DRAFT

GENERATION INTERCONECTION
REQUEST # GI-2014-11

INTERIM STUDY REPORT

FEASIBILITY STUDY REPORT
50 MW PV SOLAR, ALAMOSA COUNTY, COLORADO

XCEL ENERGY – PSCO TRANSMISSION PLANNING WEST
April 2015

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Executive Summary

Public Service Company of Colorado (PSCo) and the Customer signed a Generation Interconnection Feasibility Study Agreement to evaluate the feasibility of interconnecting 50 MW of solar photovoltaic in San Luis Valley (SLV), Colorado. The primary point of interconnection is at San Luis Valley 230 kV substation. The Customer's solar facility consists of photovoltaic solar arrays, interconnecting to a 34.5 kV collector bus with one (1) dedicated 34.5/230 kV step-up transformer. Figure 1 shows the general area of San Luis Valley Region. Figure 2 shows the one-line of the proposed project. The proposed commercial operation in-service date is November 1, 2016 with an assumed back feed date of six months prior to COD.

This request was studied both as Energy Resource (ER)[1], and Network Resource (NR)[2]. The Feasibility Study consists of the power flow (steady-state) contingency analysis and the short-circuit analysis. The power flow analysis results indicated two thermal violations attributed to GI-2014-11. PSCo has chosen to not identify any network upgrades to accommodate any anew generation interconnection for the time being because there is an ongoing study for the San Luis Valley area through the Colorado Coordinated Planning Group subcommittee.

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 by PSCo to be in service by the summer of 2016. This Feasibility Study investigated three scenarios: 1) 2016 Heavy Summer = 140 MW total load in SLV, 2) 2016 Light Spring – 45 MW total load in SLV, and 3) a sensitivity study of the 2016 Light Spring with 30 MW of Tri-State's queue in the San Luis Valley. Since the San Luis

[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.

Valley substation is jointly owned by PSCo and Tri-State, PSCo is required to consider Tri-State's queue in all of the generation interconnection studies.

Based on the Feasibility Study results, it is concluded that the 50 MW rated output of the GI-2014-11 interconnection does not qualify for Network Resource Interconnection Service (NRIS), but some level of Energy Resource Interconnection Service (ERIS) can be injected on a non-firm, as-available basis without requiring any Network Upgrades for Delivery. The addition of the proposed generation will cause one PSCo 115 kV lines, relatively close to the requested POI, to load beyond acceptable levels under the sensitivity scenario of Tri-State's 30 MW addition at San Luis Valley 115 kV (Appendix A). Under the sensitivity scenario, the Poncha – Sargent 115 kV (rated 120 MVA) is overloaded by 120%, and the Sargent – San Luis Valley 115 kV (rated 100 MVA) is overloaded by 126%. In the event that Tri-State's generation queue request gets delayed beyond the in-service date of GI-2014-11, this interconnection request can be considered NRIS without network upgrades for delivery if all of the assumptions used for this study hold.

Also, the proposed generation has caused no new voltage violations. However it should be noted that dynamic reactive power capability is required of the GI-2014-11 generation to meet the +/- 0.95 power factor requirement at the point of interconnection and the inverters need to be in automatic voltage control mode at all time.

No new 2016 Heavy Summer system intact or single contingency voltage constraints due to the subject request were found. But with heavy load conditions, existing low voltage was observed in the local 115 kV and 69 kV systems for both the pre and post project system conditions for the simulated contingencies. To mitigate the low voltage, a load shedding scheme is currently in place to trip load and increase voltage in this local area. For the purpose of this study, the required load shedding scheme was not evaluated.

Cost Estimate

- To be filled in

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.

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). The MVAR output shall be proportional with the output of the plant.

