



Interconnection Feasibility Study Request # GI-2017-11

500 MW Solar Generating Facility
Interconnecting at
Missile Site 345 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning
September 28, 2017

Executive Summary

Public Service Company of Colorado (PSCo) received an Interconnection Request (IR) on March 7, 2017 which was assigned GI-2017-11 queue position. GI-2017-11 is a solar photovoltaic (PV) facility rated at 500 MW gross electrical output that will be located in Lincoln County, Colorado. GI-2017-11 would physically interconnect to a new switching station located on the Pronghorn – Rush Creek II 345 kV radial transmission line, which is a component of the “Gen-Tie” for the planned Rush Creek Wind Project (GI-2016-3). The Gen-Tie line is expected to be in service by August 2018. Although GI-2017-11 will physically interconnect to the Gen-Tie, the Point Of Interconnection (POI) for GI-2017-11 is the 345 kV bus within the Missile Site Substation, because Missile Site is the point at which power from the generating facility is delivered to the PSCo transmission system.

The proposed 500 MW generating facility is expected to consist of 250 SMA Sunny Central 2200-US inverters, one collector substation, and a short generator tie line. Preliminary information on the generating facility’s layout suggests that the inverters will be grouped together into one 576 MVA 34.5/345 kV Main Step-up Transformer (MST). The generating facility will connect through a 345 kV line to a new switching station approximately 14 circuit miles east of the Pronghorn Switching Station, and to the Missile Site POI through the 345 kV “Gen-Tie” for Rush Creek Wind Project.

The Commercial Operation Date (COD) requested for the generating facility is November 1, 2020. Based on the requested COD, the assumed back-feed date for the facility is May 1, 2020 (approximately six months before the COD).

Figure 1 below depicts the proposed POI for GI-2017-11 and the surrounding transmission system.

