INTERCONNECTION FEASIBILITY & SYSTEM IMPACT STUDY REPORT

GENERATOR INTERCONNECTION REQUEST
GI-2017-52

36 MW PV Solar Generating Facility
Interconnecting at
Jackson Fuller 230kV Substation

XCEL ENERGY – Public Service Company of Colorado (PSCo)
October 17, 2018

Executive Summary

GI-2017-52 is a proposed 36 MW photovoltaic (PV) solar Generating Facility that will be located in El Paso County, Colorado. The Interconnection Customer designated PSCo's 230kV bus in the Jackson Fuller Substation as the Point of Interconnection (POI) – no alternative POI was specified. The GI-2017-52 Generating Facility will interconnect to the POI via the existing 230kV transmission line (Gen-Tie) of the Golden West wind generating facility. The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2019.

In this study, GI-2017-52 is evaluated for Energy Resource Interconnection Service (ERIS)[1] only consistent with the Interconnection Request and the assumptions noted within the combined Feasibility and System Impact Study Agreement. Accordingly, the 36 MW rated output of GI-2017-52 is assumed to be delivered to Colorado Springs Utilities (CSU) native load. This study report provides the results and conclusions for the system impacts of GI-2017-52 interconnection evaluated as ERIS.

The GI-2017-52 interconnection request was studied in queue order and, based on engineering judgment, it was determined that none of the higher-queued interconnection requests in PSCo's generator interconnection queue will impact the results and conclusions of this study.

The power flow analysis did not identify any thermal constraints in the transmission system in vicinity of the POI (i.e. the study area) – therefore, no network upgrades are required in the PSCo system or any of the potential Affected Systems[2]. The short-circuit and breaker duty analysis did not identify any over-dutied circuit breakers within PSCo station(s) due to GI-2017-52. Stability analysis to verify that GI-2017-52 exhibits acceptable dynamic performance for normally cleared faults in the vicinity of POI was not considered necessary since the information on Voltage Ride-Through (VRT) and Frequency Ride-Through (FRT) capability of the solar Generating Facility's dc/ac inverters provided by the Interconnection Customer is expected to result in satisfactory dynamic ride-through performance. Furthermore, it is the responsibility of the Interconnection Customer to ensure that GI-2017-52 is capable of fulfilling the VRT and FRT performance specified in the latest applicable version of NERC Reliability Standard PRC-024.

The total estimated cost of the transmission system improvements required for GI-2017-52 to qualify for ERIS interconnection is $100,000 and includes:

- $0.100 million for Transmission Provider's Interconnection Facilities (cf. Table 1)
- $0.000 million for Network Upgrades for Interconnection for ERIS (cf. Table 2)

For GI-2017-52, ERIS (after required transmission system improvements) = 36 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.

[1] **Energy Resource Interconnection Service (ERIS)** 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*)

[2] Colorado Springs Utilities (CSU), Tri-State Gas & Electric (TSGT), Western Area Power Administration –Rocky Mountain Region (WAPA-RMR)

Introduction

GI-2017-52 is a proposed 36 MW photovoltaic (PV) solar Generating Facility that will be located in El Paso County, Colorado. The GI-2017-52 Interconnection Request was received by Public Service Company of Colorado (PSCo) on December 15, 2017. The Interconnection Customer designated PSCo's 230kV bus in the Jackson Fuller Substation as the Point of Interconnection (POI) – no alternative POI was specified. The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2019.

The GI-2017-52 Generating Facility will consist of eighteen (18) GE 2.0 MW proprietary inverters, each with its own 550V/34.5kV, 2000 kVA, Z=6.0% pad-mounted step-up transformer. The solar generating facility's 34.5kV collector system will use the existing Golden West wind generating facility's Main Step-up Transformer rated 34.5/230 kV, 180/240/300 MVA and will interconnect to the POI using its 230kV transmission line (Gen-Tie).

In this study, GI-2017-52 is evaluated for Energy Resource Interconnection Service (ERIS) only consistent with the Interconnection Request and the assumptions noted within the combined Feasibility and System Impact Study Agreement. Accordingly, the 36 MW rated output of GI-2017-52 is assumed to be delivered to Colorado Springs Utilities (CSU) native load.

