Interconnection System Impact Study Report

Generator Interconnection Request
GI-2016-6

600 MW Wind Generating Facility
Interconnecting to the
Missile Site 230kV Substation

Xcel Energy – Public Service Company of Colorado (PSCo)
September 17, 2018

Executive Summary

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 Public Service Company of Colorado's (PSCo) Missile Site Substation. The commercial operation date (COD) requested for GI-2016-6 is December 31, 2018 and the requested back-feed date is August 1, 2018.

In accordance with the Interconnection Request, GI-2016-6 was studied for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS). For both ERIS and NRIS evaluation, the 600 MW rated output of GI-2016-6 is assumed to be delivered to PSCo network load, so existing PSCo generation is used as its sink.

The power flow analysis determined two thermal constraints in the PSCo transmission system due to the injection from GI-2016-6 – therefore, the associated network upgrades required for mitigation are identified. The transient stability analysis determined that all generating units remain stable (in synchronism), have positive damping and satisfy acceptable dynamic performance criteria after the GI-2016-6 interconnection. The short-circuit and breaker duty analysis determined that one circuit breaker replacement is needed at PSCo's Midway station.

The estimated costs of the recommended system improvements to interconnect the GI-2016-6 project include:

- $ 0.774 million for Transmission Provider's Interconnection Facilities
- $ 3.743 million for Network Upgrades required for Interconnection (either ERIS or NRIS)
- $ 43.838 million for additional Network Upgrades for NRIS

The total estimated cost of the transmission system improvements required for GI-2016-6 to qualify for:

- **ERIS is $4.517 Million (Tables 1 and 2); and**
- **NRIS is $48.355 Million (Tables 1, 2 and 3)**

This is contingent upon completion of the Network Upgrades identified for all applicable higher-queued Interconnection Requests (see footnotes to Table 2 and 3).

For GI-2016-6 interconnection:

NRIS (after required transmission system improvements) = 600 MW

ERIS (after required transmission system improvements) = 600 MW (output delivery assumes the use of existing firm or non-firm capacity of the PSCo Transmission System on an as-available basis.)

Note: NRIS or ERIS, in and of itself, does not convey transmission service.

Introduction

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 Public Service Company of Colorado's (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 main purpose of this Interconnection System Impact Study is to determine the system impact of interconnecting 600 MW of generation at the Missile Site 230 kV POI. As per the Interconnection Request, GI-2016-6 was studied for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS). For both ERIS and NRIS evaluation, the 600 MW rated output of GI-2016-6 is assumed to be delivered to PSCo network load, so existing PSCo generation is used as its sink.

Study Scope and Analysis Criteria

The scope of this report includes steady state (power flow) analysis, transient stability analysis, short circuit analysis and scoping level cost estimates. The power flow analysis identifies thermal and voltage violations in the PSCo transmission system and the Affected Systems as a result of the GI-2016-6 interconnection. The transient stability analysis verifies that all generating units within PSCo transmission system and the Affected Systems remain stable (in synchronism), have positive damping and satisfy acceptable dynamic performance criteria. The short circuit analysis determines the maximum available fault current at the POI and identifies the circuit-breaker(s) within PSCo station(s) that would exceed their breaker duty rating and hence need to be replaced.

PSCo adheres to applicable NERC Reliability Standards & Western Electricity Coordinating Council (WECC) Reliability Criteria, as well as its internal transmission planning criteria for system studies.

The steady state analysis criteria are as follows:
P0 - System Intact conditions:
Thermal Loading: <=100% of the normal facility rating
Voltage range: 0.95 to 1.05 per unit

P1-P2 – Single Contingencies:

Thermal Loading:	<=100% Normal facility rating
Voltage range:	0.90 to 1.10 per unit
Voltage deviation:	<=5% of pre-contingency voltage

Transient stability criteria require that all generating machines remain in synchronism and all power swings should be well damped following a contingency event. Also, transient voltage performance should meet the following WECC Disturbance-Performance criteria:

- Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds for all contingencies
- For all contingencies, following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.
- For contingencies without a fault, voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds

Cumulative Power Flow Analysis (including all higher-queued generation)

The power flow analysis was performed using the Western Electricity Coordinating Council (WECC) 2023HS (heavy summer) base case having Area 70 (PSC) load at ~8700 MW, of which ~7350 MW is the PSCo obligation/native load. The base case includes all (i.e. existing and planned) generation resources and transmission facilities expected to be in-service in Y2023.

