INFO-2020-6 Informational Study Report

10/23/2020

Table of Contents

1.0 Summary

Customer has requested an informational evaluation of the interconnection of a 100 MW Solar PV plus Battery Energy Storage System Hybrid Generating Facility interconnection at the Midway 115kV Substation. The expected Commercial Operation Date (COD) of the Generating Facility is December 2022 and the request is evaluated for Network Resource Interconnection Service (NRIS).

The total estimated cost of the transmission system improvements to interconnect INFO-2020-6 are: $3.349 Million (Tables 7 and 8)

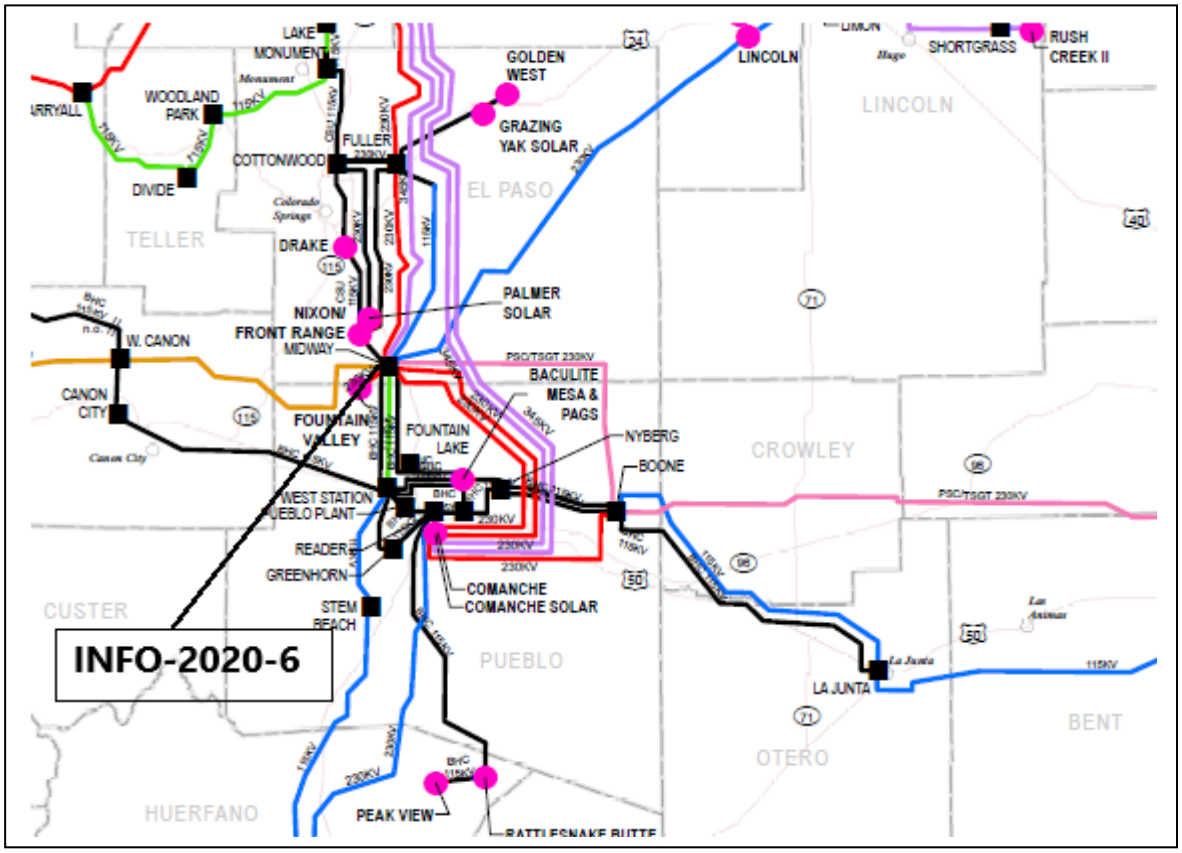
NRIS of INFO-2020-6 is: 100MW (after required transmission system improvements in Table 7 and 8)

2.0 Introduction

This report is the informational study for a 100MW Solar Photovoltaic (PV) plus Battery Energy Storage (BES) Hybrid Generating Facility with a Point of Interconnection (POI) at the Midway 115kV Substation. The request is referred to as “INFO-2020-6”. The Generating Facility is composed of a 100MW PV generator and a 50MW BES generator, with the net output at the POI limited to 100MW at all times.

