



Interconnection Feasibility Study Report Request # GI-2013-3

30 MW Solar Photovoltaic Generating Facility
Boone 115 kV Station, Colorado

Public Service Company of Colorado
Transmission Planning
July 18, 2014

Executive Summary

Public Service Company of Colorado (PSCo) received an interconnection request for a 30 MW solar photovoltaic generating facility on June 21, 2013 that was assigned GI-2013-3 as the queue number. The proposed generating facility will be located approximately 2,000 feet southeast of PSCo's Boone 230/115 kV Station. The primary point of interconnection (POI) requested for GI-2013-3 is the Boone 115 kV bus and the generating facility will interconnect to the POI using a customer owned 115 kV transmission line. The alternate POI requested is the Boone 230 kV bus and is to be studied only if problems requiring mitigation are uncovered in the studies of the primary POI. The in-service date (ISD) requested for GI-2013-3 generating facility is December 1, 2016, and the request will be studied as both a Network Resource and Energy Resource*.

This request was studied as a stand-alone generator interconnection that excluded any other new generation requests existing in the PSCo Generator Interconnection Request queue, except for the generator interconnection projects that are already planned to be in-service by the winter of 2016. The main purpose of this Feasibility Study was to evaluate the potential impact on the interconnected transmission system of PSCo and its neighboring utilities (the affected parties) due to an additional 30 MW of generation injected into the Boone 115 kV bus. It should be noted that PSCo evaluated the capacity adequacy of the transmission system beyond the POI – the Interconnection Customer is responsible for ensuring that the 115 kV tie line to the POI is adequately rated for the proposed 30 MW generation.

* Energy Resource Interconnection Service allows Interconnection Customer to connect the Large Generating Facility to the Transmission System and be eligible to deliver the Large 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 right to deliver electricity to any specific customer or Point of Delivery.



The Feasibility Study results indicate that Colorado Springs Utilities (CSU), Tri-State Generation & Transmission (TSG&T), and Black Hills Power (BHP) are affected parties due to the system impact of GI-2013-3.

Network Resource (NR)

At both the primary POI (Boone 115 kV bus) and the alternative POI (Boone 230 kV bus), the 30 MW injection from the proposed generation resulted in an increased Category B contingency loading on the following transmission facilities: PSCo/CSU's Monument – Palmer Lake 115 kV Line by 2.2% and CSU's Cottonwood – Briargate and Cottonwood – Kettle Creek 115 kV Lines by 1.0%. Since these transmission facilities are overloaded prior to GI-2013-3 and are currently being investigated for mitigation, the Network Resource Interconnection Service (NRIS) for the proposed generation is as follows:

At Boone 115 kV or Boone 230 kV POI:

NRIS = 0 MW

Before PSCo's planned Monument–Palmer Lake upgrade is in-service.

NRIS = 30 MW

After PSCo's planned Monument–Palmer Lake upgrade is in-service.

Energy Resource (ER)

Since overloaded transmission facilities exist prior to GI-2013-3, the Energy Resource Interconnection Service (ERIS) for the proposed generation is as follows:

At Boone 115 kV or Boone 230 kV POI:

ERIS = 0 MW Firm

= 30 MW on As Available basis

Before PSCo's planned Monument–Palmer Lake upgrade is in-service.

ER = 30 MW

After PSCo's planned Monument–Palmer Lake upgrade is in-service.

Short Circuit

The short circuit study results showed no new circuit breakers are overdutied due to the proposed solar generation facility.



Cost Estimates

The total estimated cost of the recommended system improvements to interconnect the project is approximately **\$1,970,000** (in 2014 dollars) and includes:

- \$1.970 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- \$0.000 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- \$0.000 million for PSCo Network Upgrades for Delivery to PSCo Loads

This work can be completed in approximately 18 months following receipt of authorization to proceed.

