Generation Interconnection Facilities Study Report

Request # GI-2010-19

120 MW Photo-Voltaic Solar Generating Plant
Pueblo County, Colorado

Public Service Company of Colorado
Transmission Planning

October 10, 2014

Executive Summary

This Interconnection Facilities Study Report summarizes the analysis performed by Public Service Company of Colorado (PSCo) to specify and estimate the cost of the equipment, engineering, procurement and construction work needed to physically and electrically connect the GI-2010-19 Photo-Voltaic (PV) Solar Generating Facility to PSCo's transmission system at the existing Comanche 230 kV station in Pueblo, Colorado, which is the requested Point of Interconnection (POI). The Commercial Operation Date (COD) requested by the Interconnection Customer is June 30, 2016, and accordingly the target Backfeed date is March 31, 2016.

Figure 1 depicts the proposed POI on the PSCo transmission network diagram. Figure 2 provides the GI-2010-19 interconnection details in the budget one-line diagram of Comanche Station. Figure 3 provides the general arrangement of the Comanche Station with the GI-2010-19 interconnection.

The total estimated cost for the interconnection facilities and network upgrades required for GI-2010-19 is $4.054 million[1] which includes the following:

- $1.488 million for Customer-Funded Interconnection Facilities
- $2.566 million for PSCo-Funded Interconnection Facilities
- $0.0 million for PSCo-Funded Network Upgrades for Delivery

The estimated time required to site, engineer, procure and construct the described facilities is 18 months from the date the Customer meets all applicable milestones as agreed to in any future LGIA.

An Engineering & Procurement Agreement was executed to facilitate completion of the interconnection facilities by the requested in-service date of June 30, 2015.

[1] Appropriation estimates considered to have an accuracy of +/- 20%.

