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
August 16, 2017

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).

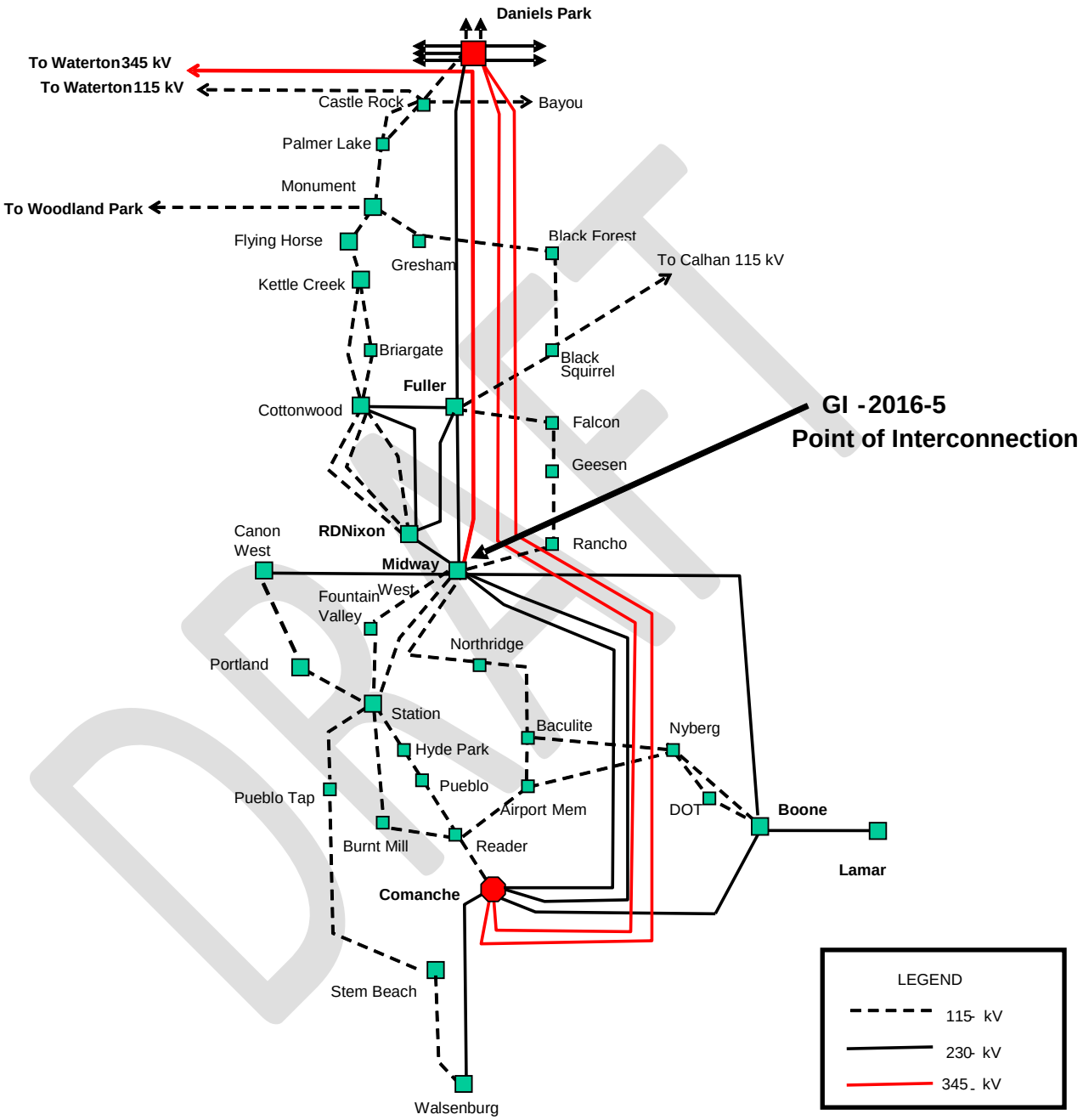
The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2019. Accordingly the approximate target Backfeed Date is assumed to be six months prior to the COD – that is, June 30, 2019.

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. GI-2016-5 was studied both as Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

For GI-2016-5 interconnection request, the Affected Parties are Black Hills Colorado Electric (BHCE), Tri-State Generation & Transmission (TSGT), Colorado Springs Utilities (CSU) and Intermountain Rural Electric Association (IREA).

