# Interconnection Feasibility Study Report
# Request # GI-2017-2

150 MW Solar Generating Facility
Interconnecting at
Missile Site 230 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning
June 27, 2017

## Executive Summary

Public Service Company of Colorado (PSCo) received an Interconnection Request (IR) on January 18, 2017 which was assigned GI-2017-2 queue position. GI-2017-2 is a solar photovoltaic generating facility rated at 150 MW gross electrical output that will be located in Arapahoe County, Colorado. The Point Of Interconnection (POI) requested for GI-2017-2 is the 230 kV bus within PSCo's Missile Site Substation. As per the IR, GI-2017-2 is studied for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

The proposed 150 MW generating facility is expected to consist of approximately 75 SMA inverters rated at 2.2 MVA each. Preliminary information on the generating facility's layout suggests that the 75 inverters will be grouped together into a 34.5 kV collector system, and the 34.5 kV collector system will connect to a 34.5/230 kV main step-up transformer. The facility will connect to the POI via an approximately one mile 230 kV line.

The Commercial Operation Date (COD) requested for the generating facility is December 31, 2019. Based on the requested COD, the assumed back-feed date for the facility is June 30, 2019 (approximately six months before the COD).

Figure 1 below depicts the proposed POI for GI-2017-2 and the surrounding transmission system.

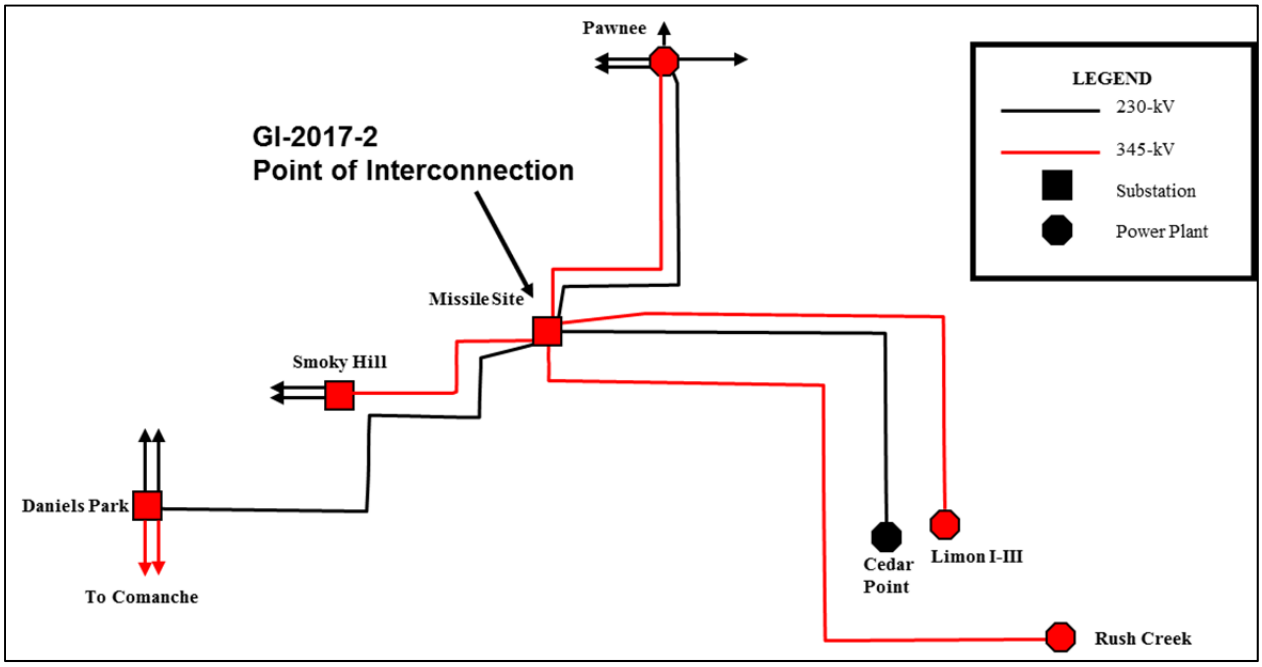


**Figure 1: Missile Site and Surrounding Transmission System**

The purpose of this Feasibility Study is to determine the feasibility of injection by the proposed 150 MW output of GI-2017-2 at the Missile Site 230 kV POI. Towards this purpose, the study also identifies the transmission improvements needed to enable delivery of the 150 MW electrical output to PSCo network loads – that is, network upgrades needed for GI-2017-2 to qualify as NRIS.