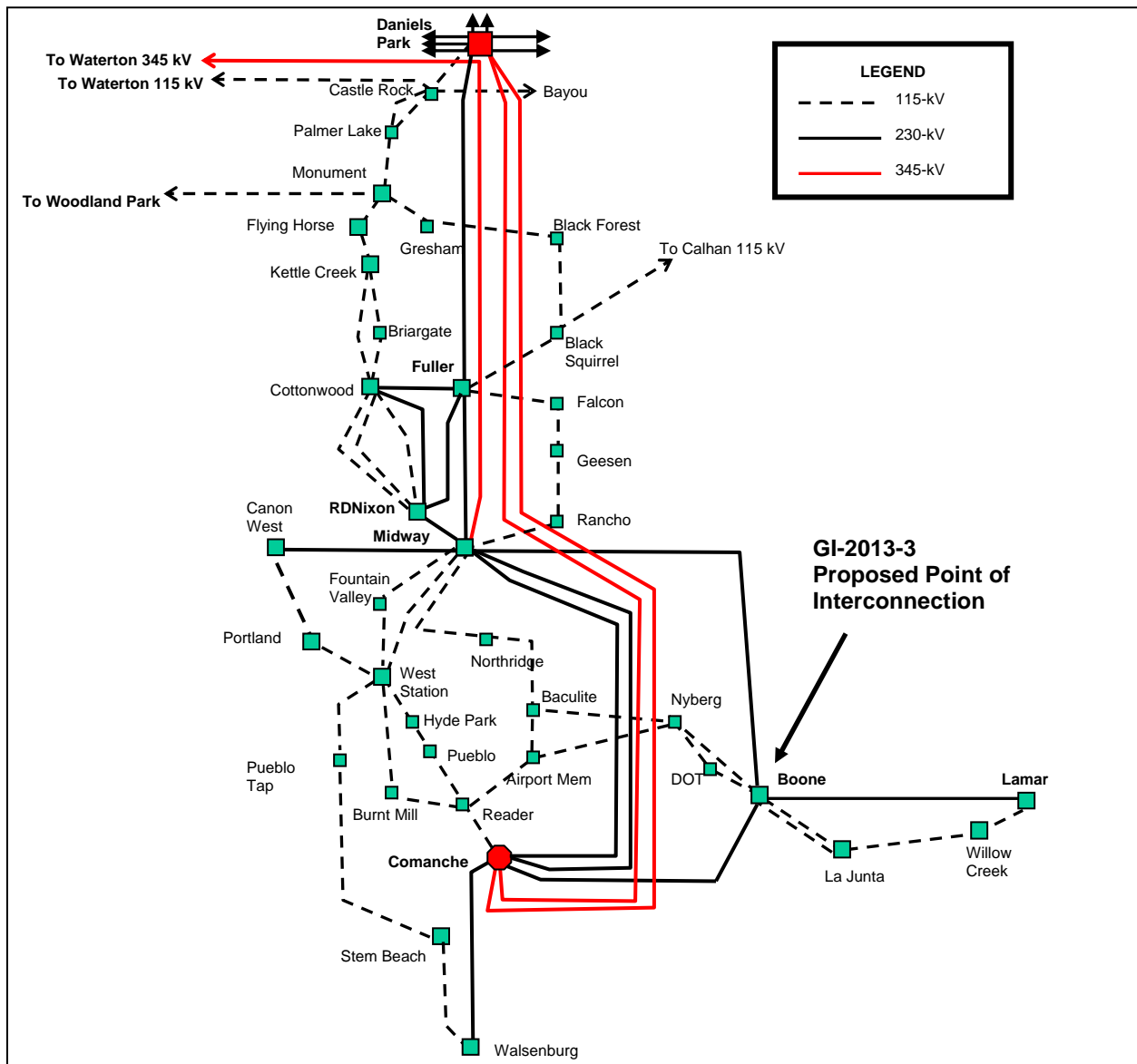


Figure 1 Boone Station and Surrounding Transmission System

Introduction

Public Service Company of Colorado (PSCo) received an interconnection request for a 30 MW solar photovoltaic generating facility on June 21, 2013 that was assigned GI-2013-3 as the queue number. The proposed generating facility will be located approximately 2,000 feet southeast of PSCo’s Boone 230/115 kV Station. The primary point of interconnection (POI) requested for GI-2013-3 is the Boone 115 kV bus and the generating facility will interconnect to the POI using a customer owned 115 kV transmission line. The alternate POI requested is the Boone 230 kV bus and is to be studied only if problems requiring mitigation are uncovered in the studies of the primary



