Generation Interconnection Facilities Study Report
Request # GI-2014-8

60 MW Photovoltaic Solar Generation
At Boone 230 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning

August 11, 2015

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 60 MW Solar Photovoltaic generator at the Boone 230 kV Substation in Pueblo County, Colorado.

The proposed solar generation plant will consist of Eaton Power Xpert Solar 1500 inverters and will be located approximately 0.25 miles northwest of the Boone Substation. GI-2014-8 will be connected to the Boone 230 kV Substation using a customer owned 230 kV tie line. The proposed solar generating facility is planned to be in-service in December 2016.

The total estimated cost for the facilities required for interconnection is **$2.50M**[1]

- $1.12 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- $1.38 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%.

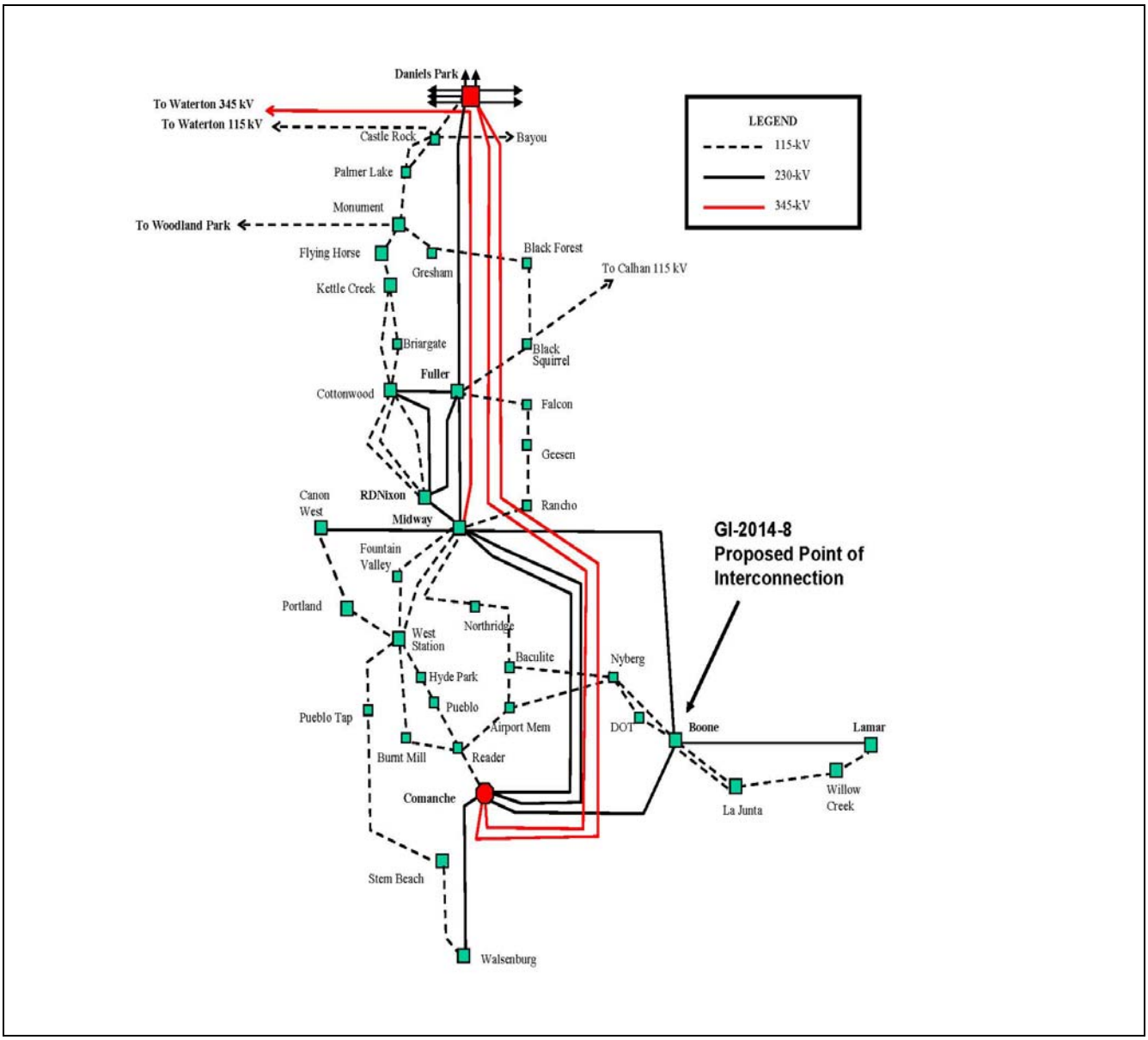

Figure 1 Boone Substation and Surrounding Transmission System

II. Introduction

PSCo received an interconnection request (GI-2014-8) for a 60MW Photovoltaic Solar generation facility on October 29, 2014. The proposed GI-2014-8 will consist of Eaton Power Xpert Solar 1500 inverters and will be located approximately 0.25 miles northwest of the Boone Substation. An agreement for a Facility Study was executed on May 11, 2015. The final Feasibility and System Impact Study report for GI-2014-8 was issued on April 3, 2015. The Feasibility Analysis did not identify any thermal or voltage violations that may be attributed to the GI-2014-8 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 60 MW at GI-2014-8 as both an Energy Resource and a Network Resource. No stability analysis was performed for GI-2014-8 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 Eaton Power Xpert Solar 1500 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 Customer (GI-2014-8) has requested an interconnection to PSCo Facilities at a 230kV bus position at the Boone Substation. Xcel Energy will be responsible for costs associated with upgrading the bus and bay position associated with the project, as well as any necessary substation land/equipment upgrades. The Customer will be responsible for the construction of their facility, the interconnecting T-line, and the LFAGC RTU.

Background

GI-2014-8 has requested an interconnection to PSCo Facilities at a 230kV bus position at Boone Substation.