Figure 1: Network Diagram with Proposed POI at Comanche Station

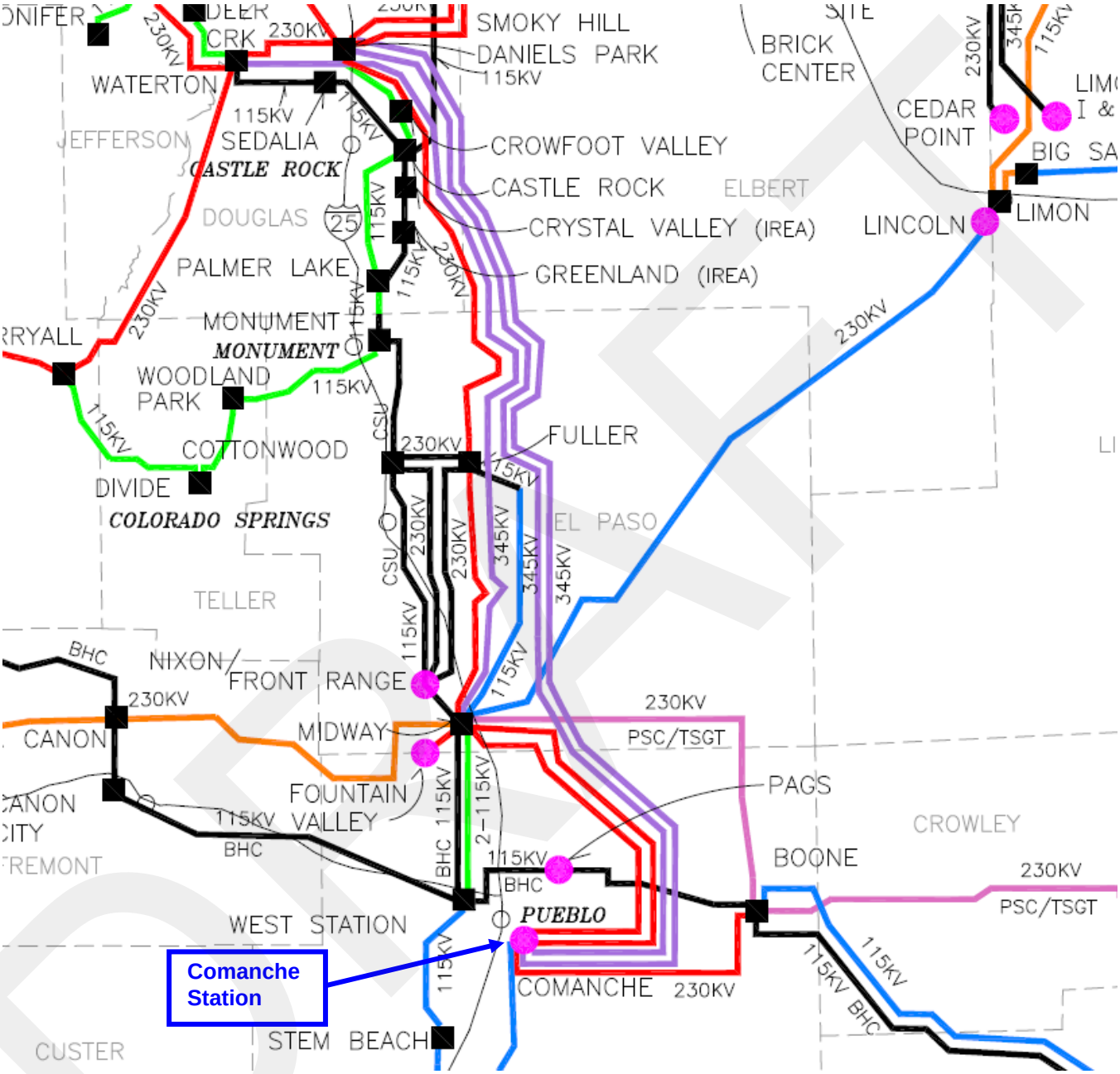


Figure 2: Comanche Station Budget One-Line Diagram with GI-2010-19 Interconnection Facilities

