Generator Interconnection Request # GI-2016-5
System Impact Study

200 MW Solar Photovoltaic (PV) Generation at Midway 115 kV
Pueblo County, Colorado

Public Service Company of Colorado
Transmission Planning
June 7, 2017

A. Executive Summary

On April 5, 2016 Public Service Company of Colorado (PSCo) received an interconnection request (GI-2016-5) for a 200 MWac solar photovoltaic (PV) generation facility in Pueblo County, Colorado. The proposed Point of Interconnection (POI) is the PSCo-owned Midway 115 kV bus within the Midway 345/230/115 kV transmission substation (see Figure 1).

The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2019 and accordingly the approximate target Backfeed Date is assumed to be six months prior to the COD - June 30, 2019.

The proposed solar photovoltaic generating facility would consist of 50 GE inverters each rated 4.0 MW. Each inverter would be connected to a pad-mounted step-up transformer (SUT) which provides voltage transformation for interconnection of the inverter and its associated PV generation source to the medium voltage power collection system within the generating plant. One main step-up transformer (MST) would provide the final transformation to allow the generating facility to interconnect to the Midway 115 kV bus POI via an overhead 115kV transmission line owned by the Interconnection Customer.

The GI-2016-5 interconnection request was studied as a stand-alone project. That is, the study did not include any other Generator Interconnection Requests (GIR) existing in PSCo's or any affected party's GIR queue, other than the interconnection requests that are considered to be planned resources for which Power Purchase Agreements have been signed. This interconnection request was studied both as Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

For this interconnection request, the potential Affected Parties are Black Hills Colorado Electric (BHCE), Tri-State Generation & Transmission (TSGT) and Colorado Springs Utilities (CSU).

The System Impact Study consisted of power flow (steady-state) contingency analysis and short-circuit analysis. No stability analysis was performed since the dynamic performance of the solar generation facility for normally cleared faults was expected to be satisfactory based on the information on Voltage Ride Through (VRT) capability of the GE dc/ac inverters provided by the Interconnection Customer. Furthermore, it is the responsibility of the Interconnection Customer to ensure that its 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-024-2.

The power flow contingency analysis identified several thermal overloads on the PSCo system and affected party's system as a result of the 200 MW injection from GI-2016-5, but did not identify any voltage violations. Therefore, Network Upgrades are required to mitigate these thermal overloads and enable the interconnection and delivery of the 200 MW output from GI-2016-5. The short circuit analysis did not identify any over-dutied circuit breakers.

Based on the System Impact Study results, it is concluded that Network Upgrades are required for the 200 MW rated output of GI-2016-5 interconnection to qualify for Network Resource Interconnection Service (NRIS)[1]. Without Network Upgrades, GI-2016-5 interconnection qualifies for Energy Resource Interconnection Service (ERIS)[2] to deliver up to 200 MW output using the existing firm or non-firm capacity on an as available basis.

Without Network Upgrades: NRIS = 0 MW and ERIS = 0 – 200 MW on an as-available basis

With Network Upgrades: NRIS = 200 MW

Cost Estimates

The total estimated cost of the required Interconnection Facilities and Network Upgrades at PSCo's Midway Station (in 2017 dollars) is **$11.216 million** and includes:

- $ 0.735 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- $ 6.565 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- $ 3.916 million for PSCo-Owned, PSCo-Funded Network Upgrades for Delivery