POI. The in-service date (ISD) requested for GI-2013-3 generating facility is December 1, 2016

Study Scope and Analysis

The Feasibility Study evaluated the transmission impacts associated with the proposed solar generation facility. The study consists of power flow and short circuit analyses. The power flow analysis identified thermal and voltage limit violations resulting from the installation of the proposed generation and an identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified any new circuit breakers overdutied due to the proposed generation and the short circuit levels at the primary POI.

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 nominal, and steady-state power flows below the thermal ratings of all facilities. Operationally, PSCo attempts to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulating (generation) buses to 1.0 per unit or higher at transmission load buses. Following a single contingency, transmission system steady state bus voltages must remain within 0.90 per unit to 1.10 per unit, and power flows within 100% of the facilities' continuous thermal ratings. Also, voltage deviations should not exceed 5%.

The project was studied as a Network Resource and Energy Resource. 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 generation facilities to serve native load customers; or (2) in an TRO 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 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 elect output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available bases. Energy Resource Interconnection Service in and of itself does not convey transmission service.

The Feasibility Study results indicate that Colorado Springs Utilities (CSU), Tri-State Generation & Transmission (TSG&T), and West Plains (WP) are affected parties due to the system impact of GI-2013-3.



Power Flow Study Models

The power flow studies were based on the WECC approved 17HS1AP_r32 case. PSCo loads in the case were adjusted to reflect the most recent (April 2013) PSCo load forecast. IREA load was also adjusted to reflect IREA's latest load forecast (November 2013). The topology was also updated to reflect current project plans. Updates were included for the PSCo, IREA, CSU, TSG&T, WAPA, PRPA, and BHCE systems.

The PSCo updates included the addition of the new Cherokee combined cycle plant and associated transmission upgrades. The new IREA Happy Canyon distribution substation connected to the Crowfoot Valley – Daniels Park 115 kV circuit was also included. A significant CSU case update was the re-termination of the Nixon end of the Kelker – Nixon 230 kV line to Front Range.

Two power flow cases were created for evaluating the impact of the proposed generator – the reference case and the study case. The study case includes the 30 MW generation dispatch at Boone 115 kV bus due to the proposed generator interconnection. An additional case was created to compare the primary POI (Boone 115 kV) with the alternate POI (Boone 230 kV).

To assess the impact of the proposed generation on the interconnected transmission system, the generation dispatch in the reference case was adjusted to create a south to north power flow stress on the Comanche – Midway – Jackson Fuller – Daniels Park transmission path. This was accomplished by adopting the generation dispatch described below that reflects the resource acquisitions approved in PSCo's 2013 Energy Resource Plan (ERP) for which Power Purchase Agreements (PPA's) have been signed. The six combustion turbines in Fountain Valley generating plant were dispatched at 242 MW rated output and the GI-2007-12 wind generation at Jackson Fuller was dispatched at 250 MW rated output. The wind generation for GI-2012-5 at Comanche was dispatched to 120 MW rated output. The Lamar DC tie was dispatched at 101 MW importing into PSCo and the Colorado Green / Twin Buttes wind generation (interconnected at Lamar) was dispatched to 97.3 MW, which is the generation level at which loss of one of the two 230/115 kV transformers at Lamar resulted in a 100% of normal rating loading level on the remaining transformer. Other PSCo thermal generating units were dispatched according to their relative production costs (merit-order). It should be noted that the Area 70 (Area PSCOLORADO) swing machine in the WECC power flow cases was moved to Fort Saint Vrain (FSV) Unit #2.

Power Flow Study Process

Contingency power flow studies were completed on the reference models and the models with the proposed new generation using PTI's PSSE Ver. 33.4.0 program. Results from each of the two cases were compared and new overloads or overloads that increased significantly in the new generation case were noted. Voltage criteria violations were also recorded. PSSE's ACCC activity was used to perform the load flow contingency analysis for PSCo Category B & C contingencies. Areas 70 and 73 were



used for contingency files (single branches and tielines). Monitored elements included branches in ties in zones 700, 703, 704, 705, 706, 710, 752, 753, 754, and 757.

