



Interconnection Feasibility Study Report
Request # GI-2016-6
Final Report

600 MW Wind Generating Facility
Missile Site 230 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning
August 5, 2016

Executive Summary

Public Service Company of Colorado (PSCo) received an Interconnection Request (IR) on April 25, 2016 which was assigned GI-2016-6 queue position. GI-2016-6 is a wind generating facility rated at 600 MW gross electrical output that will be located in Elbert, Lincoln and Kit Carson Counties in Colorado. The point of interconnection (POI) requested for GI-2016-6 is the 230 kV bus within the PSCo Missile Site Substation.

The proposed 600 MW generating facility is expected to consist of approximately 300 wind turbine generators (WTG), where each WTG is rated ~2.0 MW and is equipped with a 0.69/34.5 kV step-up transformer. Preliminary information on the wind generating facility's layout suggests that the 300 WTG's will be grouped together into three or four 34.5 kV collector systems, and each 34.5 kV collector system will connect to a 34.5/230 kV main step-up transformer (MST). The three or four MST's will be connected to the POI using a customer-owned approximately 85 miles, 230 kV radial transmission line.

The commercial operation date (COD) requested for the generating facility is December 31, 2018 and the requested back-feed date is August 1, 2018. The IR indicated that this Feasibility Study should include studies for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

The main purpose of this Feasibility Study is to determine the feasibility of interconnecting 600 MW of generation at the Missile Site 230 kV POI for delivery to PSCo network loads. Towards this purpose, the study also identifies the transmission improvements needed to enable delivery of the rated 600 MW output of GI-2016-6 to the PSCo network load for NRIS.

The Feasibility Study consisted of steady state (power flow) and short-circuit analyses. The power flow analyses were performed using a 2021 heavy summer (2021HS) base case. Three power flow models were created from the 2021HS case – a Benchmark Case which models the planned transmission system topology before the proposed GI-2016-6 interconnection (i.e. Before GI-2016-6 case), one Study Case that includes the 600 MW generation under study (i.e. After GI-2016-6 case), and another Study Case



that also includes the network upgrades identified to qualify GI-2016-6 as NRIS (i.e. After GI-2016-6 plus network upgrades case).

The power flow analysis results provided in Table A.1 in the Appendix identified the following thermal constraints for the additional 600 MW injection:

- (a) The 345/230 kV transformation capacity at Missile Site substation due to single contingency outage of Missile Site – Daniels Park 230 kV line;
- (b) The 345/230 kV transformation capacity at Smoky Hill substation due to single contingency outage of any one of the two 345/230 kV auto-transformers;
- (c) The Missile Site – Daniels Park 230 kV line for the single contingency outage of Missile Site – Smoky Hill 345kV line; and
- (d) The Clark – Jordan 230 kV underground line for several single contingencies, with the worst overload resulting from the single contingency outage of the Smoky Hill – Tollgate – Leetsdale 230 kV line.

The Pawnee – Daniels Park 345 kV project¹ is a PSCo planned project for which the Colorado Public Utility Commission (CPUC) has approved a Certificate of Public Convenience and Necessity (CPCN) that includes an in-service date of May 2022. The Company has requested that the in-service date be moved up to October 2019. This request is being considered as part of the Rush Creek Wind Project currently before the Colorado Public Utilities Commission. Therefore, this Feasibility Study evaluated the effectiveness of the planned Pawnee – Daniels Park 345 kV (P-DP) project in mitigating the thermal overloads due to the proposed 600 MW interconnection. Three thermal overloads – see (b), (c), (d) above – are mitigated by the aggregate impact of transmission improvements comprising the planned P–DP project. The only remaining thermal overload (a) is mitigated by the proposed addition of a second auto-transformer at Missile Site. The effectiveness of these planned and proposed network upgrades is evident from the power flow analysis results provided in Table A.2 in the Appendix.

The Pawnee – Daniels Park (P-DP) project alleviates the 345/230 kV transformation capacity constraint at Smoky Hill because it includes installing a 345/230 kV, 560 MVA auto-transformer at a new Harvest Mile substation, which is electrically the same as adding a third auto-transformer at Smoky Hill. Further, the Smoky Hill (Harvest Mile) – Daniels Park 345 kV line comprised in the P–DP project helps eliminate the thermal overload on the Clark – Jordan 230 kV line by redirecting a significant amount of power into Daniels Park from Smoky Hill. Also, the Missile Site – Daniels Park 345 kV line within the P–DP project provides a new parallel path from Missile Site to Daniels Park. The proposed installation of a second 345/230 kV, 560 MVA auto-transformer alleviates the transformation capacity constraint occurring at Missile Site substation. Hence these planned and proposed projects comprise the network upgrade(s) for delivery of the 600 MW rated output GI-2016-6.