Figure 1 Midway Station and Surrounding Transmission System



This System Impact Study consists 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 is 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 the affected parties' systems as a result of the 200 MW injection from GI-2016-5, but did not identify any voltage violations. Network Upgrades are required to mitigate the single contingency (N-1) thermal overloads and enable the interconnection and delivery of the 200 MW output from GI-2016-5. The incremental thermal overloads due to multiple contingencies will be mitigated by system readjustments, including generation redispatch, that will be implemented via operating procedure(s). The short circuit analysis did not identify any over-dutied circuit breakers.

The Tri-State and CSU overloads are addressed through the Palmer-Monument 115 kV line operating procedure and, therefore, are not attributed to GI-2016-5 interconnection.

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.

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

[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.

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

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.

A. 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. Accordingly the approximate target Backfeed Date is assumed to be six months prior to the COD – that is, 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. GI-2016-5 was studied both as Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

For GI-2016-5 interconnection request, the Affected Parties are Black Hills Colorado Electric (BHCE), Tri-State Generation & Transmission (TSGT), Colorado Springs Utilities (CSU) and Intermountain Rural Electric Association (IREA).

B. Study Scope and Analysis

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

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. No stability analysis was performed since the dynamic performance of the solar generation facility for normally cleared faults is 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. 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 performed 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.

C. Power Flow Study Models

The power flow studies were based on the PSSE CCPG 2020HS_r7 case (dated Sept. 16 2015). PSCo loads were adjusted to reflect the most recent PSCo load forecast for 2020 summer peak. The transmission system topology was also updated to reflect current project plans for PSCo. Additionally, CSU's Drake#5 unit was removed from the case as the unit is retired effective 2016. 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

[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.

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 is shown in Table-B.1 in Appendix B. The dispatch criteria for the various generation resource types can be seen in the tables of Appendix A.

D. 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 for N-1 and N-2 contingencies were completed on the Benchmark Cases and the Study Cases using PTI's PSSE Ver.33.6.0 program for contingency analysis. Contingency power flow studies were completed on all four power flow models using the PSS®E program. The analysis included bus-to-bus contingencies in Area70 in zones 700, 703, 704, 712 and 757. Also selected multiple contingencies in the study area were run.

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 to be within 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. Multiple contingencies on the PSCo facilities will be addressed by PSCo system readjustments (including generation curtailment) implemented via operating procedures. PSCo's criteria for N-2 contingencies is for the thermal loading of a facility to be at less than or equal to its emergency rating, and the voltage range to be between 0.9 – 1.1 per unit of nominal.

E. Power Flow Contingency Analysis Results

Summary of Thermal Analysis: Thermal analysis results are provided in Appendix A – the N-1 analysis results are given in Tables A.1 and A.2 and the N-2 analysis results are given in Table A.3.

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

Single Contingency Analysis:

The results of the single contingency analysis are given in Tables A.1 and A.2. The results show that the interconnection of GI-2016-5 caused several new thermal overloads and contributed to an increase in the existing thermal overloads of a few facilities. Some of the overloads in Tables A.1 and A.2 were eliminated with the implementation of the Palmer Lake – Monument 115kV line operating procedure. This operating procedure involves opening the Palmer Lake-Monument 115kV branch for certain overloads on the CSU system. Additionally, PSCo has a planned project (expected ISD 2017) to increase the rating of the Daniels Park – Prairie1 230kV line which will be sufficient to eliminate the post GI thermal overload. Thus, this thermal violation is not attributed to GI-2016-5 interconnection.

The following single contingency BHCE facility overload is attributable to the interconnection of GI-2016-5.

- Midway (PSCo) – West Station 115 kV line

The following single contingency PSCo facility overloads are attributable to the interconnection of GI-2016-5.

- Midway 230/115 kV transformer
- Daniels Park – Prarie1 230 kV line

The Daniels Park – Prarie1 230 kV line overload will be addressed by a PSCo planned project (expected ISD 2017) to increase the rating of the Daniels Park – Prairie1 230kV line. This will be sufficient to eliminate the post-GI thermal overload. The Tri-State and CSU overloads are addressed through the Palmer-Monument 115 kV line operating procedure. Thus, these thermal violations are not attributed to GI-2016-5 interconnection.