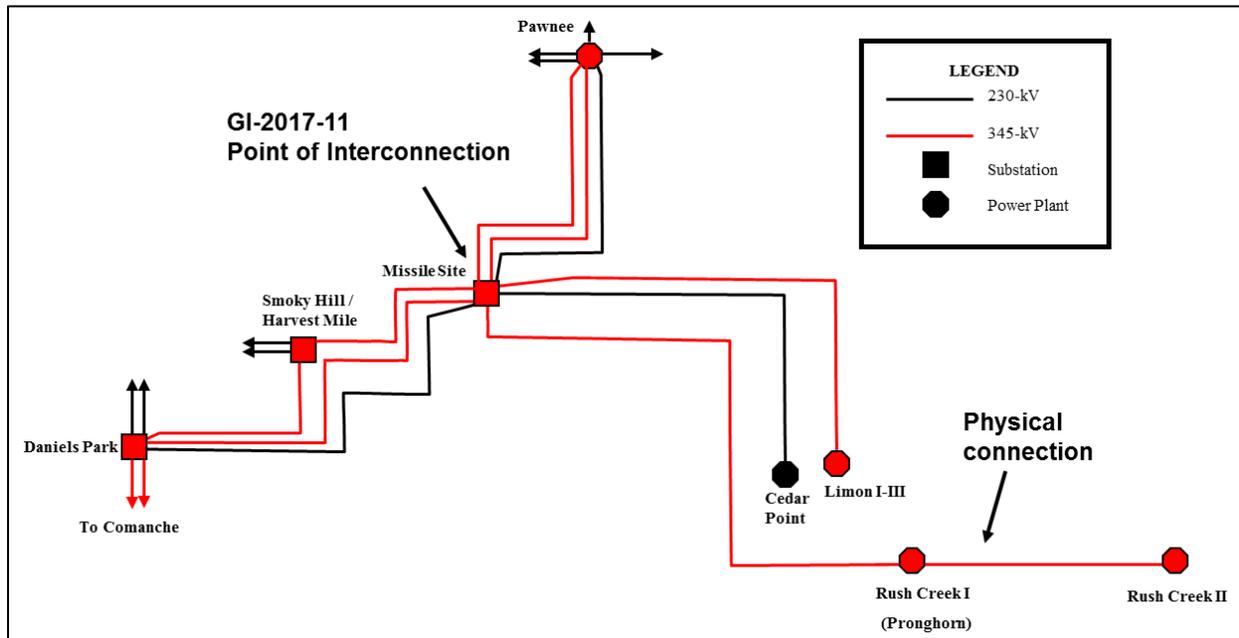


Figure 1: Missile Site and Surrounding Transmission System

The purpose of this Feasibility Study is to determine the feasibility of aggregate injection at the Missile Site 345 kV POI (for delivery to PSCo network loads) resulting from the 500 MW electrical output of the proposed GI-2017-11 in addition to the 600 MW electrical output of the planned Rush Creek Wind Project (GI-2016-3). Towards this purpose, this study also identifies the transmission improvements needed to enable delivery of the aggregate 1100 MW electrical output to PSCo network loads – that is, for GI-2017-11 to qualify as 500 MW network resource. As per the IR, GI-2017-11 is studied for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

The 500 MW electrical output of GI-2017-11 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-2017-11, 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-2017-11 interconnection (i.e. Before GI-2017-11 case).
- Study Case that also models the 500 MW output of the proposed GI-2017-11 interconnection (i.e. After GI-2017-11 case).



Studies for GI-2016-3 demonstrated that the Pawnee – Daniels Park (P-DP) 345 kV project¹ is the network upgrade needed to deliver the 600 MW output of GI-2016-3 to the PSCo system. Therefore, the P-DP project was included in the power flow and short-circuit models developed for GI-2017-11. The P-DP project is a PSCo planned transmission project for which the Colorado Public Utility Commission (CPUC) has approved a Certificate of Public Convenience and Necessity (CPCN) and has a target in-service date of October 31, 2019.

Power flow analysis performed for this Feasibility Study shows that the additional 500 MW generation injection into Missile Site Substation may cause a thermal overload of the Greenwood – Monaco 230 kV line following the loss of Smoky Hill – Leetsdale 230 kV line. The power flow analysis results are provided in Table A.1 in the Appendix (see page 15).

Short-circuit analysis performed for this Feasibility Study shows that the additional 500 MW generation injection into Missile Site Substation may result in four overdutied 230 kV circuit breakers at Daniels Park Substation.

Therefore, network upgrades are required for the proposed GI-2017-11 interconnection to achieve 500 MW NRIS². The network upgrades consist of replacing limiting equipment at Monaco substation to increase the thermal rating of the Greenwood – Monaco 230 kV line.

Consequently this Feasibility Study concludes that the GI-2017-11 interconnection qualifies for 500 MW NRIS and ERIS (in addition to the 600 MW NRIS of GI-2016-3) provided the P-DP project along with the identified Greenwood – Monaco 230 kV and Daniels Park circuit breaker network upgrades are in service.

Therefore, for GI-2017-11 interconnection:

NRIS (before network upgrades) = 0 MW

ERIS (before network upgrades) = 0 to 500 MW on “as-available” basis

NRIS and/or ERIS (after network upgrades) = 500 MW

As shown in **Tables 1–2**, (see pages 12-13) the cost for the Interconnection Facilities and the Network Upgrades for Delivery is **\$12.412 million** and includes:

- \$10.790 million for PSCo Interconnection Customer Owned; Non-affiliated, third-party Interconnection Customer Funded Interconnection Facilities
- \$1.622 million for PSCo Transmission Provider Owned; PSCo Transmission Provider Funded Network Upgrades for Delivery.

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*)



It is estimated that this work can be completed in approximately 36 months, following receipt of authorization to proceed. The schedule assumes a Certificate of Public Convenience and Necessity (CPCN) for the new 345 kV switching station on the Rush Creek Gen-Tie would be required.

No adverse impacts on the transmission systems of other entities are identified in the Feasibility Study. However, Tri-State Generation and Transmission Association (Tri-State) has requested to be included as an “affected party” for all IR’s with physical interconnections at or near the Rush Creek project, due to the proximity of their transmission system. Therefore, Tri-State is an affected party for GI-2017-11.