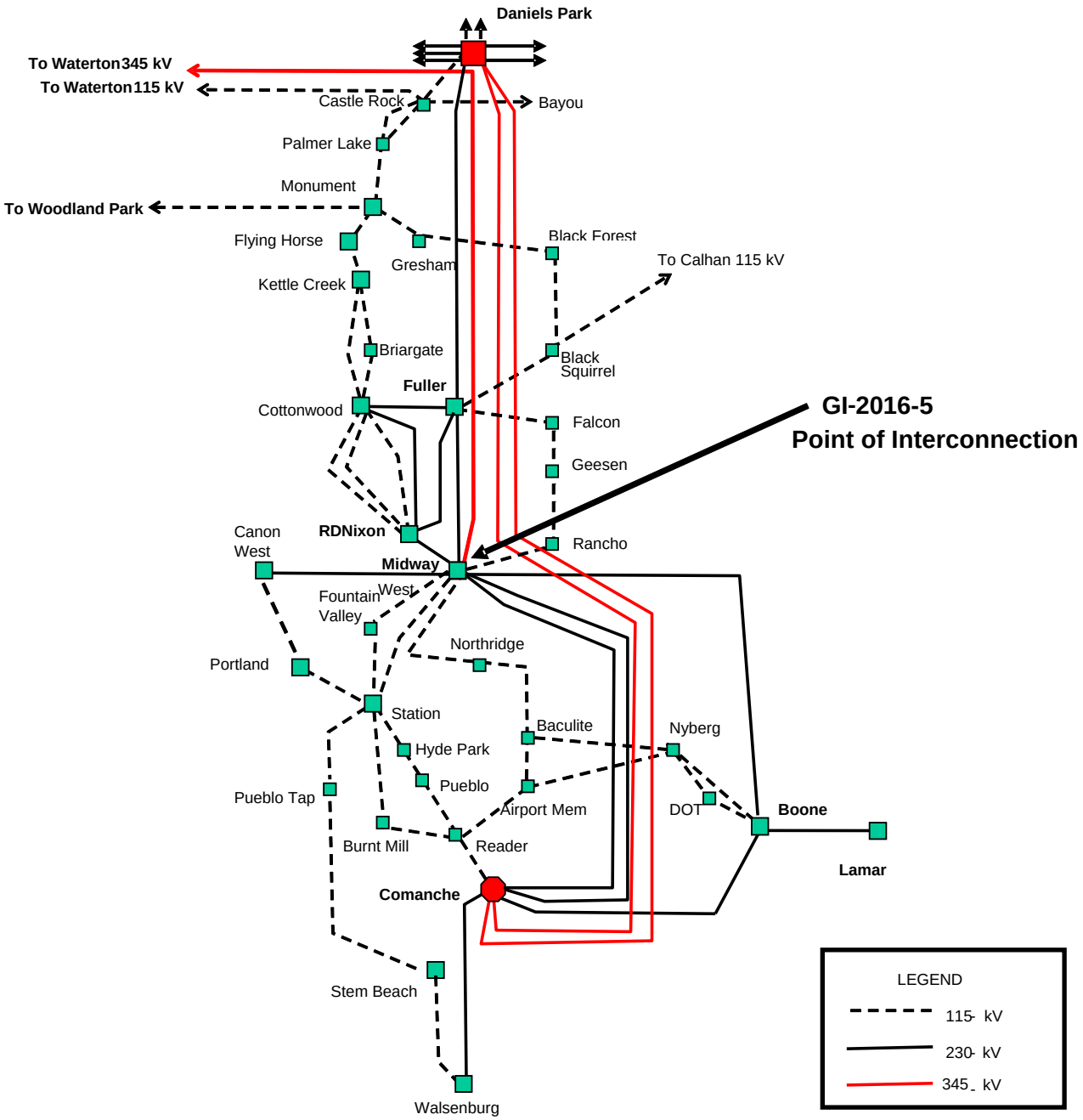
[1] Network Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission System (1) in a manner comparable to that in which the Transmission Provider integrates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

[2] Energy Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

The estimated time frame to site, design, procure and construct these Interconnection Facilities and Network Upgrades is 24 months. If a CPCN is required for Network Upgrades then additional time will likely be required.

The Interconnection Customer will need to coordinate with Black Hills Colorado Electric (BHCE) to determine the estimated cost and timeframe for the Network Upgrades needed to mitigate the thermal overloads on their transmission system attributed to GI-2016-5.

Figure 1 Midway Station and Surrounding Transmission System (2016)



B. Introduction

On April 5, 2016 Public Service Company of Colorado (PSCo) received an interconnection request (GI-2016-5) for a 200 MWac solar photovoltaic (PV) generation facility in Pueblo County, Colorado. The proposed Point of Interconnection (POI) is the PSCo-owned Midway 115 kV bus within the Midway 345/230/115 kV transmission substation (see Figure 1).

The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2019 and accordingly the approximate target Backfeed Date is assumed to be six months prior to the COD - June 30, 2019.

The proposed solar photovoltaic generating facility would consist of 50 GE inverters each rated 4.0 MW. Each inverter would be connected to a pad-mounted step-up transformer (SUT) which provides voltage transformation for interconnection of the inverter and its associated PV generation source to the medium voltage power collection system within the generating plant. One main step-up transformer (MST) would provide the final transformation to allow the generating facility to interconnect to the Midway 115 kV bus POI via an overhead 115kV transmission line owned by the Interconnection Customer.

