



Generator Interconnection Request # GI-2016-31 Feasibility Study

**51.75 MW Solar Photovoltaic (PV) Generation at Pawnee 230 kV Station
Morgan County, Colorado**

**Public Service Company of Colorado
Transmission Planning
June 7, 2017**

A. Executive Summary

On December 20, 2016 Public Service Company of Colorado (PSCo) received an interconnection request (GI-2016-31) for a 51.75 MWac solar photovoltaic (PV) generation facility in Morgan County, Colorado. The proposed Point of Interconnection (POI) is the Pawnee 230 kV bus within PSCo's Pawnee 345/230 kV substation (see Figure 1).

The Commercial Operation Date (COD) requested by the Interconnection Customer is December 1, 2019 and accordingly the approximate target Backfeed Date is assumed to be six months prior to the COD - June 1, 2019.

The proposed solar photovoltaic generating facility would consist of 23 SMA inverters, each rated 2.5 MW. Each inverter would be connected to a pad-mounted step-up transformer which provides voltage transformation for integration of the inverter and its associated PV source circuits with the medium voltage power collection system within the generating plant. One main generator step-up transformer (GSUT) would provide the final transformation to allow the generating facility to interconnect to the Pawnee 230 kV bus POI via an overhead 230 kV transmission line owned by the Interconnection Customer.

The GI-2016-31 interconnection request was studied as a stand-alone project. That is, the study did not include any other Generator Interconnection Requests (GIR) existing in PSCo's or any affected party's GIR queue, other than the interconnection requests that are considered to be planned resources for which Power Purchase Agreements have been signed. This interconnection request was studied both as Network Resource Interconnection Service (NRIS)¹ and Energy Resource Interconnection Service (ERIS)².

¹ 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



The Feasibility Study consisted of power flow (steady-state) contingency analysis and short-circuit analysis. The power flow contingency analysis did not identify any thermal overloads or voltage violations as a result of the 51.75 MW injection from GI-2016-31. The short circuit analysis did not identify any over-dutied circuit breakers.

Based on the Feasibility Study results, it is concluded that no Network Upgrades are required for the 51.75 MW rated output of GI-2016-31 interconnection to qualify for NRIS, provided the planned Pawnee-Daniels Park (P-DP) 345kV project is in service. Prior to the in-service date of P-DP project, GI-2016-31 would qualify for ERIS from 0 to 51.75 MW on as-available basis.

That is,

ERIS	= 0 – 51.75 MW	(Before P-DP project is in service)
NRIS	= 51.75 MW	(After P-DP project is in service)

For this interconnection request, the potential Affected Parties are Tri-State Generation & Transmission (TSGT) and Western Area Power Authority (WAPA).

Cost Estimates

The total estimated cost of the required Interconnection Facilities and Network Upgrades at PSCo's Pawnee Substation (in 2017 dollars) is **\$1.702 million** and includes:

