DRAFT

GENERATION INTERCONECTION
REQUEST # GI-2014-2

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

XCEL ENERGY – PSCO TRANSMISSION PLANNING WEST

October 2014

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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 115 kV substation. The Customer's solar facility consists of photovoltaic solar arrays, interconnecting to a 34.5 kV collector bus with one (1) dedicated 34.5/115 kV step-up transformer. Figure 1 shows the general area of San Luis Valley Region. Figure 2 shows the conceptual one-line of the interconnection at the San Luis Valley 115 kV yard. The proposed commercial operation in-service date is August 1, 2016 with an assumed back feed date of February 1, 2016.

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 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 Summer with 30 MW of Tri-State's queue in the San Luis Valley.

Network Resource (NR)

The addition of the proposed generation will cause one PSCo 115 kV lines, relatively close to the requested POI, to load beyond acceptable levels. The loading on the Sargent – Poncha 115 kV line increased from 13 MVA pre GI-2014-2 to 134 MVA post GI-2014-2 for loss of 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 – Poncha 230 kV line under the Light Spring loading scenario. The loading on the Sargent – San Luis Valley 115 kV line increased from 22 MVA pre GI-2014-2 to 121 MVA post GI-2014-2 for loss of the San Luis Valley – Poncha 230 kV line under the Light Spring Scenario. Both lines are rated at 120 MVA.

The loading on the Poncha - Sargent 115 kV line and Sargent – San Luis Valley 115 kV line are considered constraints by PSCo. Therefore, the constraints will need to be mitigated before the requested interconnection service can be granted. The Network Resource Capability of the proposed generation without amelioration of this constraint is limited.

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-2014-2 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.

Energy Resource (ER)

As indicated above, the addition of the GI-2014-2 generation, as proposed, will cause PSCo's Poncha - Sargent 115 kV line and Sargent – San Luis Valley 115 kV line to load beyond acceptable levels. Beyond these overloads, no other unacceptable impacts due to the GI-2014-2 generation were found. The Energy Resource Capability of the proposed generation without amelioration of this constraint is limited.

Cost Estimate

The cost for the transmission interconnection (in 2014 dollars)

The total estimated cost to interconnect the project is approximately **$5,430,000** and includes:

- $810,000 for PSCo-Owned, Customer-Funded interconnection facilities
- $840,000 for PSCo-Owned, PSCo-Funded interconnection facilities
- $3,780,000, Tri-State and PSCo, network upgrades for interconnection

See cost and schedule for an approximate in service date in Table 2, Table 3, and Table 4. There will be major network upgrades needed to the current transmission system to transfer full power to PSCo native loads. That cost has yet to be determined.