The proposed Commercial Operation Date (COD) of INFO-2020-6 is December 2022.The geographical location of the Transmission System near the POI is shown in Figure 1 below.

Figure 1 – INFO-2020-6 Point of Interconnection



3.0 Study Scope

The scope of the study only includes power flow analysis to evaluate the steady-state thermal and voltage limit violations in the PSCo Transmission System and Affected Systems resulting from the addition of INFO-2020-6 for NRIS at the Midway 115kV Substation. The scope of this report also includes reactive power analysis and cost estimates (no accuracy) for Interconnection Facilities, Station Upgrades and Network Upgrades.

Per the Study Request the 100 MW rated output of GI-2014-6 is assumed to be delivered to PSCo native load, so existing PSCo generation is used to sink the generator output. As requested by the Customer the studies include an additional Scenario analysis as discussed later in this report.

The steady state analysis will identify thermal and voltage violations in the PSCo system and the neighboring systems using the study criteria in Section 3.2 and study methodology in Section 3.3.

3.1 Study Pocket Determination

As shown in Figure 1, the request is located in the “Southern Colorado” study pocket. Hence the study analysis is based on the Southern Colorado study pocket analysis only.

3.2 Study Criteria

PSCo adheres to applicable NERC Reliability Standards and WECC Reliability Criteria, as well as its internal transmission planning criteria for studies. The following Steady-State Criteria is used for the reliability analysis of the PSCo system and Neighboring Utility systems.

P0 - System Intact conditions:

Thermal Loading: <=100% Normal facility rating

Voltage range: 0.95 to 1.05 per unit

P1 & P2-1 – Single Contingencies:

Thermal Loading: <=100% Normal facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: <=8% of pre-contingency voltage

P2 (except P2-1), P4, P5 & P7 – Multiple Contingencies:

Thermal Loading: <=100% Emergency facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: <=8% of pre-contingency voltage

3.3 Study Methodology

The steady state assessment is performed using PSSE V33 and the ACCC tool.

3.3.1 Steady State Assessment methodology

The thermal and voltage impacts are identified by running the same set of contingencies on the Benchmark Case and the Study Case and comparing the results.

For PSCo facilities, thermal violations attributable to INFO-2020-6 include any facilities without a pre-existing thermal violation that (i) resulted in a thermal loading >100% post the generator addition and (ii) contributed to an incremental loading increase of 2% or more to the benchmark case loading.

For non-PSCo facilities, thermal violations attributed to INFO-2020-6 include all new facility overloads with a thermal loading of >100% and existing thermal overloads that increased by 1% or more from the benchmark case overload post the generator addition.

The voltage violations assigned to INFO-2020-6 include new voltage violations which resulted in a further variation of 0.05 per unit.

Any non-PSCo system voltage violations are identified as Affected System violations in the study.

3.4 Study Area

The Study Area for Southern Colorado study pocket includes WECC designated zones 704, 710, and 712. The neighboring utilities included in the analysis include Tri-State Generation and Transmission Inc. (TSGT), Black Hills Energy (BHE), Colorado Spring Utilities (CSU), Intermountain Rural Electric Association (IREA) and Western Area Power Administration (WAPA) systems in the study area.

4.0 Modeling Assumptions

The study is performed using the 2023HS case developed for the 2019 Colorado Coordinated Planning Group TPL1-4 studies.