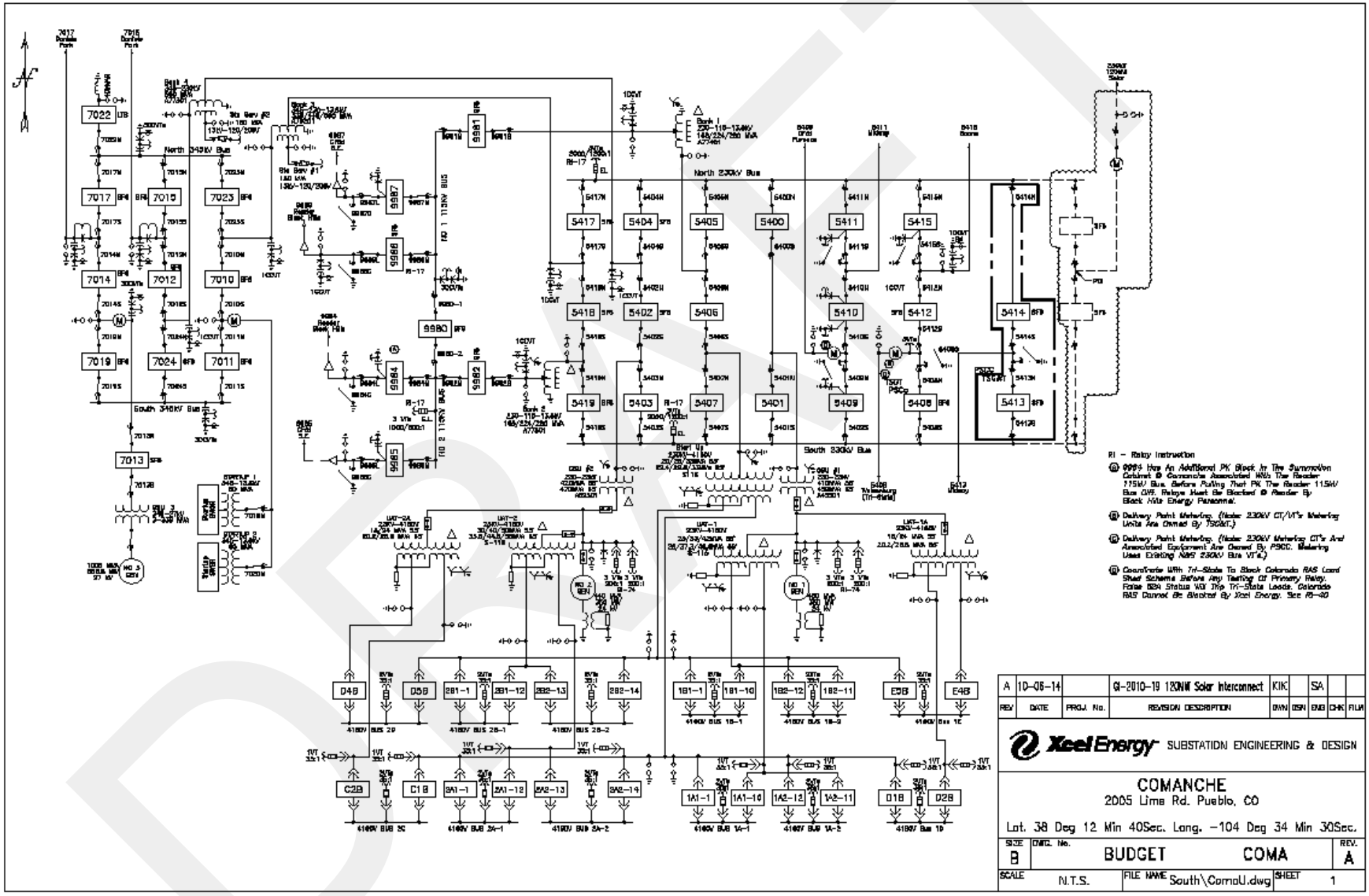
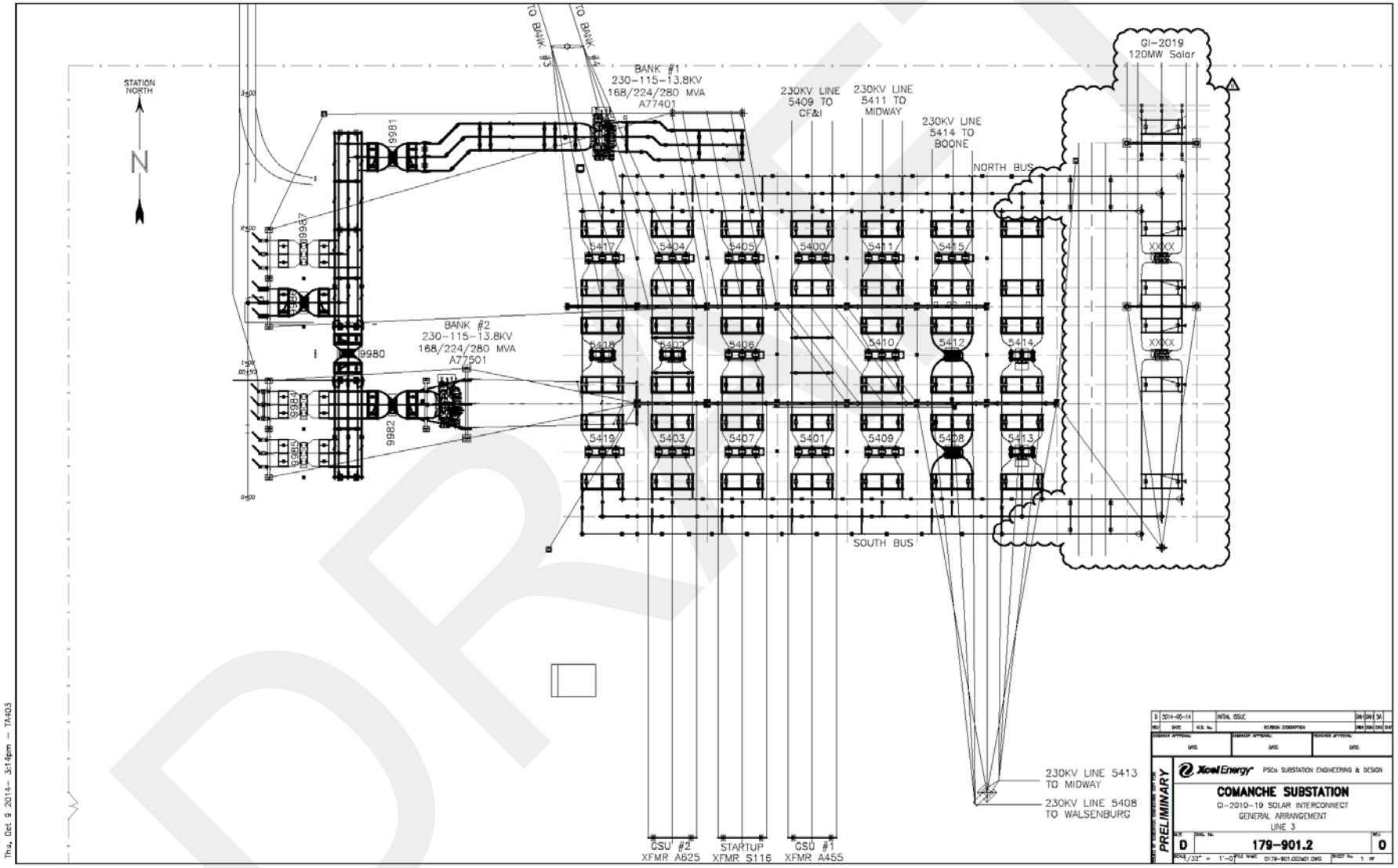