The GI-2017-52 interconnection request was studied in queue order and, based on engineering judgment, it was determined that none of the higher-queued interconnection requests in PSCo's generator interconnection queue will impact the results and conclusions of this study.

Study Scope and Analysis Criteria

The scope of this study 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/or in the Affected Systems due to the GI-2017-52 interconnection. The transient stability analysis verifies that synchronous generating units within the PSCo transmission system and the Affected Systems remain stable, and that GI-2017-52 demonstrates acceptable voltage ride-through and frequency ride-through (VRT and FRT) capability during disturbances in electrical proximity to the POI. 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) System Performance Criteria, as well as its internal transmission performance criteria for planning 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

P3-P7– Multiple Contingencies:

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

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.

Further, every Generating Facility is required to have the capability to satisfy the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in the latest applicable version of NERC Reliability Standard PRC-024.

Power Flow Study Models

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 Benchmark case for GI-2017-52 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. The cumulative Study case (with GI-2017-52) was developed by adding the proposed GI-2017-52 and dispatching it, along with the existing Golden West wind generation, at respective rated output (100% of nameplate rating). PSCo generation was used as sink for the incremental Golden West injection and CSU generation was used as sink for the 36 MW injection of GI-2017-52.

Power Flow Analysis Results

The power flow analysis simulated single contingencies within the transmission system surrounding the POI for GI-2017-52. The single contingency analysis did not identify any new thermal or voltage limit violations that are attributable to GI-2017-52. Several pre-existing thermal violations exist in the Benchmark case due to the higher-queued interconnection requests, and are expected to be mitigated by the respective network upgrades associated with them. None of the pre-existing thermal violations are significantly impacted by the GI-2017-52 injection and hence no network upgrades are required for the delivery of its rated 36 MW output to CSU native load.

Stability Analysis Results

Stability analysis to verify that GI-2017-52 exhibits acceptable dynamic performance for normally cleared faults in the vicinity of POI was not considered necessary since the information on Voltage Ride-Through (VRT) and Frequency Ride-Through (FRT) capability of the solar Generating Facility's dc/ac inverters provided by the Interconnection Customer is expected to result in satisfactory dynamic ride-through performance. Furthermore, it is the responsibility of the Interconnection Customer to ensure that GI-2017-52 is capable of fulfilling the VRT and FRT performance specified in the latest version of NERC Reliability Standard PRC-024.

Short Circuit and Breaker Duty Analysis Results

The calculated short circuit levels and Thevenin system equivalent impedances at the POI are tabulated below.

Short Circuit Parameters at the GI-2017-52 Jackson Fuller 230kV Substation POI

	Without Proposed Generation	With Proposed Generation
Three Phase Current	19348.9A	19765.8A
Single Line to Ground Current	15259.6A	15380A
Positive Sequence Impedance	0.76354+j7.32366	0.76354+j7.32366
Negative Sequence Impedance	0.76751+j7.32334	0.76751+j7.32334
Zero Sequence Impedance	2.68611+j13.3247	2.68611+j13.3247

A preliminary breaker duty study did not identify any circuit breakers that are over-dutied due to the proposed GI-2017-52 interconnection.

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).

Costs Estimates and Assumptions

Transmission Provider has specified and estimated the cost of the equipment, engineering, procurement and construction work needed to interconnect GI-2017-52. The results of the engineering analysis for facilities owned by the Transmission Provider are estimates and are summarized in Tables 1 and 2.

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

Conclusions

The total estimated cost of the transmission system improvements required for GI-2017-52 to qualify for ERIS interconnection is $100,000 and includes:

- $0.100 million for Transmission Provider's Interconnection Facilities (cf. Table 1)
- $0.000 million for Network Upgrades for Interconnection for ERIS (cf. Table 2)

For GI-2017-52, ERIS (after required transmission system improvements) = 36 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

Element	Description	Cost Est. (Millions)
PSCo's Jackson Fuller 230kV Substation	Interconnect via the existing Golden West Wind Generator's Transmission Line (Gen-Tie). • Associated transmission line communications, relaying and testing	**$0.080**
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$0.100**
Time Frame	**Site, design, procure and construct**	**12 months**

Table 2 – Network Upgrades required for Interconnection (for ERIS or NRIS)

