Generation Interconnection Facilities Study Report
Request # GI-2014-12

53 MW Solar Photovoltaic Generation
Boone 115 kV Substation, Colorado

Transmission Planning West
Xcel Energy Services

March 4, 2016

I. 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 siting, engineering, equipment procurement and construction needed to interconnect a 53 MW Solar Photovoltaic generation facility at the Boone 115 kV Substation located in Pueblo County, Colorado.

The proposed solar generation plant will consist of twenty six (26) SMA KODIAK 2.2MVA inverters. GI-2014-12 will be connected to the Boone 115 kV Substation using a customer owned 4.8 mile long 115 kV tie line. The proposed solar generating facility has a commercial operation date of July 1, 2016 and a backfeed date of April 1, 2016.

The total estimated cost for the facilities required for interconnection is **$1.56M**[1]

- $1.472 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- $0.087 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- $0.00 million for PSCo Network Upgrades for Delivery

The estimated time required to site, engineer, procure and construct the facilities described is at least 18 months from the date the Customer meets all applicable Milestones as agreed to in any future LGIA. An Engineering & Procurement Agreement can be executed to facilitate completion of the interconnection facilities.

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

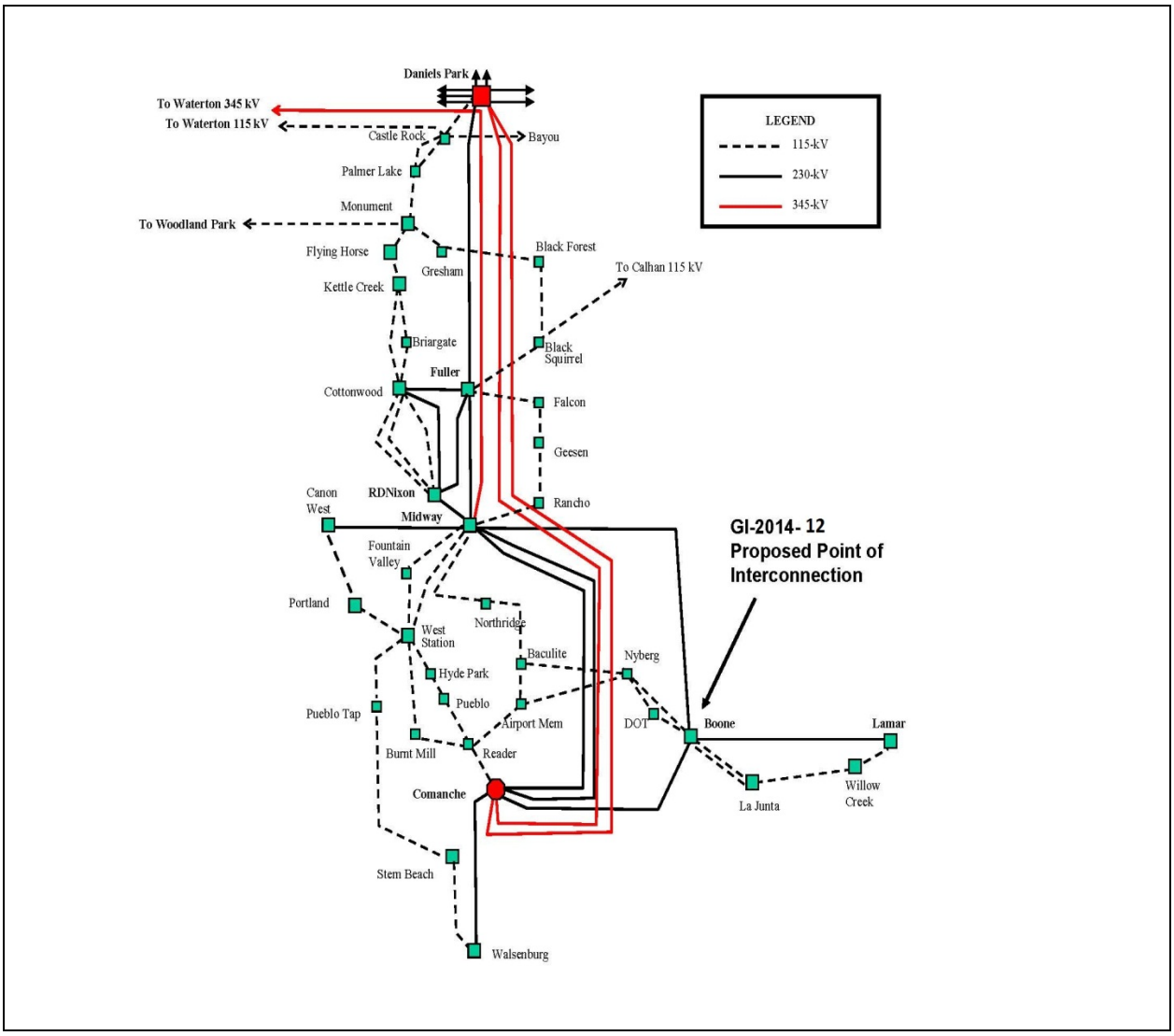


Figure 1 Boone Substation and Surrounding Transmission System

II. Introduction

PSCo received the study request for GI-2014-12 on November 13, 2014. The original design of GI-2014-12 consisted of sixty eight 750KW inverters and two 500 KW inverters. On January 21, 2015, the Interconnection Customer has reduced the generation facility size to 53MW and the design was changed to include twenty six SMA KODAIAK 2.2MVA inverters. According to the new design of the generation facility, the gross output at the inverter terminals will be 54.3MW and net injection capacity at the Boone 115 kV Substation will be 53MW. Each inverter will have a 385V/34.5 kV step up transformer in an arrangement referred to as a Power Conversion Station (PCS). The entire Generating facility will consist of 26 PCS. A single 34.5/115 kV star grounded/star grounded/delta 33/55MVA transformer will step-up the voltage to 115 kV for delivery through the generator tie line. A 6 Mvar shunt capacitor will connect to the 34.5 kV collector bus for additional voltage support as required.