Figure 3: Comanche Station General Arrangement with GI-2010-19 Interconnection Facilities



I. Introduction

On November 16, 2010, Public Service Company of Colorado (PSCo) received an interconnection request (GI-2010-19) for a 120 MW photovoltaic (PV) solar generation facility in Pueblo County, Colorado. The proposed Point of Interconnection (POI) is the Comanche 230 kV bus within the Comanche 345/230/115 kV transmission substation (see Figure 1). The Commercial Operation Date (COD) requested by the Interconnection Customer is June 30, 2016, and accordingly the target Backfeed date is March 31, 2016.

The photovoltaic solar generation facility will consist of 100 Power Electronics Freesun HE 1200_U dc/ac inverters, each rated 1200 kVA ac, 390V ac, 0.90 lead – 0.90 lag adjustable power factor. The generation facility will consist of six (6) 34.5 kV feeders comprising the collector system — four feeders will have 16 daisy-chained inverters, and the remaining two feeders will have 18 daisy-chained inverters. One 390V / 34.5kV, 2640 kVA unit step-up transformer (UT) will be installed for every pair of inverters, resulting in 8 daisy-chained UTs in four feeders and 9 daisy-chained UTs in two feeders. The generating plant will have one main GSU rated 34.5/230 kV, 78/104/130 MVA, Z=10% and will connect to the Comanche 230kV bus POI via a 0.25 mile 795 ACSR overhead conductor line owned by the Interconnection Customer.

The Feasibility Study was completed on April 22, 2013, followed by the completion of Interconnection System Impact Study on May 28, 2014. The purpose of Interconnection Facilities Study is to specify and estimate the cost of the equipment, engineering, procurement and construction work needed to implement the conclusions of the Interconnection System Impact Study in accordance with Good Utility Practice to physically and electrically connect the GI-2010-19 large generating facility to PSCo's transmission system at the Comanche 230 kV Station.

II. Project Scope

The scope of this project is to construct a new 230kV bay consisting of two SF6 circuit breakers and five gang switches in the Comanche 230kV switchyard – metering units, lightning arresters, one additional gang switch for the metering units, two dead-end structures, and a static mast will also be installed in the interconnection facilities. Interconnection Customer is responsible for the installation of LF/AGC RTU in their generation facility along with communications circuit for RTU and ring-down line. Customer funded equipment shall consist of metering units along with structures and foundations, line arresters with structures and foundations, a gang switch with its structure and foundations, two dead-end structures with their foundations, and line protection relays.

The one-line diagram and general arrangement of the interconnection details are in Figure 2 and Figure 3 respectively.

III. Interconnection Facilities & Network Upgrades for GI-2010-19 Interconnection

Requirements for interconnection of new generation to the Xcel Energy Operating Companies' transmission system can be found in the *Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW – Version 3.0*[2], last revised in December 2006. These guidelines describe the technical and protection requirements for generator interconnection and also require that the Interconnection Customer be in compliance with all applicable criteria, guidelines, standards, requirements, regulations, and procedures issued by the North American Electric Reliability Council, Public Utility Commission or their successor organizations.

A. FERC and/or NERC Compliance Requirements

Critical Infrastructure Protection (CIP) Asset

Comanche is an existing BES facility and is a CIP Critical Asset station – this was verified on October 1, 2014.

Facility Ratings and Smart One Lines

All transmission facilities in Comanche station will be rated as per PSCo's current facility rating methodology. No special BIL requirements due to altitude or contamination issues apply since Comanche station is 4844 feet above sea level.

