Feasibility Study Report
Generation Interconnection Request # GI-2017-10

150MW Solar Photovoltaic Facility
Tap on the Pawnee – Brick Center 230kV line
Arapahoe County, Colorado

Transmission Planning West
Xcel Energy
August 18, 2017
(Draft Pending Short Circuit Analysis)

Executive Summary

The GI-2017-10 ("GI") is a 150MW solar photovoltaic generation facility that will be located in Arapahoe County, Colorado. The GI facility will be made up of fifty (50) FS3000CU15 inverters and two 34.5/230kV, 75MVA step-up transformers. The proposed Point of Interconnection (POI) is a tap on the Pawnee – Brick Center 230kV line, at approximately sixteen (16) miles from the Brick Center Substation. The tap point will constitute building a new 230kV switching station which will be referred to as "GI-2017-10 230kV Switching Station" in this report. The GI Customer did not request a secondary POI.

The proposed Commercial Operation Date (COD) is November 30, 2019, accordingly the backfeed date is assumed to be June 30, 2019, approximately six (6) months before the COD.

The GI-2017-10 generation interconnection study requested both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS) analysis.

The GI output is assumed to be serving PSCo native load, so existing PSCo generation is used as its sink.

The study did not show any thermal or voltage limit violations ~~or any circuit breaker capability exceedance~~ due to the interconnection of GI-2017-10. Pending short circuit analysis,

ERIS for GI-2017-10 = 150MW
NRIS for GI-2017-10 = 150MW

The total estimated cost of the recommended system improvements to interconnect the project is approximately $12.14 million and includes:

- $ 1.055 million for PSCo-Owned, Customer-Funded Transmission Provider Interconnection Facilities
- $ 11.085 million for PSCo-Owned, PSCo-Funded Network Facilities for Interconnection
- $ 0 million for PSCo-Funded Network Upgrades for Delivery

A Certificate of Public Convenience and Necessity (CPCN) will be required for construction of the GI-2017-10 230kV Switching Station. PSCo anticipates that it may take up to 18 months from the receipt of the Customer's Notice to Proceed (NTP) to file and obtain a CPCN from the Colorado Public Utilities Commission. This is in addition to the estimated 18 months needed to design, procure and construct the project. The total period from NTP to COD is estimated to be 36 months. Based on the total 36 month

time frame estimated for permitting and construction of the GI-2017-10 230kV Switching Station, the Customer's proposed November 2019 COD cannot be met.