Notable Items

This is an interconnection project. The final ownership and payment terms will be discussed in the LGIA.

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. The project cost for Transmission Asset Management (TAM) is given in Tables 1,2 and 3.

Interconnection / Customer Cost Responsibility

The project cost will be reimbursable by the customer as per the LGIA.

B. FERC and/or NERC Compliance Requirements

Critical Infrastructure Protection (CIP) Asset

The CIP status of this substation was has been verified.

Facility Ratings and Smart One-Lines

This substation has Bulk Electric System facilities.

A smart one-line already exists for this substation. The existing smart one-line will be updated to include the changes made by this project. Facility ratings changes will be handled via the GIST2 system, and will be reviewed and approved per the Procedure for Review and Approval of GIST2-Created Facility Ratings.

C. Right of Way/Permitting

A small substation expansion will be required for this project. It will not require more land to be purchased. The size of the expansion will be approximately 80' x 150', which will include a new dead-end, switch, metering units, and arresters.

Appropriate SWMP, GESC, and S&LR Permits will need to be evaluated and obtained if necessary.

D. Electrical Features

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

The addition of 60MW of generation capacity to Boone Substation will not require any upgrade of existing equipment. A new transmission line will be installed by the interconnection customer with enough capacity to carry the expected current (approximately 150A). The new bay position and line termination will be installed by Xcel Energy and will be designed to exceed the expected amount of current, including contingency for an N-1 condition.

Fault Current

Location \ Type of Fault	Three Phase (A)	Single-Line-to-Ground (A)
230kV Bus (Existing)	9,439	8,593
230kV Bus (2021)	11,496	10,986
115kV Bus (Existing)	10,862	10,145
115kV Bus (2021)	16,491	15,579

Electrical Removals & Relocations

The section of bus where the new equipment is being installed will be removed.

The fence and grounding around the new dead-end and equipment will be expanded and the fence will be replaced.

The battery system will need to be removed and replaced with a larger battery.