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) = 100% of rated capacity = 600 MW
- ✓ GI-2017-11 (Missile Site 345kV) = 100% of rated capacity = 500 MW

Aggregate Generation Dispatched at Missile Site in Benchmark Case = 1280 MW

Aggregate Generation Dispatched at Missile Site in Study Case(s) = 1780 MW

The GI-2017-11 *Benchmark Case* was derived from the 2021HS base case by changing the aggregate area generation dispatch at Pawnee and Missile Site to 1018 and 1280 MW as noted above. The previously proposed GI-2016-3 generating plant was added at the Missile Site 345kV bus and dispatched at 600 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-2017-11 *Study Case* was created by adding the proposed GI-2017-11 solar generating plant in the Benchmark Case and dispatching it at 500 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: $\leq 100\%$ Normal facility rating³

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: $\leq 5\%$ of pre-contingency voltage

P3-P7 – Multiple Contingencies:

Thermal Loading: $\leq 100\%$ Emergency facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: $\leq 5\%$ of pre-contingency voltage

As is evident from the power flow analysis results performed for this study, the additional 500 MW generation injection into Missile Site Substation has the potential to overload the Greenwood – Monaco 230 kV line following the loss of the Smoky Hill – Leetsdale 230 kV line. Results are shown in the power flow analysis results provided in Table A.1 in the Appendix. Therefore, power flow network upgrades are required for the proposed GI-2017-11 interconnection to achieve 500 MW NRIS⁴. The network upgrade consists of replacing limiting substation equipment to increase the thermal rating of the Greenwood – Monaco 230 kV line.

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

⁴ 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](#))



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.
- 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. Accordingly, for GI-2017-11, the 0.95 lag – 0.95 lead dynamic reactive power is measured at the metered interface between the Generating Facility and the Interconnection Facilities of the GI Customer – that is, at the metering location shown in the conceptual one-line in Figure 2. 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 zero reactive power flow under no load conditions (i.e. all or most generators off-line).
- 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 four 230 kV circuit breakers at Daniels Park Substation will be over-dutied by interconnecting the proposed GI-2017-11 solar generation facility. The base case scenario before GI-2017-11 included preliminary models for all planned transmission system improvements and resource additions projected through the end of 2020 – hence the short circuit study case includes the P-DP transmission project and the Rush Creek (GI-2016-3) wind generation project. Replacement of the four over-dutied breakers at Daniels Park is included in the Network Upgrades for Delivery required for GI-2017-11 to qualify as NRIS.

GI-2017-11 Impact on Short Circuit Levels and Thevenin Impedances at Missile Site 345 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-2017-11 Y2020	17,574	14,257	Z1(pos)= 0.833 +j 11.304 Z2(neg)= 0.876 +j 11.299 Z0(zero)= 3.850 +j 18.942
After GI-2017-11 Y2020	18,211	15,100	Z1(pos)= 0.828 +j 10.907 Z2(neg)= 0.868 +j 10.902 Z0(zero)= 3.635 +j 17.403



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-2017-11 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.

Figure 2 below represents a conceptual one-line of the proposed interconnection of GI-2017-11 generating facility in the Missile Site Substation 345 kV bus.

Figure 3 shows the substation layout of the physical interconnection at the new switching station.

As shown in **Tables 1-2**, the total cost for the Transmission Provider Interconnection Facilities and Network Upgrades is **\$12.415 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 thirty six (36) months from receipt of the Customer's Notice to Proceed (NTP) to the Backfeed date. The schedule assumes a Certificate of Public Convenience and Necessity (CPCN) for the new 345 kV switching station on the Rush Creek Gen-Tie would be required.