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.

Addition of GI-2016-5 did not cause any new or incremental voltage violations.

Multiple Contingency Analysis:

The results of the multiple contingency analyses with the Palmer Lake – Monument 115kV Line operating procedure are given in Table A.3.

The incremental overloads on the following BHCE facilities are attributable to the interconnection of GI-2016-5

- Midway (PSCo) – West Station 115 kV
- Pueblo Tap – West Station 115 kV
- Canon City – Skala 115 kV
- Portland – Skala 115 kV

Since the study simulated heavy south – north flows with renewable resources dispatched at 85% of the nameplate capacity for solar and 80% for wind, the thermal overloads caused by PSCo multiple contingencies will be addressed by system readjustments (including generation curtailment) implemented via operating procedures. Therefore, PSCo facility overloads and affected party facility overloads caused by PSCo contingencies are not attributed to the GI-2016-5 interconnection.

F. 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.

G. Stability 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.

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 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). 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

J. Cost Estimates and Assumptions

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 = +101 MW (dispatched @ 100% of Installed Import Capacity)
Gas: Fountain Valley CTs = 216 MW (dispatched @ 90% of Installed Capacity)
Coal: Comanche 3 = 788 MW (dispatched @ 100% of Installed Capacity)
Wind:
Jackson Fuller Wind = 200 MW (dispatched @ 80% of Installed Capacity)
Twin Buttes (I and II) Gen = 120 MW (dispatched @ 80% of Installed Capacity)
Colorado Green = 129.6 MW (dispatched @ 80% of Installed Capacity)
Solar PV: 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	43.7	45.0 / 36.4	141	145 / 118	100 / 81.6	None – System Intact
Briar Gate S – Cottonwood S 115 kV	Line	CSU	150 / 192	177	118 / 92.2	191	127 / 159	9.0 / 66.8	Cottonwood N – Kettle Creek S 115 kV
Cottonwood N – Kettle Creek S 115 kV	Line	CSU	162 / 180	193	119 / 107	207	128 / 115	9.0 / 8.0	Briar Gate S – Cottonwood S 115 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	23.4	29.3 / 29.3	143	179 / 179	150 / 150	Midway 115/230 kV
Midway 115/230 kV	Txfm	PSCo	97 / 120	40.2	41.5 / 33.5	178	183 / 148	142 / 115	Midway (PSCo) – West Station 115 kV
Daniels Park – Prairie1 230kV	Line	PSCo	478 / 478	458	95.8 / 95.8	507	106 / 106	10.2 / 10.2	Daniels Park – Prairie3 230 kV

				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**
BLKFORTP – BLK SQMV	Line	TSGT	81 / 81	76.1	93.9 / 93.9	87.5	108 / 108	14.1 / 14.1	Flyhorse S – Kettle Creek N 115 kV
Fuller 230/115kV	Txfm	TSGT	100 / 100	96.9	96.9 / 96.9	101	101 / 101	4.1 / 4.1	Midway BR – Rancho 115 kV
Midway 115 / 230 kV	Txfm	PSCo	97 / 120	50.8	52.4/ 42.3	151	156 / 126	104 / 84	All Front Range Units outage

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

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

Lamar DC Tie = +101 MW (dispatched @ 100% of Installed Import Capacity)
Gas: Fountain Valley CTs = 216 MW (dispatched @ 90% of Installed Capacity)
Coal: Comanche 3 = 788 MW (dispatched @ 100% of Installed Capacity)
Wind:
Jackson Fuller Wind = 200 MW (dispatched @ 80% of Installed Capacity)
Twin Buttes (I and II) Gen = 120 MW (dispatched @ 80% of Installed Capacity)
Colorado Green = 129.6 MW (dispatched @ 80% of Installed Capacity)
Solar PV: 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	43.0	44.0 / 35.8	139	143 / 116	99 / 80.2	None – System Intact
Briar Gate S – Cottonwood S 115 kV	Line	CSU	150 / 192	144	95.9 / 75.0	149	99.0 / 77.6	3.1 / 1.6	Cottonwood N – Kettle Creek S 115 kV
Cottonwood N – Kettle Creek S 115 kV	Line	CSU	162 / 180	151	93.0 / 83.9	156	96.1 / 86.7	3.1 / 2.8	Briar Gate S – Cottonwood S 115 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	23.4	29.2 / 29.2	143	179 / 179	150 / 150	Midway 115/230 kV
Midway 115/230 kV	Txfm	PSCo	97 / 120	39.4	40.7 / 32.8	177	182 / 148	141 / 115	Midway – West Station 115 kV
Daniels Park – Prairie1 230kV	Line	PSCo	478 / 478	467	97.7 / 97.7	516	108 / 108	10.3 / 10.3	Daniels Park – Prairie3 230 kV
BLKFORTP – BLK SQMV 115kV	Line	TSGT	81 / 81	62.9	77.6 / 77.6	68.1	84.1 / 84.1	6.5 / 6.5	Flyhorse S – Kettle Creek N 115 kV