Electrical Installations (Major Equipment)

The new 230kV line termination will be overhead from the GI-2014-8 Facility. The line will terminate at a new dead-end north of the substation. From this dead end, the conductor will attach to a switch, metering units, and arresters. It will then take a flying tap over to the new bay position where it will terminate on the existing Xcel Energy owned bus.

Construction will need to be coordinated with GI-2014-8 Customer, who is responsible for the construction of the transmission line from their facility to the Boone Substation termination point.

Arresters and a CCVT will also need to be added to the Boone to Comanche 230 kV line.

Electrical Equipment Enclosure (EEE)

This project will not require a new EEE.

AC System

The AC system is adequate for the proposed additions.

DC System

The DC system is NOT adequate for the proposed additions to the substation. The DC system will need to be replaced with a new battery. Currently there are multiple battery systems including (2) 24VDC Batteries for Microwave and (1) 125VDC Battery system. There are multiple ongoing projects at this substation

and the battery load will need to be evaluated as part of this project to determine the correct size needed.

Grounding

Grounding calculations have been done with new fault current values that take into account the new equipment and updated generation projections. The calculations show that the existing ground grid will be sufficient to accommodate the new equipment and fault current values.

Lightning Protection

A lightning protection study has been completed and shows that the existing static wires will NOT be sufficient to protect the new equipment. New static wires will be installed to the new dead-ends. The interconnection customer will install static wires on the transmission line to their generation facility.

Trenching & Cable

New duct bank will need to be installed as part of this project. This will include a duct run from the new breaker position to the EEE. Pull pits will also be installed. All new cables will be pulled for the new equipment.

E. Civil Features

Grading & Fencing

The existing fence will be expanded to accommodate the added equipment in the 230kV yard. The expansion will be roughly 300’ of new fence.

The standard ¾” crushed rock will be installed in all new areas and any area that is disturbed by construction.

The need for improved drainage and/or a detention pond will be evaluated at a later date.

Storm Water Permit

The need for a storm water permit will be evaluated at a later date. Most likely, one will be required.

SPCC (Oil Containment)

Since we are not adding or removing any oil filled equipment, there will be no need for any SPCC work.

Foundations & Structures

A soil boring report will need to be generated in order to accurately size the foundations. All structures will be standard Xcel Energy structures used on previous jobs.

The following concrete slab foundations will be installed:

Quantity	Description	Approx. Size
15	Single structure supports	
4	Dead-End Foundations	
1	Breaker Foundation	

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

Structure Quantity	Steel Description	Steel Wt./ Structure	Drilled Piers		
			Pier Qty/ Structure	Approx. Size	
				Dia.	Depth
15	Single Structure Supports				
4	Dead-End Towers				
2	Dead-End Girders				

F. Protection Features

This protection recommendation is for the installation of new transmission line protection for a 230kV line from Boone to GI-2014-8 60MW solar plant. This line will be connected to a new ring bus position in the Boone 230kV yard, connecting between existing circuit breaker 5337 and the new circuit breaker 5332.

The primary protective scheme is a 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 5332 and 5337 trip coils #1 and initiate breaker failure for both circuit breakers. Further, it will initiate reclose for 5332. An output on the SEL-411L relay is used as SCADA channel alarm.

The secondary protection scheme is a line current differential (87L) scheme utilizing a SEL-411L relay (PKG-S). The SEL-411L relay will also implement a backup step distance and 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-411L, by the pilot scheme or the backup step distance and ground overcurrent, will operate 5332and 5337 trip coils #2

and initiate breaker failure for both circuit breakers. Further, it will initiate reclose for 5332. An output on the SEL-411L relay is used as SCADA channel alarm.

A Direct Transfer Trip (DTT) scheme is implemented in an SEL-2506. A normally closed (NC) cutoff switch, 85CO-3 DTT, can be used to disable the DTT. The DTT keying will be initiated by the breaker failure lockout relays 5332 86BF and 5337 86BF. Receiving DTT from the remote terminal will operate an output on the SEL-2506. This output operates auxiliary relay, 94 DTT, which will consequently operate trip coils #1 of 5332 and 5337 and block closing of both breakers.