The short circuit analysis results based on the 2017-18 transmission topology did not identify the need for any network upgrades for the proposed GI-2016-6 interconnection.

¹ More information at: <http://www.transmission.xcelenergy.com/Projects/Colorado>



Consequently this Feasibility Study concludes that the GI-2016-6 interconnection would not achieve 600 MW NRIS[^] until the planned Pawnee – Daniels Park 345 kV project and the proposed Missile Site second auto-transformer project are placed in service. As noted in the 2016 project update², advancing the in-service date to October 2019 for Pawnee – Daniels Park Project is intended by petitioning the CPUC to modify their previous decision.

Prior to the planned and proposed network upgrades being placed in-service, GI-2016-6 may be interconnected as ERIS^{*} to deliver its output using the existing firm or non-firm transmission capacity on an “as available” basis.

Therefore, for GI-2016-6 interconnection:

NRIS (before network upgrades) = 0 MW

NRIS (after network upgrades) = 600 MW

ERIS (before network upgrades) = 0 to 600 MW on “as-available” basis

Tables 1 and 2 provide the cost estimates for the Transmission Provider Interconnection Facilities. The estimated total cost for the required Interconnection Facilities is **\$6.387M** (of which \$2.534M is Interconnection Customer Funded and \$3.853M is Transmission Provider Funded).

Table 3 provides the cost estimates for the Network Upgrades for Delivery. The estimated total cost for the planned Pawnee – Daniels Park project is **\$178.3M**.

However, the estimated cost for the proposed second auto-transformer project at Missile Site is TBD (to be determined).

**Total Estimated Cost for Interconnecting GI-2016-6 as NRIS =
~\$184.7M + TBD cost of second Missile Site auto-transformer**

Total Estimated Cost for Interconnecting GI-2016-6 as ERIS = ~\$6.4M

[^] 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*)

² More information at:

<http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Projects/CO/Pawnee-Daniels/CO-Transmission-Pawnee-Daniels-March-2016-Project-Update.pdf>

^{*} 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. (*section 3.2.1 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-2016-6 (Missile Site 230kV) = 100% of rated capacity = 600 MW

Aggregate Generation Dispatched at Missile Site in Benchmark Case = 680 MW

Aggregate Generation Dispatched at Missile Site in Study Case(s) = 1280 MW

The GI-2016-6 *Benchmark Case* was derived from the 2021HS base case by changing the generation dispatch at Pawnee and Missile Site as noted above. Also, transmission facilities comprising the Pawnee –Daniels Park project modeled in the 2021HS case were removed in the Benchmark Case.

Two GI-2016-6 *Study Cases* were created -- without and with the network upgrades. The GI-2016-6 *Study Case without network upgrades* was created by adding the GI-2016-6 generating plant at Missile Site 230kV bus into the Benchmark Case and dispatching it at 600 MW rated output. The GI-2016-6 *Study Case with network upgrades* was created by adding the Pawnee –Daniels Park Project’s transmission facilities to the previous case.

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 (N-0) 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 0.90 – 1.05 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 rating is the seasonal continuous rating of the transmission facility – but PSCo allows use of eight-hour facility rating for 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.

Based on the results of the steady-state power flow analyses on the Benchmark and Study Cases provided in Table A.1 in the Appendix, it is evident that injecting 600 MW at Missile Site 230 kV bus results in heavy N-1 post-contingency thermal overloads on the Missile Site 345/230 kV auto-transformer, the Smoky Hill 345/230 kV auto-transformers, the Missile Site – Daniels Park 230 kV overhead line, and the Clark – Jordan 230 kV underground line.

Without any transmission improvements (i.e. network upgrades) to mitigate these four thermal constraints – that is, by only utilizing the existing capability of PSCo’s transmission system – the GI-2016-6 interconnection qualifies for NRIS at 0 MW and for ERIS within the 0–600 MW output range based on the “as available” firm or non-firm capacity of the existing transmission system.