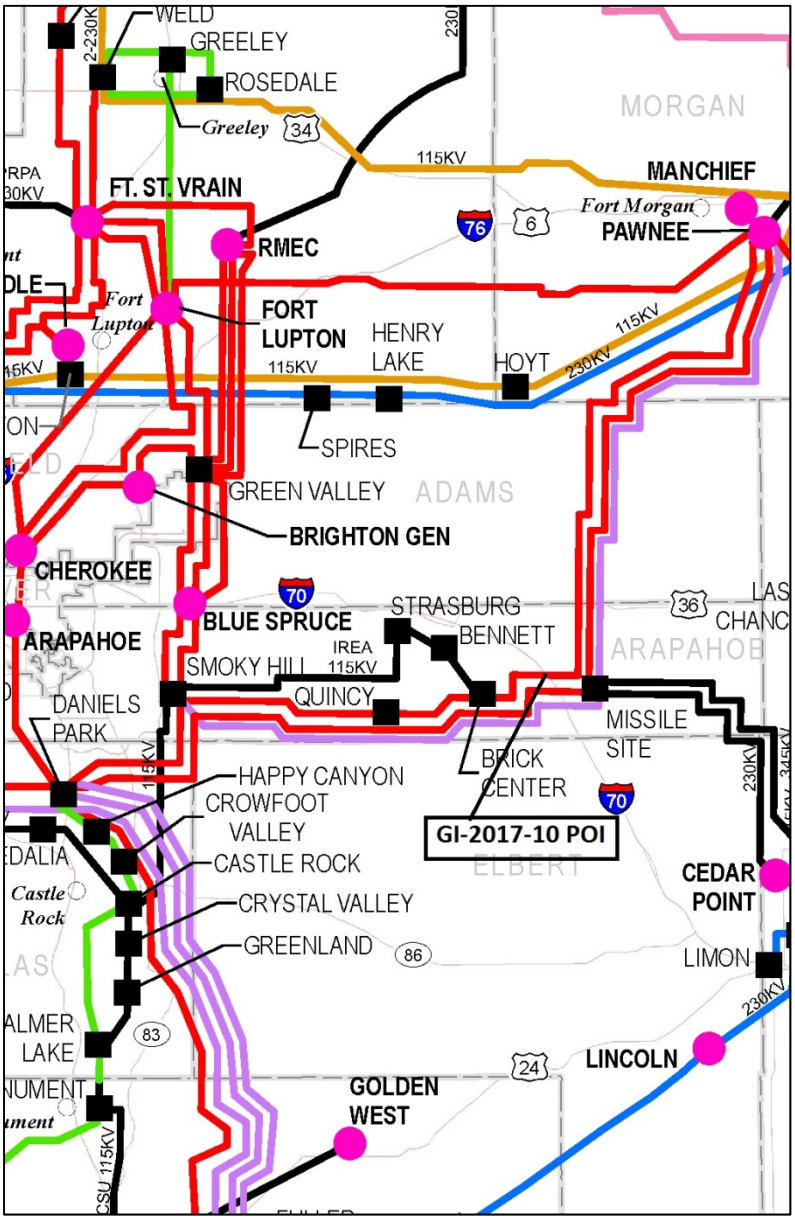

Figure – 1: GI-2017-10 Proposed POI and Study area

Introduction

The GI-2017-10 ("GI") is a 150MW solar photovoltaic generation facility that will be located in Arapahoe County, Colorado. Public Service Company of Colorado (PSCo) received the feasibility study request for the GI on February 27, 2017, and a scoping meeting was held on March 20, 2017. The GI facility will be made up of fifty (50) FS3000CU15 inverters and two 34.5/230kV, 75MVA step-up transformers. The proposed Point of Interconnection (POI) is a tap on the Pawnee – Brick Center 230kV line, at approximately sixteen (16) miles from the Brick Center Substation. The GI facility will interconnect to the PSCo system at the tap point using a 230kV Customer owned tie-line. The tap point will constitute building a new 230kV switching station which will be referred to as "GI-2017-10 230kV Switching Station" in this report. The study request did not identify a secondary POI.

The proposed Commercial Operation Date (COD) is November 30, 2019, accordingly the backfeed date is assumed to be June 30, 2019, approximately six (6) months before the COD.

The study requested both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS) analysis.

The GI output is assumed to be serving PSCo native load, so existing PSCo generation is used as the sink.

The potential affected party for this GI is Intermountain Rural Electric Association (IREA).

Study Scope and Analysis Criteria

The scope of this report includes steady state (power flow) analysis, short circuit analysis and indicative level cost estimates. The power flow analysis identified thermal and voltage violations in the PSCo system and the affected party's system as a result of the interconnection of the GI. Several single contingencies were studied. Short circuit analysis determines the maximum available fault current at the POI. In addition, the breaker duty study determines if any breakers in the neighboring substations exceed their breaker duty ratings and 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 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

The GI was studied for both Energy Resource Interconnection Service (ERIS) and Network Resource Interconnection Service (NRIS).

Energy Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm

capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

Network Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission system (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

Power Flow Study Models

The power flow case used for the study was the WECC 2022HS case released on 8/31/2016, which was reviewed and finalized for the 2017 Colorado Coordinated Planning Group studies. The Pawnee – Daniels Park 345kV project (expected to be in-service in 2019) and the Rush Creek Generation (expected to be in-service in 2018) are modeled in-service in the case.

The generation dispatch in the WECC base case was adjusted to create a reasonably stressed flow in the study area which comprises WECC designated zones 700, 706 and 704. This was accomplished by adopting the generation dispatch given in Table-9 below. Figure-1 shows the system map of the study area and the POI.

The GI-2017-10 interconnection was studied as a stand-alone project. That is, the study did not include any other Generator Interconnection Requests (GIR) existing in PSCo's or an affected party's GIR queue, other than the interconnection requests that are considered to be planned resources for which Power Purchase Agreements have been signed.

Two power flow cases were created for evaluating the feasibility of GI-2017-10 interconnection – the benchmark case and the study case. The benchmark case modeled the system without GI-2017-10, whereas the study case included GI-2017-10. The PSSE modeling data provided by the Customer was incomplete, so the GI was studied using the following generator modeling data: Pmax=150MW, Pmin=0MW, R=0, X=1p.u., Qmax=50Mvar(@0.95pf lag) and Qmin=−50Mvar (@0.95pf lead).

PSCo's Comanche#2 unit was used as the sink for the 150 MW generation injection from GI-2017-10.

Power Flow Study Process

The steady state analysis was performed using PTI's PSSE Ver. 33.6.0 program and the ACCC contingency analysis tool.

The thermal violations on PSCO facilities attributed to the GI interconnection included any facility without a pre-existing thermal violation but resulted in a thermal loading >100% post GI interconnection and contributed to a 2% increase in the facility loading compared to the benchmark case loading.

Also, pre-existing thermal violations in the benchmark case are attributable to the GI interconnection if the planned PSCo upgrade is insufficient to mitigate the (increased) thermal violation in the study case. In such case, only the additional facility rating increase (beyond the PSCo planned uprate) required to accommodate the full NRIS capacity will be attributed to GI.