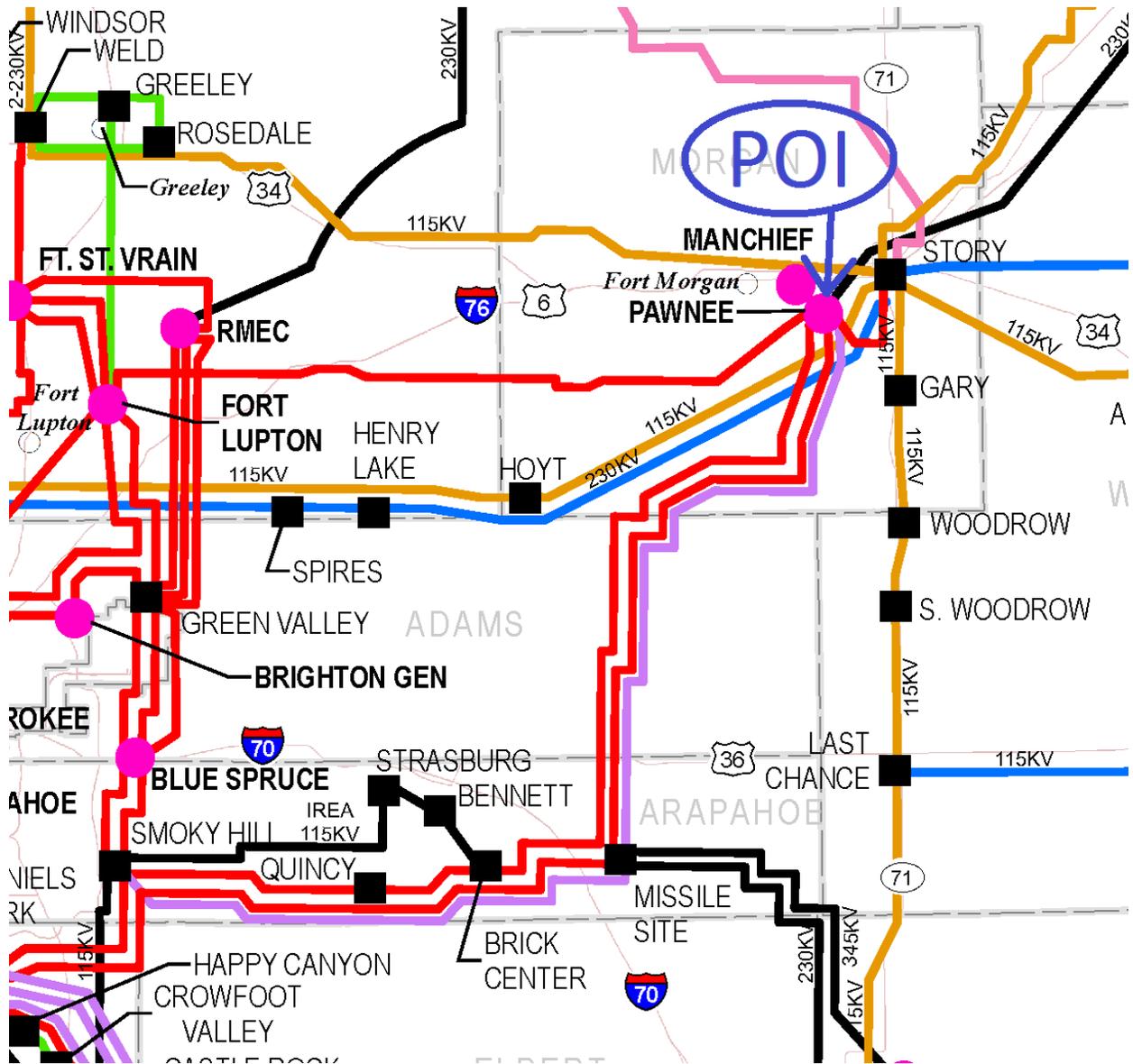
- \$ 0.835 million for Transmission Provider's Interconnection Facilities – Interconnection Customer Funded
- \$ 0.867 million for Network Upgrades for Interconnection– PSCo Transmission Funded
- \$ 0.000 million for Network Upgrades for Delivery – PSCo Transmission Funded

The estimated time frame to site, design, procure and construct these Interconnection Facilities and Network Upgrades is 18 months.

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.

² 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.

Figure 1 POI at Pawnee Station and Surrounding Transmission System (2017)





B. Introduction

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For this interconnection request, the potential Affected Parties are Tri-State Generation & Transmission (TSGT) and Western Area Power Authority (WAPA).

C. Study Scope and Analysis

This interconnection request was studied both as Network Resource Interconnection Service (NRIS)³ and Energy Resource Interconnection Service (ERIS)⁴.

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⁴ 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.



The Feasibility Study scope consisted of performing power flow analysis to evaluate the steady-state thermal and/or voltage limit violations in the transmission system resulting from the proposed generator interconnection. The Feasibility Study scope also consisted of short-circuit analysis to determine any over-dutied circuit breakers due to the proposed generator interconnection. Together these analyses help to identify potential Network Upgrades required to deliver the 51.75 MW rated output of the proposed generation to load, for both NRIS and ERIS.

PSCo adheres to NERC & WECC System Performance Criteria, as well as internal system performance criteria for transmission system planning studies.