The GI-2016-5 interconnection request was studied as a stand-alone project. That is, the study did not include any other Generator Interconnection Requests (GIR) existing in PSCo's or any affected party's GIR queue, other than the interconnection requests that are considered to be planned resources for which Power Purchase Agreements have been signed. This interconnection request was studied both as Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

For this interconnection request, the potential Affected Parties are Black Hills Colorado Electric (BHCE), Tri-State Generation & Transmission (TSGT) and Colorado Springs Utilities (CSU).

C. Study Scope and Analysis

This interconnection request was studied both as Network Resource Interconnection Service (NRIS)[3] and Energy Resource Interconnection Service (ERIS)[4].

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

[4] Energy Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

The System Impact Study scope consisted of performing power flow analysis to evaluate the steady-state thermal and/or voltage limit violations in the transmission system resulting from the proposed generator interconnection. The System Impact Study scope also consisted of short-circuit analysis to determine any over-dutied circuit breakers due to the proposed generator interconnection. Together these analyses help to identify potential Network Upgrades required to deliver the 200 MW rated output of the proposed generation to load, for both NRIS and ERIS. Steady-state thermal analysis was also done for certain N-2 contingencies.

PSCo adheres to NERC & WECC System Performance Criteria, as well as internal system performance criteria for transmission system planning studies.

D. Power Flow Study Models

The power flow studies were based on the PSSE CCPG 2020HS_r7 case (dated Sept. 16 2015). The following Area 70 loads in the case were adjusted to reflect the most recent PSCo load forecast for 2020: PSCo, WAPA, and PSCo's wholesale customers. The transmission system topology was also updated to reflect current project plans for PSCo. The taps on TSGT's Monument 1 and 2 69/115 kV transformers were changed to 1.0 pu to mitigate voltage issues inherent in the CCPG case.

Four power flow cases were created for evaluating the system impact of the proposed generator interconnection. The first two cases were a Benchmark Case (without GI-2016-5) and a Study Case (with GI-2016-5). The other two cases were the exact same as the Benchmark and Study Cases, however the Palmer Lake-Monument line was opened to reflect an operating procedure put into place that will occur during certain outage conditions to mitigate thermal overloads on CSU 115kV transmission facilities (see Appendix A).

To assess the impact of the proposed generation on the interconnected transmission system, the generation dispatch in the reference case was adjusted to create a south to north power flow stress on the Comanche – Midway - Jackson Fuller – Daniels Park transmission path. This was accomplished by adopting a generation dispatch that accounts for future known generation plans, including planned retirements, additions, as well as current Purchase Power Agreements. PSCo generation was dispatched according to PSCo Transmission Planning's internal GI dispatch methodology.[5]

[5] *Variable Energy Resource (VER) Dispatch Assumptions used in PSCo Transmission Planning's System Impact/Performance Studies – specifically in Generator Interconnection & Deliverability Studies for PSCo Designated Network Resources (DNR)*

E. Power Flow Study Process

The study area was defined as Zones 700, 703, 704, 705, 709, 710, 712, 754 and 757. Contingency power flow studies were completed on the Benchmark Cases and the Study Cases using PTI's PSSE Ver.33.6.0 program and PSS®E Ver. 33.6.0 ACCC contingency analysis. Automated contingency power flow studies were completed on all power flow models using the PSS®E program, switching out single elements one at a time for all of the elements (lines and transformers) in the study area. Upon switching each element out, the program re-solves the power flow model.

PSCo adheres to all applicable NERC Standards & WECC Criteria for Bulk Electric System (BES) acceptable performance, as well as its internal transmission planning criteria for all studies. During system intact conditions, PSCo's steady-state performance criteria require the transmission bus voltages remain within 0.95 – 1.05 per unit of nominal and the power flows stay below the applicable normal ratings of the transmission facilities. Following a single contingency, the steady state bus voltages must remain within 0.9 – 1.1 per unit of nominal, and the power flows must continue to stay below the applicable normal facility ratings. For N-1 post-contingency system conditions, the applicable normal ratings are the seasonal continuous rating of the transmission facility – but PSCo allows the use of eight-hour facility ratings for transformers for which it is available. Further, PSCo does not rely on 30-minute emergency ratings of transmission facilities for meeting N-1 system performance in planning studies.