The effectiveness of the planned Pawnee – Daniels Park 345 kV (P-DP) project in mitigating the thermal overloads resulting from the 600 MW injection of the GI-2016-6 interconnection was evaluated. Three thermal overloads are mitigated by the aggregate impact of transmission improvements comprising the planned P–DP project. The only remaining thermal overload is mitigated by the proposed addition of a second auto-transformer at Missile Site. The power flow analysis results provided in Table A.2 in the Appendix demonstrate that the GI-2016-6 interconnection will achieve NRIS for its rated 600 MW output after the planned and proposed network upgrades are placed in service.

Therefore, for GI-2016-6 interconnection:

NRIS (before network upgrades) = 0 MW

NRIS (after network upgrades) = 600 MW

ERIS (before network upgrades) = 0 to 600 MW on “as-available” basis

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 requires all Interconnection Customers to have the reactive capability to achieve +/- 0.95 power factor at the POI, with the maximum reactive capability (corresponding to rated output) available at all output levels. Furthermore, Xcel Energy requires all Generating Facilities to have dynamic voltage control capability and maintain the POI voltage specified by the Transmission Operator as long as the generating plant is on-line, producing power and it is not called upon to operate outside its 0.95 lag – 0.95 lead power factor range capability at the POI.
- 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 POI. Further, for wind generating plants to meet the LVRT (Low Voltage Ride Through) performance requirements specified in FERC Order 661-A, an appropriately sized and located dynamic reactive power device (DVAR, SVC, etc.) may also need to be installed within the generating plant.
- 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).

Short Circuit Analysis

The short circuit study results show that no circuit breakers in the Missile Site station (or any adjoining station) will be over-dutied by interconnecting the proposed GI-2016-6 wind generation facility.

GI-2016-6 Impact on Short Circuit Levels and Breaker Duty Margins at Missile Site 230 kV POI

System Condition	Three-Phase (3-Ph) Fault Level (Amps)	Single-Line-to-Ground (SLG) Fault Level (Amps)	Breaker Duty Margin for 3-Ph Fault	Breaker Duty Margin for SLG Fault
Before GI-2016-6 Y2017-18	13,814	11,880	64.3 %	69.7%
After GI-2016-6 Y2017-18	15,314	13,380	60.5 %	65.9%



Costs Estimates and Assumptions

Scoping level cost estimates (+/- 30% accuracy) for the Transmission Provider Interconnection Facilities and Network Upgrades for Delivery were developed by PSCo Engineering.

Tables 1–3 below list the transmission improvements needed to accommodate the interconnection and delivery of GI-2016-6 generation output as NRIS. The estimated total cost for the Interconnection Facilities is **\$6.387M** (of which \$2.534M Interconnection is Customer Funded and \$3.853M PSCo is Transmission Provider Funded) and for the Network Upgrades for Delivery is **\$178.3M plus TBD cost of second Missile Site auto-transformer**. The transmission improvements are subject to change upon a more detailed and refined design.

Figure 1 below represents a conceptual one-line diagram of the proposed interconnection at Missile Site Station 230 kV bus.

GI-2016-6 INTERCONNECTION TO MISSILE SITE 230KV

TP1F: TRANSMISSION PROVIDER INTERCONNECTION FACILITIES.



TP1F - PSCD TRANSMISSION FUNDED
INSTALL BREAKERS AND SWITCHES NEEDED FOR NEW
230KV LINE TO GI-2016-6



TP1F - INTERCONNECTION CUSTOMER FUNDED
INSTALL NEW 230KV LINE TERMINAL TO GI-2016-6
INSTALL NEW 150MVAR CAP BANK.