D. Power Flow Study Models

The power flow studies were based on the WECC 2021 heavy summer base case which includes the Pawnee-Daniels Park and Rush Creek Generation projects. Two power flow cases were created for evaluating the system impact of the proposed generator interconnection. The first case was a Benchmark Case (without GI-2016-31) and a Study Case (with GI-2016-31). PSCo generation was dispatched according to PSCo Transmission Planning's internal GI dispatch methodology.⁵

E. Power Flow Study Process

The study area was defined as Zones 700, 706, 752, and 754. Contingency power flow studies were completed on the Benchmark Cases and the Study Cases using PTI's PSSE Ver.33.6.0 program and PSS®E Ver. 33.6.0 ACCC contingency analysis. Automated contingency power flow studies were completed on all power flow models using the PSS®E program, switching out single elements one at a time for all of the elements (lines and transformers) in the study area. Upon switching each element out, the program re-solves the power flow model.

PSCo adheres to all applicable NERC Standards & WECC Criteria for Bulk Electric System (BES) acceptable performance, as well as its internal transmission planning criteria for all studies. During system intact conditions, PSCo's steady-state performance criteria require the transmission bus voltages remain within 0.95 – 1.05 per unit of nominal and the power flows stay below the applicable normal ratings of the transmission facilities. Following a single contingency, the steady state bus voltages must remain within 0.9 – 1.1 per unit of nominal, and the power flows must continue to stay below the applicable normal facility ratings. For N-1 post-contingency system conditions, the applicable normal ratings is the seasonal continuous rating of the transmission facility – but PSCo allows use of eight-hour facility ratings for

⁵ Variable Energy Resource (VER) Dispatch Assumptions used in PSCo Transmission Planning's System Impact/Performance Studies – specifically in Generator Interconnection & Deliverability Studies for PSCo Designated Network Resources (DNR)



transformers for which it is available. Further, PSCo does not rely on 30-minute emergency ratings of transmission facilities for meeting N-1 system performance in planning studies.

F. Power Flow Contingency Analysis Results

Thermal Analysis: No new thermal violations occurred as a result of the GI-2016-31 interconnection.

Voltage Analysis: No new voltage violations occurred as a result of the GI-2016-31 interconnection.

G. Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect its Large Generating Facility with Public Service of Colorado's (PSCo) Transmission System in accordance with the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW* (available at:

<http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Interconnection/Interconnections-POL-TransmissionInterconnectionGuidelineGreat20MW.pdf>).

In addition, wind generating plant interconnections must also fulfill the performance requirements specified 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 are expected to adhere to the Rocky Mountain Area Voltage Coordination Guidelines (RMAVCG). Accordingly, since the POI for this interconnection request is located within Northeast Colorado - Region 7 defined in the RMAVCG; 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 (Attachment N effective 10/14/2016) requires all non-synchronous Generator Interconnection (GI) Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the high side of the generator substation. Furthermore, Xcel Energy requires every Generating Facility to have dynamic voltage control capability to assist in maintaining the POI voltage schedule specified by the Transmission Operator as long as the Generating Facility does not have to operate outside its 0.95 lag – 0.95 lead dynamic power factor range capability.
- 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 (34.5 kV or 345 kV bus) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/- 0.95 power factor and the 1.02 – 1.03 per unit voltage range standards at



the POI. Further, it is the responsibility of the Interconnection Customer to compensate their generation tie-line to ensure minimal (approximately zero) reactive power flow into the POI when the generating facility is producing <10% rated output.

- The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial operation date of the generating plant that it can safely and reliably operate within the required power factor and voltage ranges (noted above).
- The Interconnection Customer has the responsibility to ensure that its generating facility is capable of meeting the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in NERC Reliability Standard PRC-024-1.

H. Short Circuit Analysis Results

The calculated short circuit levels and Thevenin system equivalent impedances for the POI at the Pawnee 230 kV bus are tabulated below. No circuit-breakers at Pawnee 230 kV bus or at the neighboring buses were found to be over-dutied due to the proposed interconnection.