				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**
Fuller 230/115kV	Txfm	TSGT	100 / 100	84.0	84.0 / 84.0	84.6	84.6 / 84.6	0.6 / 0.6	Midway BR – Rancho 115 kV
Midway 115 / 230 kV	Txfm	PSCo	97 / 120	50.4	52.0 / 42.0	154	158 / 128	106 / 86	All Front Range Units outage

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

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

Lamar DC Tie = +101 MW (dispatched @ 100% of Installed Import Capacity)
Gas: Fountain Valley CTs = 216 MW (dispatched @ 90% of Installed Capacity)
Coal: Comanche 3 = 788 MW (dispatched @ 100% of Installed Capacity)
Wind:
Jackson Fuller Wind = 200 MW (dispatched @ 80% of Installed Capacity)
Twin Buttes (I and II) Gen = 120 MW (dispatched @ 80% of Installed Capacity)
Colorado Green = 129.6 MW (dispatched @ 80% of Installed Capacity)
Solar PV: Comanche = 102 MW (dispatched @ 85% of Installed Capacity)

Table A.3 - GI-2016-5 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	97 / 120	0	0 / 0	139	143 / 116	143 / 116	Midway – West Station 115 kV and Midway-Northridge 115 kV (Midway BR-PSCo 115 kV open)
Midway 115 / 230 kV	Txfm	PSCo	97 / 120	125	129 / 104	244	252 / 203	123 / 99	2x Comanche – Daniels Park 345 kV Lines
Fountain Valley – Desert Cove 115 kV	Line	BHE	119 / 119	121	101 / 101	156	131 / 131	30 / 30	2x Comanche – Daniels Park 345 kV Lines
Fountain Valley – Midway BR 115 kV	Line	BHE	115 / 115	120	104 / 104	154	134 / 134	30 / 30	2x Comanche – Daniels Park 345 kV Lines
Midway PSCo – Midway BR 230 kV	Line	PSCo / WAPA	430 / 478	520	121 / 109	645	150 / 135	29 / 26	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	145	121 / 121	181	151 / 151	30 / 30	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**
Midway BR – Rancho 115 kV	Line	TSGT	92 / 92	88.9	96.6 / 96.6	101	110 /110	13.4 / 13.4	2x Comanche – Daniels Park 345 kV Lines
Monument – Flyhorse N 115 kV	Line	CSU	142 / 156	67.7	47.7 / 43.4	80.5	56.7 / 51.6	9.0 / 8.2	2x Comanche – Daniels Park 345 kV Lines
Rancho – Lorson Ranch 115 kV	Line	TSGT	92 / 92	87.1	94.7 / 94.7	99.4	108 / 108	13.3 / 13.3	2x Comanche – Daniels Park 345 kV Lines
Flyhorse S – Kettle Creek N 115 kV	Line	CSU	162 / 180	80.8	49.9 / 44.9	93.8	57.9 / 52.1	8.0 / 7.2	2x Comanche – Daniels Park 345 kV Lines
Briargate S – Cottonwood S 115 kV	Line	CSU	150 / 192	140	93.3 / 72.9	145	96.5 / 75.5	3.2 / 2.6	Cottonwood N 115 kV bus
BlkFrtTp – BlkSqmv 115 kV	Line	TSGT	81 / 81	146	180 / 180	151	186 / 186	6.0 / 6.0	Cottonwood N and S 115 kV buses
Midway 115 / 230 kV	Txfm	PSCo	97 / 120	25.6	26.4 / 21.3	100	103 / 80.0	76.6 / 58.7	Midway-Waterton 345 kV and Daniels Park-Fuller 230 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	26.8	33.5 / 33.5	83.8	105 / 105	71.5 / 71.5	Midway-Waterton 345 kV and Daniels Park-Fuller 230 kV
Pueblo Tap – West Station 115 kV	Line	BHCE	92 / 92	86.5	94.0 / 94.0	93.8	102 / 102	8.0 / 8.0	Midway-Waterton 345 kV and Daniels Park-Fuller 230 kV
Canon City – Skala 115 kV	Line	BHCE	119 / 119	115	96.8 / 96.8	134	113 / 113	16.2 / 16.2	(Midway Breaker Outage) Midway BR 115 and 230 kV buses Midway PS – Fuller 230 kV
Midway 115 / 230 kV	Txfm	PSCo	97 / 120	15.5	16.0 / 12.9	104	107 / 86.7	91 / 73.8	(Midway Breaker Outage) Midway BR 115 and 230 kV buses Midway PS – Fuller 230 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	24.8	31.0 / 31.0	84.0	105 / 105	74 / 74	(Midway Breaker Outage) Midway BR 115 and 230 kV buses Midway PS – Fuller 230 kV
Portland – Skala 115 kV	Line	BHCE	119 / 119	121	102 / 102	140	118 / 118	16 / 16	(Midway Breaker Outage) Midway BR 115 and 230 kV buses Midway PS – Fuller 230 kV