Breaker failure, sync check, and reclosing for 5332 are implemented using SEL-351 relay (5332 PKG-BF). The breaker failure scheme will be initiated by the operation of the primary SEL-411L relay (PKG-P) and secondary SEL-411L relay (PKG-S). The trip output of the breaker failure relay will operate the breaker lockout relay (5332 86BF), which will consequently trip and block closing of 5337 and 5415 and initiate a direct transfer trip (DTT) to the remote terminal via the SEL 2506. The reclosing of 5332 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-411L relay (PKG-S). The close output of the relay will operate the close coil of 5332. Another output provides SCADA reclose-enable status. Further, an output is used to provide SCADA alarm in case of sync failure.

Breaker failure for 5337 is currently implemented using SEL-501 relay (5337 PKG-BF). That will not change in this project.

A summary of the protection:

Line Protection

- Primary Line Protection: PKG-P, SEL-411L
    - Part Number: 0411L1X4X5B8DCXH57424XX
    - Firmware Version: R115
- Secondary Line Protection: PKG-S, SEL-411L
    - Part Number: 0411L1X4X5B8DCXH57424XX
    - Firmware Version: R115
- Breaker Failure, Sync Closing, Reclosing 5332 PKG-BF, SEL-351
    - Part Number: 0351S6XHD3J5421
    - Firmware Version: R515
- Direct Transfer Trip Communications: SEL 2506
    - Part Number: 250603414X
    - Firmware Version: NA

G. Control Features

General

New Relaying and controls will be installed as part of this project. A new relay panel for the line will be installed in the EEE.

Transmission Breaker Reclosing Controls

There will be supervisory control of the 5332 breaker.

Sync Check and Reclosing will be initiated by the SEL 351 on the 5332 breaker.

Control Panel Locations

Panel #	Panel Description	Size
(TBD)	New 230kV Line to RES America	28” x 90”

Removals

See the Local Annunciation section below for details on the LCU removal and replacement.

H. Communication Features

Wide Area Network (WAN)

It is assumed that the Boone Substation WAN connection will be upgraded as part of the fiber/network portfolio of projects which will upgrade communication to several substations presently on Xcel private communication infrastructure. The upgrade will include a WAN connection, edge router and switch provided by Business Systems as well as a router and switch provided by Transmission.

Relay Remote Access/Substation LAN

The local area network (LAN) will also be as part of the Fiber/Network upgrades to include a Transmission firewall, switch, and Ethernet capability to the communication processors.

Remote Terminal Unit (RTU)

Substation RTU—The existing substation RTU is a GE D20M++ with adequate I/O for this installation.
Real-Time/Boundary Area Metering—The existing boundary area RTU and communication link will be utilized for this installation with the addition of a new SEL-735 meter for the new line metering. No power quality metering requirements are anticipated for this installation.

Local Annunciation

The existing HMI/LCU is adequate is a first generation LCU on a 286 compatible computer platform. This LCU is no longer supported and cannot be expanded to include the control or monitoring of the new line, breaker and associated equipment. Because of this the HMI/LCU will need to be upgraded as part of this project.

Telephone Protection

The existing telephone service is being provided via the microwave on the Xcel private network. It is up to Business Systems whether this circuit will be converted to VOIP and will not affect this project.

Programmable Logic Controller

Not applicable for this facility.

Protection Communication

Transmission Line Protection Pilot Schemes

New Interconnection Line Protection—A primary line differential with backup POTT scheme is implemented over OPWG requiring 2 separate protection channels will be installed as part of the new transmission line being constructed by the customer to the new solar collector substation.