Power Flow Results

The results of the Network Resource contingency analysis are summarized in the tables in the Appendix. The results of the Category B contingency analysis, displayed in Table 5, show three 115 kV transmission facilities with thermal overloads – two of these 115 kV facilities are wholly-owned by CSU and the third 115 kV facility (Monument-Palmer Lake) is a tie-line between CSU and PSCo. Since these transmission facilities are overloaded prior to the GI-2013-3 interconnection, none of these thermal overloads can be attributed to the proposed 30 MW injection at Boone by GI-2013-3. The mitigation approach for these facilities is being analyzed as part of a study for an earlier generation interconnection request in the area. The preliminary mitigation approach is to limit the magnitude of power flow through the Monument – Palmer Lake 115 kV line using a reactive device. The effectiveness of this mitigation approach is evident from the Category B contingency results shown in Table 7 for one potential solution, i.e. series reactor in the Monument – Palmer Lake 115 kV line.

No new violations of the voltage limit criteria (0.9 - 1.05 pu) or the voltage deviation criteria (< 5%) were caused in PSCo's interconnected transmission system due to the addition of GI-2013-3 generating facility.

Network Resource (NR)

At both the primary POI (Boone 115 kV bus) and the alternative POI (Boone 230 kV bus), the 30 MW injection from the proposed generation resulted in an increased Category B contingency loading on the following transmission facilities: PSCo/CSU's Monument – Palmer Lake 115 kV Line by 2.2% and CSU's Cottonwood – Briargate and Cottonwood – Kettle Creek 115 kV Lines by 1.0%. Since these transmission facilities are overloaded prior to GI-2013-3 and are currently being investigated for mitigation, the Network Resource Interconnection Service (NRIS) for the proposed generation is as follows:

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**ERIS = 0 MW Firm
 = 30 MW on As Available basis
 Before PSCo’s planned Monument–Palmer Lake upgrade is in-service.**

**ER = 30 MW
 After PSCo’s planned Monument–Palmer Lake upgrade is in-service.**

Short Circuit Analysis

The short circuit study results showed no new circuit breakers are overdutied due to the proposed solar generation facility. The study found the single-line-to-ground (SLG) and 3-phase fault duty at Boone 115 kV bus (including GI-2013-3) shown in Table 1 below.

Table 1 - Short Circuit Levels s at the Boone 115 kV POI

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance (R + jX) (Ohms)
System Intact	16,650	15,740	Z1(pos)= 0.49816 +j 3.99672 Z2(neg)= 0.52290 +j 3.99340 Z0(zero)= 0.61331 +j 4.69369



Costs Estimates and Assumptions

GI-2013-13 (Feasibility Study Report)

July 14, 2014

Scoping level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by Public Service Company of Colorado (PSCO) Engineering. The cost estimates are in 2014 dollars with escalation and contingency 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, material/equipment procurement, construction and commissioning of these new substation and transmission line 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 **\$1,970,000**. **Figure 2** below represents a conceptual one-line of the proposed interconnection into the 115kV bus at the Boone Transmission Substation. 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.