B. Right of Way / Site Permitting

No land purchase or station expansion will be required. PSCo Engineering and Construction will be responsible for getting the required construction permits.

C. Electrical Features

Current Carrying Capacity of Affected/Tapped/New Transmission Lines

The substation equipment ratings are adequate for this project.

Fault Current

The existing pre-project and the future post-project fault current values in Comanche 230 kV station are tabulated below.

[2] Interconnection Guidelines can be found at www.xcelenergy.com.

Type of Fault / Location	Three Phase Fault (A)	Single-Line-to-Ground (A)
	Before GI-2010-19	
230kV North Bus	24759	28939
230kV South Bus	24759	28939
	After GI-2010-19	
230kV North Bus	24759	29034
230kV South Bus	24759	28939

Electrical Removals & Relocations

There will be no electrical removal for this project.

Electrical Installations (Major Equipment)

PSCo Funded: PSCo installed and funded equipment shall be: two new 230kV SF6 breakers along with their foundations, five gang switches along with their foundations and structures, and a static mast with its foundation will be installed.

Customer Funded: Customer funded equipment shall be metering units along with their structures and foundations, two dead-end structures with their foundations, line arresters with their structures and foundations, and protection relays for the new line. Customer will be responsible for installing LF/AGC RTU at their generating facility along with phone line for RTU and ring-down line.

Electrical Equipment Enclosure (EEE)

Electrical equipment enclosure is adequate for this project.

AC System

AC system is adequate for this project.

DC System

Currently, house power for 115kV and 230kV yard equipments are being supplied from a 1300AH plant battery as well as 126AH battery from the control building. The 126AH battery is serving loads such as relays for relay panel 8S, Bank1, Bank2, 230kV circuit breakers 5413 & 5414, and 115kV circuit breaker 9986. DC calculations were conducted and it was determined that the existing 126AH is adequate for its existing loads in addition with the new loads (Two 230kV SF6 breakers, and four relays).

Grounding

Grounding will need to be expanded due to the installation of the new bay.

Xcel Energy

Lightning Protection

Lightning protection is adequate for the existing equipments. Line arresters, shield wires, and a static mast will need to be installed for the new equipment.

Trenching & Cable

New duct bank along with four pulpits will be installed for this project. The existing duct bank is not adequate. New cables will be run from new breakers to the EEE.

D. Civil Features

Grading & Fencing

- The existing crushed rock is in good condition. However, resurfacing will need to be done due to installation of circuit breaker foundations and cable trenching.
- There is adequate space on site for construction parking.
- BMP's (Best management practices or erosion control) will be required.

Foundations & Structures

The following foundations will be installed:

Quantity	Description	Approx. Size
2	230 kV SF6 Breakers	10'-0" x 10'-0" x 2'-6" (concrete slab) (1x each)
6	230kV Gang Switches	30" dia x 8'-0" Pier & Cap (2x each)
3	Metering Units	30" dia x 8'-0" Pier & Cap (1x each)
3	Line Arresters	30" dia x 8'-0" Pier & Cap (1x each)
4	Dead-End Structures	5'-0" dia x 16'-0" Pier & Cap (1x each tower)
30	Bus Support Structures	30" dia x 8'-0" Pier & Cap (1x each)

All structures will be master or previously designed structures. The 230kV dead-end structures will be vendor designed welded tubular steel; all others will be rectangular HSS sections.

Storm Water Permit
A SWMP will likely be required. The expected disturbed area to accomplish this scope is 1.0 acres.
RE FIRM Panel 0801470355B, “OTHER AREAS ZONE X - Areas determined to be outside 500-year flood plain.”

Electrical Equipment Enclosure (EEE) or Switchgear Building
No new EEE will be installed for this project.

Fire protection (Fire protection wall, and fire protection layer around EEE)
Fire protection will not be required for this project.

SPCC (Oil Containment)
No oil containment will be required for this project.

Civil Removals & Relocations
None will be required for this project.

E. Protection Features

This protection recommendation is for the installation of transmission line protection for the new 230kV line from Comanche to the GI-2010-19 generating facility. This transmission line will be connected to a new breaker-and-a-half position in the Comanche 230kV yard, with two new circuit breakers, yet to be numbered.

A summary of the Line Protection package is given below, followed by a detailed design description.