No stability analysis was performed since the dynamic performance of the solar generation facility for normally cleared faults was expected to be satisfactory based on the information on Voltage Ride Through (VRT) capability of the GE dc/ac inverters provided by the Interconnection Customer. Furthermore, it is the responsibility of the Interconnection Customer to ensure that its 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-024-2.

F. Power Flow Contingency Analysis Results

Thermal Analysis: New thermal overloads did occur as a result of the GI-2016-5 interconnection and are shown in Tables A.1 and A.2 in Appendix A. N-2 analysis results are shown in Tables A.3 and A.4.

Voltage Analysis: No new voltage violations occurred as a result of the GI-2016-5 interconnection.

As defined in Section C above, Energy Resource Interconnection Service (ERIS) allows the Customer to deliver a Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis.

Therefore, until Network Upgrades to mitigate overloads due to GI-2016-5 are placed in-service (Table 4), the GI-2016-5 output would be deliverable only as ERIS using the existing firm/non-firm transmission capacity on an as available basis. After the Network Upgrades are placed in-service, the GI-2016-5 rated output would be deliverable as Network Resource Interconnection Service (NRIS).

G. Voltage Regulation and Reactive Power Capability

The following voltage regulation and reactive power capability requirements are applicable to this interconnection request:

- To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system are expected to adhere to the Rocky Mountain Area Voltage Coordination Guidelines (RMAVCG). Since the POI for this interconnection request is located within Region 4 – SouthEast Colorado, the applicable ideal transmission system voltage profile range is 1.02–1.03 per unit at Regulating Buses.
- Xcel Energy's OATT (Attachment N effective 10/14/2016) requires all non-synchronous Generator Interconnections (GI) to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the high voltage side (transmission bus) of the generating station.
- Generating Facilities interconnected to the PSCo transmission system must meet the POI voltage schedule specified by the Transmission Operator, as long as the Generating Facility is on-line and producing power. The Generating Facilities are expected to achieve this by providing dynamic reactive power (Mvar) proportionate to the actual power (MW) output within the 0.95 leading to 0.95 lagging power factor range.
- The Interconnection Customer has the responsibility to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAR), and the locations of any additional static reactive power equipment needed within the Generating Facility in order to provide the level of dynamic reactive power capability to meet the 0.95 leading to 0.95 lagging power factor standard. The Interconnection Customer may need to perform additional studies for this purpose.
- The Interconnection Customer has the responsibility to ensure that its Generating Facility is capable of meeting the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in NERC Reliability Standard PRC-024-2.
- Prior to commercial operation, the Interconnection Customer must demonstrate to the satisfaction of PSCo Transmission Operator that the Generating Facility can safely and reliably operate within the required power factor and voltage ranges noted above.

H. Short Circuit Analysis Results

The calculated short circuit levels and Thevenin system equivalent impedances for the POI at the Midway 115kV bus are tabulated below. No circuit-breakers at Midway 115kV bus or at the neighboring buses were found to be over-dutied due to the proposed interconnection.

Table 1 – Short Circuit Levels at the Midway 115 kV POI

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance R +j X (ohms)
Before GI-2016-5 Interconnection	12,038	11,075	Z1(pos) = 0.73579 + j5.46595 Z2(neg) = 0.76217 + j5.46448 Z0(zero) = 0.34623 + j6.95924
After GI-2016-5 Interconnection	12,038	11,894	Z1(pos) = 0.73579 + j5.46595 Z2(neg) = 0.76217 + j5.46448 Z0(zero) = 0.28454 + j5.72137

I. Study Conclusion

Based on the Feasibility Study results, it is concluded that Network Upgrades are required for the 200 MW rated output of GI-2016-5 interconnection to qualify for Network Resource Interconnection Service (NRIS). Without Network upgrades, GI-2016-5 interconnection qualifies for Energy Resource Interconnection Service (ERIS) to deliver up to 200 MW output using the existing firm or non-firm capacity on an as available basis.

Without Network Upgrades: NRIS = 0 MW and ERIS = 0 – 200 MW on an as-available basis

With Network Upgrades: NRIS = 200 MW

The Interconnection Customer will need to coordinate with the Affected Party Black Hills Colorado Electric (BHCE) whose facilities were determined to be overloaded as a result of GI-2016-5 to determine the estimated cost and timeframe for Network Upgrades needed on their transmission system.