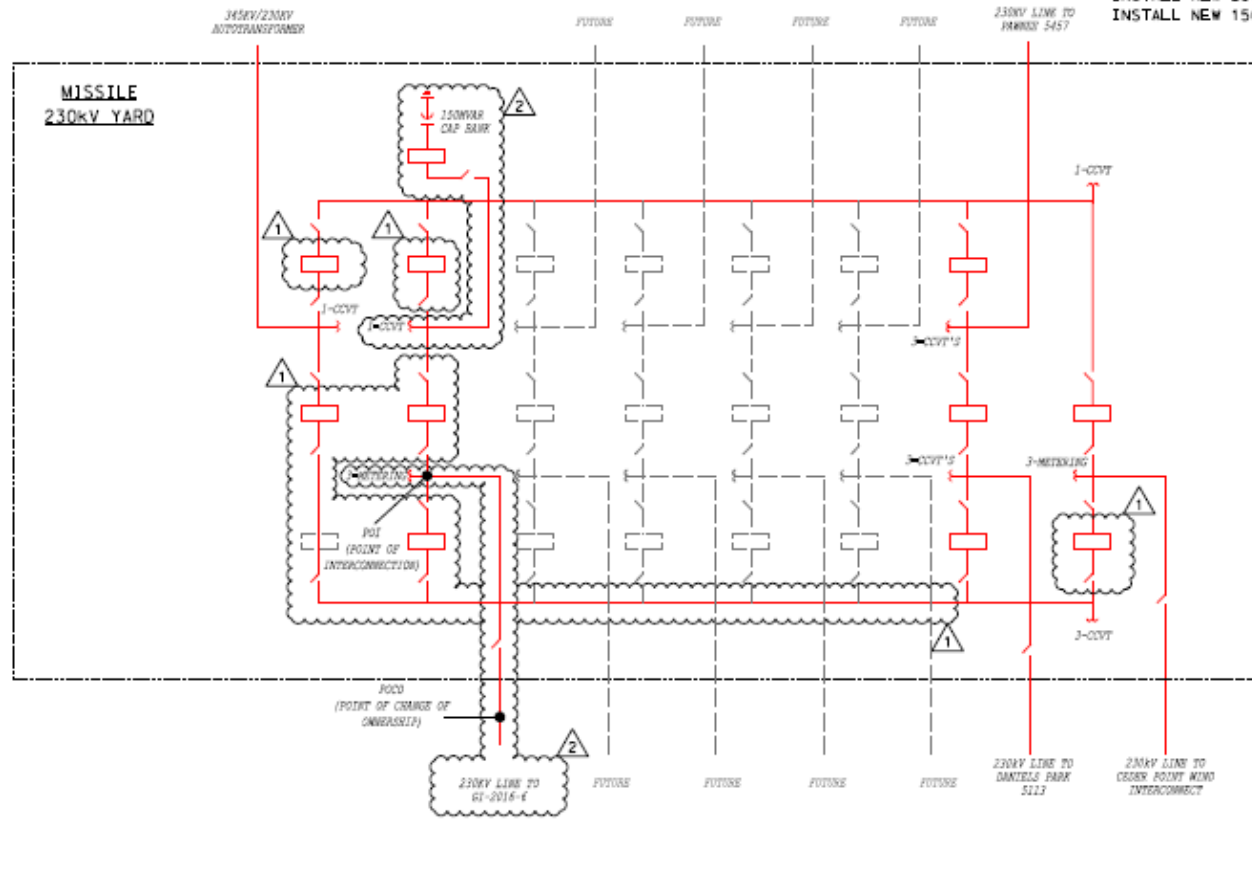


Figure 1 GI-2016-6 Interconnection to 230kV Bus in Missile Site Substation

**Table 1: Transmission Provider’s Interconnection Facilities –
Interconnection Customer Funded**

Element	Description	Cost Est. (Millions)
PSCo’s Missile Site 230 kV Transmission Substation	Interconnect Customer to the 230kV bus at the Missile Site Substation. The new equipment includes: <ul style="list-style-type: none"> • One 230kV, 3000 amp IPO circuit breaker • One 230kV, 150MVAR shunt capacitor bank • Two 230kV, 3000 amp gang switches • Three 230kV Combo PT/CT metering units • Six 230kV lightning arresters • Primary metering for Load Frequency/Automated Generation Control • Power Quality Metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing 	\$2.339
	Transmission line tap from Customer’s last line structure outside of PSCo’s yard into new bay position (assumed 300’ span, conductor, hardware and labor).	\$0.075
Customer’s 230 kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment.	\$0.120
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$2.534
Time Frame	Site, design, procure and construct	24 Months

**Table 2: Transmission Provider’s Interconnection Facilities –
PSCo Transmission Funded**

Element	Description	Cost Estimate (Millions)
PSCo’s Missile Site 230 kV Transmission Substation	Interconnect Customer to the 230kV bus at the Missile Site Substation. The new equipment includes: <ul style="list-style-type: none"> • Six 230kV, 3000 amp circuit breakers • Eight 230kV, 3000 amp gang switches • Associated station controls, communications, supervisory and SCADA equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated equipment and system testing 	\$3.853
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	\$3.853
Time Frame	Site, design, procure and construct	24 months