The 150 MW electrical output of GI-2017-2 IR was studied as a stand-alone project. That is, the study did not include any prior-queued IR's existing in PSCo's or any affected party's Generation Interconnection queue except those IR's which are:

a) considered to be PSCo planned resources in recognition of their signed Power Purchase Agreements, or
b) assumed in-service as per the agreed-upon study assumptions with the Interconnection Customer.

The Feasibility Study consisted of steady state (power flow) and short-circuit analyses. The power flow analyses were performed using two power flow models developed for GI-2017-2, both of which are based on the WECC 2021 heavy summer (2021HS) base case. The two power flow models are:

- Benchmark Case which models the planned 2021 transmission system prior to the GI-2017-2 interconnection (i.e. Before GI-2017-2 case).
- Study Case that also models the 150 MW output of the proposed GI-2017-2 interconnection (i.e. After GI-2017-2 case).

The Pawnee – Daniels Park (P-DP) 345 kV project[1] is a PSCo planned project for which the Colorado Public Utility Commission (CPUC) has approved a Certificate of Public Convenience and Necessity (CPCN) and has an in-service date of October 31, 2019. Studies for GI-2016-3 demonstrated that the Pawnee – Daniels Park project is the network upgrade needed to deliver the 600 MW output of GI-2016-3 to the PSCo system. Therefore, that project was included in the power flow models.

Power flow analysis results provided in Table A.1 in the Appendix (see page 11) show that the additional 150 MW injection into Missile Site Substation has no significant differential impact on the transmission system and, therefore, no network upgrades are required. Consequently this Feasibility Study concludes that the proposed GI-2017-2 interconnection qualifies for 150 MW ERIS and NRIS[2] without any network upgrades.

That is, for GI-2017-2 interconnection, with no network upgrades (provided the planned P-DP project is in service):

NRIS = 150 MW
ERIS = 150 MW

No adverse impacts on the transmission systems of other entities are identified in the Feasibility Study and, therefore, no affected parties are identified for GI-2017-2.

As shown in **Tables 1–3** (see pages 9-10), the total cost for the Interconnection Facilities and the Network Upgrades is **$1.803 million** and includes:

- $0.855 million for PSCo-Owned, Interconnection Customer Funded Transmission Provider Interconnection Facilities
- $0.948 million for PSCo-Owned, PSCo Funded Network Upgrades for Interconnection

It is estimated that this work can be completed in approximately 18 months, following receipt of authorization to proceed.

[1] More information at: http://www.transmission.xcelenergy.com/Projects/Colorado
[2] Network Resource Interconnection Service allows Interconnection Customer 's Large Generating Facility to be designated as a Network Resource, up to the Large Generating Facility's full output, on the same basis as existing Network Resources interconnected to Transmission Provider's Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur. (*section 3.2.2 of Attachment N in Xcel Energy OATT*)

## Power Flow N-1 Contingency Analysis

The 2021HS base case was updated to dispatch the existing and planned generation within the Pawnee and Missile Site "generation pockets" (i.e. aggregate of generation in the local area) at their respective highest coincident output deemed appropriate for the planning of adequate transmission capacity. This was done in accordance with the generation dispatch assumptions practiced by PSCo Transmission Planning function to study the feasibility and system impact of generator interconnection requests as a Transmission Provider. Accordingly, the existing, planned and proposed generating plants at Pawnee and Missile Site stations were dispatched as noted below.