- Primary Line Protection: PKG-P, SEL-311L
  - Part Number: 0311L1HD03254X2XX
  - Firmware Version: R413
- Secondary Line Protection: PKG-S, SEL-311L
  - Part Number: 0311L1HD03254X2XX
  - Firmware Version: R413
- Breaker Failure, Sync Closing, Reclosing BKR 1: BKR 1 PKG-BF, SEL-351
  - Part Number: 035163C4A542X1
  - Firmware Version: R511
- Breaker Failure BKR2, Sync Closing BKR 2: BKR 2 PKG-BF, SEL-351
  - Part Number: 035163C4A542X1
  - Firmware Version: R511

The primary protective scheme is a line current differential (87L) scheme utilizing a SEL-311L relay (PKG-P). The SEL-311L relay will also implement a backup step distance and ground overcurrent scheme. A Direct Transfer Trip (DTT) scheme is implemented in the PKG-P relay. A normally closed (NC) cutoff switch, 85CO-1 PKG-P, can be used to disable the pilot scheme and DTT; the 85CO-1 switch status (channel status) is monitored by the RTU through an output on the SEL-311L relay.

The operation of the trip output of the SEL-311L, by the pilot scheme or the backup step distance and ground overcurrent, will operate BKR1 and BKR2 trip coils #1 and initiate breaker failure for both circuit breakers. Further, it will initiate reclose for BKR1 and send a trip status to the DFR. An output on the SEL-311L relay is used as SCADA channel alarm. The DTT keying will be initiated by the breaker failure lockout relays BKR1 86BF and BKR2 86BF. An output on the PKG-P SEL-311L relay is used as DTT-sent status to the DFR. Receiving DTT from the remote terminal will operate an output on the PKG-P SEL-311L relay. This output operates auxiliary relay, 94 DTT-1, which will consequently operate trip coils #1 of BKR1 and BKR2 and block closing of both breakers.

The secondary protection scheme is a line current differential (87L) scheme utilizing a SEL-311L relay (PKG-S). The SEL-311L relay will also implement a backup step distance and ground overcurrent scheme. A DTT scheme is implemented in the PKG-S relay. A normally closed (NC) cutoff switch, 85CO-2 PKG-S, can be used to disable the pilot scheme and DTT; the 85CO-2 switch status (channel status) is monitored by the RTU through an output on the SEL-311L relay. The operation of the trip output of the SEL-311L, by the pilot scheme or the backup step distance and ground overcurrent, will operate BKR1 and BKR2 trip coils #2 and initiate breaker failure for both circuit breakers. Further, it will initiate reclose for BKR1 and send a trip status to the DFR. An output on the SEL-311L relay is used as SCADA channel alarm. The DTT keying will be initiated by the breaker failure lockout relays BKR1 86BF and BKR2 86BF. An output on the PKG-P SEL-311L relay is used as DTT-sent status to the DFR. Receiving DTT from the remote terminal will operate an output on the PKG-S SEL-311L relay. This output operates auxiliary relay, 94 DTT-2, which will consequently operate trip coils #1 of BKR1 and BKR2 and block closing of both breakers.

Breaker failure, sync check, and reclosing for BKR1 are implemented using SEL-351 relay (BRK1 PKG-BF). The breaker failure scheme will be initiated by the operation of the primary SEL-311L relay (PKG-P) and secondary SEL-311L relay (PKG-S). The trip output of the breaker failure relay will operate the breaker lockout relay (BKR1 86BF), which will consequently trip and block closing of BKR 2 and initiate a direct transfer trip (DTT) to the remote terminal via the PKG-P and PKG-S SEL 311L relays. The trip output of the breaker failure relay will also operate the North 230kV bus differential lockout relay (86BS) and send a trip status to the DFR. The reclosing of BKR1 can be blocked remotely through SCADA or manually using a normally closed cutoff switch, 79CO. The reclosing can be initiated by the primary SEL-311L relay (PKG-P) or the secondary SEL-311L relay (PKG-S). The close output of the relay will operate the close coil of BKR1. Another output provides SCADA reclose-enable status. Further, an output is used to provide SCADA alarm in case of sync failure.