The cumulative study case for GI-2016-6 was developed starting from the 2023HS base case by using a top down (sequential) cumulative approach to add all higher-queued generation in the PSCo GIR queue, along with associated network upgrades.

Following steps comprised developing the cumulative study case:

- The first NRIS GIR (i.e. Project 1) in the queue was added to the 2023HS base case and its rated MW output was dispatched by decrementing the MW output of generation that is PSCo's existing/planned designated network resource. A valid power flow solution was obtained for the resulting "cumulative GIR-1" case.
- The above step was repeated for the next GIR in the queue to create the "cumulative GIR-2" case.
- The cumulative study case for GI-2016-6 is the final outcome of repeating the above for each of the higher-queued GIR's requesting NRIS, up to and including GI-2016-6.

The resulting cumulative study case for GI-2016-6 consisted of 1533 MW aggregate new generation that was dispatched to sink within the PSCO Balancing Area – this was accomplished

by decrementing the MW output of existing PSCo generating units by curtailing and/or decommitting them. The cumulative GI-2016-6 study case was then used to determine the thermal constraints attributable to GI-2016-6 under System Intact (N-0) conditions, and thus identify the network upgrades required for GI-2016-6 to qualify as NRIS. This determination is contingent upon all network upgrades for the higher-queued requests being placed in-service.

Voltage Regulation and Reactive Power Capability

Interconnection Customer is 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 Southeast Colorado - Region 4 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 (34.5kV or 230kV 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. Finally, 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).

Transient Stability Analysis

The transient stability analysis simulated six disturbances in the GI-2016-6 study dynamics case. The study dynamics case was developed by including the GI-2014-5, GI-2016-3 and GI-2016-4 generating facilities and the transmission facilities comprising the Pawnee – Daniels Park project. Finally, the dynamic model for Vestas V110 VCSS 2.0MW wind turbine generators proposed to be installed in the GI-2016-3, GI-2016-4 and GI-2016-6 generating facilities was integrated into the study dynamics case.

The transient stability analysis consisted of verifying the stability performance for the following six normally cleared three-phase fault disturbances for which acceptable stability performance of the planned GI-2016-3 and GI-2014-5 interconnections has already been verified.

A. NERC Category P1 (single contingency) Disturbances
   Three-phase, close-in fault at bus designated by asterisk (*) with normal clearing of 6 cycles
   1. Missile Site* – Pawnee #1 345 kV Line
   2. Missile Site* – Smoky Hill 345 kV Line
   3. Missile Site* – Daniels Park 345 kV Line
   4. Missile Site 345*/230 kV transformer

B. NERC Category P7 (common structure double contingency) Disturbances
   Three-phase, close-in fault at bus designated by asterisk (*) with normal clearing of 6 cycles
   1. Pawnee – Missile Site* #1 & #2 345 kV double circuit tower line
   2. Missile Site* – Smoky Hill and Missile Site* – Daniels Park 345 kV double circuit tower line

The transient stability results indicate that unacceptable/degraded stability performance does not occur due to the proposed GI-2016-6 interconnection. The following results were obtained for every disturbance analyzed:

- ✓ No machines lost synchronism with the system
- ✓ No transient voltage drop violations were observed
- ✓ Machine rotor angles displayed positive damping

Furthermore, it is the responsibility of the Interconnection Customer to ensure that its generating facility is capable of meeting the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in the NERC Reliability Standard PRC-024.

Short Circuit and Breaker Duty Analysis

This analysis identified one overdutied circuit breaker at PSCo's Midway 230kV station due to the GI-2016-6 interconnection.

Costs Estimates and Assumptions

Transmission Provider has specified and estimated the cost of the equipment, engineering, procurement and construction work needed to interconnect GI-2016-6. The results of the engineering analysis for facilities owned by the Transmission Provider are estimates and are summarized in Tables 1 and 2.