4.1 Base Case Modeling

The Base Case is created from the 2023HS case by making the following modifications.
The following approved transmission projects in PSCo's 10-year transmission plan which are expected to be in-service before August 2023 are modeled:

- Cloverly 115kV Substation – ISD 2021
- Graham Creek 115kV Substation – ISD 2022
- Husky 230/115kV Substation – ISD 2022
- Ault – Husky 230kV line – ISD 2022
- Husky – Graham Creek – Cloverly 115kV line – ISD 2022
- Monument – Flying Horse 115kV Series Reactor – ISD 2022
- Avery Substation – ISD 2021
- High Point Substation – ISD 2022
- Titan Substation – ISD 2022
- Gilman – Avon 115kV line – ISD 2022
- Upgrade Villa Grove – Poncha 69kV Line to 73MVA – ISD 2021
- Upgrade Poncha – Sargent – San Luis Valley 115kV line to 120MVA – ISD 2021
- Greenwood – Arapahoe - Denver Terminal 230kV line – ISD 2022

All transmission facilities are modeled at their expected ratings for 2023 Summer season. Also, the following facility uprate projects are modeled at their planned future ratings:

- Upgrade Allison – SodaLakes 115kV line to 318MVA – ISD 2021
- Upgrade Daniels Park – Priarie1 230kV line to 576MVA – ISD 2021
- Upgrade Greenwood – Priarie1 230kV line to 576MVA – ISD 2021
- Upgrade Daniels Park – Priarie3 230kV line to 576MVA – ISD 2021
- Upgrade Greenwood – Priarie3 230kV line to 576MVA – ISD 2021
- Upgrade Waterton – Martin2 tap 115kV line to 189MVA – ISD 2021
- Upgrade Leetsdale – Monaco 230kV line to 560MVA – ISD 2021
- Upgrade Waterton – Martin1 tap 115kV line to 189MVA – ISD 2023
- Upgrade MidwayPS – MidwayBR 2340kV transmission line to 525MVA – ISD 2021

The following additional changes were made to the TSGT model in the Base Case per further review and comment from TSGT:

- Fuller – Vollmer – Black Squirrel 115kV line modeled at 173MVA – ISD 2022
- Fuller 230/115kV, 100MVA #2 transformer – ISD 2023

The following additional changes were made to the Black Hills Energy (BHE) model in the Base Case per further review and comment from BHE:

- Burnt Mill – Greenhorn 115kV Rebuild - ISD 1/21/2021
- Desert Cove - Ftn Valley Rebuild – ISD 1/22/2021
- Nyberg - Airport Memorial Rebuild - ISD 1/22/2021
- Pueblo West substation – ISD 4/13/2021
- Pueblo Reservoir – Burnt Mill 115kV Rebuild – ISD 8/31/2021
- Boone - South Fowler 115kV Project – ISD 10/1/2021
- North Penrose Substation – ISD 1/2022
- West Station – Pueblo Res 115kV Rebuild – ISD 1/31/2022

The following additional changes were made to the Colorado Springs Utilities (CSU) model in the Base Case per further review and comment from CSU:

- The Cottonwood – Tesla 34.5kV line is modeled open and Kettle Creek – Tesla 34.5kV line is modeled closed on the CSU system – ISD 2023
- Briargate S 115/230kV transformer project tapping the Cottonwood – Fuller 230kV line – ISD 2023

The Base Case model includes the existing PSCo generation resources and existing resources in the Affected Systems. The other generation modeled in the Base Case are -

- GI-2017-12, GI-2018-24, and 1RSC-2020 in the PSCo Generation Interconnection Queue
- The following projects in the IREA System
  - 80MW Pioneer Solar PV facility interconnecting on the Victory – Brick Center 115kV line – COD 12/31/2020
  - 75MW Hunter Solar PV facility interconnecting at Brick Center 115kV Substation – COD 2/1/2022
- The following projects in the TSGT System
  - TI-18-0809, 100MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line
  - TI-19-1016, 40MW NRIS/ERIS Solar, Walsenburg-Gladstone 230kV line (schedule to NM)

The Gladstone phase shifter is modeled at 80MW.