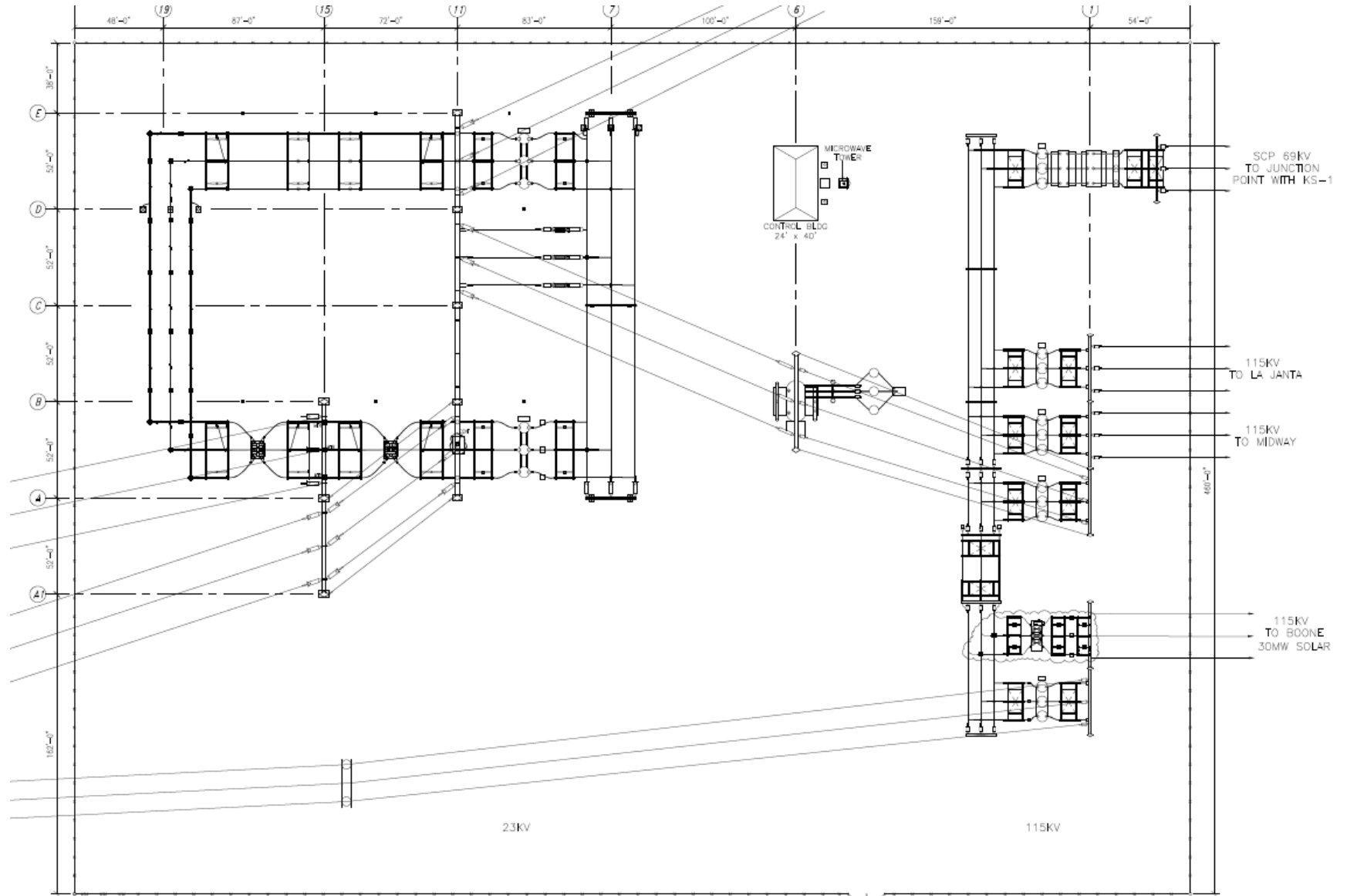


Figure 2 Boone Substation Interconnection



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

Element	Description	Cost Est. (Millions)
Boone 115kV Transmission Substation	Interconnect Customer to tap at the Boone 115kV Transmission Substation (into the 115kV bus). The new equipment includes: <ul style="list-style-type: none"> • 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 	\$1.490
	Transmission line tap into substation. Structure, conductor, insulators, hardware and labor.	\$0.161
Customer's 115kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment.	\$0.309
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction.	\$0.010
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$1.970
Time Frame	Site, design, procure and construct	18 Months

Table 3: PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
	N/A	

Table 4: PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
	N/A	

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.
- Tri-State and/or Xcel (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 facilities is approximately 18 months after authorization to proceed has been obtained.
- 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.
- No new substation land will need to be acquired.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.