Pawnee local "generation pocket"

- ✓ Pawnee Fossil Fuel generation = 100% of rated capacity = 536 MW
- ✓ Manchief Gas generation = 90% of rated capacity = 252 MW
- ✓ Peetz Logan Wind generation = 40% of rated capacity = 230 MW

***Aggregate Generation Dispatched at Pawnee in all Cases = 1018 MW***

Missile Site local "generation pocket"

- ✓ Cedar Point (Missile Site 230kV) = 80% of rated capacity = 200 MW
- ✓ Limon I, II, III (Missile Site 345kV) = 80% of rated capacity = 480 MW
- ✓ GI-2016-3 (Missile Site 345kV) = 80% of rated capacity = 480 MW
- ✓ GI-2017-2 (Missile Site 230kV) = 100% of rated capacity = 150 MW

***Aggregate Generation Dispatched at Missile Site in Benchmark Case = 1160 MW***

***Aggregate Generation Dispatched at Missile Site in Study Case(s) = 1310 MW***

The GI-2017-2 *Benchmark Case* was derived from the 2021HS base case by changing the aggregate area generation dispatch at Pawnee and Missile Site to 1018 MW and 1160 MW as noted above. The previously proposed GI-2016-3 generating plant was added at the Missile Site 345kV bus and dispatched at 480 MW rated output. Transmission facilities comprising the Pawnee –Daniels Park (P-DP) project modeled in the 2021HS case were retained in the Benchmark Case since they comprise the network upgrades identified for GI-2016-3. The GI-2017-2 *Study Case* was created by adding the proposed GI-2017-2 solar generating plant in the Benchmark Case at the Missile Site 230 kV bus and dispatching it at 150 MW rated output.

PSCo adheres to applicable NERC Reliability Standards & WECC Reliability Criteria for Bulk Electric System (BES) acceptable performance, as well as its internal performance criteria for planning studies. For steady state analysis, the performance criteria are as follows:

P0 - System Intact conditions:
Thermal Loading: <=100% Normal facility rating
Voltage range: 0.95 to 1.05 per unit

P1-P2 – Single Contingencies:
Thermal Loading: <=100% Normal facility rating[3]
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

P3-P7– Multiple Contingencies:
Thermal Loading: <=100% Emergency facility rating
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

As is evident from the power flow analysis results performed for this study, the additional 150 MW generation injection into Missile Site Substation causes no significant differential impact (greater than 2 percent power flow change) on the transmission system nor exceedance of applicable facility ratings. Therefore, no network upgrade is required for the proposed GI-2017-2 interconnection to achieve 150 MW NRIS.

Consequently, this Feasibility Study concludes that the proposed GI-2017-2 interconnection qualifies for 150 MW ERIS and NRIS.

Therefore, for GI-2017-2 interconnection at Missile Site 230 kV POI, with no network upgrades (provided the planned P-DP project is in service):

NRIS = 150 MW
ERIS = 150 MW

## 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). 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.

[3] PSCo allows use of eight-hour facility rating for transformers for which it is available.

- Xcel Energy's OATT (Attachment N effective 10/14/2016) requires all 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 230 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 high side of the generator substation. Further, it is the responsibility of the Interconnection Customer to compensate their generation tie-line to ensure minimal reactive power flow under no load conditions.
- The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service 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-024-2.

## Short Circuit Analysis

The short circuit study results show that no circuit breakers in the Missile Site Substation (or located elsewhere in PSCo's system) will be over-dutied by interconnecting the proposed GI-2017-2 solar generation facility. The base case scenario before GI-2017-2 included preliminary models for all expected transmission system improvements projected through the end of 2019 (which includes P-DP project) and it also included preliminary modeling for the proposed GI-2016-3 generation project.

**GI-2017-2 Impact on Short Circuit Levels and Thevenin Impedances at Missile Site 230 kV POI**

| System Condition | Three-Phase (3-Ph) Fault Level (Amps) | Single-Line-to-Ground (SLG) Fault Level (Amps) | Thevenin System Equivalent Impedance (R + jX) (Ohms) |
|---|---|---|---|
| Before GI-2017-2 Y2019 | 19,872 | 18,574 | Z1(pos)= 0.459 +j 6.667<br>Z2(neg)= 0.478 +j 6.665<br>Z0(zero)= 0.949 +j 8.034 |

| System Condition | Three-Phase (3-Ph) Fault Level (Amps) | Single-Line-to-Ground (SLG) Fault Level (Amps) | Thevenin System Equivalent Impedance (R + jX) (Ohms) |
|---|---|---|---|
| After GI-2017-2 Y2019 | 20,017 | 19,160 | Z1(pos)= 0.459 +j 6.667<br>Z2(neg)= 0.478 +j 6.665<br>Z0(zero)= 0.875 +j 7.649 |