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

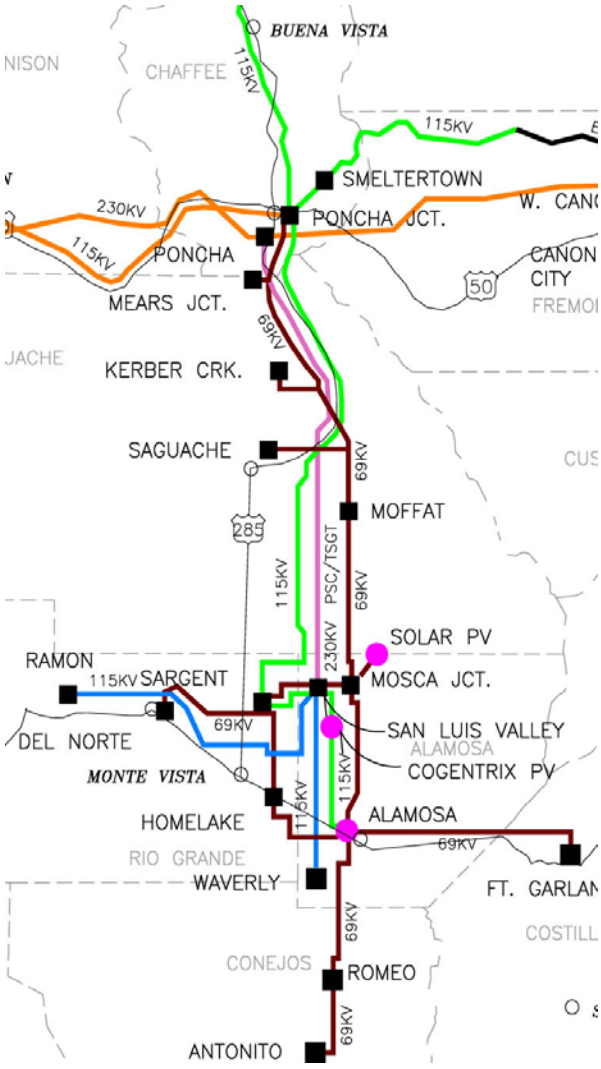
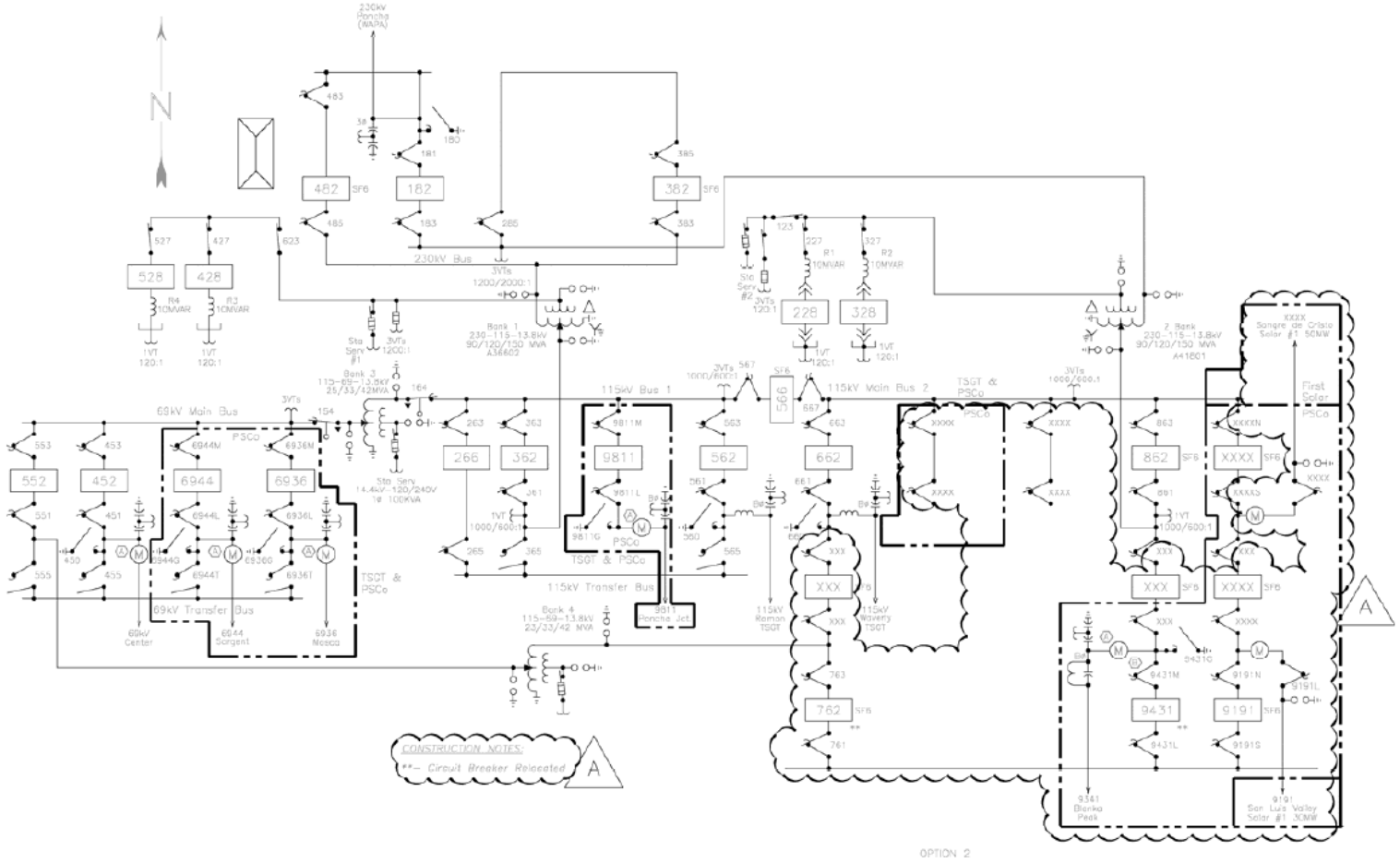


Figure 2: Proposed San Luis Valley substation One-line with Project Interconnection

Option #2



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 115 kV substation. The Customer's solar facility consists of photovoltaic solar arrays, interconnecting to a 34.5 kV collector bus with one (1) dedicated 34.5/115 kV step-up transformer. Figure 1 shows the general area of San Luis Valley Region. Figure 2 shows the conceptual one-line of the interconnection at the San Luis Valley 115 kV yard. The proposed commercial operation in-service date is August 1, 2016 with an assumed back feed date of February 1, 2016.