Breaker failure and sync closing for BKR2 is implemented using SEL-351 relay (BKR2 PKG-BF). The breaker failure scheme will be initiated by the operation of the primary SEL-311L relay (PKG-P) and secondary SEl-311L relay (PKG-S). The trip output of the breaker failure relay will operate the breaker lockout relay (BKR 2 86BF), which will consequently trip and block closing of BKR 1, and initiate direct transfer trip (DTT) to the remote terminal via the PKG-P and PKG-S SEL 311L

relays . The trip output of the breaker failure relay will also operate the South 230kV bus differential lockout relay (86BS) and send a trip status to the DFR. The closing can only be initiated remotely via SCADA or manually at the substation; there is no auto-reclosing on BKR 2. A relay output is used to operate BKR 2 close coil for successful close initiated remotely via SCADA or manually at the substation. Another output provides SCADA alarm in case of sync failure.

F. Control Features

Control Panel Locations

One relay panel will be installed for this project – the EEE has room for an additional relay panel.

RTU

The existing RTU is at Comanche 230/115kV yard is Landis and Gyrs. This RTU has enough spare points for the new projects. Upgrading this RTU is beyond the scope of this project.

Removals

None.

G. Project Operating Concerns and Facility Outages

Facility Outages / Temporary Configurations

None exist at this time.

Mobile Substation or Transformer

None.

Material Staging Plan

All major equipment will be staged at the job site. Stock materials will be ordered and staged through Border States.

IV. Cost Estimates and Assumptions

Scoping level cost estimates for Interconnection Facilities and Network/ Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by Xcel Energy/PSCo Engineering staff. The cost estimates are in 2014 dollars with escalation and contingencies applied (AFUDC is not included) and are based upon typical construction costs for previously performed similar construction.
These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, material/equipment procurement and construction of these new PSCo facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The estimated total cost for the GI-2010-19 interconnection project is **$4.054M.** Tables 1, 2 and 3 given below list the transmission improvements required to accommodate the interconnection and delivery of GI-2010-19 generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines.

Table 1 – PSCo Owned, Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Comanche 230kV Transmission Substation	Interconnect Customer to the 230kV bus at the Comanche 230kV Substation. The new equipment includes: • Extend the 230kV Bus at to a new bay location • One new transmission line transition structure • One 230 kV gang switch and one grounding switch • Three 230 kV line arresters • Connect the new 230kV position to the bus • New relaying for the new transmission line. • Power Quality Metering (230kV line from Customer) • Three 230kV lightning arresters • One relay panel (transformer breaker panel) • One new underground transmission line transition structure • Associated communications, 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	**$1.199**
Customer's 230kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment. Install a new relay panel at the customer generation site. Connect SCADA from the site to the Lookout Control Center.	**$0.289**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$1.488**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 2 – PSCo Owned, PSCo Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Comanche 230kV Transmission Substation	Interconnect Customer to the 230kV bus at the Comanche 230kV Substation. The new equipment includes: • Three 230 kV gang switches • Install a new 230 kV bay by extending the busses to the east • Five 230 kV gang switches • Two 230 kV breakers • Modify the relaying for the new bay position	**$2.566**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$2.566**
Time Frame	**Site, design, procure and construct**	**12 months**

Table 3 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
	Not Required	
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0.0**
Time Frame	**Site, design, procure and construct**	**Not Applicable**

	Total Project Estimate	**$4.054**

Cost Estimate Assumptions

- Scoping level cost estimates (+/- 30% accuracy) for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery were developed by Xcel Energy/PSCo Engineering.
- Standard contingency factors for cost estimates are: Material: 10%, Labor and Equipment: 20%
- Cost Estimates are based on 2014 dollars (appropriate contingency and escalation applied).
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- A CPCN is not required for the construction of Interconnection Facilities and Network Upgrades.

- The Generation Facility is not within PSCo's retail electric service territory. Therefore, costs for retail load metering are not included in these estimates.
- Interconnection Customer's 230 kV transmission line construction scope will include stringing OPGW up to the line termination into Comanche Substation.
- Power Quality Metering (PQM) will be required on the Interconnection Customer's 230 kV transmission line terminating into Comanche Substation.
- Line and Substation bus outages will need to be authorized during the construction period to meet the requested backfeed date. Obtaining construction outages could be problematic due to summer construction window and may potentially delay the backfeed date.
- The estimated time to design, procure and construct the Interconnection Facilities and Network Upgrades is approximately 12 months after authorization to proceed has been obtained.
- PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.