J. Cost Estimates and Assumptions

GI-2016-5 (System Impact Study Report)
March 2, 2017

PSCo Engineering has developed Scoping level cost estimates (SE's) for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery of the Interconnection Customer's generation. The cost estimates are in 2017 dollars with escalation and contingency applied (AFUDC is not included). Scoping Estimates are based upon typical construction costs for previously performed similar construction projects and have a +/- 30% level of accuracy. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new PSCo facilities. The estimates do not include the costs for any other Customer owned equipment and associated design and engineering.

The estimated total cost of the facilities and upgrades for the interconnection is **$11,216,000.**

Figure 2 below is a conceptual one-line of the proposed interconnection of the Customer's 200 MW Solar Photovoltaic (PV) Generation at the Midway Substation 115 kV bus.

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 2: Transmission Provider's Interconnection Facilities – Interconnection Customer Funded

Element	Description	Cost Est. (Millions)
PSCo's Midway 115 kV Transmission Substation	Interconnect Customer to the 115kV bus at Midway Substation. The new equipment includes: • One 115kV, 3000 amp gang switch • Three 115kV CT/PT metering units • Three 115kV lightning arresters • Power Quality Metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Transmission line communications, relaying and testing	**$0.660**
	Transmission line tap from Customer's last line structure outside of PSCo's yard into new bay position (assumed 300' span, conductor, hardware and labor).	**$0.075**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$0.735**
Time Frame	**Design, procure and construct**	**24 Months**

Table 3: Network Upgrades for Interconnection – PSCo Owned & Funded

Element	Description	Cost Estimate (Millions)
PSCo's Midway 115kV Transmission Substation	Interconnect Customer to the 115kV bus at Midway Substation. The new equipment includes: • Electrical Equipment Enclosure and Auxiliary Systems • Station Batteries and Battery Charger • Eight 115kV, 3000 amp circuit breakers • Twelve 115kV, 3000 amp gang switches • Three 115kV CCVTs • Associated station controls, • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated equipment and system testing • Associated fence and yard improvements	**$5.830**
	Communications, supervisory and SCADA equipment	**$0.650**
	Siting and Permitting activities to expand substation	**$0.085**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$6.565**
Time Frame	**Site, design, procure and construct**	**24 months**

Table 4 –Network Upgrades for Delivery – PSCo Owned & Funded

Element	Description	Cost Est. (Millions)
PSCo's Midway 115kV Transmission Substation	Interconnect Customer to the 115kV bus at Midway Substation. The new equipment includes: • One 230/115, 280MVA Transformer • Associated equipment and materials	**$3.916**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$3.916**
	Design, procure and construct	**24 Months**
	Total Project Estimate	**$11.216**

Cost Estimate Assumptions

- Scoping level project cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery have a +/- 30% accuracy.
- Estimates are based on 2017 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 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.
- Xcel Energy (or its Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo Transmission owned and maintained facilities.
- A CPCN will not be required for the interconnection facilities construction.
- A CPCN may be required should the PUC rule that the Network Upgrades (Transformer Upgrade) are not "normal course of business". This will extend the estimated time for completion.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer Substation. PSCo / Xcel will need indications, readings and data from the LFAGC RTU.

Xcel Energy

Appendix A - Power Flow Thermal Results

N-1 Contingencies

GI-2016-5 (200 MW) Interconnection at Midway 115 kV POI

2020 Summer Heavy Load (2020) – Colorado South-North Flow Stress

Lamar DC Tie = 0 MW Colorado Green = 0 MW Twin Buttes Wind Gen = 15.8 MW

PSCo 2013 Electric Resource Plan (ERP) Generation:

Gas Gen: Fountain Valley CTs = 216 MW (dispatched @ 90% of Installed Capacity)

Wind Gen: Jackson Fuller = 100 MW (dispatched @ 40% of Installed Capacity)

Solar PV Gen: Comanche = 102 MW (dispatched @ 85% of Installed Capacity)

Table A.1 – GI-2016-5 with Palmer Lake – Monument 115 kV line closed (normal operation)