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 to 1.05 pu system intact or 0.90 to 1.05 pu post contingent.

This project was studied as a Network 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.

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 115 kV bus.

The following is a summary of Project GI-2014-2 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	= 34.5/115 kV step up transformer rated at 50 MVA, 9.3% positive sequence impedance on the transformer base, X/R Ratio of infinity, Winding ratio - 30
Voltage Regulation	= None initially modeled, 1.03 p.u at the San Luis Valley 115 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

115 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 115 kV bus, will need to be controlled according to the Interconnection Guidelines.

Post GI-2014-2 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-2014-2 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.

The following Post-GI-2014-2 steady state models were developed.

- GI-2014-2_post.sav- 2016 Heavy Summer
- GI-2014-2_post.sav- 2016 Light Spring
- GI-2014-2_sen.sav-2016 Light Spring Sensitivity

These models included the GI-2014-2 generation modeled with +/- 0.90 power factor of dynamic reactive power capability, holding 1.03 p.u voltage at the San Luis Valley 115 kV bus. More detailed modeling information is given in the Modeling of Request Section of this report.

Pre GI-2014-2 Model Development

The Post GI-2014-2 Models, described above, were modified by turning off the new generation to create the Pre GI-2014-2 Models. The Cherokee generation was incremented by 50 MW to compensate.

The following Pre-GI-2014-2 steady state models were developed.

- GI-2014-2_pre.sav- 2016 Heavy Summer

- GI-2014-2_pre.sav- 2016 Light Spring
- GI-2014-2_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-2014-2 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-2014-2 Analysis and only slightly impacted by the GI-2014-2 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-2014-2 Analysis and only slightly impacted by the GI-2014-2 generation were not considered constraints by PSCo. Also a few Zone 710 voltage violations found as outside of acceptable limits in the GI-2014-

2_pre analysis, identified as known issues by PSCo and only slightly impacted by the GI-2014-2 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-2014-2 model to results from the Post GI-2014-2 model to determine the impact of the GI-2014-2 generation on the transmission system.

Power Flow Results

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.

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

Thermal

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

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

2) Sargent – San Luis Valley 115 kV (rated 120 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

Thermal

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

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

4) Sargent – San Luis Valley 115 kV (rated 120 MVA)

Voltage

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

Network Resource (NR) = 0 MW

The addition of the proposed generation will cause one PSCo 115 kV lines, relatively close to the requested POI, to load beyond acceptable levels. The loading on the Sargent – Poncha 115 kV line increased from 13 MVA pre GI-2014-2 to 134 MVA post GI-2014-2 for loss of the San Luis Valley – Poncha 230 kV line under the Light Spring loading scenario. The loading on the Sargent – San Luis Valley 115 kV line increased from 22 MVA pre GI-2014-2 to 121 MVA post GI-2014-2 for loss of the San Luis Valley – Poncha 230 kV line under the Light Spring Scenario. Both lines are rated at 120 MVA.

The loading on the Poncha - Sargent 115 kV line and Sargent – San Luis Valley 115 kV line are considered constraints by PSCo. Therefore, the constraints will need to be mitigated before the requested interconnection service can be granted. The Network Resource Capability of the proposed generation without amelioration of this constraint is limited.

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-2014-2 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.

Energy Resource (ER) = 0 MW

As indicated above, the addition of the GI-2014-2 generation, as proposed, will cause PSCo's Poncha - Sargent 115 kV line and Sargent – San Luis Valley 115 kV line to load beyond acceptable levels. Beyond these overloads, no other unacceptable impacts due to the GI-2014-2 generation were found. The Energy Resource Capability of the proposed generation without amelioration of this constraint is limited.

Short Circuit

A short circuit study was conducted to determine the fault currents (single-line-to-ground or three-phase) at the San Luis Valley 115 kV bus. Table 1 summarizes the approximate fault currents at the San Luis Valley 115 kV bus with the addition of the 50 MW solar facility.

Table 1 – Short-circuit study results at San Luis Valley 115 kV bus.