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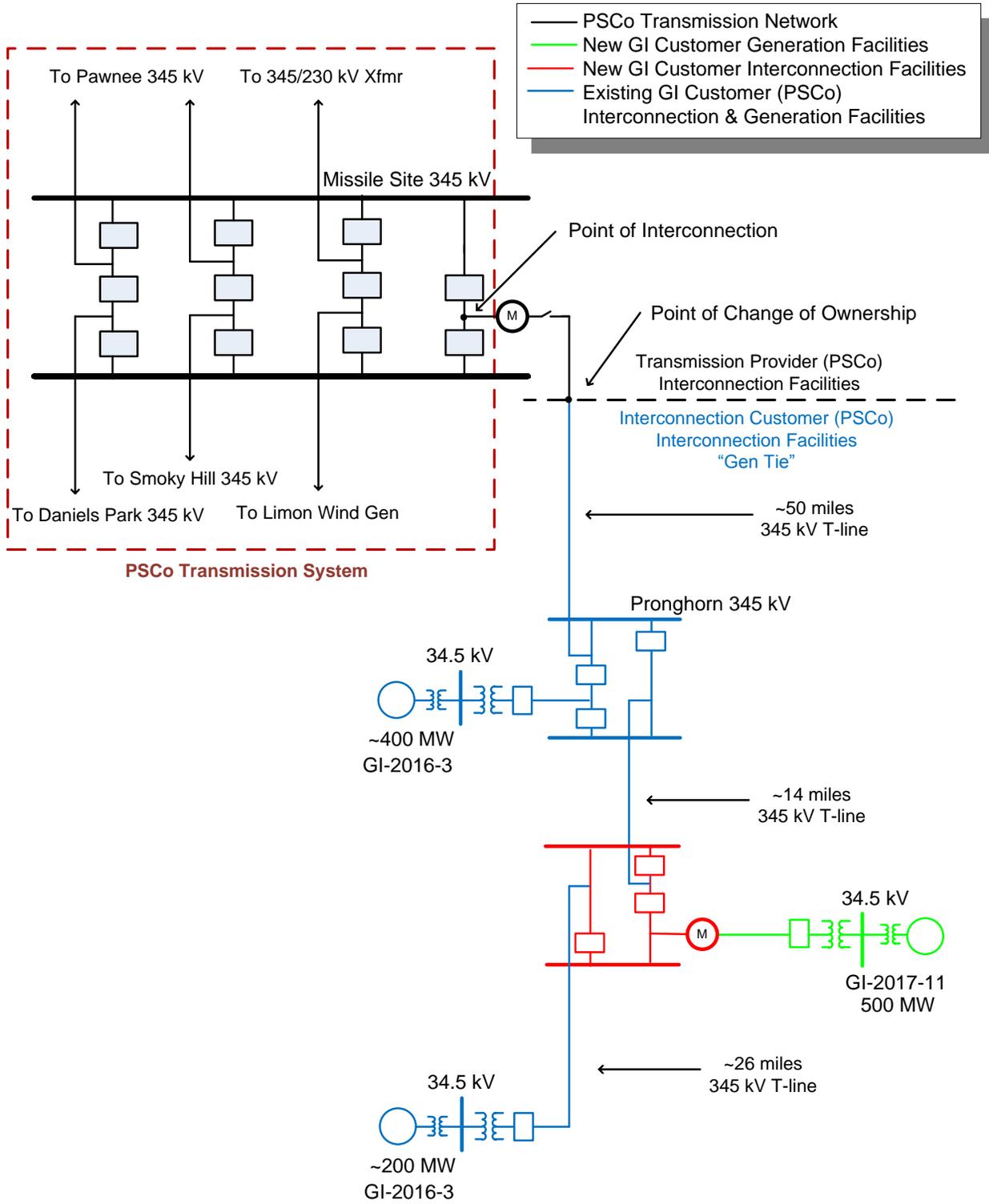