Table 1 – Short Circuit Levels at the Pawnee 230 kV POI

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance R +j X (ohms)
Before GI-2016-31 Interconnection	30,731	34,451	Z1(pos) = 0.298+j4.311 Z2(neg) = 0.364+j4.311 Z0(zero) = 0.245+j2.906
After GI-2016-31 Interconnection	30,938	34,721	Z1(pos) = 0.298+j4.311 Z2(neg) = 0.364+j4.311 Z0(zero) = 0.242+j2.881

Assumptions:

- The impedance of the generator tie line was estimated using the 3 mile length indicated on the one-line supplied by the Interconnection Customer.



I. Study Conclusion

Based on the Feasibility Study results, it is concluded that no Network Upgrades are required for the 51.75 MW rated output of GI-2016-31 interconnection to qualify for NRIS, provided the planned Pawnee-Daniels Park (P-DP) 345kV project is in service. Prior to the in-service date of P-DP project, GI-2016-31 would qualify for ERIS from 0 to 51.75 MW on as-available basis.

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J. Cost Estimates and Assumptions

PSCo Engineering has developed Indicative level cost estimates (IE) for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the Interconnection Customer's proposed generation facility. Indicative Estimates are based upon typical construction costs for previously performed similar construction projects; however they have no specified level of accuracy. The cost estimates are in 2017 dollars with escalation and contingencies applied. AFUDC is not included. 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 Customer owned equipment and associated design and engineering.

The estimated total cost for the required Interconnection Facilities and Network/Infrastructure Upgrades is **\$1,702,000.00**

Figure 2 below is a conceptual one-line of the proposed interconnection. The Point of Interconnection (POI) will be a tap on the Pawnee Substation 230kV bus.

The following Tables 2-4 list the improvements required to accommodate the interconnection and the delivery of the Customer's 51.75 MW solar facility generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to revision as a more detailed and refined design is produced.



Table 2: Transmission Provider’s Interconnection Facilities – Interconnection Customer Funded

Element	Description	Cost Est. (Millions)
PSCo’s Pawnee 230kV Transmission Sub Station	Interconnect Customer to the Pawnee Sub 230kV bus. The new equipment includes; <ul style="list-style-type: none"> • One (1) motor operated 230kV disconnect switch • Three (3) 230kV combination CT/PT metering units • One (1) 230kV CCVT • Power Quality Metering (230kV line from Customer) • Three (3) surge arresters • Two (2) relay panels • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing 	\$0.782
	Transmission line tap into substation. Conductor, hardware, and installation labor.	\$0.053
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$0.835
Time Frame	Design, procure and construct	18 Months



Table 3: Network Upgrades for Interconnection– PSCo Transmission Funded

Element	Description	Cost Estimate (Millions)
PSCo's Pawnee 230kV Transmission Sub Station	Interconnect Customer to the Pawnee Sub 230kV bus. The new equipment includes; <ul style="list-style-type: none"> • One (1) 230kV circuit breaker • Two (2) 230kV gang switches • 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 	\$0.782
	Siting and Land Rights support for substation land acquisition and construction.	\$0.085
	Total Cost Estimate for PSCo-Owned, Network Upgrades for Interconnection	\$0.867
Time Frame	Site, design, procure and construct	18 Months

Table 4 – PSCo Network Upgrades for Delivery – PSCo Transmission Funded

Element	Description	Cost Est. (Millions)
NA	None identified	NA
	Total Cost Estimate for PSCo Network Upgrades for Delivery	\$0
Duration	Design, procure, permit and construct	NA
	Total Project Estimate	\$1.702

Cost Estimate Assumptions

- Indicative level project cost estimates (IE) for Interconnection Facilities were developed by PSCo Engineering. No level of accuracy is specified for IE's.
- Estimates are based on 2017 dollars (appropriate contingency and escalation applied).
- Allowance for Funds Used During Construction (AFUDC) has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.



- 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 18 months (after authorization to proceed has been obtained).
- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date due.
- 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 the substation as part of the transmission line construction scope.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer Substation. PSCo / Xcel will need indications, readings and data from the LFAGC RTU.
- Power Quality Metering (PQM) will be required on the Customer's 115 kV line terminating into Proposed Switching Station.
- The Solar Generation Facility is not in PSCo's retail service territory. The customer will need to work with the local electric distribution service provider to acquire station service for their facility.