## Costs Estimates and Assumptions

PSCo Engineering has developed an Indicative Estimate (IE) for Transmission Provider Interconnection Facilities and Network Upgrades required for the proposed GI-2017-2 Interconnection. The cost estimates are in 2017 dollars with escalation and contingency applied (AFUDC is not included). Indicative Estimates are based upon typical construction costs for previously performed similar construction projects; however they have no specified level of accuracy. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new PSCo facilities. These estimates do not include the costs for any other Customer owned equipment and the associated design and engineering.
Error! Reference source not found. below represents a conceptual one-line of the proposed interconnection of GI-2017-2 generating facility in the Missile Site Substation 230 kV bus.

As shown in **Tables 1-3**, the total cost for the Transmission Provider Interconnection Facilities and Network Upgrades is **$1.803 million**. 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.

The estimated project duration is eighteen (18) months from receipt of the Customer's Notice to Proceed (NTP) to the Backfeed date.

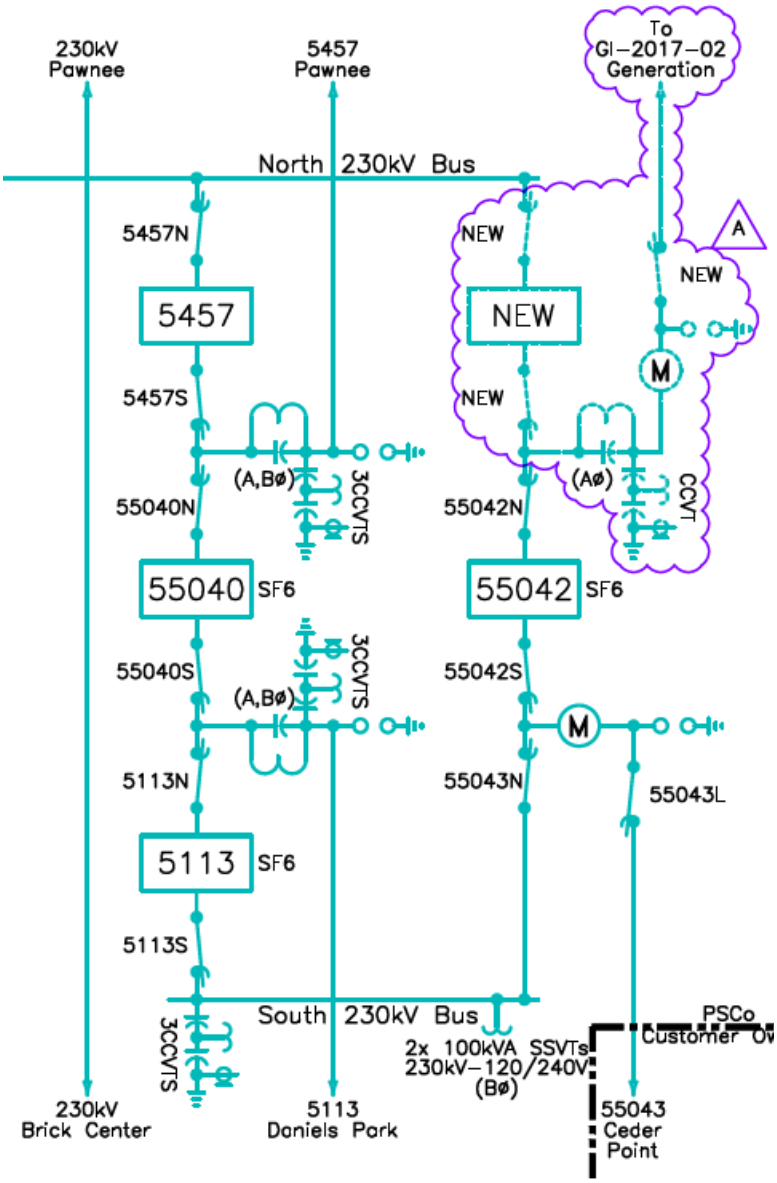


**Figure 2: GI-2017-2 Interconnection to 230 kV Bus in Missile Site Substation**

**Table 1 – PSCo Owned; Interconnection Customer Funded Transmission Provider Interconnection Facilities**

| Element | Description | Cost Est. (Millions) |
|---|---|---|
| **PSCo's Missile Site 230kV Transmission Sub Station** | Interconnect Customer to the Missile Site Sub 230kV bus.<br>The new equipment includes;<br>• One (1) motor operated 230kV disconnect switch<br>• Three (3) 230kV combination CT/PT metering units<br>• Power Quality Metering (230kV line from Customer)<br>• Three (3) surge arresters<br>• Two (2) relay panels<br>• Associated bus, wiring and equipment<br>• Associated foundations and structures<br>• Associated transmission line communications, relaying and testing | **$0.805** |
| | Transmission line tap into substation. Conductor, hardware, and installation labor. | **$0.050** |
| | **Total Cost Estimate for PSCo-Owned, Customer-Funded Transmission Provider Interconnection Facilities** | **$0.855** |
| **Time Frame** | **Design, procure and construct** | **18 Months** |

**Table 2 – PSCo Owned; PSCo Funded Network Upgrades for Interconnection**

| Element | Description | Cost Estimate (Millions) |
|---|---|---|
| **PSCo's Missile Site 230kV Transmission Sub Station** | Interconnect Customer to the Missile Site Sub 230kV bus.<br>The new equipment includes;<br>• One (1) 230kV circuit breaker<br>• Two (2) 230kV gang switches<br>• Associated communications, supervisory and SCADA equipment<br>• Associated line relaying and testing<br>• Associated bus, miscellaneous electrical equipment, cabling and wiring<br>• Associated foundations and structures<br>• Associated road and site development, fencing and grounding | **$0.863** |