				Facility Contingency Loading Without GI-2016-5 (Benchmark Case)		Facility Contingency Loading With GI-2016-5 (Study Case)			
Monitored Facility (Line or Transformer)	Type	Facility Owner	Branch Rating MVA (Norm/Emer)	Flow in MVA (Current Equiv)	Flow in % Current Equiv of Normal/Emer Rating	Flow in MVA (Current Equiv)	Flow in % Current Equiv of Normal/Emer Rating	% Change	Contingency Outage
Midway 115/230 kV	Txfm	PSCo	97 / 120	33.2	33.5 / 27.7	127.5	131 / 106	97.5 / 78.3	None – System Intact
Briar Gate S – Cottonwood S 115 kV	Line	CSU	150 / 192	146.2	95.6 / 76.0	155.9	104 / 81.2	8.4 / 5.2	Cottonwood N – Kettle Creek S 115 kV
Cottonwood N – Kettle Creek S 115 kV	Line	CSU	162 / 180	155.2	95.8 / 86.2	167.7	104 / 93.2	8.2 / 7.0	Briar Gate S – Cottonwood S 115 kV
Boone – La Junta Tap 115 kV	Line	TSGT	79 / 79	128.7	160 / 160	129	160 / 160	0 / 0	Boone – Lamar 230 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	19.5	24.3 / 24.3	142	173 / 173	149 / 149	Midway 115/230 kV
Midway 115/230 kV	Txfm	PSCo	97 / 120	32.5	31.7 / 27.1	168	170 / 140	138 / 113	Midway (PSCo) – West Station 115 kV
Midway 115/230 kV	Txfm	PSCo	97 / 120	84.9	87.5 / 70.8	191	197 / 159	110 / 88.2	2x Comanche – Daniels Park 345 kV Lines

N-1 Contingencies

GI-2016-5 (200 MW) Interconnection at Midway 115 kV POI

2020 Summer Heavy Load (2020) – Colorado South-North Flow Stress

Lamar DC Tie = 0 MW Colorado Green = 0 MW Twin Buttes Wind Gen = 15.8 MW

PSCo 2013 Electric Resource Plan (ERP) Generation:

Gas Gen: Fountain Valley CTs = 216 MW (dispatched @ 90% of Installed Capacity)

Wind Gen: Jackson Fuller = 100 MW (dispatched @ 40% of Installed Capacity)

Solar PV Gen: Comanche = 102 MW (dispatched @ 85% of Installed Capacity)

Table A.2 – GI-2016-5 with Palmer Lake – Monument 115 kV line open (as per Palmer Lake operating procedure)

				Facility Contingency Loading Without GI-2016-5		Facility Contingency Loading With GI-2016-5			
Monitored Facility (Line or Transformer)	Type	Facility Owner	Branch Rating MVA (Norm/Emer)	Flow in MVA (Current Equiv)	Flow in % Current Equiv of Normal/Emer Rating	Flow in MVA (Current Equiv)	Flow in % Current Equiv of Normal/Emer Rating	% Change	Contingency Outage
Midway 115/230 kV	Txfm	PSCo	97 / 120	32.9	33.1 / 27.4	126.6	131 / 106	97.9 / 78.6	None – System Intact
Briar Gate S – Cottonwood S 115 kV	Line	CSU	150 / 192	131.5	86 / 68.5	135.3	90.2 / 70.5	4.2 / 2.0	Cottonwood N – Kettle Creek S 115 kV
Cottonwood N – Kettle Creek S 115 kV	Line	CSU	162 / 180	137.2	83.1 / 76.2	141.4	87.3 / 78.6	4.2 / 2.4	Briar Gate S – Cottonwood S 115 kV
Boone – La Junta Tap 115 kV	Line	TSGT	79 / 79	128.7	160 / 160	129	160 / 160	0 / 0	Boone – Lamar 230 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	19.4	24.2 / 24.2	142.2	173 / 173	149 / 149	Midway 115/230 kV
Midway 115/230 kV	Txfm	PSCo	97 / 120	30.1	30.3 / 25.1	167.7	169 / 140	135 / 113	Midway – West Station 115 kV
Midway 115/230 kV	Txfm	PSCo	97 / 120	84.9	87.1 / 70.8	190.7	197 / 159	110 / 88.2	2x Comanche – Daniels Park 345 kV Lines

