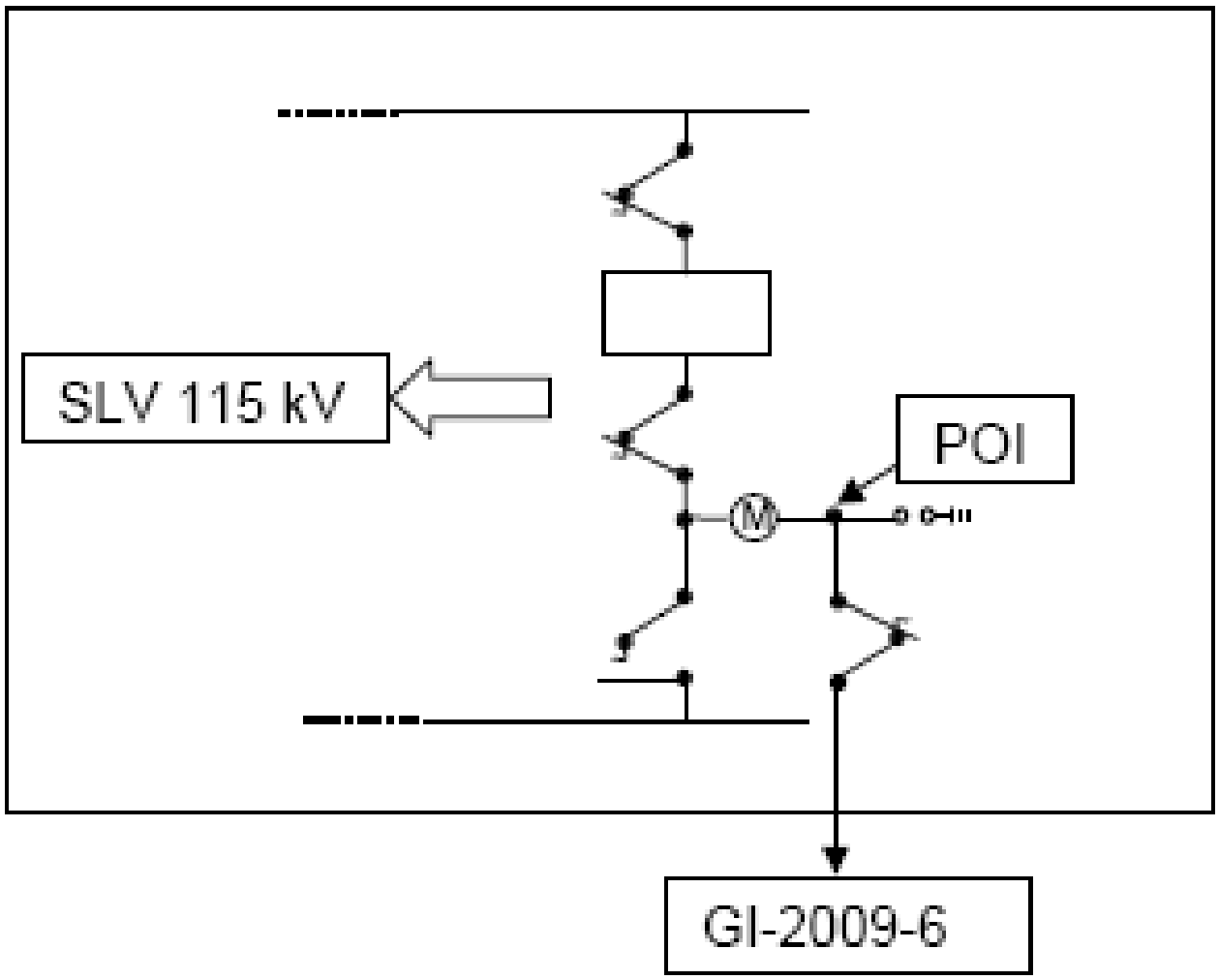

Figure 2: Generation interconnection diagram

Introduction

PSCo Transmission received a large generator interconnection request to interconnect 30 MW solar facility consists of arrays of fixed tilt, thin-film, photovoltaic modules, with a commercial operation date of December 1, 2011 and a back feed date of June 1, 2011. The proposed solar facility will be located in Alamosa County, Colorado and will be interconnected into the San Luis Valley 115 kV bus. 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 combined Feasibility/System Impact 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 and facility study phases.

Power Flow Study Models

The power flow studies were based on PSCo 2011 summer base case, which was derived from the 2012 summer budget 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 30 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 34.5/115 kV, 30 MVA main step-up transformers, 115 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)
2010 HS	Alamosa CT	OFF
	Solar at Mosca	8
	Greater Sandhill	19
	Comanche 1 and 2	620
	Comanche 3	700
	Lamar DC Tie	101 (East -> West)
	GI-2009-6 (15 MW expansion)	30

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 30 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 30 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. 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 30 MW without modifications to the substation. The existing SLV 115 kV yard has enough room for an additional bay for future 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 30 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. The MVAR output shall be proportional with the output of the plant.
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) 115 kV bus. Table 2 summarizes the approximate fault currents at the SLV 115 kV bus with the addition of the 30 MW solar facility.

Table 2: Short-Circuit Study Results

System Condition	3Φ (A)	S-L-G (A)	Thevenin (R, X p.u.)
System Intact	I1=3787 I2=I0=0 IA=IB=IC= 3787	I1=I2=1606 3I0=4819 IA=4819 IB=IC=0	Z1=0.02001, 0.13105 Z2=0.02002, 0.13106 Z0=0.00334, 0.04740

PSCo Substation Engineering indicated that the addition of the 30 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 115 kV substation.