Figure 2: GI-2017-11 Interconnection to 345 kV Bus in Missile Site Substation

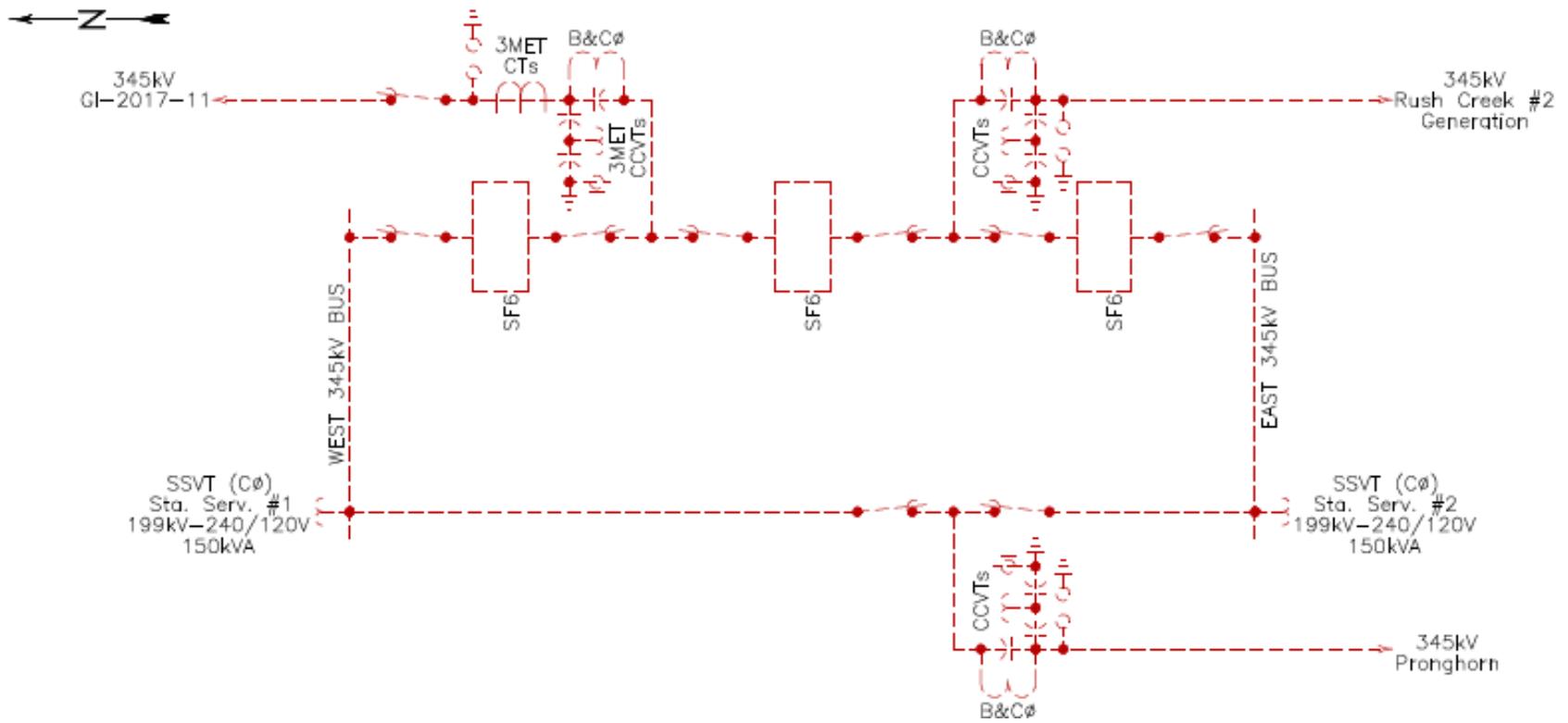


Figure 3: GI-2017-11 Physical Interconnection to the Gen-Tie

Table 1 – PSCo Interconnection Customer Owned; Non-affiliated, third-party Interconnection Customer Funded Interconnection Facilities⁵

Element	Description	Cost Estimate (Millions)
PSCo's new 345kV Switching Station	Interconnect Customer to the proposed switching station tapping the Missile Site-Rush Creek 345 kV gen-tie line. The new equipment includes: <ul style="list-style-type: none"> • Three (3) 230kV circuit breaker • Eight (8) 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 	\$9.400
PSCo's new 345kV Switching Station Expansion	Interconnect Customer to the proposed switching station tapping the Missile Site-Rush Creek 345 kV gen-tie line. The new equipment includes: <ul style="list-style-type: none"> • Three (3) 230kV circuit breaker • Eight (8) 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 • Transmission line tap into substation 	\$1.055
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction.	\$0.335
	Total Cost Estimate for PSCo Interconnection Customer Owned; Non-affiliated, third-party Interconnection Customer Funded Interconnection Facilities	\$10.790
Time Frame	Regulatory, site, design, procure and construct	36 Months