For affected party facilities, all new thermal violations with loading >100% are attributable to the GI interconnection. For pre-existing thermal violations, only the incremental loading increase is attributed to the GI interconnection.

The voltage violations attributed to GI included any new voltage range and voltage deviation violations. Increments in the existing voltage violations are attributed to the GI if the increase is fairly significant.

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 (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 (34.5 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. 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).

Power Flow Results

Single Contingency Analysis:

The benchmark case and study case did not have any system intact (P0) thermal or voltage limit violations.

The single contingency analysis showed one thermal violation. The overload on the Havana1- Chambers 115kV line increases from 108.5% in the pre-GI case to 109.7% after the addition of GI-2017-10. PSCo has a project to increase the rating of this line to 159MVA and the new rating of the line should be adequate to eliminate the post-GI overload. So this overload is not attributed to the addition of GI-2017-10.

The single contingency analysis did not show any voltage limit violations due to the addition of GI-2017-10.

Short Circuit

Will be provided in the final report

Conclusion

Since the study did not find any thermal and voltage limit violations attributable to the addition of GI-2017-10, pending breaker duty analysis

ERIS for GI-2017-10 = 150MW
NRIS for GI-2017-10 = 150MW

Costs Estimates and Assumptions

Cost Estimates were developed by PSCo Engineering. Cost Estimates are indicative level only. Indicative Estimates are based upon typical construction costs for previously performed similar construction projects; however they have no specified level of accuracy. The cost estimates are in 2017 dollars with escalation and contingencies applied. The estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new PSCo facilities. The estimates in this report do not include the cost for any Customer owned equipment and associated design and engineering.

The estimated total cost for the required Interconnection Facilities and Network/Infrastructure Upgrades is $12,140,000.

Figure-2 below is a conceptual one-line of the new GI-2017-20 230kV Switching station tapping the Pawnee – Brick Center 230kV line.

The following Tables 2, 3 and 4 list the system improvements required to accommodate the interconnection of GI-2017-10. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to revision as a more detailed and refined design is produced.

A Certificate of Public Convenience and Necessity (CPCN) will be required for construction of the GI-2017-10 230kV Switching Station. PSCo anticipates that it may take up to 18 months from the receipt of the Customer's Notice to Proceed (NTP) to file and obtain a CPCN from the Colorado Public Utilities Commission. This is in addition to the estimated 18 months needed to design, procure and construct the project. The total period from NTP to COD is estimated to be 36 months. Based on the total 36 month time frame estimated for permitting and construction of the GI-2017-10 230kV Switching Station, the Customer's proposed November 2019 COD cannot be met.

- 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.
- PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained 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.
- This project is completely independent of other queued projects and their respective ISD's.

- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer Substation. PSCo / Xcel will need indications, readings and data from the LFAGC RTU.
- Power Quality Metering (PQM) will be required on the Customer's 230kV line terminating into Proposed Switching Station.
- The Customer's Generation Facility is not in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates.

Table 2 – PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Estimate (Millions)
GI-2017-10 230kV Switching Station	Interconnect Customer at the new Switching Station. The new equipment includes; • One (1) motor operated 230kV disconnect switch • Three (3) 230kV combination CT/PT metering units • One (1) 230kV CCVT • Power Quality Metering (230kV line from Customer) • Three (3) surge arresters • Two (2) relay panels • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$1.000**
	Transmission line tap into substation. Conductor, hardware, and installation labor.	**$0.055**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$1.055**
Time Frame	**Design, procure and construct**	**18 Months**

Table 3 - PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Estimate (Millions)
GI-2017-10 230kV Switching Station	Interconnect Customer to the Pawnee – Smoky Hill 230kV Line. The new equipment includes; • 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	**$11.000**
	Siting and Land Rights support for substation CPCN, land acquisition, and construction.	**$0.085**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$11.085**
Time Frame	**Site, design, procure, permit and construct**	**36 Months**

Table 4 – PSCo Network Upgrades for Delivery

Element	Description	Cost Estimate (Millions)
NA	None identified	**NA**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0**
Duration	**Design, procure, permit and construct**	**NA**
	Total Project Estimate	**$12.140**

A. Power Flow Contingency Analysis Results

Notes –

1. All thermal loadings are highlighted in yellow and violations are identified in red.
2. Thermal overloads are calculated using the normal rating of the facility.