The final Feasibility and System Impact Study report for GI-2014-12 was issued on October 1, 2015. The Feasibility Analysis did not identify any thermal or voltage violations that may be attributed to the GI-2014-12 interconnection. However, the power flow analysis did identify several pre-existing thermal overloads that must be mitigated. PSCo Transmission Planning has an operating procedure in place to mitigate these pre-existing thermal overloads. This operating procedure will allow generation of 53 MW at GI-2014-12 as both an Energy Resource and a Network Resource. No stability analysis was performed for GI-2014-12 since the dynamic performance of the solar generation facility for normally cleared faults was expected to be satisfactory based on the proprietary information on Voltage Ride Through (VRT) capability of the SMA KODIAK inverters provided by the Interconnection Customer. Furthermore, it is the responsibility of the Interconnection Customer to ensure that the 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-024-1.

III. General Interconnection Facilities Description

A. Project Purpose & Scope

The purpose of this project is to install a new 115 kV interconnection for a 53 MW solar photovoltaic generation facility interconnection at Boone 115 kV bus.

Notable Items

This is an interconnection project. The final ownership and payment terms will be discussed in the LGIA. Development and Xcel's contractual obligations will be determined at a later date pending the start of construction.

Distribution vs. Transmission Asset Ownership and Cost Responsibility

The substation primary function is presently defined as Transmission. This project will not change the primary function of the substation when complete assuming no other changes.

Interconnection / Customer Cost Responsibility

The detailed contractual obligations will be determined at a later date. Since this is a radial interconnection, very little upgrades to the Xcel Network are required. Therefore the customer will be responsible for nearly 100% of direct interconnection cost.

B. FERC and/or NERC Compliance Requirements

Critical Infrastructure Protection (CIP) Asset

The CIP status of this substation was has been verified.

Bulk Electric System Status (BES)

This is a BES facility

Facility Ratings and Smart One-Lines

The detailed contractual obligations will be determined at a later date. The customer will be responsible for nearly 100% of direct interconnection cost.

C. Right of Way/Permitting

The project will occur inside the Boone substation perimeter. It is assumed that no right of way access or building permit will be required. This will need to be verified with Siting and Land Rights during the appropriate stage. All permitting and right of way access for the GI-2014-12 generation facility and transmission tie-line will be the responsibility of the developer.