⁵ Consistent with Part VII, Section 46.1 *Interconnection to the PSCo Transmission System through the Rush Creek Generator Tie Line ("Gen-Tie")* within Xcel Energy's revised OATT filed for approval.

Table 2 – PSCo Transmission Provider Owned; PSCo Transmission Provider Funded Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
PSCo's Monaco 230kV Transmission Substation	Upgrade/replace limiting substation equipment to achieve required MVA ratings on circuit 5281 Monaco-Greenwood OH/UG Line: <ul style="list-style-type: none"> Six - 1272 dual jumpers 	\$0.022
PSCo's Daniels Park 230kV Substation	Update circuit breakers. The new equipment includes: <ul style="list-style-type: none"> Four (4) 230kV circuit breakers Associated bus, wiring and equipment Associated foundations and structures Associated transmission line communications, relaying and testing 	\$1.600
	Total Cost Estimate for PSCo Network Upgrades for Delivery Facilities	\$1.622
Time Frame	Design, procure and construct	18 months

Cost Estimate Assumptions:

- Indicative level project cost estimates for Interconnection Facilities and Infrastructure Upgrades for Delivery, PSCo Funded Network Upgrades for Delivery (with no level of accuracy) were developed by PSCo Engineering
- Estimates are based on 2016 and similar type projects.
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Generation Facility is not in the PSCo retail service territory. Therefore, no costs for retail load (distribution) facilities and metering required for station service are included in these estimates.
- Assuming the substation land acquisition (40 acres) planned for Xcel's project will be sufficient for this project substation expansion and build-out. No additional land required.
- Assuming a 3-breaker ring installation with required relaying, interconnection and communications facilities.
- PSCo (or our Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo-owned and maintained facilities.
- Assuming a CPCN will be required. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection and network delivery facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.



- 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.
- Customer will string OPGW fiber into substation (Rush Creek II) as part of the transmission line construction scope.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.

Conclusion

The power flow and short circuit analysis performed for this Feasibility Study shows that the additional 500 MW generation injection into Missile Site Substation may cause a thermal overload of the Greenwood – Monaco 230 kV line following the loss of Smoky Hill – Leetsdale 230 kV line as well as overduty four 230 kV circuit breakers at Daniels Park substation.

Therefore, for GI-2017-11 interconnection:

NRIS (before network upgrades) = 0 MW

ERIS (before network upgrades) = 0 to 500 MW on “as-available” basis

NRIS and/or ERIS (after network upgrades) = 500 MW

The estimated total cost for the required upgrades for the interconnection is \$12.412 million. It is estimated that this work can be completed in approximately 36 months, following receipt of authorization to proceed. The schedule assumes a Certificate of Public Convenience and Necessity (CPCN) for the new 345 kV switching station on the Rush Creek Gen-Tie would be required.

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%)

600 MW output from GI-2016-3 is dispatched to sink at Blue Spruce, Rocky Mountain Energy Center, & Comanche

500 MW output from GI-2017-11 is dispatched to sink at Spindle, Rocky Mountain Energy Center & Comanche

**Table A.1 – Differential Impact⁶ of GI-2017-11 on Facility Loadings
With Pawnee – Daniels Park 345kV Project In-Service**

				Branch N-1 Loading Before 500 MW GI		Branch N-1 Loading After 500 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-2017-11	N-1 Contingency Outage
Greenwood – Monaco 230 kV	Line	PSCo	404	404	100%	464.6	115%	15%	Smoky Hill -- Leetsdale 230 kV

⁶ Due to proposed 500 MW generation increase at Missile Site 345 kV Substation