System Condition	3Φ (A)	S-L-G (A)
Pre-Project	I1=4637	I1=I2=5900
Post-Project	I1=6516	I1=I2=7870

Cost Estimate

The cost for the transmission interconnection (in 2014 dollars)

The total estimated cost to interconnect the project is approximately **$5,430,000** and includes:

- $810,000 for PSCo-Owned, Customer-Funded interconnection facilities
- $840,000 for PSCo-Owned, PSCo-Funded interconnection facilities
- $3,780,000, Tri-State and PSCo, network upgrades for interconnection

See cost and schedule for an approximate in service date in Table 2, Table 3, and Table 4. There will be major network upgrades needed to the current transmission system to transfer full power to PSCo native loads. That cost has yet to be determined.

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

Element	Description	Cost Est. (Millions)
San Luis Valley 115kV Transmission Substation	Interconnect Customer to tap at the San Luis Valley 115kV Transmission Substation (into the 115kV bus). The new equipment includes: • One 115kV gang switch • Three 115kV arresters • One set 115kV CT/PT metering units • Associated bus, wiring and equipment • Associated site development, grounding, foundations and structures • Associated transmission line communications, relaying and testing	**$0.375**
	Transmission line relocation and tap into substation. Structures, conductor, insulators, hardware and labor.	**$0.265**
Customer's 115kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment.	**$0.150**
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction.	**$0.020**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$0.810**

Table 3 – PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Estimate (Millions)
San Luis Valley 115kV Transmission Substation	Interconnect Customer to tap at San Luis Valley 115kV Transmission Substation (into the 115kV bus). The new equipment includes: • One 115kV circuit breaker • Three 115kV gang switches • Three 115kV arresters • One station battery system • Associated communications, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, miscellaneous electrical equipment, cabling and wiring • Associated foundations and structures • Associated road and site development, fencing and grounding	**$0.820**
	Siting and Land Rights support for substation land acquisition and construction.	**$0.020**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$0.840**
Time Frame	**Site, design, procure and construct**	**18 Months**

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

Element	Description	Cost Est. (Millions)
San Luis Valley 115kV Transmission Substation	PSCo/Tri-State Network Upgrades required to interconnect Customer to tap at San Luis Valley 115kV Transmission Substation (into the 115kV bus). Build out to a 3-breaker ring bus. The new equipment includes: • Five 115kV circuit breakers • Twelve 115kV gang switches • Nine 115kV arresters • Six 115kV PLC coupling capacitors • PLC System • One station battery system • Associated communications, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, miscellaneous electrical equipment, cabling and wiring • Associated foundations and structures • Associated road and site development, fencing and grounding	**$3.760**
	Siting and Land Rights support for substation land acquisition and construction.	**$0.020**
	Total Cost Estimate for PSCo/Tri-State Network Upgrades for Delivery Facilities	**$3.780**
Time Frame	**Site, design, procure and construct**	**18 Months**

Cost Estimate Assumptions

- Scoping level project cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering.
- Estimates are based on 2014 dollars (appropriate contingency and escalation included).
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Solar Generation Facility is not in PSCo's retail service territory. Therefore, no costs for retail load (distribution) facilities and metering required for station service are included in these estimates.
- PSCo and/or Tri-State (or our Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.

- The estimated time to site, design, procure and construct the interconnection and network delivery facilities is approximately 18 months after authorization to proceed has been obtained.
- A CPCN will may be required for the interconnection and network delivery facilities construction.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- No new substation land will need to be acquired.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- PSCo and Tri-State collaboratively discussed and agree that due to the number of transmission elements connected onto the San Luis Valley Sub 115kV bus, the substation will need to be expanded and built out to a 3-breaker ring bus configuration to support this interconnection.

GI-2014-2
Appendix A - Detailed Steady State Analysis Results

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

Table 5 – Thermal Impacts of Interest

Limiting Element	Rating N/E	HS Pre GI-2014-2		HS Post GI-2014-2		LSp Pre GI-2014-2		LSp Post GI-2014-2		LSp Sen GI-2014-2		Contingency
		MVA	%	MVA	%	MVA	%	MVA	%	MVA	%	
PONCHA-SARGENT 115 kV	120	13	11	66	51	86	72	134	112	163	142	PONCHA – SLV 230 kV
SARGENT-SAN LUIS VALLEY 115 kV	120	22	18	65	51	79	66	121	101	147	127	PONCHA – SLV 230 kV

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Appendix B - Generation Dispatch

Dispatch of All Generating Units in the Immediate Vicinity of GI-2014-2 (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	19	19	19	19
IBERDROLA_PV	S2	30	30	30	30
COGENTRIX_PV	S1	30	30	30	30
SUNPOWER	S1	52	52	52	52
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	4.95	4.95	4.95	4.95
TRI-STATE'S QUEUE	S1	30	0	0	30