Communications Plan Recommendation Summary:

Phone Isolation Wall Board:

- N/A – phone will be supplied by the microwave system

Communications Panel:

- Fibertronics FT-1RU3AP Patch Panel
- 2 each Fibertronics FT-DLC24LSBLK LC24 Pack Quad Plate
- 2 each Fibertronics FT-TRAY24 Splice Tray
- 4 each Fibertronics SP-12LCSM3 LC Pigtails
- Fibertronics FT-BLANK Blank Panel

Remote Automation Generator Control (AGC)

- Raymar Modem – To Be Installed at Customers Facility, Procured by Customer

Line Panels

- 1 each SEL-2830 Single-Mode Fiber Optic Transceiver/Modem

HMI/LCU/Annunicator Panel:

- NovaTech Orion LX HMI including Touchscreen Monitor, Keyboard, Trackball

RTU/SCADA Panel:

- NA

Note: The equipment listed above is only the major substation communication equipment. All racks, panels, terminal blocks, fuse and fuse blocks, wiring, and cable assemblies need to be added by the substation design engineer.

I. Project Operating Concerns and Outages

This is an interconnection project. There will need to be extensive coordination and communication with the interconnection customer in order to successfully complete this project.

Outages/Temporary Configurations

To perform work on the new bay position, line 5415 to Comanche (Breakers 5337 and 5415) will need to be taken out for a short while to open the existing 5332S and 5337N Switches. After these switches are open the North 230kV bus will be out of service. Operations will need to be notified of how long the North bus will need to be out to complete construction as the ring bus will be open for the duration.

It will be possible to complete construction of the new switch (5332L), arresters, metering units, and dead end, before the North 230kV bus outage occurs.

J. Material Staging Plan

Stock materials will be ordered and staged through Scott Kennedy.

K. Related Projects

No Substation WO's exist at this time. When Capital WO's are created, the Xcel Energy funded, Customer funded, T-Line, and Communications work will all need to be coordinated

L. Estimate Discussion

The standard contingency factors for estimates are as follows:

- Appropriation Est. Contingency Factors: Material:10%, Labor and Equipment:10%

M. 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: A Survey will need to be completed for this project. It should include the area outside the fence where the new equipment will be located.

☒ Soil boring results are not available. Explain: Soil borings will need to be done for this project. The data for this project is outdated.

☐ Unusual soils or environmental conditions exist. Explain:

☒ Key materials or items need decisions or approvals. Explain: An LGIA will determine many aspects of this project, including ownership, cost allocation, and final schedules.

☒ Potential permitting delays or unusual requirements exist. Explain: This is an interconnection project. Coordinating with the interconnection customer could prove difficult. The schedule they have proposed is also pretty aggressive.

☐ There are difficult or seasonal outage requirements. Explain:

☐ There are conflicting outage requirements. Explain:

☒ There are risks due to who will construct the project and their availability. Explain: Internal Xcel Crews have not decided if they will take the project or not. The interconnection customer is constructing the T-Line and the LFAGC.

☐ 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: Boone Substation has many TIF drawings that will need to be updated as part of this project.

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 2015 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 **$2.52 million.** Figure 2 below represents a conceptual one-line of the proposed interconnection into the 230kV 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. System improvements are subject to change upon a more detailed and refined design.

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

Element	Description	Cost Est. (Thousands)
Boone 230kV Transmission Substation	Interconnect Customer to tap at the Boone 230kV Transmission Substation (into the 230kV bus). The new equipment includes: • One 230kV gang switch • Three 230kV arresters • One set 230kV CT/PT metering units • Associated bus, wiring and equipment • Associated site development, grounding, foundations and structures • Associated station controls, line relaying and testing	**$987.8**
Boone 230kV Transmission Substation	Communication rack and associated equipment	**$136.3**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$1,124.1**
Time Frame	Site, design, procure and construct	**18 Months**

Table 2: PSCo Owned; PSCo Funded Interconnection Network Facilities

	Description	Cost Estimate (Thousands)
Boone 230kV Transmission Substation	Interconnect Customer to tap at Boone 230kV Transmission Substation (into the 230kV bus). The new equipment includes: • One 230kV circuit breaker • Two 230kV gang switches • Associated breaker failure relaying, station controls and testing • Associated bus, miscellaneous electrical equipment, cabling and wiring • Associated foundations and structures • Associated road and site development and grounding • Associated station battery upgrades	**$1,378.8**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$1,378.8**
	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	**$0.00**

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 2015 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 and network delivery 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.