> Table 1: "Transmission Provider's Interconnection Facilities" includes the nature and estimated cost of the Transmission Provider's Interconnection Facilities and an estimate of the time required to complete the construction and installation of such facilities.
>
> Table 2: "Network Upgrades required for Interconnection (applicable for either ERIS or NRIS)" includes the nature and estimated cost of the Transmission Provider's Network Upgrades necessary to accomplish the interconnection and an estimate of the time required to complete the construction and installation of such facilities.

Upgrades identified in Tables 1 and 2 are illustrated in Figure 1 which shows the physical and electrical connection of the Interconnection Customer's Generating Facility to the Transmission Provider's Transmission System. The one-line diagram also identifies the electrical switching configuration of the interconnection equipment, including, without limitation: the transformer, switchgear, meters, and other station equipment.

Transmission Provider has also specified and estimated the cost of the equipment, engineering, procurement and construction work of additional Network Upgrades required for NRIS. The results of the engineering analysis for facilities owned by the Transmission Provider are estimates and are summarized in Table 3.

> Table 3: "Additional Network Upgrades required for NRIS" includes the nature and estimated cost of the Transmission Provider's additional Network Upgrades required for NRIS and an estimate of the time required to complete the construction and installation of such facilities.

The estimated costs of the recommended system improvements to interconnect the GI-2016-6 project include:

- $ 0.774 million for Transmission Provider's Interconnection Facilities (cf. Table 1)

- $ 3.743 million for Network Upgrades required for Interconnection for either ERIS or NRIS (cf. Table 2)
- $ 43.838 million for additional Network Upgrades for NRIS (cf. Table 3)

The cost responsibilities associated with these transmission system improvements shall be handled as per current FERC guidelines.

Conclusion

The total estimated cost of the transmission system improvements required for GI-2016-6 to qualify for:

- **ERIS is $4.517 Million (Tables 1 and 2); and**
- **NRIS is $48.355 Million (Tables 1, 2 and 3)**

This is contingent upon completion of the Network Upgrades identified for all applicable higher-queued Interconnection Requests (see footnotes to Table 2 and 3).

For GI-2016-6 interconnection:

NRIS (after required transmission system improvements) = 600 MW

ERIS (after required transmission system improvements) = 600 MW (output delivery assumes the use of existing firm or non-firm capacity of the PSCo Transmission System on an as-available basis.)

Note: NRIS or ERIS, in and of itself, does not convey transmission service.

Table 1 –Transmission Provider's Interconnection Facilities (for information only)

Element	Description	Cost Est. (Millions)
Missile Site 230kV Substation	Interconnect Customer to tap at the Missile Site 230kV bus. The new equipment includes: • One 230kV deadend structure • Three 230kV arresters • One set (of three) high side metering units • Fiber communication equipment • Associated station controls, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$0.699**
	Transmission line tap into substation.	**$0.055**
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	**$0.020**
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$0.774**
Time Frame	**Design, procure and construct**	**18 Months**

Table 2 - Network Upgrades for Interconnection (applicable for either ERIS or NRIS) *

Element	Description	Cost Estimate (Millions)
Missile Site 230kV Substation	Install a terminal on the 230kV bus, including completing the five position ring bus to a breaker and a half bus arrangement. The new equipment includes: • Four 230kV 3000A circuit breakers • Four 230kV 2000A disconnect switches • Three (3) 230kV bus CCVTs • North and South bus differentials • Station controls • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing Communication upgrades to the 230kV EEE, including a DFR and RTU upgrades.	**$3.723**
	Siting and Land Rights support (no additional land is required)	**$0.020**
	Total Cost Estimate for Network Upgrades for Interconnection (ERIS)	**$3.743**
Time Frame	**Site, design, procure and construct**	**18 Months**

*** Not contingent on completion of Network Upgrades for Interconnection identified for any higher queued Interconnection Requests.**