D. Electrical Features

Transmission Lines: Current Carrying Capacity of Affected/Tapped/New

The existing Boone substation equipment is anticipated to meet the additional ampacity ratings from the GI-2014-12 interconnection.

Fault Current

All fault levels were calculated using CAPE. The table below outlines the fault levels at the Boone substation with GI-2014-12 addition.

Type of Fault / Location	Three Phase (A)	Single-Line-to-Ground (A)
115kV Main Bus	13,042	11,818

Electrical Removals & Relocations

No electrical removals are required. No temporary structures are required.

Electrical Installations (Major Equipment)

One 145 kV, 3000A, 40 kA, -40 deg. C, SF6 gas circuit breaker will be installed. The circuit breaker will have four sets of 2000:5A multi-ratio BCTs.

Three 115 kV, 2000 A, group-operated, vertical-break disconnect switches will be installed for breaker and line isolation.

Three single-phase metering units with 115 kV, 0.3% accuracy CCVT and 300:5A single-ratio CT will be installed.

Three 76 kV MCOV station-class, polymer surge arresters will be installed. The arresters will be mounted on new structures on the ground.

The rigid bus will consist of 4" schedule 40 aluminum tubular bus rated for 3263 A. The circuit breaker, switch and metering unit connections will be made with 2-1590 MCM AAC conductor per phase rated for 2258 A. The taps to the surge arresters will be 556.4 MCM AAC conductor. All substation conductor ratings are based on 2ft/sec wind speed and 85 ºC top temperature, per E.D. Standard 6.01.01.

Electrical Equipment Enclosure (EEE)

A total of three panels are expected for this project; one for line protection, one for breaker operation, one for communications (see related sections below.) Based on the available drawings, the existing EEE provides sufficient space in the panel rows for the addition of three panels for this project. Therefore, expansion of the EEE is not included in this scope.

AC System

The AC system will need to be field verified during detailed design as the record prints on the AC system are lacking several details required to complete a detailed system study.

DC System

The DC system is NOT adequate for the proposed additions to the substation. A detailed DC system study will need to be completed during the detailed design. The DC system will need to be field verified during detailed design as the record prints on the DC system are lacking several details required to complete a detailed DC system study.

Grounding

The existing ground grid encompasses the new 115kV bay area but will need to be extended due to the new deadend structure being located outside the existing loop. New grounding tails will be installed to ground the new equipment and steel structures. All new grounding will be completed in accordance with the latest Xcel Energy standards. Additional yard surface rock will be installed as necessary to establish a minimum 4" deep surface layer.

An updated grounding study will need to be performed to account for the additional generation and increase in available fault current. Any inadequacies in the grounding will need to be remediated.

Lightning Protection

New 76 kV MCOV station-class, polymer surge arresters will be installed on the new GI-2014-12 transmission tie-line for protection against lighting strikes and high voltage switching transients on the line conductors.

Additional shield spikes will be provided on the new deadend structure, and an OPGW shield wire will be required on the transmission line, but no additional shield wires inside the substation will be installed.

Trenching & Cable

New control cables will be installed for all new equipment. Existing conduits and pull vaults between the 115 kV bay and EEE will need to be evaluated to see if there is adequate space for new cables to the 115 kV breaker and metering units. Conduit could be installed between an existing pull vault and final equipment locations. Trenching may be required from the EEE to the new equipment, if existing installed conduit system is not adequate.

Wave/Line Traps

No new wave traps will be installed for this project. Communications between the line position and the PV farm substation are expected to be via new OPGW on the transmission line provided by Customer.

E. Civil Features

Grading & Fencing

Existing soil boring reports appear to be of good quality and no new soil borings will be required for this project. Parking at the site will be sufficient to support construction activities. No new grading or fencing will be required for this project.

Storm Water Permit

It is assumed a storm water permit will not be required as total land disturbed will be less than one acre. This will need to be verified with Siting and Land Rights during the appropriation estimate stage.

SPCC (Oil Containment)

The new metering units will contain approximately 70 gallons each of insulating oil. It is not expected that oil containment will be needed for this total volume of oil.