Element	Description	Cost Est. (Millions)
Not Applicable	Not Applicable (N/A).	**$0.000**
	Siting and Land Rights support for substation construction -- N/A	**$0.000**
	Total Cost Estimate for Network Upgrades for Interconnection	**$0.000**
Time Frame	**Site, design, procure and construct**	**N/A**

Cost Estimate Assumptions

- Scoping level (+/-30% accuracy) cost estimates for Interconnection Facilities were developed by PSCo Engineering.
- Estimates are based on 2018 dollars (appropriate contingency and escalation applied).
- Allowance for Funds Used During Construction (AFUDC) has been excluded.
- Labor is estimated for straight time only with no overtime included.
- Lead times for materials were considered for the schedule.
- The solar generation facility is not in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates.
- PSCo (or its Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- The estimated time to design, procure and construct the Transmission Provider Interconnection Facilities is approximately 12 months after authorization to proceed has been obtained.
- A CPCN will not be required for the construction of Transmission Provider Interconnection Facilities.
- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date due.
- Power Quality Metering (PQM) will be required on the Customer's 230kV line terminating into Transmission Provider's Substation.
- 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.

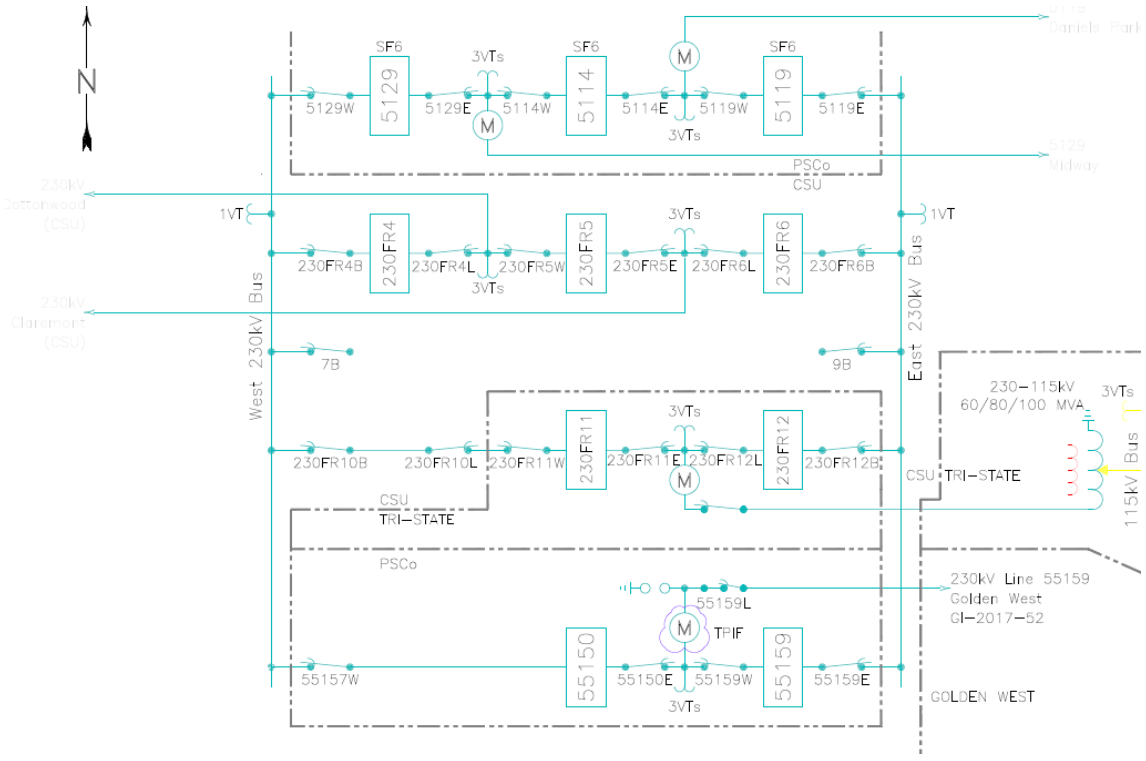

Figure 1 – GI-2017-52 Interconnection to Jackson Fuller 230kV Substation via the existing Golden West Wind Generating Facility's Gen-Tie (Transmission Line 55159)