Table 3 – Additional Network Upgrades for NRIS *

Element	Description	Cost Est. (Millions)
PSCo's 5283 Leetsdale-Monroe transmission line	The Leetsdale-Monroe 230 kV HPFF underground line is continuously rated at 398 MVA. Replace the line and any other termination equipment with an XLPE underground line to achieve rating of 687 MVA (1725A) or higher.	**$41.103**
PSCo's 5281 Greenwood-Leetsdale transmission line	Reconductor 5281 to meet 576MVA using 795 ACCR conductor.	**$2.735**
PSCo's Midway 230kV Substation	Replace one (1) 230kV circuit breaker	**$0.539**
	Total Cost Estimate for Network Upgrades for NRIS	**$43.838**
Time Frame	**Site, design, procure and construct**	**36 Months**
	Total Project Estimate	**$48.355**

*** Contingent on completion of the Network Upgrades for NRIS identified for higher-queued Interconnection Requests GI-2016-3 and GI-2015-1.**
For details, refer to Table 3 in the Facilities Study reports for GI-2016-3 and GI-2015-1.

Cost Estimate Assumptions

- Scoping level cost estimates for Interconnection Facilities and Network Upgrades have a specified accuracy of +/- 30%.
- Estimates are based on 2018 dollars (appropriate contingency and escalation applied).
- Labor is estimated for straight time only – no overtime included. Assumes contracted construction for the majority of the work.
- Lead times for materials were considered for the schedule.
- Estimates are developed assuming typical construction costs for previous completed projects. These estimates include all applicable labor and overheads associated with the siting support, engineering, design, material/equipment procurement, construction, testing and commissioning of these new substation and transmission line facilities.
- The Generation Facility is in PSCo's retail service territory. Therefore, costs for retail load metering are included in these estimates.

- PSCo (or it's Contractor) crews will perform all construction, wiring, and testing and commissioning for PSC owned and maintained facilities.
- The estimated time to site, design, procure and construct the Transmission Provider's Interconnection Facilities and Network Upgrades required for Interconnection is approximately 18 months after authorization to proceed has been obtained.
- The estimated time to site, design, procure and construct the additional Network Upgrades for NRIS is approximately 36 months after authorization to proceed has been obtained.
- A CPCN may be required for additional Network Upgrades for NRIS.
- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and necessitate extending the back-feed date.
- Estimates do not include the cost for any Customer owned equipment and associated design and engineering.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at the 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 the POI.
- Customer will string optical ground wire (OPGW) cable into the substation as part of their transmission line construction scope.