Civil Removals & Relocations

One bay of a 115 kV double bay dead-end structure and associated drilled pier foundations for the dead-end tower will need to be removed to provide adequate space for the new 115kV bay. Other possible existing foundations or below grade foundations may need to be verified or removed.

Foundations & Structures

The foundation sizes are based on the existing soil report, dated December 1974. The estimate includes the costs of surveying, staking, concrete testing, and inspection. Soil to be under slabs will be corrected up to 7’ below grade.

The following concrete slab foundations will be installed:

Quantity	Description	Approx. Size
1	115 kV Gas Circuit Breaker	6’x10’x1’

The following galvanized steel structures with drilled pier foundations will be installed:

Structure Quantity	Rolled Steel Description	Steel Wt./ Structure	Drilled Piers		
			Pier Qty/ Structure	Approx. Size	
				Dia.	Depth
2	115 kV Single Phase Bus Supports	581 lbs	1	2.5’	36”
3	115 kV Single Phase Metering Unit Stand	581 lbs	1	2.5’	36”
3	115 kV Arrester Stand	581 lbs	1	2.5’	36”
3	115 kV Three Phase Switch Stand	2,738 lbs	2	2.5’	36”
1	115 kV Taper Tubular Dead-End	39,315 lbs	2	5’-6”	60”
	Total Rolled Steel Weight	50,434 lbs			

All structures will be rolled steel with exception of the 115 kV dead-end which will be taper tubular. The 115 kV structures for the dead-end, switch stands, metering units stands, arrester stands, and bus supports will use master drawings. The dead-end will not have a porch for mounting the switches.

Switchgear Building

No expansion of the EEE is included in the scope of this project. New switchgear will not be installed as part of this project.

Fire Protection (Fire protection wall, and fire protection layer around IEEE)

No fire protection is required for the scope of work being completed on this project

F. Protection Features

Transmission Line Protection (115 kV)

The primary protective scheme will be line current differential (87L) scheme utilizing a SEL-411L relay (PKG-P). The SEL-411L relay will also implement a backup step distance and ground overcurrent scheme. A normally closed (NC) cutoff switch, 85CO-1 PKG-P, can be used to disable the pilot scheme. The operation of the trip output of the SEL-411L, by the pilot scheme or the backup step distance and ground overcurrent, will operate 115 kV breaker 8135 trip coil #1 and initiate breaker failure. Further, it will initiate reclose for 115 kV breaker 8135.

The secondary protection scheme will be step distance (21) scheme utilizing a SEL-311C relay (PKG-S). The SEL-311C relay will also implement a backup ground overcurrent scheme. A normally closed (NC) cutoff switch, 85CO-2 PKG-

S, can be used to disable the pilot scheme. The operation of the trip output of the SEL-311C, by the pilot scheme or the backup ground overcurrent, will operate 115 kV breaker 8135 trip coil #2 and initiate breaker failure. Further, it will initiate reclose for 115 kV breaker 8135.

Line relay malfunction and loss of AC alarms will be annunciated and sent to EMS. In addition, MWatt, MVar, kVolt, and fault distance location analog points will be sent to the EMS. These points will be generated by the primary SEL-411L relay.

A Direct Transfer Trip (DTT) scheme will be implemented in a SEL-2506. A normally closed (NC) cutoff switch, 85CO-3 DTT, will be used to disable the DTT. The DTT keying will be initiated by the breaker failure lockout relay 8135 86BF. Receiving the DTT from the remote terminal will operate an output on the SEL-2506. This output operates trip and block closing of 115kV breaker 8135 via an 86TT lockout relay.

Transmission Breaker Protection (115 kV)

Breaker failure, sync check, and reclosing for 115kV breaker 8135 are implemented using SEL-351S relay (8135 PKG-BF). The breaker failure scheme will be initiated by the operation of the primary SEL-411L relay (PKG-P) or secondary SEL-311C relay (PKG-S). The trip output of the breaker failure relay will operate the breaker lockout relay (8135 86BF), which will consequently trip and block closing of 8134, 8131, 9637, 8136, and 8132 and initiate a direct transfer trip (DTT) to the remote terminal via the SEL-2506. 115kV breaker 8135 reclosing can be blocked remotely through SCADA or manually using a normally closed cutoff switch, 79CO. The reclosing can be initiated by the primary SEL-411L relay (PKG-P) or the secondary SEL-311C relay (PKG-S). The close output of the relay will operate the 115 kV breaker 8135 close coil.