4.2 Scenario Case Modeling

The Scenario Case is created by making the following modeling changes to the Base Case created in Section 4.1:

- Expected facility ratings in 2023
- The following facility uprate projects are modeled at their planned future ratings:
  - Upgrade Adobe – Uintah 230kV line to 315.1MVA – ISD 2021
  - Upgrade Ault – Windsor 230kV line to 575.6MVA – ISD 2021
  - Upgrade Beaver Creek – Avon – Vail 115kV line to 119.5MVA – ISD 2021
  - Upgrade Buckley34 – Smokyhill 230kV line to 505.9MVA – ISD 2021
  - Upgrade CabinCreek – Dillon 230kV line to 633.8MVA – ISD 2021
  - Upgrade Cherokee – NorthPS 115kV line to 199.4MVA – ISD 2021
  - Upgrade Comanche – MidwayPS 230kV line #1 to 478MVA – ISD 2021
  - Upgrade Dainels Park 345/230kV # T4 to 560MVA – ISD 2021
  - Upgrade Grandjunction – Montrose 345kV line to 956.1MVA – ISD 2021
  - Upgrade Rifle_Cu – Grandjunction_CU 345kV line to 717.1MVA – ISD 2021
  - Upgrade Weld 230/115kV # 1 transformer to 280MVA – ISD 2021

The Gladstone phase shifter flow is modeled at 120MW.

5.0 Study Analysis

The INFO-2020-6 is studied in the Southern Colorado study pocket.

5.1 Voltage and Reactive Power Capability Evaluation

The following voltage regulation and reactive power capability requirements at the POI are applicable to the generator:

- Xcel Energy's OATT requires all non-synchronous Generator Interconnection 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.
- 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 (on the Interconnection Customer's facility) 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 at the high side of the main step up transformer. 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 reactive power analysis performed in this report is an indicator of the reactive power requirements at the POI and the capability of the generator to meet those requirements. All generators are required to design their interconnection to meet the POI voltage control requirements that will be specified by the Transmission Operator.

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 the regulating voltage of the POI.

According to the modeming data provided by the Customer, the generator model is as follows: PV: Pmax = 100.87MW, Pmin = 0, Qmax = 44.5Mvar, Qmin= 17Mvar.

BES: Pmax = 51MW, Pmin = -51MW, Qmax = 9.672Mvar, Qmin= 9.672Mvar.

Additionally, the Generating Facility includes a 15Mvar shunt capacitor bank.

The reactive capability analysis indicates that generator is capable of maintaining ±0.95pf at the high side of the main step-up transformer only for the PV and PV plus BES modes of operation. The BES operation alone is not capable of meeting the reactive power requirements at the high side of the main step-up transformer.