Figure 1: San Luis Valley region

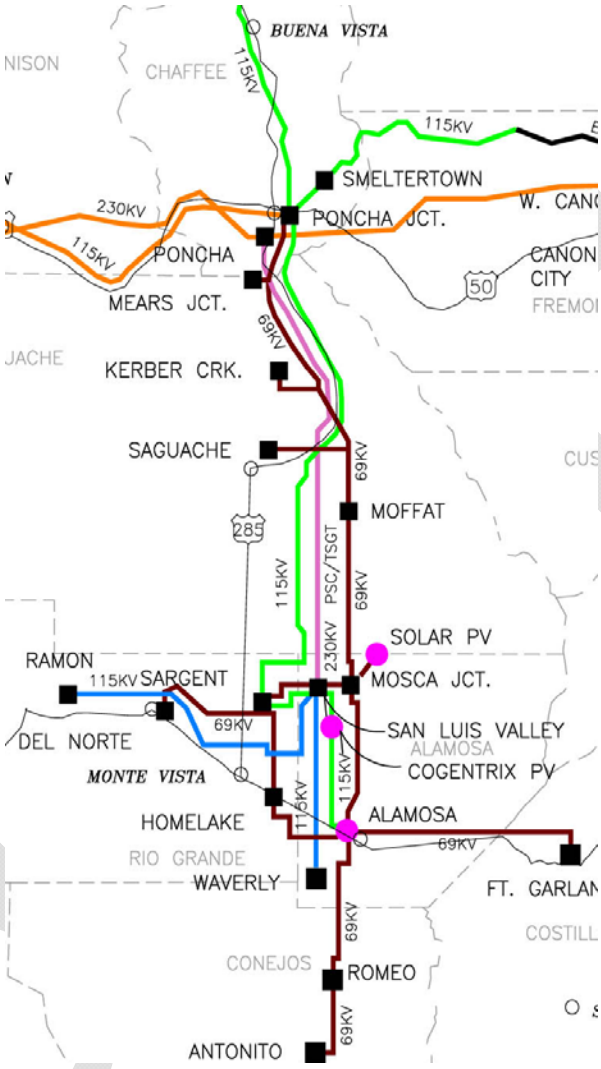
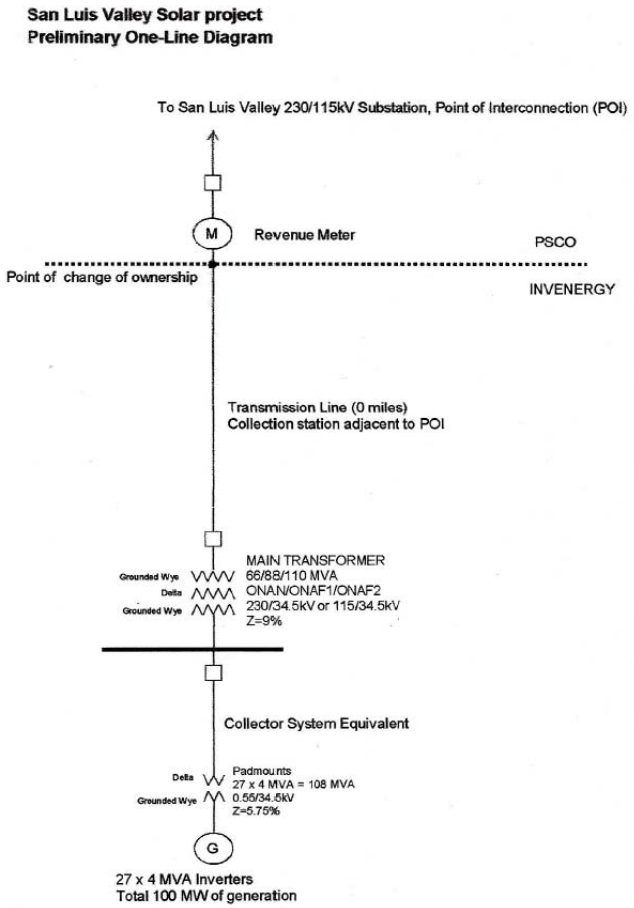


Figure 2: Proposed One-line of GI-2014-11



Introduction

Public Service Company of Colorado (PSCo) and the Customer signed a Generation Interconnection Feasibility Study Agreement to evaluate the feasibility of interconnecting 50 MW of solar photovoltaic in San Luis Valley (SLV), Colorado. The primary point of interconnection is at San Luis Valley 230 kV substation. The Customer's solar facility consists of photovoltaic solar arrays, interconnecting to a 34.5 kV collector bus with one (1) dedicated 34.5/230 kV step-up transformer. Figure 1 shows the general area of San Luis Valley Region. Figure 2 shows the one-line of the proposed project. The proposed commercial operation in-service date is November 1, 2016 with an assumed back feed date of six months prior to COD.

A Feasibility Study (FeS) Agreement was executed on January 23, 2015, but the study did not commenced until a week later due to missing power flow data.

For this interconnection request, the direct Affected Party is Tri-State G&T (TSGT).

Study Scope and Analysis

The Feasibility study evaluated the transmission impacts associated with the proposed generation increase. It consisted of steady-state power flow and short circuit analyses. The steady-state power flow analysis identified any thermal or voltage limit violations resulting from the generation addition and determined the network upgrades required to mitigate the violations. The short circuit analysis evaluated the impact on the transmission system of the increase in available fault current due to the generation addition and determined the breaker upgrades required to accommodate the increase in available fault current.