Breaker failure lockout, relay, reclose status, sync malfunction, and single/dual trip coil failure alarms will be annunciated and sent to the EMS. Also, three-phase breaker amps will be sent to the EMS. These alarms and analog points will be generated by the SEL-351S relay. Breaker trip/close will be provided locally and from the EMS.

Transmission Bus (115 kV)

A current transformer from 115 kV breaker 8135 will be included in the 115 kV high impedance bus differential scheme.

G. Control Features

General

The existing control design for this substation follows the traditional approach. The new relaying and control for this project will utilize the traditional approach as well.

Transmission Breaker Reclosing Controls

The new 115 kV breaker will have remote close supervised by sync/dead line/dead bus implemented in the SEL-351S. The new 115 kV breaker will not have automatic reclose to avoid closing generation into an existing fault.

Transmission LTC Controls

No new transformer LTC schemes will be implemented on this project.

Auto-Sectionalizing/Auto-Transfer

No new auto-sectionalizing or auto-transfer schemes will be implemented on this project.

Digital Fault Recorder

There currently is not a Digital Fault Recorder at this site and this project will not install one.

Control Panel Locations

Panel #	Panel Description	Size
6F	Orion RTU Cabiet	36”
7F	115 kV PV Boone Interconnect Line Protection	28”
8F	115 kV Breaker 8135 Control and Breaker Failure	28”

Removals

There are no removals anticipated for the scope of this project.

H. Communication Features

Remote Terminal Unit (RTU)

There are plenty of spare analog status, digital status and control points available in the RTU for this project. The new circuit breaker and relays added on this project will communicate controls, alarms, status through hardwired points to the

RTU. Fault distance and metering information will be passed through communication signals to the RTU.

Real-Time/Boundary Area Metering will utilize the existing area RTU and communication link along with the installation of a new SEL-735 meter for the new line metering. The new SEL-735 meter will be installed in the new line protection panel.

Local Annunciation

Boone substation has an existing LCU for local annunciation. The existing LCU is NOT adequate. A new NovaTech Orion LX HMI including touchscreen Monitor, Keyboard and Trackball will be installed.

Telephone Protection

A detailed review by Business Systems will be needed to decide

Relay Remote Access

There are available spare ports on the existing communication processor for all new relays added on this project.

Programmable Logic Controller/Feed Load Monitoring/Informatin-flow/Others

Not applicable for this facility.

Fiber Optic cable

The piloted relaying communications for the 115 kV transmission tie-line will be accomplished using a fiber optic communications channel via a new 24-fiber OPGW shield wire installed on the new line. A new direct-burial fiber optic cable will be installed in PVC conduit from the new fiber patch panel to be located in the new communications rack to the new OPGW termination and splice box on the new 115kV dead-end structure. New fiber optic patch cords will be installed from the patch panel to the SEL-411L primary relay, SEL-311C secondary relay, and SEL-2506 for direct transfer trip. All new fiber optics will be single-mode.

Removals

There is no communication removals required for this project

I. Project Operating Concerns and Outages

Outages/Temporary Configurations

This project will require a partial outage on the 115kV main bus for connecting the new 115kV bay phase conductors, and to make the required modifications to the 115kV bus protection.

Mobile Substation or Transformer

A mobile transformer will not be required for this project.

Environmental

There are no environmental concerns with this project.

J. Material Staging Plan

All major materials will be shipped directly to the substation. All other materials will be ordered and staged through the Pueblo Service Center.

K. Estimate Discussion

The standard contingency factors for estimates are as follows:

- Appropriation Est. Contingency Factors: Material:10%, Labor and Equipment:10%
- The estimate for this project utilizes the standard contingency levels

L. Risk Check List

Risk factors identified at the time the Design Guide Package was prepared are indicated below. Explanations indicate the action taken, if any, in the estimate as a result, such as additional contingencies or multipliers that were applied.