Table 2 - Reactive capability evaluation

Gen MW / Mvar	Configuration	15 Mvar Cap bank Status	Gen Voltage (p.u.) (PV/BES)	Main Step-up Transformer High Side				POI			
				Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
101MW / 38.9 Mvar	PV&BES	On	1.047 / 1.042	1.025	99.9	44.5	0.913 (lag)	1.025	99.8	44.4	0.914 (lag)
101MW / 54.2 Mvar	PV&BES	Off	1.054 / 1.042	1.025	99.8	43.5	0.917 (lag)	1.025	99.7	43.4	0.917 (lag)
101 MW / -54.2 Mvar	PV&BES	Off	0.985 / 1.000	1.003	99.7	-66	0.834 (lead)	1.003	99.6	-66.1	0.833 (lead)
100.9 MW / 44.5 Mvar	PV	On	1.062 / 1.035	1.026	99.5	48.4	0.899 (lag)	1.026	99.5	48.3	0.900 (lag)
100.9 MW / 44.5 Mvar	PV	Off	1.043 / 1.015	1.021	99.5	33.1	0.949 (lag)	1.02	99.5	33	0.949 (lag)
100.9 MW / -44.5 Mvar	PV	Off	0.983 / 1.002	1.003	99.3	-57.2	0.867 (lead)	1.003	99.3	-57.3	0.866 (lead)
51MW / 9.67 Mvar	BES	On	1.005 / 1.018	1.016	50.6	24.6	0.899 (lag)	1.016	50.6	24.6	0.899 (lag)
51MW / 9.67 Mvar	BES	Off	0.995 / 1.008	1.011	50.6	9.9	0.981 (lag)	1.01	50.6	9.8	0.981 (lag)
51MW / -9.67 Mvar	BES	Off	0.998 / 0.993	1.003	50.6	-9.7	0.982 (lead)	1.003	50.6	-9.4	0.983 (lead)
0 MW / 17.7 Mvar	PV&BES	Off	0.987 / 1.000	1	0	-12.6	N/A	1	0	-12.6	N/A

5.2 Southern Colorado Study Pocket Analysis

5.2.1 Benchmark Case Modeling

The Benchmark Case and Scenario Benchmark Case were created from Base Case and Scenario Base Case respectively by changing the study pocket generation dispatch to reflect a heavy south to north flow on the Comanche – Midway – Jackson Fuller – Daniels Park transmission system as shown in Table 3 below.

Table 3 – Generation Dispatch Used to Create the Benchmark Case and Scenario Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Benchmark Status	Benchmark PGen (MW)	Scenario Status	Scenario PGen (MW)	PMax (MW)
COMAN_1 24.000	C1	1	360	1	360	360
COMAN_2 24.000	C2	1	365	1	365	365
COMAN_3 27.000	C3	1	869	1	869	869
COMAN_PV 34.500	S1	1	102	1	104.1	122.5
CO_GRN_E 34.500	W1	1	64.8	1	64.8	81
CO_GRN_W 34.500	W2	1	64.8	1	64.8	81
FTNVL1&2 13.800	G1	1	36	1	36	40
FTNVL1&2 13.800	G2	1	36	1	36	40
FTNVL3&4 13.800	G3	1	36	1	36	40
FTNVL3&4 13.800	G4	1	36	1	36	40
FTNVL5&6 13.800	G5	1	36	1	36	40
FTNVL5&6 13.800	G6	1	36	1	36	40
JKFULGEN 0.6900	W1	1	199.5	1	199.5	250
LAMAR_DC 230.00	DC	0	0	0	0	210
TWNBUTTE 34.500	W1	1	33.4	1	33.4	75
SUNPOWER 34.500	S1	1	33.8	1	33.8	52
SI_GEN 0.6000	1	1	6.1	1	25.5	30
TBII_GEN 0.6900	W	1	15.96	1	60.8	76
TI-18-0809 0.6300	PV	0	0	1	85	100
TI-19-1016 0.6300	PV	0	0	1	34	40
GI-2018-24 34.500	S1	1	200	0	200	250
GI-2019-6 34.500	S1	0	0	1	0	240
PI-2020-2	S1	1	160	0	160	200

5.2.2 Study Case Modeling

A Study case and a Scenario Study Case were created from the Benchmark Case and the Scenario Benchmark Case respectively by modeling INFO-2020-6 at the Midway115kV Substation. The 100 MW NRIS output from the generator was sunk to Pawnee.

5.2.3 Steady State Analysis Results

The results of the single contingency analysis on the Scenario Case are given in Table 4 below.