Table 5 – Summary of thermal violations from Single Contingency Analysis

				Facility Loading Without GI-2017-10		Facility Loading With GI-2017-10			
Monitored Facility (Line or Transformer)	Type	Owner	Branch Rating MVA (Norm/Emer)	N-1 Flow MVA	N-1 Flow % of Rating (Norm/Emer)	N-1 Flow MVA	N-1 Flow % of Rating (Norm/Emer)	% Change	NERC Single Contingency
Havana1 - Chambers 115kV	Line	PSCo	120/154	130.4	108.7%/84.7%	131.9	109.9%/85.6%	1.2%	Havana2 - Chambers 115kV

Table 6 – Generation Dispatch in the Study Area (Gross Capacity in MW's)

PSCo:

Bus	LF ID	MW
Limon1	W1	160.8
Limon2	W2	160.8
Limon3	W3	160.8
Manchief	G1	126
Manchief	G2	126
Cedar Point	W1	200
Pawnee	C1	531
RushCreek1	W1	320
RushCreek2	W2	160
Peetz Logan	W	230.2

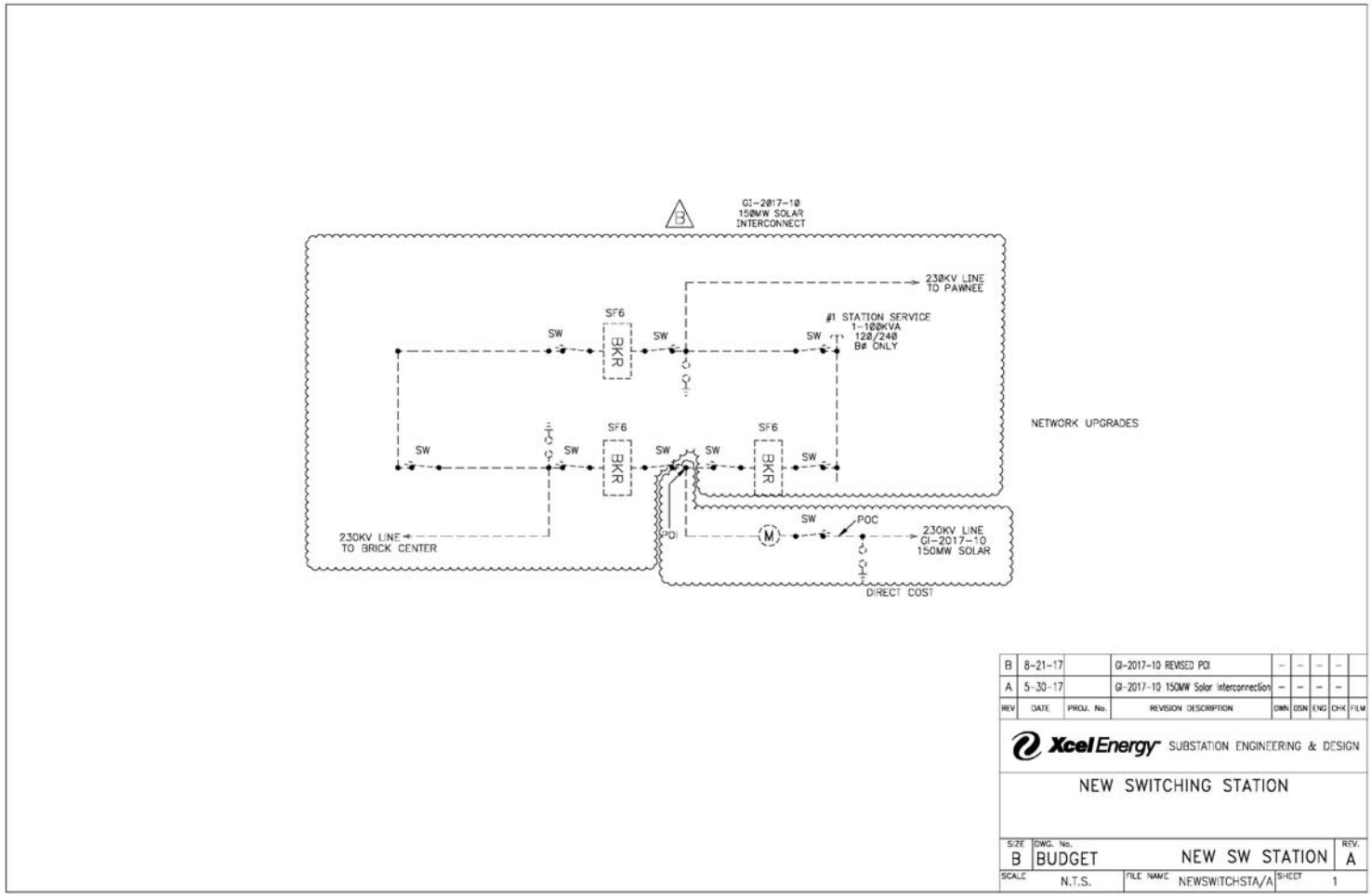

Figure-2: Conceptual One-Line Diagram of the GI-2017-10 230kV Switching Station