V. Engineering, Procurement & Construction Schedule

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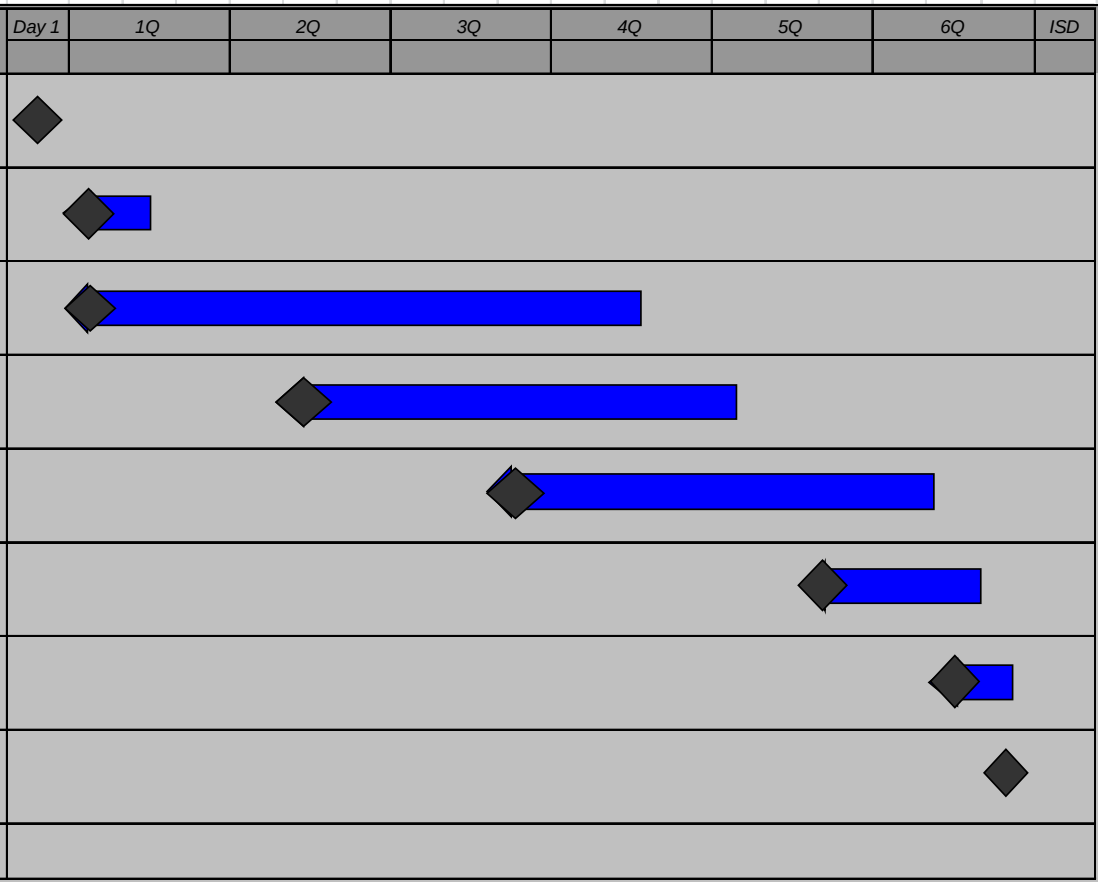
ID	Task Name	Duration
2	Authorization to Proceed: Execution of Interconnection Agreement	0w
3	Sighting & Land Rights and Permitting	6w
4	Substation Design & Engineering	40w
5	Substation Material Procurement	36w
6	Substation Construction	36w
7	Relay, Protection & Control Equipment Testing	10w
8	Final Commissioning	4w
9	Project Completion / Backfeed	0w
10		