Table 4 – Overloads identified in Single Contingency Analysis – Scenario Case

Overloaded Facility	Type	Owner	Facility Normal Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to INFO-2020-6	Single Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Daniels Park – Prairie1 230kV #1	Line	PSCo	576	639.3	111.0%	650.9	113.0%	2.0%	Greenwood – Prairie3 230kV #1
Greenwood – Prairie3 230kV # 1	Line	PSCo	576	599.0	104.0%	610.6	106.0%	2.0%	Daniels Park – Prairie1 230kV #1
MidwayPS 115/230kV # 1	Xfmr	PSCo	97	52.4	54.0%	102.8	106.0%	52.0%	Fountain Valley – Desert Cove 115kV #1
Waterton – Martin2 tap 115kV #1	Line	PSCo	127	128.1	100.9%	130.2	102.5%	1.6%	Chatfield – Waterton 230kV #1

All the single contingency overloads are mitigated when the Comanche #1 unit is modeled offline.

The results of the multiple contingency analysis on the Scenario Case are given in Table 5 below. The multiple contingency analysis shows several new overloads after the addition of INFO-2020-6. Per TPL1-4, multiple contingency overloads can be mitigated using system adjustments, including generation redispatch (existing and GIRs under study) and/or operator actions. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the multiple contingencies on the PSCo system. These future mitigations will address the existing and new overloads, and all generation additions in the Southern Colorado study pocket may become part of the mitigations and may be subject to automatic generation adjustments.

Table 5 – Overloads identified in Multiple Contingency Analysis – Scenario Case

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in NRIS Study Case		% Change due to INFO-2020-6	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Fountain S – RD_Nixon 115kV #1	Line	CSU	212	248.0	117.0%	250.2	118.0%	1.0%	Kelker North – South 230kV bus tie
Greenwood – Prairie3 230kV # 1	Line	PSCo	576	570.8	99.1%	586.4	101.8%	2.7%	Daniels Park – Greenwood 230kV & Daniels Park – Missile Site 230kV
MidwayPS 115/230kV #1	Xfmr	PSCo	120	73.2	61.0%	124.8	104.0%	43.0%	Comanche – Daniels Park 345kV # 1 & Comanche – Tundra 345kV # 1
Palmer Lake – Monument 115kV #1	Line	PSCo/ CSU	108	113.0	104.6%	121.9	112.9%	8.3%	Midway – Waterton 345kV # 1 & Midway – Fuller 230kV # 1

The single contingency analysis on the 2023HS case did not identify any thermal violations.

The results of the multiple contingency analysis on the 2023HS are given in Table 6 below. The multiple contingency analysis shows several new overloads after the addition of INFO-2020-6. Per TPL1-4, multiple contingency overloads can be mitigated using system adjustments, including generation redispatch (existing and GIRs under study) and/or operator actions. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the PSCo multiple contingencies studies in Table 6 below. These future mitigations will address the existing and new overloads, and all generation additions in the Southern Colorado study pocket may become part of the mitigations and may be subject to automatic generation adjustments.

Table 6 –Overloads identified in Multiple Contingencies – 2023HS Case

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in NRIS Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
MidwayPS – MidwayBR 230kV #1	Line	PSCo	525	509.3	97.0%	540.8	103.0%	6.0%	Midway – Waterton 345kV #1 & Midway – Jackson Fuller 230kV #1
Palmer Lake – Monument 115kV #1	Line	PSCo/ CSU	108	110.2	102.0%	118.8	110.0%	8.0%	Midway – Waterton 345kV #1 & Daniels Park - Jackson Fuller 230kV #1

There are no Affected Systems identified in the study analysis.

6.0 Cost Estimates and Assumptions

The PSCo Engineering has developed cost estimates (with no accuracy) for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of INFO-2020-6 at the Midway 115kV Substation. The cost estimates are in 2020 dollars with escalation and contingencies applied. Allowances for Funds Used During Construction (AFUDC) is not included. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of these new PSCo facilities. This estimate does not include the cost for any Customer owned equipment and associated design and engineering.

- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- INFO-2020-6 Generating Facility is not in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates.

- PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- Customer will install two (2) redundant fiber optics circuits into the Transmission provider's substation as part of its interconnection facilities construction scope.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- Line outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested back feed date due.
- Power Quality Metering (PQM) will be required on the Customer's generation tie-line terminating into the POI.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer Substation. PSCo / Xcel will need indications, readings and data from the LFAGC RTU.