Appendix

Power Flow Contingency Analysis Results

Table 5: N-1 Differentially Overloaded Facilities ¹ for High Coincidence Wind/Solar Generation Dispatch in the Pueblo Area

				Branch N-1 Loading Before GI-2013-3		Branch N-1 Loading After GI-2013-3			
Monitored Facility (Line or Transformer)	Type	Owner	Facility Rating MVA (Norm/Emer)	N-1 Flow in MVA	N-1 Flow in % of Rating (Norm/Emer)	N-1 Flow in MVA	N-1 Flow in % of Rating (Norm/Emer)	Differential % Impact	NERC Category B Contingency Outage
Monument-Palmer Lake 115 kV	Line	PSCo/CSU	120 / 120	121.4	101.2% / 101.2%	124.1	103.4% / 103.4%	2.2% / 2.2%	Daniels Park-Fuller 230 kV Line
Cottonwood-Briargate 115 kV	Line	CSU	150 / 192	167.4	116.6% / 87.2%	176.4	117.6% / 91.9%	1.0% / 4.7%	Cottonwood - Kettle Creek 115 kV
Kettle Creek-Cottonwood 115 kV	Line	CSU	162 / 180	188.1	116.1% / 104.5%	189.7	117.1% / 105.4%	1.0% / 0.9%	Cottonwood-Briargate 115 kV line

¹ Due to proposed 30 MW generation increase at Boone 115 kV or 230 kV Station



Table 6: N-2 Differentially Overloaded Facilities² for High Coincidence Wind/Solar Generation Dispatch in the Pueblo Area

Monitored Facility (Line or Transformer)	Type	Owner	Facility Rating MVA (Norm/Emer)	Branch N-1 Loading Before GI-2013-3		Branch N-1 Loading After GI-2013-3		Differential % Impact	NERC Category C Contingency Outage
				N-1 Flow in MVA	N-1 Flow in % of Rating	N-1 Flow in MVA	N-1 Flow in % of Rating		
Midway-Fountain Valley 115 kV	Line	WP	119 / 119	153	129.3% / 129.3%	158	133.4% / 133.4%	2.8% / 2.8%	Comanche-Daniels Park 345 kV Line Nos. 1 & 2
Desert Cove-Fountain Valley 115 kV	Line	WP	119 / 119	156	130.7% / 130.7%	160	134.8% / 134.8%	2.7% / 2.7%	Comanche-Daniels Park 345 kV Line Nos. 1 & 2
Monument-Palmer Lake 115 kV	Line	PSCo/ CSU	120 / 120	176	147.2% / 147.2%	179	150.4% / 150.4%	3.2% / 3.2%	Midway-Waterton 345 kV Line Daniels Park-Jackson Fuller 230 kV Line
Monument-Flying Horse 115 kV	Line	CSU	142 / 156	189	132.8% / 121.2%	193	135.5% / 123.7%	2.8% / 2.5%	Midway-Waterton 345 kV Line & Daniels Park-Jackson Fuller 230 kV Line
Midway 230 kV sectionalizing breaker	Brkr	PSCo	430 / 478	476	107.8% / 99.6%	486	110.2% / 101.7%	2.8% / 2.1%	Midway-Jackson Fuller 230 kV Line & Midway 345/230 kV Transformer
Kettle Creek-Flying Horse 115 kV	Line	CSU	162 / 180	200	122.6% / 111.1%	204	125.0% / 113.3%	2.4% / 2.2%	Midway-Waterton 345 kV Line & Daniels Park-Jackson Fuller 230 kV Line
Daniels Park-Jackson Fuller 230 kV	Line	PSCo	478 / 478	539	113.5% / 113.5%	548	115.6% / 115.6%	2.1% / 2.1%	Comanche-Daniels Park 345 kV Line Nos. 1 & 2
Daniels Park 345/230 kV Transformer No. 2	Tran	PSCo	560 / 644	703	125.6% / 109.2%	713	127.4% / 110.7%	1.8% / 1.5%	Daniels Park 345/230 kV Transformer Nos. 3 & 4
Daniels Park 345/230 kV Transformer No. 3	Tran	PSCo	560 / 644	703	125.6% / 109.2%	713	127.4% / 110.7%	1.8% / 1.5%	Daniels Park 345/230 kV Transformer Nos. 2 & 4
Daniels Park 345/230 kV Transformer No. 4	Tran	PSCo	560 / 644	703	125.6% / 109.2%	713	127.4% / 110.7%	1.8% / 1.5%	Daniels Park 345/230 kV Transformer Nos. 2 & 3
Black Forest-Black Squirrel Tap 115 kV	Line	TSG&T	81 / 81	110	139.5% / 139.5%	111	140.9% / 140.9%	1.4% / 1.4%	Cottonwood-Briargate 115 kV line & Cottonwood-Kettle Creek 115 kV Line
Cottonwood-Kettle Creek 115 kV	Line	CSU	162 / 182	229	141.1% / 125.8%	231	142.4% / 126.9%	1.3% / 1.1%	Cottonwood-Briargate 115 kV Line & Jackson Fuller-Black Squirrel 115 kV Line
Geesen-LorsonRanch 115 kV	Line	TSG&T	90 / 90	105	119.0% / 119.0%	106	120.3% / 120.3%	1.2% / 1.2%	Kettle Creek-Flying Horse 115 kV Line & Jackson Fuller 230/115 kV Transformer No. 1
Rancho-Lorson Ranch 115 kV	Line	TSG&T	92 / 92	112	121.8% / 121.8%	113	123.1% / 123.1%	1.2% / 1.2%	Kettle Creek-Flying Horse 115 kV Line & Jackson Fuller 230/115 kV Transformer No. 1
Midway-Rancho 115 kV	Line	TSG&T	92 / 92	115	124.0% / 124.0%	116	125.3% / 125.3%	1.2% / 1.2%	Kettle Creek-Flying Horse 115 kV Line & Jackson Fuller 230/115 kV Transformer No. 1
Cottonwood-Briargate 115 kV	Line	CSU	150 / 192	216	142.7% / 112.5%	218	143.9% / 113.5%	1.2% / 1.0%	Cottonwood-Kettle Creek 115 kV Line &