This Feasibility study analyzed the impact of this addition, located in South Central Colorado, in accordance with PSCo's study criteria. PSCo adheres to NERC and WECC Reliability Criteria, as well as internal Company criteria for planning studies. The criterion used to identify thermal injection constraints met or exceeded the following criteria:

- There was a detrimental change in the facility loading due to the subject request.

- The resultant facility loading exceeded 100% of the continuous rating (Rate A in PSS/E) system intact or post contingent.

The criterion used to identify voltage injection constraints met or exceeded the following criteria.

- There was a detrimental change in bus voltage due to the subject request.
- The resultant bus voltage was outside of the acceptable range of 0.95 p.u. to 1.05 p.u. system intact or 0.90 p.u. to 1.05 p.u. post contingency.

This project was studied as a Network Resource and Energy Resource. NRIS shall mean an Interconnection Service that allows the Interconnection Customer to integrate its 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. NRIS in and of itself does not convey transmission service. ERIS shall mean an Interconnection Service that allows the Interconnection Customer to connect to the Transmission Provider's system and be eligible to deliver the generating facility's output using the existing firm or non-firm capacity of the transmission system on an "as available" basis. Energy Resource Interconnection Service does not in and of itself convey any delivery service.

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.

Power Flow Study Models

WECC coordinates the preparation of regional power flow cases for transmission planning purposes. PSCo developed a starting point model, 2016HS.sav, with a 2016 summer peak load representation from the WECC 2014HS2 base case that was approved in March of 2014 for use in the steady state analyses. From the 2014HS2 case, PSCo developed a second model, 2016LSp.sav, to look at the off-peak loading condition.

Modeling of Request

The new 50 MW photovoltaic solar power plant will transform the collected solar energy to DC electricity and utilize an inverter to convert to AC electricity. The photovoltaic solar power plant

will be connected through a dedicated step-up transformer with a terminal voltage of 34.5 kV. For study purposes, the photovoltaic solar power plant was initially modeled as rated at 50 MVA with +/- 0.90 power factor. This facility will be interconnected to the PSCo system at the SLV 230 kV bus.

The following is a summary of Project GI-2014-11 parameters as modeled by PSCo in the 2016HS.sav and 2016LSp.sav steady state models:

Total Plant Capacity	= 50 MW
Reactive Capability	= +/- 0.90 power factor initially modeled,
Generator Step-up Transformer	= 34.5/230 kV step up transformer rated at 50 MVA
Voltage Regulation	= None initially modeled,
	1.03 p.u at the San Luis Valley 230 kV bus

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 with which 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 the 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--34.5 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 POI, SLV 230 kV bus, will need to be controlled according to the Interconnection Guidelines.

Post GI-2014-11 Model Development

Analyses were performed using a 2016 heavy summer, and a 2016 light spring model, all derived from the WECC approved 2014hs2.sav model. The only modification made to the 2014hs2.sav model to form the Post-GI-2014-11 2016 Heavy Summer Model was the increase in loads in San Luis Valley zone 710 (2% increase). For the 2016 Light Spring case, the total load in the San Luis Valley was scaled down to 45 MW to reflect the minimum load recorded historically. A sensitivity generation was developed from the 2016 Light Spring case by adding 30 MW of solar generation in the affected party's (Tri-State) queue for the San Luis Valley. Based on PSCo Transmission Planning guidelines, all existing photovoltaic generators in the San Luis Valley area are being modeled at 85% of name plate rating for all system studies.

The following Post-GI-2014-11 steady state models were developed.

- GI-2014-11_post.sav- 2016 Heavy Summer
- GI-2014-11_post.sav- 2016 Light Spring
- GI-2014-11_sen.sav-2016 Light Spring Sensitivity

These models included the GI-2014-11 generation modeled with +/- 0.90 power factor of dynamic reactive power capability, holding 1.03 p.u voltage at the San Luis Valley 230 kV bus. More detailed modeling information is given in the Modeling of Request Section of this report.

Pre GI-2014-11 Model Development

The Post GI-2014-11 Models, described above, were modified by turning off the new generation to create the Pre GI-2014-11 Models. The Cherokee generation was incremented by 50 MW to compensate.

The following Pre-GI-2014-11 steady state models were developed.

- GI-2014-11_pre.sav- 2016 Heavy Summer
- GI-2014-11_pre.sav- 2016 Light Spring
- GI-2014-11_sen.sav-2016 Light Spring Sensitivity

Models were solved with transformer tap, switched shunt, phase shifter, DC tap adjustment and area interchange adjustment enabled.