Appendix B – Generation dispatch

Benchmark Case – Before GI-2016-5

PSCo:

Bus	ID	MW
Comanche PV	S1	102
Comanche	C1	360
Comanche	C2	359
Comanche	C3	788
Lamar DC Tie	DC	101
Fountain Valley	G1	36
Fountain Valley	G2	36
Fountain Valley	G3	36
Fountain Valley	G4	36
Fountain Valley	G5	36
Fountain Valley	G6	36
Colorado Green	1	64.8
Colorado Green	2	64.8
Twin Butte	W	60
Twin Butte II	W1	60
Jackson Fuller	W1	100
Jackson Fuller	W2	100
RMEC 1	G1	130
RMEC 2	G2	130
RMEC 3	G3	275
Alamosa CT	G1	0
Alamosa CT	G2	0
GE Solar	S1	25.5
Greater Sandhill	S1	16.2
SLV Solar	S1	44.2

BHCE:

Bus	ID	MW
BUSCHWRTG1	G1	4
BUSCHWRTG2	G2	4
BUSCHWRTG3	G3	4
E Canon	G1	0
PP_MINE	G1	0
Pueblo Diesels	G1	0
Pueblo Plant	G1	0
Pueblo Plant	G2	0.0
R.F. Diesels	G1	0.0

Airport Diesels	G1	0.0
Canyon City	C1	0
Canyon City	C1	0
Baculite 1	G1	90
Baculite 2	G1	90
Baculite 3	G1	40.0
Baculite 3	G2	40.0
Baculite 3	S1	24
Baculite 4	G1	40.0
Baculite 4	G2	40.0
Baculite 4	S1	24
Baculite 5	G1	40

CSU:

Bus	**ID**	**MW**
Birdsale1	1	0.0
Birdsale 2	1	0.0
Birdsale 3	1	0.0
RD Nixon	1	212.4
Tesla	1	13.2
Drake 5	1	Retired
Drake 6	1	71.6
Drake 7	1	131.5
Nixon CT 1	1	0.0
Nixon CT 2	1	0.0
Front Range CC 1	1	138.8
Front Range CC 2	1	139.6
Front Range CC 3	1	162.7

Study Case – With GI-2016-5

Bus	**ID**	**MW**
GI-2016-5	S1	200 (+200)
Comanche 2	C2	360 (+1)
St. Vrain 1	G1	176 (-95)
St. Vrain 2	G3	70 (-20)
St. Vrain 3	G3	70 (-20)
St. Vrain 4	G4	70 (-20)
St. Vrain 5	G5	70 (-20)
St. Vrain 6	G6	70 (-20)

Appendix C – Engineering Drawings

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