² Due to proposed 30 MW generation increase at Boone 115 kV or 230 kV Station



				Branch N-1 Loading Before GI-2013-3		Branch N-1 Loading After GI-2013-3			
Monitored Facility (Line or Transformer)	Type	Owner	Facility Rating MVA (Norm/Emer)	N-1 Flow in MVA	N-1 Flow in % of Rating	N-1 Flow in MVA	N-1 Flow in % of Rating	Differential % Impact	NERC Category C Contingency Outage
									Jackson Fuller-Black Squirrel 115 kV Line
Falcon MV-Geesen 115 kV	Line	TSG&T	90 / 90	92	104.0% / 104.0%	93	105.2% / 105.2%	1.1% / 2.2%	Kettle Creek-Flying Horse 115 kV Line & Jackson Fuller 230/115 kV Trans. No 1



Series Reactor (X = 20.0%) Added in the Monument-Palmer Lake 115 kV Line

Table 7: N-1 Differentially Overloaded Facilities ³ for High Coincidence Wind/Solar Generation Dispatch in the Pueblo Area

				Branch N-1 Loading Before GI-2013-3		Branch N-1 Loading After GI-2013-3			
Monitored Facility (Line or Transformer)	Type	Owner	Facility Rating MVA	N-1 Flow in MVA	N-1 Flow in % of Rating	N-1 Flow in MVA	N-1 Flow in % of Rating	Differential % Impact	NERC Category B Contingency Outage
Monument-Palmer Lake 115 kV	Line	PSCo/CSU	120 / 120	58.8	49.0% / 49.0%	60.0	50.0% / 50.0%	1.0%	Daniels Park-Fuller 230 kV Line
Cottonwood-Briargate 115 kV	Line	CSU	150 / 192	154.5	103.0% / 80.5%	155.6	103.7% / 81.0%	0.5%	Cottonwood - Kettle Creek 115 kV
Kettle Creek-Cottonwood 115 kV	Line	CSU	162 / 180	163.6	101.0% / 90.9%	164.8	101.7% / 91.6%	0.7%	Cottonwood-Briargate 115 kV line

³ Due to proposed 30 MW generation increase at Boone 115 kV or 230 kV Station