Table 3: PSCo Network Upgrades for Delivery

Element	Sub Cost (Millions)	Cost Est. (Millions)
Siting and Land Rights Permitting / Acquisition		\$ 7.0
Pawnee –Daniels Park 345kV Line Costs		\$118.5
Pawnee – Missile Site – Harvest Mile – Daniels Park 345kV Transmission Line		
Substation Costs for Pawnee –Daniels Park 345kV Project		\$ 52.8
Pawnee Substaton	\$ 5.8	
Missile Site Substaton	\$ 7.0	
Harvest Mile Substation	\$27.7	
Smoky Hill Substation	\$ 5.4	
Daniels Park Substation	\$ 6.9	
Cost Estimate for Planned Network Upgrades (Pawnee – Daniels Park 345kV Project)		\$178.3
Cost Estimate for Proposed Network Upgrade (Second 345/230kV transformer at Missile Site Substation)		TBD
Install Missile Site 345/230kV Auto-Transformer #2	TBD	
Time Frame to site, design, procure and construct		54 months
Total Cost Estimate for Planned & Proposed Network Upgrades for Delivery		\$178.3 + TBD

Cost Estimate Assumptions

- Scoping level project cost estimates for Interconnection Facilities and Network Upgrades for Delivery (+/- 30% accuracy) were developed by PSCo Engineering.
- Estimates are based on 2016 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 estimated time to site, design, procure and construct the Interconnection Facilities is approximately 24 months after authorization to proceed has been obtained.
- A CPCN will be required for the construction of Interconnection Facilities.
- No new substation land will need to be acquired.



- The estimated time to site, design, procure and construct the Network Upgrades for Delivery is approximately 36 months after authorization to proceed has been obtained.
- The 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.
- Xcel Energy (or its Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo Transmission owned and maintained facilities.

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-2016-6 is dispatched to sink at Spindle (268 MW), Ft St Vrain (264 MW) & Ft Lupton (50 MW)

Table A.1 – Differential Impact³ of GI-2016-6 on Facility Loadings Without Network Upgrades

Monitored Facility (Line or Transformer)	Type	Owner	Summer Normal (Continuous / 8-hour) Facility Rating in MVA	Branch N-1 Loading Before 600 MW GI		Branch N-1 Loading After 600 MW GI		Differential Impact of GI-2016-6	N-1 Contingency Outage
				Flow in MVA	Flow in % of Summer Normal Rating	Flow in MVA	Flow in % of Summer Normal Rating		
Smoky Hill 345/230 kV # T4/T5	Xfmr	PSCo	560 / 644	637.5	99.0%	832.0	129.2%	+30.2%	Smoky Hill 345/230 kV # T5/T4
Missile Site 345/230 kV # T1	Xfmr	PSCo	560 / 644	255.1	39.6%	681.6	105.8%	+66.2%	Missile Site – Daniels Park 230kV
Missile Site – Daniels Park 230kV	Line	PSCo	741	598.0	80.5%	854.9	114.2%	+33.7%	Missile Site – Smoky Hill 345 kV
Clark – Jordan 230 kV	Line	PSCo	331	310.5	94.1%	343.6	104.2%	+10.1%	Smoky Hill -- Leetsdale 230 kV

Table A.2 – After GI-2016-6 with Planned Pawnee – Daniels Park 345kV Project as Network Upgrade

Monitored Facility (Line or Transformer)	Type	Owner	Summer Normal (Continuous / 8-hour) Facility Rating in MVA	Branch N-1 Loading After 600 MW GI			N-1 Contingency Outage
				Flow in MVA	Flow in % of Summer Normal Rating	% Flow Reduction	
Smoky Hill 230/345 kV # T4/T5	Xfmr	PSCo	560 / 644	373.8	58.0%	-71.2%	Smoky Hill 230/345 kV # T5/T4
Missile Site 345/230 kV # T1	Xfmr	PSCo	560 / 644	725.8	112.7% [♣]	+6.9%	Missile Site – Daniels Park 230kV
Missile Site – Daniels Park 230kV	Line	PSCo	741	556.0	73.6%	-40.6%	Missile Site – Smoky Hill 345 kV
Clark – Jordan 230 kV	Line	PSCo	331	259.5	78.0%	-26.2%	Smoky Hill -- Leetsdale 230 kV

♣ Mitigated by the installing a second auto-transformer in parallel as an additional network upgrade

³ Due to proposed 600 MW generation increase at Missile Site 230 kV Station