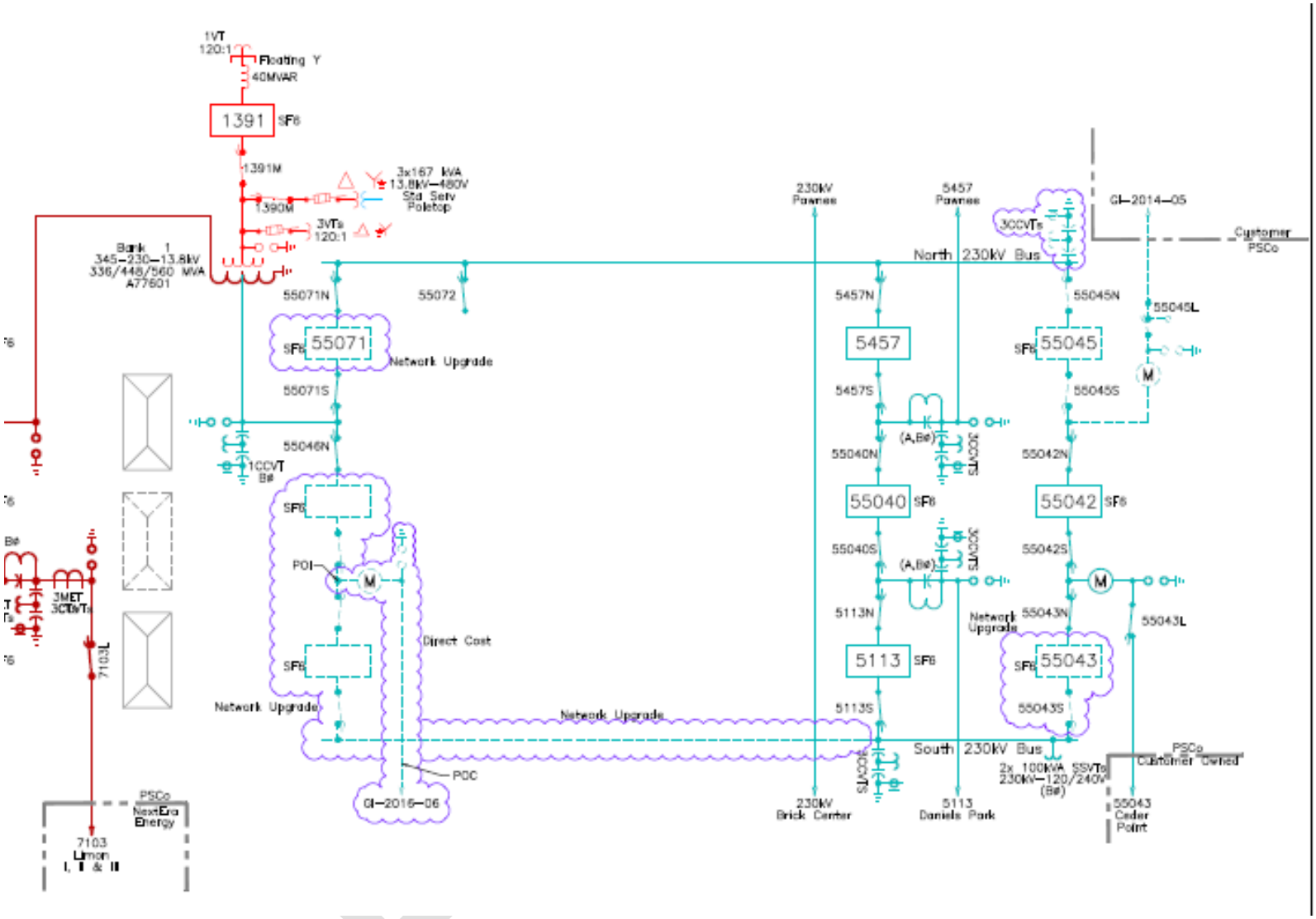

Figure 1. GI-2016-6 Interconnection Facilities and Network Upgrades in Missile Site Substation

Attachment 1 – Standalone SIS Report

(For Information Only)

Executive Summary

This attachment provides the results of GI-2016-6 studied without higher queued projects not-yet in-service or their associated upgrades in the model and is for informational purposes only.

The power flow analysis determined two thermal constraints in the PSCo transmission system due to the injection from GI-2016-6 – therefore, the associated network upgrades required for mitigation are identified. The transient stability analysis determined that all generating units remain stable (in synchronism), have positive damping and satisfy acceptable dynamic performance criteria after the GI-2016-6 interconnection. The short-circuit analysis determined that no circuit-breaker(s) within any PSCo station(s) are overdutied after the GI-2016-6 interconnection.

This study identifies the required transmission improvements and cost estimates assuming no higher queued projects or their associated transmission facilities are in-service and so the results are for information only.

The estimated (illustrative) costs of the recommended system improvements to interconnect the GI-2016-6 project when evaluated on a standalone basis include:

- $ 0.699 million for Transmission Provider's Interconnection Facilities
- $ 3.723 million for Network Upgrades required for Interconnection (either ERIS or NRIS)
- $ 13.253 million for additional Network Upgrades for NRIS

The total estimated (illustrative) cost of the transmission system improvements required for GI-2016-6 to qualify for:

- **ERIS is $4.422 Million (Tables 1 and 2); and**
- **NRIS is $17.675 Million (Tables 1, 2 and 3)**

Introduction

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 Public Service Company of Colorado's (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 main purpose of this Interconnection System Impact Study is to determine the system impact of interconnecting 600 MW of generation at the Missile Site 230 kV POI. As per the Interconnection Request, GI-2016-6 was studied for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS). For both ERIS and NRIS evaluation, the 600 MW rated output of GI-2016-6 is assumed to be delivered to PSCo network load, so existing PSCo generation is used as its sink.