☐ Survey information is not available. Explain:.

☐ Soil boring results are not available. Explain:.

☐ Unusual soils or environmental conditions exist. Explain:

☐ Key materials or items need decisions or approvals. Explain:

☐ Potential permitting delays or unusual requirements exist. Explain:

☒ There are difficult or seasonal outage requirements. Explain: The existing 115kV position 8134 will require outages at this time to make the new

connections to the 115 kV bus. The bus 115 kV differential protection will need to be out of service to add the new circuits from 8135.

☐ There are conflicting outage requirements. Explain:

☐ There are risks due to who will construct the project and their availability. Explain:

☐ Unusual construction techniques will be required. Explain:

☐ There are risks associated with plans to reuse existing material. Explain:

☐ There are potential alternatives still under consideration. Explain:

☐ Material prices are likely to change or volatile. Explain:

☐ Material lead times are likely to be longer than estimated. Explain:

☐ Labor prices are likely to change. Explain:

☐ There are existing erosion problems. Explain:

☐ The existing oil containment may not be adequate. Explain:

☐ The existing lightning protection may not be adequate. Explain:

☐ The existing bus and equipment ampacity may not be adequate. Explain:

☒ The existing drawings are incomplete and inaccurate. Explain: Existing AC & DC service drawings will need to be verified. Additional time should be added for engineering design. Existing foundation plan drawing may not be up to date. A few additional foundations may need to be removed if they are actually installed, but the cost should not significantly impact the estimates.

Notes and Comments:

IV. Cost Estimates and Assumptions

Appropriation level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 20% accuracy) were developed by Public Service Company of Colorado (PSCo) / Xcel Energy (Xcel) Engineering. The cost estimates are in 2016 dollars with escalation and contingency included. AFUDC is not included. 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. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The estimated total cost for the interconnection is **$1.56 million.** Figure 2 below represents a conceptual one-line of the proposed interconnection into the 115V bus at the Boone Transmission Substation. These estimates do not include costs for any other Customer owned equipment and associated design and engineering. The following tables list the improvements required to accommodate the interconnection and the delivery of the Project 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 Boone 115kV Transmission Substation	Interconnect Customer to the 115kV bus at the Boone 115kV Substation. The new Customer Funded construction includes: • One (1) new transmission line dead end structure • Three (3) single-phase metering units • Three (3) 115 kV gang switches • One (1) grounding switch • Three (3) line arresters • New relaying for the new transmission line. • Power Quality Metering (115kV line from Customer) • One relay panel (transformer breaker panel) • 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	**$1.472**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$1.472**
Time Frame	Site, design, procure and construct	**18 Months**

Table 2: PSCo Owned; PSCo Funded Interconnection Network Facilities

	Description	Cost Estimate (Millions)
PSCo's Boone 115kV Transmission Substation	Interconnect Customer to the 115kV bus at the Boone 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	**$0.087**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$0.087**
	Site, design, procure and construct	**18 Months**

Table 3 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
	Not Applicable	
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$0**
Time Frame	**Site, design, procure and construct**	
	Total Project Estimate	**$1.559**