Appendix

A. Project One-Line of the Boone Substation with GI-2014-8 Interconnection

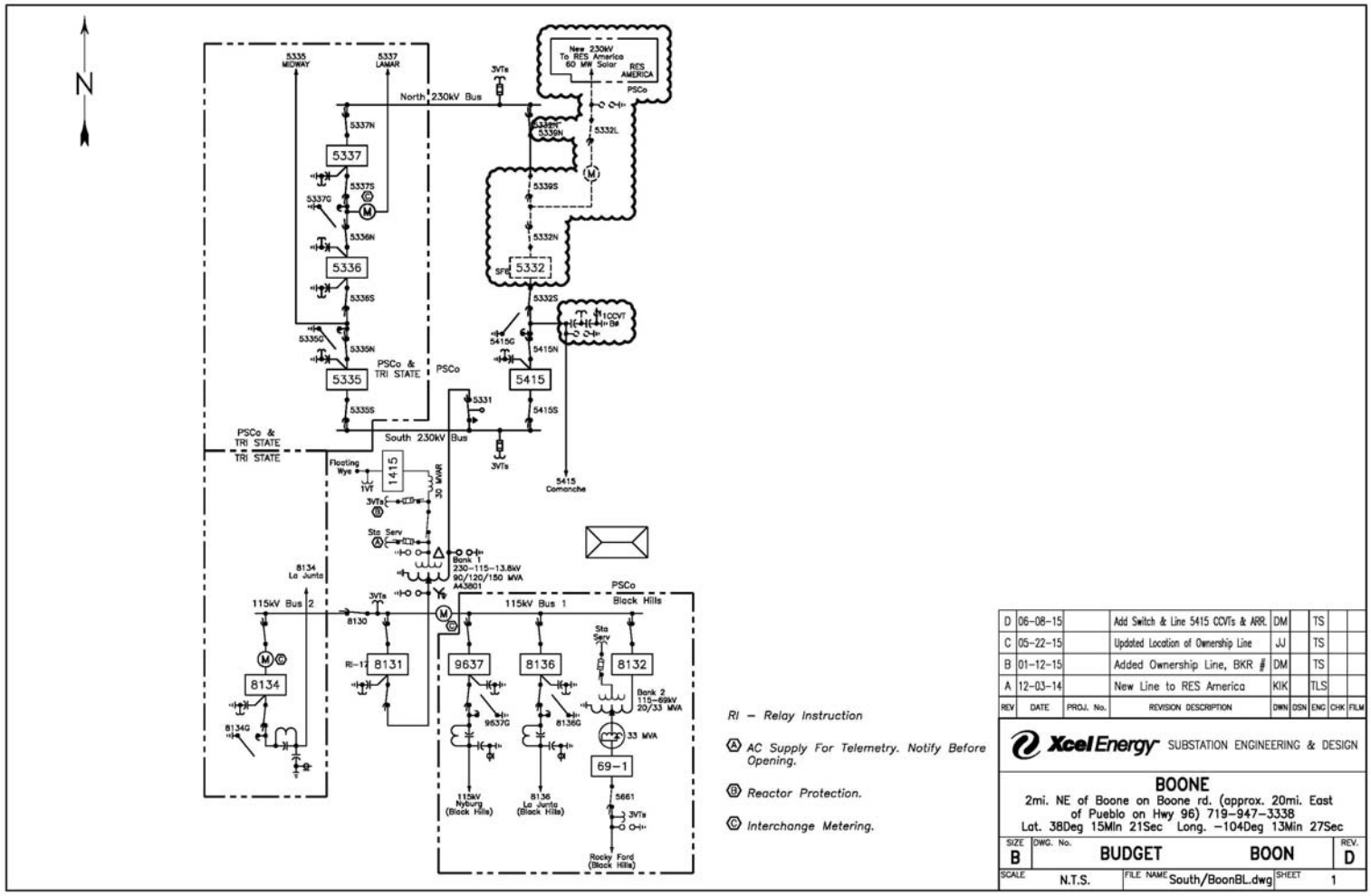


Figure 2 - Boone Substation One-Line with GI-2014-8

B. Boone Substation General Arrangement with GI-2014-8