Study Scope and Analysis Criteria

The scope of this report includes steady state (power flow) analysis, transient stability analysis, short circuit analysis and scoping level cost estimates. The power flow analysis identifies thermal and voltage violations in the PSCo transmission system and the Affected Systems as a result of the GI-2016-6 interconnection. The transient stability analysis verifies that all generating units within PSCo transmission system and the Affected Systems remain stable (in synchronism), have positive damping and satisfy acceptable dynamic performance criteria. The short circuit analysis determines the maximum available fault current at the POI and identifies the circuit-breaker(s) within PSCo station(s) that would exceed their breaker duty rating and hence need to be replaced.

PSCo adheres to applicable NERC Reliability Standards & Western Electricity Coordinating Council (WECC) Reliability Criteria, as well as its internal transmission planning criteria for system studies.

The steady state analysis criteria are as follows:
P0 - System Intact conditions:
Thermal Loading: <=100% of the normal facility rating
Voltage range: 0.95 to 1.05 per unit
P1-P2 – Single Contingencies:
Thermal Loading: <=100% Normal facility rating
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

Transient stability criteria require that all generating machines remain in synchronism and all power swings should be well damped following a contingency event. Also, transient voltage performance should meet the following WECC Disturbance-Performance criteria:

- Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds for all contingencies

- For all contingencies, following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.
- For contingencies without a fault, voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds

Standalone Power Flow Analysis

The power flow analyses were performed using a 2021 heavy summer (2021HS) base case. Two 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 but without any higher queued projects or related upgrades), and a Study Case that includes the 600 MW generation under study (i.e. After GI-2016-6 case).

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.

The steady-state power flow analysis determined that the additional 600 MW injection due to GI-2016-6 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 two Smoky Hill 345/230 kV auto-transformers, the Missile Site – Daniels Park 230 kV overhead line, and the Clark – Jordan 230 kV underground line.

Three of the above four thermal overloads resulting from the 600 MW injection of the GI-2016-6 interconnection are mitigated by the aggregate impact of transmission improvements comprising the planned Pawnee – Daniels Park (P-DP) 345 kV project. The remaining thermal overload is mitigated by the addition of a second auto-transformer at Missile Site.

Voltage Regulation and Reactive Power Capability

Interconnection Customer is 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 Southeast Colorado - Region 4 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 (34.5kV or 230kV 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. Finally, 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).

Standalone Transient Stability Analysis

The standalone transient stability analysis simulated six disturbances in the GI-2016-6 study dynamics case. The study dynamics case was developed by including the planned GI-2014-5 and GI-2016-3 generating facilities and the planned transmission facilities comprising the Pawnee – Daniels Park project. Finally, the dynamic model for Vestas V110 VCSS 2.0MW wind turbine generators proposed to be installed in the GI-2016-6 generating facility was integrated into the study dynamics case.

The standalone transient stability analysis consisted of verifying the stability performance for the following six normally cleared three-phase fault disturbances.

A. NERC Category P1 (single contingency) Disturbances
   Three-phase, close-in fault at bus designated by asterisk (*) with normal clearing of 6 cycles
   1. Missile Site* – Pawnee #1 345 kV Line
   2. Missile Site* – Smoky Hill 345 kV Line
   3. Missile Site* – Daniels Park 345 kV Line
   4. Missile Site 345*/230 kV transformer

B. NERC Category P7 (common structure double contingency) Disturbances
   Three-phase, close-in fault at bus designated by asterisk (*) with normal clearing of 6 cycles
   1. Pawnee – Missile Site* #1 & #2 345 kV double circuit tower line
   2. Missile Site* – Smoky Hill and Missile Site* – Daniels Park 345 kV double circuit tower line

The standalone transient stability results indicate that unacceptable/degraded stability performance does not occur due to the proposed GI-2016-6 interconnection. The following results were obtained for every disturbance analyzed:

- ✓ No machines lost synchronism with the system
- ✓ No transient voltage drop violations were observed
- ✓ Machine rotor angles displayed positive damping

Standalone Short Circuit and Breaker Duty Analysis

The standalone short circuit and breaker duty analysis results did not identify the need for any network upgrades for the proposed GI-2016-6 interconnection.