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Costs Estimates and Assumptions

The estimated total cost for the required upgrades is **$685,000**.

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 115 kV Substation	Interconnect customer to the 115 kV bus at San Luis Valley Substation • 115 kV bidirectional metering • Three 115 kV combination CT/PT instrument transformers • Dead-end structure to terminate customer's line • One 115 kV, 2000 A, gang operated switch • Associated foundations and structures • Associated line relaying and testing	**$0.207**
	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	**$0.230**

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

Element	Description	Cost Est. (Millions)
SLV 115 kV Substation	Interconnect Customer's to line at PSCo's SLV 115 kV Substation. The new equipment includes: • One (1) 115 kV, 40 kA, circuit breaker • Three (3) 115 kV, 2000 A, gang operated switches • Transmission Line Relaying • Associated Structures and Foundations	**$0.455**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$0.455**
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 be 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.

Xcel Energy

Comments from Tri-State G&T

1. Exec Summary - The first report for the 15 MW request states a requested back-feed ISD of 8/1/2010 in both the Exec Summary, and later on pg. 5 in the Intro section. It should be stated in the Exec Summary & Intro Sections that this date is not feasible, and acknowledge that a comment is made later in the report Cost Estimates and Assumptions section that it will take 18 months to site, engineer, procure & construct the interconnection at SLV Sub. This should be confirmed with Steve Mundorf & Tri-State Engineering's group as the report states that Tri-State is the responsible party for operation & maintenance of the 115kV bus at SLV Sub. The 6/1/21011 back-feed ISD stated for the 30 MW report may better be able to be achieved, but again would need to be confirmed by Subs Engineering. I have reviewed the 115kV bus arrangement at SLV. There are currently 8 breakers in the main & transfer arrangement which includes a sectionalizing breaker. An additional bay position would require enlarging the yard to the east. As a note, Xcel owns 2 of the existing 115kV line bays, however TS is the Maint. and Operating Agent for SLV under the USA agreement and would take the lead on any expansion of this facility. I agree with the 18 month (from Agreements) schedule to expand the 115kV bus.

2. Exec Summary - The reports state on pg. 2, and again on pg. 6 that "the existing SLV yard has enough room for an additional bay for future interconnection." This would need to be confirmed with Tri-State's Engineering group before it is stated as such in this report. Confirmed, albeit, it will be a 9 breaker M&T arrangement.

3. Reactive Power & Voltage Regulation - The reports mention on pg. 2 (bottom) that the Customer must show the ability to operate "within" the required +/-0.95 p.f. range from 0 to max MW facility rating at the POI.

a. Later in the Power Flow Study Models section (pg. 5) it states that the PV inverters were modeled at 1.0 p.f., but had the capability to operate from 0.95 lag to lead. In discussions I have had with one of the PV solar designers that Tri-State has had involvement with, it has been stated that the PN Inverters can operate in off-unity p.f. mode, but only in a p.f. control operational mode, and do not have the ability to operate in a voltage regulate / control mode (i.e. maintaining a voltage set-point, and automatically adjusting the VAR output or input). The Customer should be asked to clarify the facility's operational capabilities.

b. In the Power Flow Study Scope & Analysis section (pg. 5) it states that "Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 p.u. or higher at generation buses". Furthermore, as Tri-State operates and maintains the 115kV bus / POI location at SLV sub, won't this Customer facility have to meet Tri-State's operational criteria? As such, the report should mention / include Tri-State's operational criteria for voltage regulation within 1.02 - 1.04 puV, reactive power controllability across 0.95 p.f. lag to lead, etc., and will need to further be specified and identified as being needed / required in the System Impact study. These Tri-State criteria / requirements can be supplied to PSCo and the Customer upon request.

c. In the Power Flow Study Results and Conclusions section (pg. 7) it lists in item 1 that the facility should maintain a p.f. within the range of 0.95 lag to lead at the POI, and then in item 3 that the Customer must supply studies to demonstrate that the Customer facilities can meet this reactive power capability, and lastly in item 5 that details on the reactive power equipment

ratings, type, etc. need to be determined by the Customer. The report should clearly state whether or not the power flow studies performed in this study have indicated if the Customer facilities as modeled are able to meet the p.f. (and voltage regulation) reactive capabilities. Clearly, if the PV inverters were modeled at 1.0 p.f. they are not meeting the 0.95 p.f criteria at the POI (5 MVAR lag-lead at 15 MW, and 10 MVAR lag-lead at 30 MW).

4. Short Circuit Study Results – The Table 2 on pg. 7 lists available 3-ph and SLG fault levels at the 115kV SLV POI bus with the generation on. I suggest that this table should be expanded to include the 3-ph and SLG fault levels for the generation off-line and on-line for both system max (N-0) and system min (N-1) conditions, as well as the transmission system 115kV POI Thevenin Equivalent Z1 & Z0 impedances with the gen off-line for max (N-0) and min (N-1) conditions. This is required to determine the max switched caps sizing to meet the transmission system max step voltage (3% for Tri-State) criteria.

5. Cost Estimates and Assumptions (pgs. 8 – 9) – These assumptions for equipment costs, schedule, and 115kV bay availability need to be commented on by Tri-State's Subs Engineering group as it appears to me that it would be Tri-State that would be building this interconnection for PSCo. The estimates look reasonable but are plus or minus 30%. I would further imagine that it will be up to the Customer to sign any contracts that are separately required for this construction, as it would fall outside of the specific scope of any IA that is signed between the Customer and PSCo as part of the Customer's IR in PSCo's LGIP queue.