Cost Estimate Assumptions

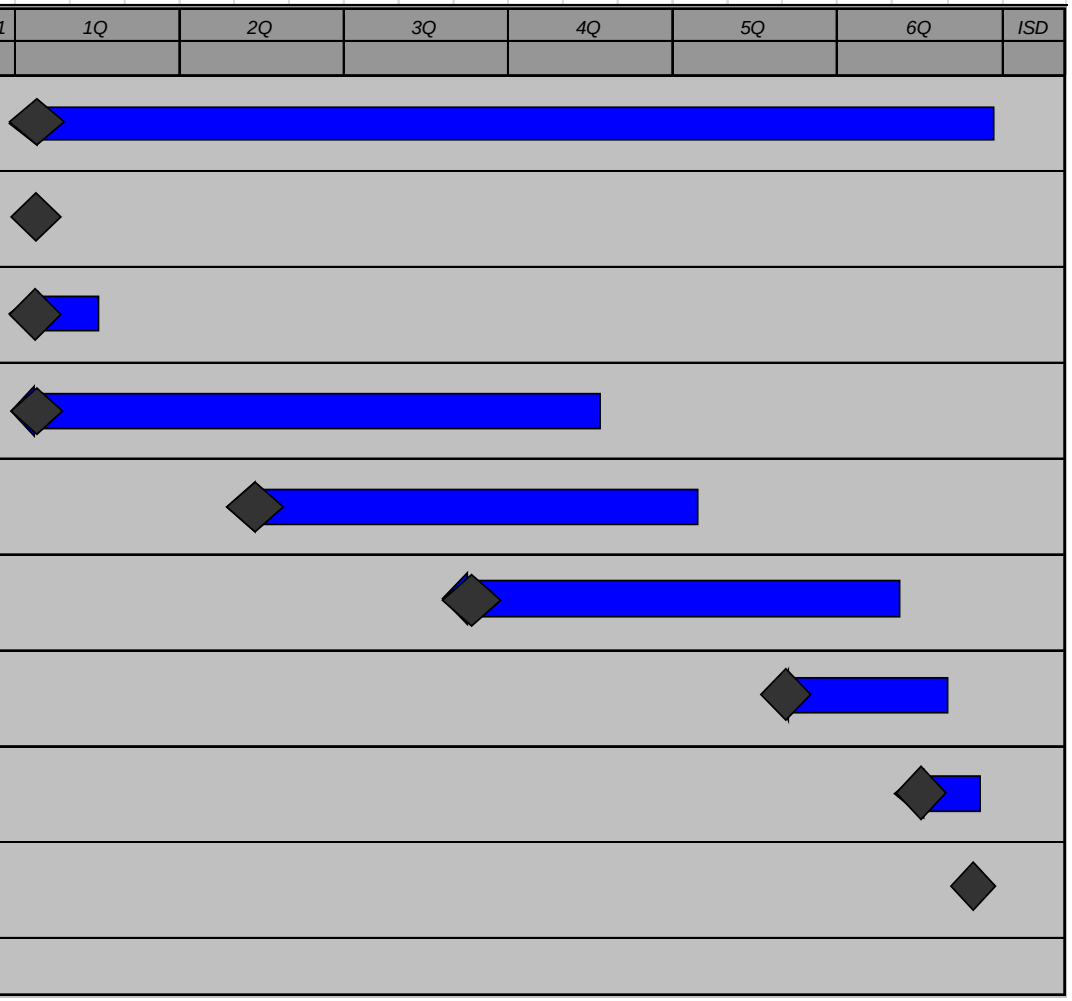
- Appropriation level project cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 20% accuracy) were developed by PSCo / Xcel Engineering.
- Estimates are based on 2016 dollars (appropriate contingency and escalation included).
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Solar Generation Facility is not in PSCo's retail service territory. Therefore, no costs for retail load (distribution) facilities and metering required for station service are included in these estimates.
- PSCo / Xcel (or our Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.

- The estimated time to site, design, procure and construct the interconnection facilities is approximately 18 months after authorization to proceed has been obtained.
- A CPCN will not be required for the interconnection and network delivery facilities construction.
- The Customer will be required to design, procure and install a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer Substation. Costs for the LF/AGC are not included in the estimates provided.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- No new substation land will need to be acquired.
- Power Quality Metering (PQM) will be required on the Customer's 115 kV line terminating into the Boone Substation

V. Engineering, Procurement & Construction Schedule

GI-2014-12 Facilities Study Report
53 MW Solar Interconnection @ Boone 115kV Substation

ID	Task Name	Duration
1	GI-2014-12 Facillities Study Report 53 MW Solar Interconnection	78w
2	Authorization to Proceed: Execution of Interconnection Agreement	0w
3	Sighting & Land Rights and Permitting	6w
4	Substation Design/Transmission Line Design & Engineering	40w
5	Substation/Transmission Line Material Procurement	36w
6	Substation/Transmission line Construction	36w
7	Relay, Protection & Control Equipment Testing	10w
8	Final Commissioning	4w
9	Project Completion / Backfeed	0w
10		