N-2 Contingencies

GI-2016-5 (200 MW) Interconnection at Midway 115 kV POI

2020 Summer Heavy Load (2020) – Colorado South-North Flow Stress

Lamar DC Tie = 0 MW Colorado Green = 0 MW Twin Buttes Wind Gen = 15.8 MW

PSCo 2013 Electric Resource Plan (ERP) Generation:

Gas Gen: Fountain Valley CTs = 216 MW (dispatched @ 90% of Installed Capacity)

Wind Gen: Jackson Fuller = 100 MW (dispatched @ 40% of Installed Capacity)

Solar PV Gen: Comanche = 102 MW (dispatched @ 85% of Installed Capacity)

Table A.3 – GI-2016-5 with Palmer Lake – Monument 115 kV line closed (normal operation)

				Facility Contingency Loading Without GI-2016-5 (Benchmark Case)		Facility Contingency Loading With GI-2016-5 (Study Case)			
Monitored Facility (Line or Transformer)	**Type**	**Facility Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow in MVA (Current Equiv)**	**Flow in % Current Equiv of Normal/Emer Rating**	**Flow in MVA (Current Equiv)**	**Flow in % Current Equiv of Normal/Emer Rating**	**% Change**	**Contingency Outage**
Midway 115 / 230 kV	Txfm	PSCo / BHE	97 / 97	0	0 / 0	201	202 / 202	202 / 202	Midway – West Station 115 kV and Midway-Northridge 115 kV (Midway BR-PSCo 115 kV open)
Fountain Valley – Desert Cove 115 kV	Line	BHE	119 / 119	97.6	82.0 / 82.0	119	100 / 100	18.0 / 18.0	2x Comanche – Daniels Park 345 kV Lines
Fountain Valley – Midway BR 115 kV	Line	BHE	115 / 115	96.5	83.9 / 83.9	118	103 / 103	19.1 / 19.1	2x Comanche – Daniels Park 345 kV Lines
Midway PSCo – Midway BR 230 kV	Line	PSCo / WAPA	430 / 478	384	89.3 / 80.3	453	105 / 94.8	15.7 / 14.5	2x Comanche – Daniels Park 345 kV Lines
Palmer – Monument 115 kV	Line	CSU / PSCo	142 / 157	130	91.5 / 82.8	158	111 / 101	19.5 / 18.2	2x Comanche – Daniels Park 345 kV Lines
Desert Cove – West Station 115 kV	Line	BHE	120 / 120	120	100 / 100	142	118 / 118	18.0 / 18.0	2x Comanche – Daniels Park 345 kV Lines
Midway BR – Rancho 115 kV	Line	TSGT	92 / 92	84.0	91.3 / 91.3	92.3	100 / 100	8.7 / 8.7	2x Comanche – Daniels Park 345 kV Lines
Monument – Flyhorse N 115 kV	Line	CSU	142 / 156	133	93.7 / 85.3	158	111 / 101	17.3 / 15.7	2x Comanche – Daniels Park 345 kV Lines

				Facility Contingency Loading Without GI-2016-5 (Benchmark Case)		Facility Contingency Loading With GI-2016-5 (Study Case)			
Monitored Facility (Line or Transformer)	**Type**	**Facility Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow in MVA (Current Equiv)**	**Flow in % Current Equiv of Normal/Emer Rating**	**Flow in MVA (Current Equiv)**	**Flow in % Current Equiv of Normal/Emer Rating**	**% Change**	**Contingency Outage**
Rancho – Lorson Ranch 115 kV	Line	TSGT	92 / 92	82.2	89.4 / 89.4	90.5	98.4 / 98.4	9.0 / 9.0	2x Comanche – Daniels Park 345 kV Lines
Flyhorse S – Kettle Creek N 115 kV	Line	CSU	162 / 180	145	89.5 / 80.6	170	105 / 94.4	15.5 / 13.8	2x Comanche – Daniels Park 345 kV Lines
Briargate S – Cottonwood S 115 kV	Line	CSU	150 / 192	146	97.3 / 76.0	159	106 / 82.8	8.7 / 6.8	Cottonwood N bus
BlkFrtTp – BlkSqmv 115 kV	Line	TSGT	81 / 81	90.9	112 / 112	101	125 / 125	13.0 / 13.0	Cottonwood N and S buses

