Request # GI-2010-4
Combined Generation Interconnection Feasibility/System Impact Study Report

30 MW Photovoltaic Facility, San Luis Valley, Colorado

PSCo Transmission Planning
September 16, 2010

Executive Summary

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 in San Luis Valley (SLV), Colorado. The primary point of interconnection is approximately 3 miles south of San Luis Valley substation on the San Luis Valley – Alamosa 115 kV transmission line. A 3-breaker substation will be built underneath the line to accommodate the interconnection. The Customer's solar facility consists of arrays of dual-axis tracking, High Concentrating Photovoltaic Systems, interconnecting to a 13.8 kV collector bus with one (1) dedicated 13.6/115 kV step-up transformer, see figure 1. Figure 2 shows the conceptual one-line of the interconnection at the SLV 115 kV yard.

The proposed commercial operation in-service date is April 1, 2012 with an assumed back feed date of November 1, 2011. During the course of the study, PSCo has determined that it is feasible to interconnect to the grid at the proposed point of interconnection with no major network upgrades.

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.

Energy Resource

The ER portion of this study determined that the Customer could provide 30 MW without major network upgrades. The existing SLV – Alamosa 115 kV line has adequate capacity for an additional

[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.

30 MW of injection. 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 2010 dollars)

The total estimated cost to interconnect the project is approximately **$3,934,000** and includes:

- $500,000 for PSCo-Owned, Customer-Funded interconnection facilities
- $3,410,000 for PSCo-Owned, PSCo-Funded interconnection facilities
- $24, 000 for Network Upgrades for Delivery, PSCo-Funded

See cost and schedule for an approximate in service date in Table 3, Table 4, Table 5, and Table 6. 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 3-breaker ring switching station would be approximately 12 months from the Authorization to Proceed to the completion of the project.

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.