Figure 2 is a conceptual one-line of INFO-2020-6 at the Midway 115kV Substation.

The estimated total cost of the Transmission Provider's Interconnection Facilities identified in the study are shown in Table 7.

Table 7 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
Midway 115 kV Transmission Substation	Interconnect Customer to tap at the 115 kV bus at the Midway 115kV Substation. The new equipment includes: - Install one 115kV line position - Three 115 kV line arresters - Station Controls - Switch Gang 115kV - Equipment Foundations (5) - Site Grounding system - Structure Substation Equipment and Bus 115kV - 115kV Tower Substation Deadend - Transformer Instrument Current Potential Voltage C (does not include AFDUC)	$1.179
	Last span into Midway Substation, between Point of Change of Ownership and Point of Interconnection within Midway Substation	$0.150
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$1.349**
Time Frame	**Site, design, procure and construct**	**18 Months**

Table 8 – Station Network Upgrades

Element	Description	Cost Est. (Millions)
PSCo's Midway 115kV Transmission Substation	Interconnect Customer to the 115 kV bus at the Midway 115 kV Substation. The new equipment includes: • Three 115kV disconnect Switches • One 115kV circuit breaker • One power quality panel • Associated communications, supervisory and SCADA equipment • Associated bus, wiring and equipment • Associated foundations and structures	$2.000
	Total Cost Estimate for Station Upgrades	**$2.000**
Time Frame	**Site, design, procure and construct**	**18 Months**

7.0 Summary of Informational Interconnection Study Results:

The total estimated cost of the transmission system improvements to interconnect INFO-2020-6 are: $3.349 Million (Tables 7 and 8)

NRIS of INFO-2020-6 is: 100MW (after required transmission system improvements in Table 7 and 8)

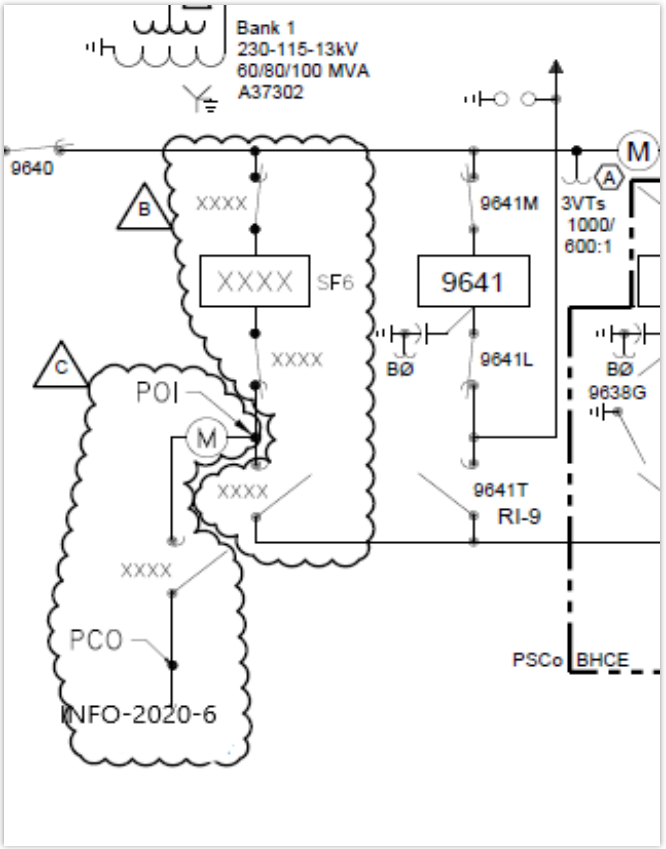


Figure 5 – Preliminary One-line of INFO-2020-6 Interconnecting at the Midway 115kV Substation