Power Flow Study Process

Siemens Power Technologies, Inc. (PTI) PSS/E and ACCC computer power flow programs and evaluation software were used to determine system performance. Comparisons were made between the Pre and Post GI-2014-11 results.

The study area was defined as areas 70 PSCOLORADO and 73 WAPA R.M. in the study models. All study area elements were monitored. The study considered only the following contingency categories in the study area for the steady state analysis.

- Category A (System Intact).
- Category B (Single Contingencies).

Thermal and voltage injection constraints were identified based on the following study criteria:

- The criterion used to flag thermal overloads was 100% of the monitored element's continuous rating (Rate A in PSS/E). Thermal overloads found on elements outside of

Zone 710 which were both found as overloads in the Pre GI-2014-11 Analysis and only slightly impacted by the GI-2014-11 generation were not considered constraints by PSCo.

- The criterion used to flag voltage violations met or exceeded the following criteria.
    - There was a detrimental change in bus voltage due to the subject request.
    - The resultant bus voltage was outside of the acceptable range of 0.95 to 1.05 p.u system intact or 0.90 p.u. to 1.05 p.u. during a single contingency. Voltage violations found on elements outside of Zone 710 which were both found as voltage violations in the Pre GI-2014-11 Analysis and only slightly impacted by the GI-2014-11 generation were not considered constraints by PSCo. Also a few Zone 710 voltage violations found as outside of acceptable limits in the GI-2014-11_pre analysis, identified as known issues by PSCo and only slightly impacted by the GI-2014-11 generation were not considered constraints by PSCo.

During the ACCC contingency analysis, models were solved with transformer tap and switched shunt adjustments locked; phase shifter and DC tap adjustments enabled and area interchange adjustment disabled. The analysis results were obtained by comparing results from the Pre GI-2014-11 model to results from the Post GI-2014-11 model to determine the impact of the GI-2014-11 generation on the transmission system.

Steady State Power Flow Analysis

A contingency analysis was performed using models, criteria, and methodology described earlier in this report. The incremental impact of the 50 MW request was evaluated by comparing flows and voltages with and without the 50 MW request. This study has identified the system intact and single-event contingency (N-1) interconnection constraints. All system intact and N-1 interconnection constraints will require mitigation prior to granting the subject request.

2016 Heavy Summer Analysis Results (140 MW of Loads in SLV)

Thermal

No 2016 Heavy Summer system intact or single contingency thermal constraints due to the subject request were found.

Voltage

No new 2016 Heavy Summer system intact or single contingency voltage constraints due to the subject request were found. But with heavy load conditions, existing low voltage was observed in the local 115 kV and 69 kV systems for both the pre and post project system conditions for the simulated contingencies. To mitigate the low voltage, a load shedding scheme is currently in place to trip load and increase voltage in this local area. For the purpose of this study, the required load shedding scheme was not evaluated.

2016 Light Spring Analysis Results (45 MW of Loads in SLV)

Thermal

One N-1 thermal constraint due to the subject request was found.

1) Sargent – San Luis Valley 115 kV (rated 100 MVA)

Voltage

No new 2016 Light Summer system intact or single contingency voltage constraints due to the subject request were found.

2016 Light Spring – Sensitivity Analysis

This is a light spring case with an additional 30 MW of Tri-State's potential generation interconnection at San Luis Valley 115 kV bus.

Thermal

Two N-1 thermal constraints due to the subject request were found.

2) Poncha – Sargent 115 kV (rated at 120 MVA)

3) Sargent – San Luis Valley 115 kV (rated 100 MVA)

Voltage

No new 2016 Light Summer system intact or single contingency voltage constraints due to the subject request were found.

Based on the Feasibility Study results, it is concluded that the 50 MW rated output of the GI-2014-11 interconnection does not qualify for Network Resource Interconnection Service (NRIS),

but some level of Energy Resource Interconnection Service (ERIS) can be injected on a non-firm, as-available basis without requiring any Network Upgrades for Delivery. The addition of the proposed generation will cause one PSCo 115 kV lines, relatively close to the requested POI, to load beyond acceptable levels under the sensitivity scenario of Tri-State's 30 MW addition at San Luis Valley 115 kV (Appendix A). Under the sensitivity scenario, the Poncha – Sargent 115 kV (rated 120 MVA) is overloaded by 120%, and the Sargent – San Luis Valley 115 kV (rated 100 MVA) is overloaded by 126%. In the event that Tri-State's generation queue request gets delayed beyond the in-service date of GI-2014-11, this interconnection request can be considered NRIS without network upgrades for delivery if all of the assumptions used for this study hold.