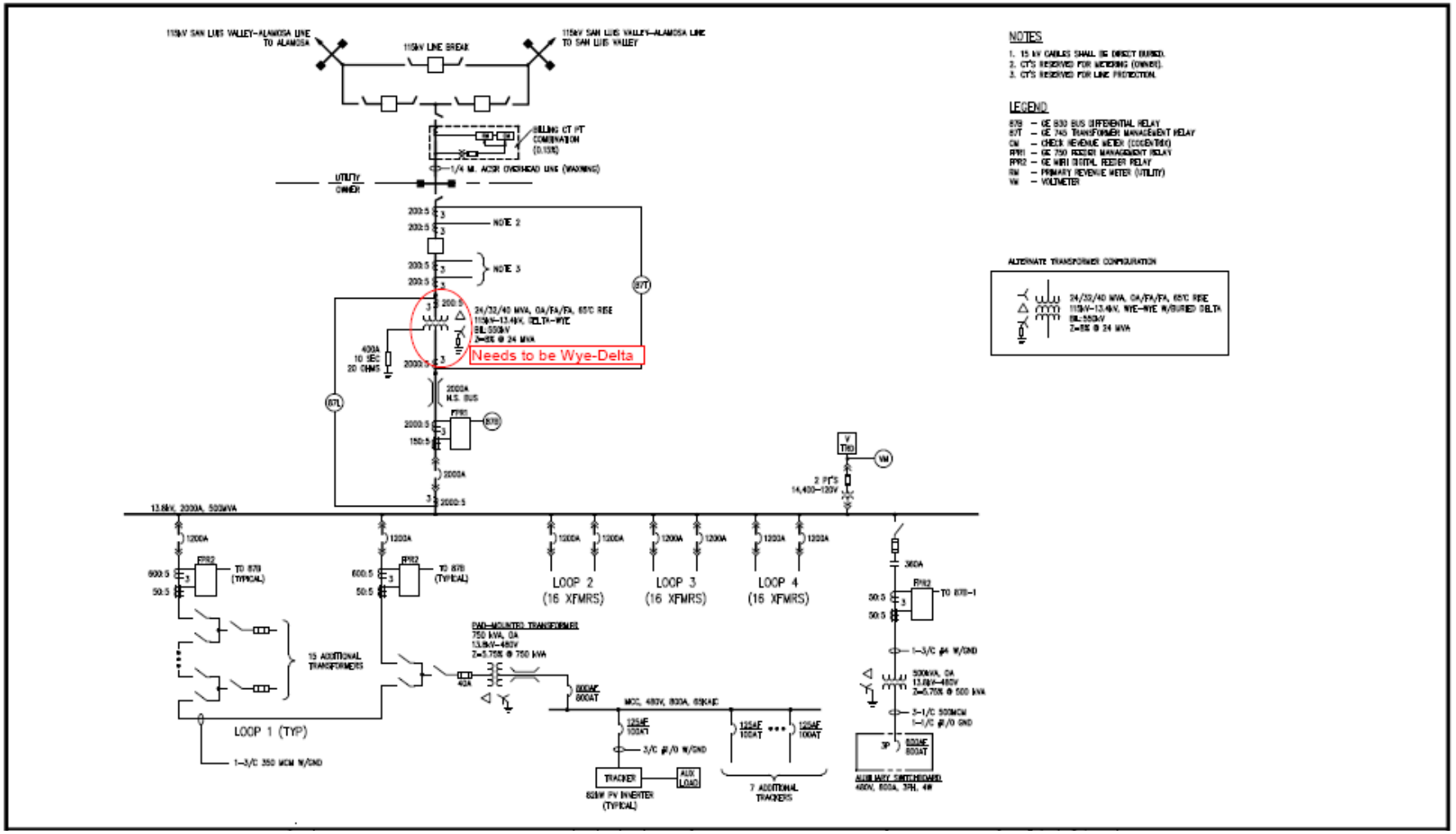

Figure 1: One-line diagram of the Customer's solar generation facility

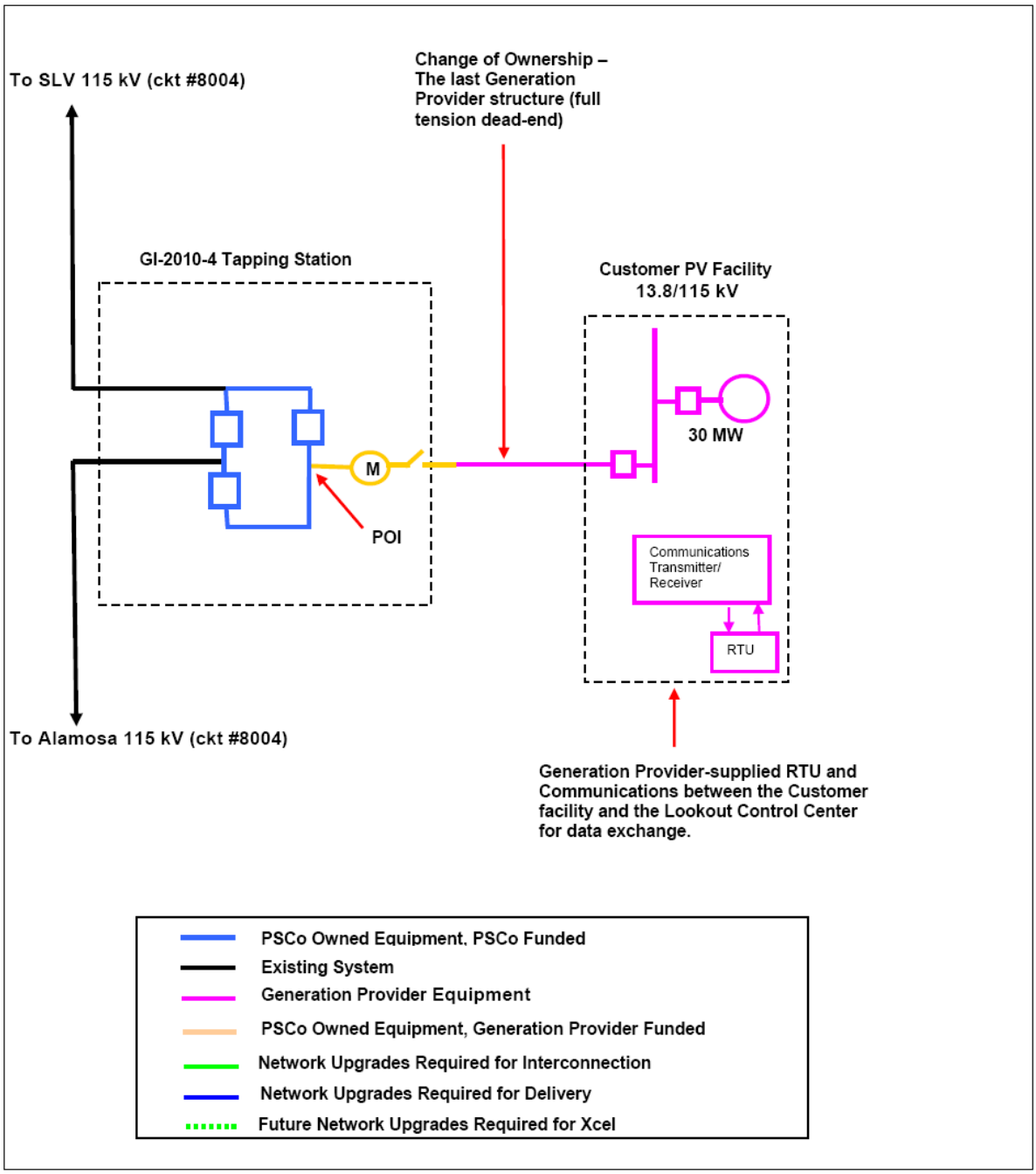

Figure 2: Generation interconnection diagram

Introduction

PSCo Transmission received a large generator interconnection request to interconnect 30 MW solar facility consists of arrays of dual-axis tracking, High Concentrating Photovoltaic Systems, with a commercial operation date of April 1, 2012 and a back feed date of November 1, 2011. The proposed solar facility will be located in Alamosa County, Colorado and will be interconnected at approximately 3 miles south of the San Luis Valley substation on the SLV – Alamosa 115 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 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 (872 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 13.8 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 13.6/115 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)
2011 HS	Alamosa CT	OFF
	Solar at Mosca	8
	Greater Sand Hill	19
	GI-2009-5 & 6	30
	GI-2009-10	125
	GI-2010-4	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 major network upgrades. 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=5298 I2=I0=0 IA=IB=IC= 5298	I1=I2=1800 3I0=5400 IA=5400 IB=IC=0	Z1=0.01227, 0.09395 Z2=0.01228, 0.09396 Z0=0.01629, 0.08797

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.

Costs Estimates and Assumptions

Scoping level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering. The cost estimates are in 2010 dollars with escalation and contingencies applied (AFUDC is not included) and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new PSCo facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The estimated total cost for the required upgrades for is **$3,934,000.** These estimates do not include costs for any other Customer owned equipment and associated design and engineering. The following tables list the improvements required to accommodate the interconnection and the delivery of the Project generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon a more detailed and refined design.

Table 3 – PSCo Owned; Customer Funded Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's New Blanca Peak 115kV Transmission Substation	Interconnect Customer to tap at PSCo's Blanca Peak 115kV Substation (sectionalizing the SLV-Alamosa 115kV OH Line). The new equipment includes: • One 115kV gang switch • Three 115V combination CT/PT metering units • Three 115kV lightning arresters • One relay panel • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$0.210**