| | Siting and Land Rights support for substation land acquisition and construction. | **$0.085** |
| | **Total Cost Estimate for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection** | **$0.948** |
| **Time Frame** | **Design, procure and construct** | **18 Months** |

**Table 3 – PSCo Owned; PSCo Funded Network Upgrades for Delivery**

| Element | Description | Cost Est. (Millions) |
|---|---|---|
| | None identified at this point | **N/A** |
| | **Total Cost Estimate for PSCo-Owned, PSCo-Funded Network Upgrades for Delivery** | **$0** |
| **Time Frame** | **Design, procure and construct** | **N/A** |

## Cost Estimate Assumptions:

- Indicative level project cost estimates (IE) for Interconnection Facilities and Network Upgrades 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.
- All substation construction can be accomplished within PSCo's existing property boundaries. No additional land is required.
- PSCo (or its 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 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 230 kV line terminating into Missile Site Substation.
- The Customer's 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.

# Appendix – Power Flow N-1 Contingency Analysis Results

**High Coincidence Generation Dispatch at Pawnee & Missile Site:**

**Pawnee 230kV (100% Coal + 90% Gas + 40% Wind) = 1018 MW;**
**Missile Site 345kV Wind = 480 MW (80%); Missile Site 230kV Wind = 200 MW (80%)**
**480 MW output from GI-2016-3 is dispatched to sink at Blue Spruce, Rocky Mountain Energy Center, & Comanche**
**150 MW output from GI-2017-2 is dispatched to sink at Rocky Mountain Energy Center & Comanche**

**Table A.1 – Differential Impact[4] of GI-2017-2 on Facility Loadings**
**With Pawnee – Daniels Park 345kV Project In-Service**

| | | | | Branch N-1 Loading Before 150 MW GI | | Branch N-1 Loading After 150 MW GI | | | |
|---|---|---|---|---|---|---|---|---|---|
| Monitored Facility (Line or Transformer) | Type | Owner | Summer Normal (Continuous) Facility Rating in MVA | Flow in MVA | Flow in % of Summer Normal Rating | Flow in MVA | Flow in % of Summer Normal Rating | Differential Impact of GI-2017-2 | N-1 Contingency Outage |
| Greenwood – Monaco 230 kV | Line | PSCo | 404 | 391 | 96.1% | 404.1 | 100% | 3.9% | Smoky Hill -- Leetsdale 230 kV |
| Leetsdale – Monaco 230 kV | Line | PSCo | 396 | 354 | 89.2% | 366.8 | 92% | 2.8% | Smoky Hill -- Leetsdale 230 kV |

[4] **Due to proposed 150 MW generation increase at Missile Site 230 kV Substation**