Also, the proposed generation has caused no new voltage violations. However it should be noted that dynamic reactive power capability is required of the GI-2014-11 generation to meet the +/- 0.95 power factor requirement at the point of interconnection and the inverters need to be in automatic voltage control mode at all time.

No new 2016 Heavy Summer system intact or single contingency voltage constraints due to the subject request were found. But with heavy load conditions, existing low voltage was observed in the local 115 kV and 69 kV systems for both the pre and post project system conditions for the simulated contingencies. To mitigate the low voltage, a load shedding scheme is currently in place to trip load and increase voltage in this local area. For the purpose of this study, the required load shedding scheme was not evaluated.

Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect their Large Generating Facilities with Public Service of Colorado's (PSCo) Transmission System in conformance to the Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW (available at http://www.xcelenergy.com/staticfiles/xe/Regulatory/Transmission-Interconnection-GuidelinesGreat-20MW.pdf). Wind and Solar generating plant interconnections (Variable Energy Resources) must also conform to the performance requirements in FERC Order 661-A. Accordingly, the following voltage regulation and reactive power capability requirements (at the

POI) are applicable to this interconnection request: • To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system must adhere to the Rocky Mountain Area Voltage Coordination Guidelines. Accordingly, since the POI for this request is located within Southeast Colorado Region 4; the applicable ideal transmission system voltage profile range is 1.02 – 1.03 per unit at regulated buses and 1.0 – 1.03 per unit at non-regulated buses. • Xcel Energy's OATT requires all Interconnection Customers to have the reactive capability to achieve +/− 0.95 power factor at the POI, with the maximum "full output" reactive capability available at all output levels. Furthermore, Xcel Energy requires all Interconnection Customers to have dynamic voltage control and maintain the voltage specified by the Transmission Operator within the limitation of +/− 0.95 power factor at the POI, as long as the generating plant is on-line and producing power. • It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAR), and the locations (690 V, 34.5 kV or 230 kV bus) of any additional static reactive power equipment needed within the generating plant in order to have the reactive capability to meet the +/− 0.95 power factor and the 1.02 – 1.03 per unit voltage range standards at the POI. The Interconnection Customer may need to perform additional studies for this purpose.

Short Circuit

- To be filled in

Cost Estimate

- To be filled in

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

Table 3 – PSCo Owned; PSCo Funded Interconnection Network Facilities

Table 4 – PSCo/Tri-State Network Upgrades for Interconnection

Cost Estimate Assumptions

- To be filled in

GI-2014-11
Appendix A - Detailed Steady State Analysis Results

No 2016 Heavy Summer Thermal or Voltage constraints were found. However, one 2016 Light Spring Thermal constraints were identified.

Table 5 – Thermal Impacts of Interest

Limiting Element	Rating N/E	16HS Pre GI-2014-11		16HS Post GI-2014-11		16LSp Pre GI-2014-11		16LSp Post GI-2014-11		16LSp Sen GI-2014-11		Contingency
		MVA	%	MVA	%	MVA	%	MVA	%	MVA	%	
PONCHA-SARGENT 115 kV	120	32	28	16	16	65	57	113	96	138	120	PONCHA – SLV 230 kV
SARGENT-SAN LUIS VALLEY 115 kV	100	0.4	17	42	42	63	53	105	105	126	126	PONCHA – SLV 230 kV

GI-2014-11

Appendix B - Generation Dispatch

Dispatch of All Generating Units in the Immediate Vicinity of GI-2014-11 (Zone 710)

Bus	LF Id	Maximum Generation MW	2016 Heavy Summer MW	2016 Light Spring MW	2016 Light Spring Sensitivity MW
G-SANDHIL_PV	S1	16	13.6	13.6	13.6
IBERDROLA_PV	S2	30	25.5	25.5	25.5
COGENTRIX_PV	S1	30	25.5	25.5	25.5
SUNPOWER	S1	52	44.2	44.2	44.2
ALMSACT1	G1	17	Off-line	Off-line	Off-line
ALMSACT2	G2	19	Off-line	Off-line	Off-line
SLV_SOLAR	S1	50	50	50	50
MOSCA	NT	8	6.8	6.8	6.8
TRI-STATE'S QUEUE	S1	30	0	0	25.5

*Note – On average, all photovoltaic generation in the San Luis Valley are at 85% of name plate for all generation interconnection studies per PSCo Planning interconnection guidelines, effective March, 2015.