	Transmission line tap into substation. Structure, conductor, hardware and installation labor.	**$0.290**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$0.500**
Time Frame	**Design, procure and construct**	**12 Months**

Table 4 – PSCo Owned; PSCo Funded Interconnection Facilities

Element	Description	Cost Estimate (Millions)
PSCo's New Blanca Peak 115kV Transmission Substation	Interconnect Customer to tap at PSCo's Blanca Peak 115kV Substation (sectionalizing the SLV-Alamosa 115kV OH Line). The new equipment includes: • Three 115kV circuit breakers • Eleven 115kV gang switches • Six 115kV CCVT's • One 115kV SSVT (station service) • 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	**$3.390**
	Siting and Land Rights support for substation land acquisition and construction.	**$0.020**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$3.410**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 5 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
Alamosa Terminal 115kV Substation	Remote end relay upgrades (O&M)	**$0.012**
San Luis Valley 115kV Substation	Remote end relay upgrades (O&M)	**$0.012**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0.024**
	Design, procure and construct	**12 months**
	Total Project Estimate	**$3.934**

Cost Estimate Assumptions

- Scoping level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering.
- Estimates are based on 2010 dollars (appropriate contingency and escalation applied).
- 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 metering are included in these estimates.
- PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- The estimated time to design, procure and construct the interconnection facilities is approximately 12 months after authorization to proceed has been obtained.
- This project is completely independent of other queued projects and their respective ISD's.
- A CPCN will not be required for the interconnection facilities construction.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- All land will be acquired and required permitting completed by the Customer. PSCo will require a 280' x 320' substation yard. A subdivision process will be required to acquire PSCo's substation land.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- Relay settings will need to be changed for line protection at Alamosa Terminal and San Luis Valley substation for this break in line 8004.
- Estimated earth fill would level out a 2% grade across entire yard.
- Station service provided primarily from a station service VT and secondly by the local utility provider.
- No LF/AGC RTU needed. EMS data will be collected through the substation RTU like was done at Mosca Junction substation solar interconnect.

Table 6 – Project schedule