N-2 Contingencies

GI-2016-5 (200 MW) Interconnection at Midway 115 kV POI

2020 Summer Heavy Load (2020) – Colorado South-North Flow Stress

Lamar DC Tie = 0 MW Colorado Green = 0 MW Twin Buttes Wind Gen = 15.8 MW

PSCo 2013 Electric Resource Plan (ERP) Generation:

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Wind Gen: Jackson Fuller = 100 MW (dispatched @ 40% of Installed Capacity)

Solar PV Gen: Comanche = 102 MW (dispatched @ 85% of Installed Capacity)

Table A.4 – GI-2016-5 Table A.3 monitored facilities with Palmer Lake – Monument 115 kV line open (as per Palmer Lake operating procedure)

				Facility Contingency Loading Without GI-2016-5		Facility Contingency Loading With GI-2016-5			
Monitored Facility (Line or Transformer)	Type	Facility Owner	Branch Rating MVA (Norm/Emer)	Flow in MVA (Current Equiv)	Flow in % Current Equiv of Normal/Emer Rating	Flow in MVA (Current Equiv)	Flow in % Current Equiv of Normal/Emer Rating	% Change	Contingency Outage
Midway 115 / 230 kV	Txfm	PSCo / BHE	97 / 97	0	0 / 0	196	202 / 202	202 / 202	Midway – West Station 115 kV and Midway-Northridge 115 kV (Midway BR-PSCo 115 kV open)
Fountain Valley – Desert Cove 115 kV	Line	BHE	119 / 119	94.4	79.3 / 79.3	115	96.6 / 96.6	17.3 / 17.3	2x Comanche – Daniels Park 345 kV Lines
Fountain Valley – Midway BR 115 kV	Line	BHE	115 / 115	93.2	81.0 / 81.0	114	99.1 / 99.1	18.1 / 18.1	2x Comanche – Daniels Park 345 kV Lines
Midway PSCo – Midway BR 230 kV	Line	PSCo / WAPA	430 / 478	366	85.1 / 76.6	429	99.8 / 89.7	14.7 / 13.1	2x Comanche – Daniels Park 345 kV Lines
Palmer – Monument 115 kV	Line	CSU / PSCo	142 / 157	-	-	-	-	-	2x Comanche – Daniels Park 345 kV Lines
Desert Cove – West Station 115 kV	Line	BHE	120 / 120	117	97.5 / 97.5	138	115 / 115	17.5 / 17.5	2x Comanche – Daniels Park 345 kV Lines
Midway BR – Rancho 115 kV	Line	TSGT	92 / 92	74.8	81.3 / 81.3	81.1	88.2 / 88.2	6.9 / 6.9	2x Comanche – Daniels Park 345 kV Lines

				Facility Contingency Loading Without GI-2016-5		Facility Contingency Loading With GI-2016-5			
Monitored Facility (Line or Transformer)	**Type**	**Facility Owner**	**Branch Rating MVA (Norm/Emer)**	**Flow in MVA (Current Equiv)**	**Flow in % Current Equiv of Normal/Emer Rating**	**Flow in MVA (Current Equiv)**	**Flow in % Current Equiv of Normal/Emer Rating**	**% Change**	**Contingency Outage**
Monument – Flyhorse N 115 kV	Line	CSU	142 / 156	51.4	36.2 / 32.9	58.6	41.3 / 37.6	5.1 / 4.7	2x Comanche – Daniels Park 345 kV Lines
Rancho – Lorson Ranch 115 kV	Line	TSGT	92 / 92	73.0	79.3 / 79.3	79.4	86.3 / 86.3	7.0 / 7.0	2x Comanche – Daniels Park 345 kV Lines
Flyhorse S – Kettle Creek N 115 kV	Line	CSU	162 / 180	63.5	39.2 / 35.3	71.0	43.8 / 39.4	4.6 / 4.1	2x Comanche – Daniels Park 345 kV Lines
Briargate S – Cottonwood S 115 kV	Line	CSU	150 / 192	134	89.3 / 69.8	136	90.7 / 70.8	1.4 / 1.0	Cottonwood N bus
BlkFrtTp – BlkSqmv 115 kV	Line	TSGT	81 / 81	141	174 / 174	145	179 / 179	5 / 5	Cottonwood N and S buses

Appendix B – Engineering Drawings

Figure 2: One-Line of Proposed GI-2016-5 Interconnection at Midway 115kV Station