A. Project One-Line of the Boone Substation with GI-2014-12 Interconnection

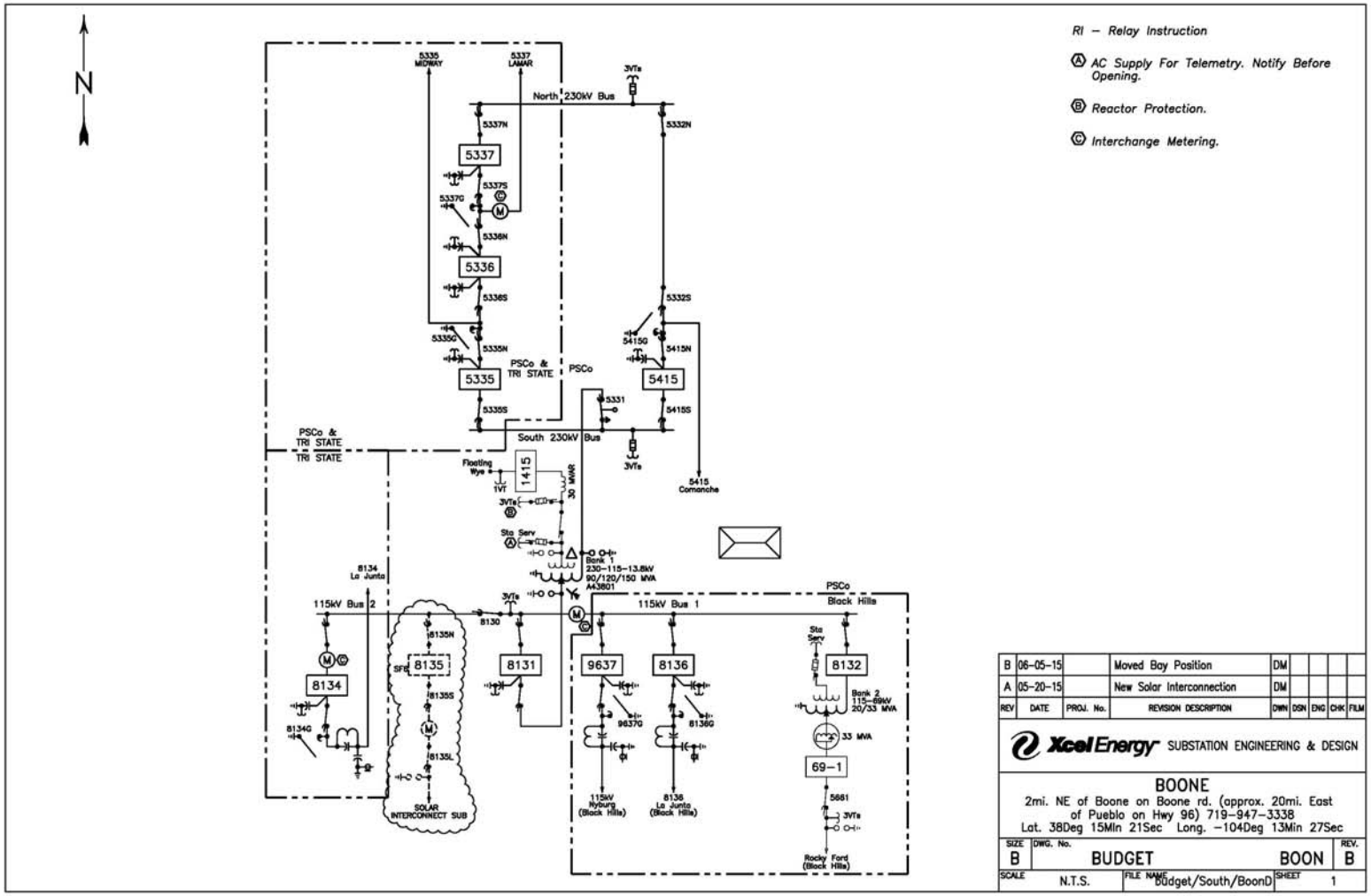


Figure 2 - Boone Substation One-Line with GI-2014-12

B. Boone Substation General Arrangement with GI-2014-12