Conclusion

This standalone System Impact Study concludes that the GI-2016-6 interconnection cannot achieve 600 MW NRIS until the planned Pawnee – Daniels Park 345 kV project and the second auto-transformer at Missile Site are both placed in service.

This study identifies the required transmission improvements and cost estimates assuming no higher queued projects or their associated transmission facilities are in-service and so the results are for information only.

Tables 1–3 below provide the cost estimates for the Transmission Provider Interconnection Facilities and Network Upgrades identified in this standalone System Impact Study.
The cost responsibilities associated with these transmission system improvements shall be handled as per current FERC guidelines.

The total estimated cost of the transmission system improvements required for GI-2016-6 to qualify for:

- **ERIS is $4.517 Million (Tables 1 and 2); and**
- **NRIS is $17.770 Million (Tables 1, 2 and 3)**

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

Table 1 –Transmission Provider's Interconnection Facilities (for information only)

Element	Description	Cost Est. (Millions)
Missile Site 230kV Substation	Interconnect Customer to tap at the Missile Site 230kV bus. The new equipment includes: • One 230kV deadend structure • Three 230kV arresters • One set (of three) high side metering units • Fiber communication equipment • Associated station controls, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$0.699**
	Transmission line tap into substation.	**$0.055**
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	**$0.020**
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$0.774**
Time Frame	**Design, procure and construct**	**18 Months**

Table 2 - Network Upgrades for Interconnection applicable for either ERIS or NRIS (for information only)

Element	Description	Cost Estimate (Millions)
Missile Site 230kV Substation	Install a terminal on the 230kV bus, including completing the five position ring bus to a breaker and a half bus arrangement. The new equipment includes: • Four 230kV 3000A circuit breakers • Four 230kV 2000A disconnect switches • Three (3) 230kV bus CCVTs • North and South bus differentials • Station controls • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing Communication upgrades to the 230kV EEE, including a DFR and RTU upgrades.	**$3.723**
	Siting and Land Rights support (no additional land is required)	**0**
	Total Cost Estimate for Network Upgrades for Interconnection (ERIS)	**$3.723**
Time Frame	**Design, procure and construct**	**18 Months**

Table 3: Additional Network Upgrades for NRIS (for information only)

Element	Description	Cost Estimate (Millions)
Missile Site 345/230kV Substation	Construct a 2nd 345/230kV, 560MVA autotransformer at Missile Site. Installed equipment includes: • One 345/230kV, 560MVA autotransformer • Two 345kV SF6 circuit breakers • Five 345kV disconnect switches • One 345kV CCVT • Two 230kV SF6 circuit breakers • Three 230kV disconnect switches • One 230kV CCVT • Associated equipment foundations and steel support structures • Equipment relaying and control panels (Transformer differential, Transformer bus differential, breaker failure and control). • Associated electrical equipment, bus, wiring and grounding	**$13.253**
	Total Cost Estimate for Additional Network Upgrades	**$13.253**
Time Frame	**Design, procure and construct**	**18 Months**

Cost Estimate Assumptions

- Scoping level cost estimates for Interconnection Facilities and Network Upgrades have a specified accuracy of +/- 30%.
- Estimates are based on 2018 dollars (appropriate contingency and escalation applied).
- Labor is estimated for straight time only – no overtime included. Assumes contracted construction for the majority of the work.
- Lead times for materials were considered for the schedule.
- Estimates are developed assuming typical construction costs for previous completed projects. These estimates include all applicable labor and overheads associated with the siting support, engineering, design, material/equipment procurement, construction, testing and commissioning of these new substation and transmission line facilities.
- The Generation Facility is in PSCo's retail service territory. Therefore, costs for retail load metering are included in these estimates.
- PSCo (or it's Contractor) crews will perform all construction, wiring, and testing and commissioning for PSC owned and maintained facilities.

- The estimated time to site, design, procure and construct the Transmission Provider's Interconnection Facilities and Network Upgrades required for Interconnection is approximately 18 months after authorization to proceed has been obtained.
- The estimated time to site, design, procure and construct the additional Network Upgrades for NRIS 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 necessitate extending the back-feed date.
- Estimates do not include the cost for any Customer owned equipment and associated design and engineering.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at the 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 the POI.
- Customer will string optical ground wire (OPGW) cable into the substation as part of their transmission line construction scope.

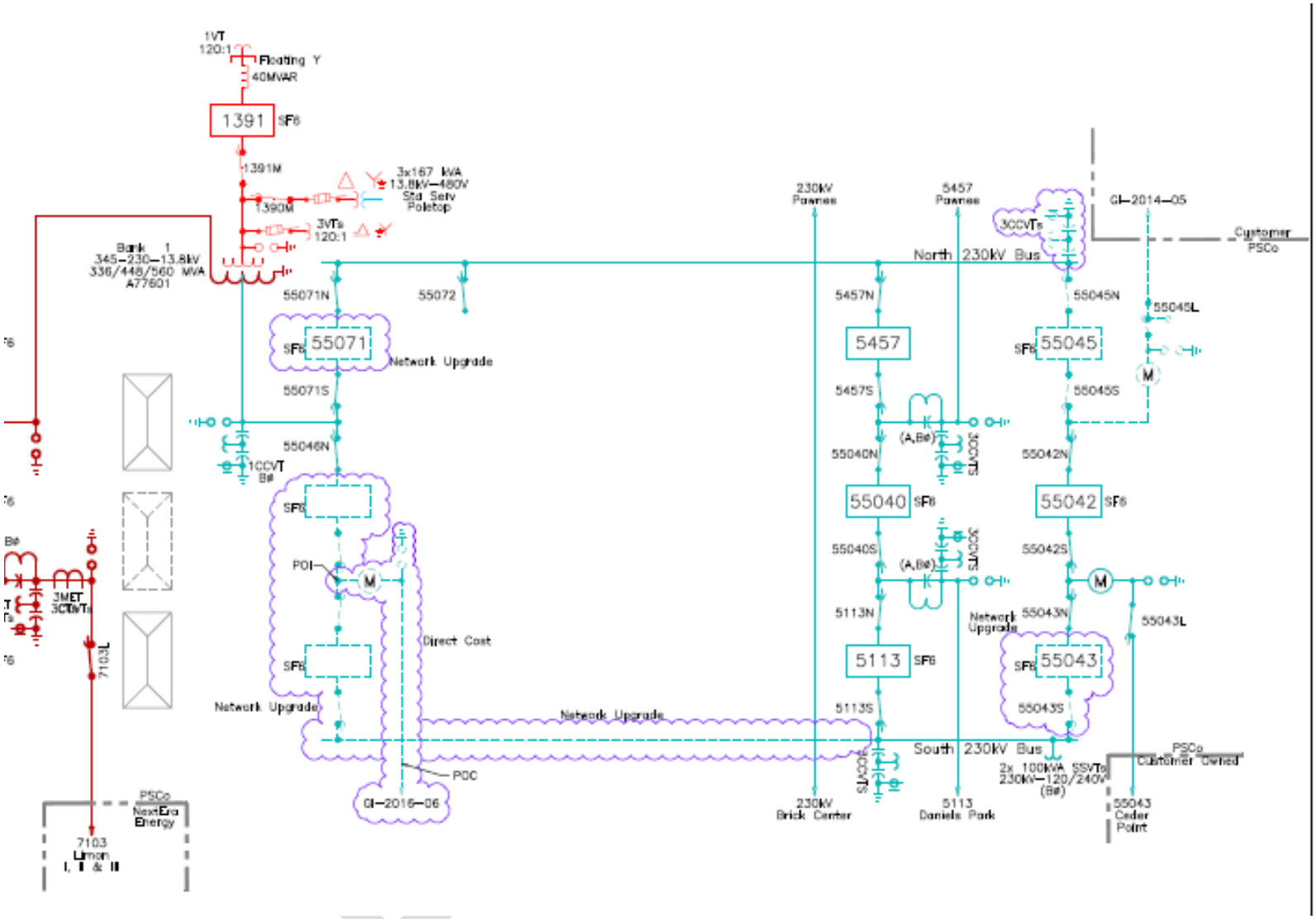

Figure 1. GI-2016-6 Interconnection Facilities and Network Upgrades in Missile Site Substation