



Generator Interconnection Request # GI-2016-22 Feasibility Study

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

Public Service Company of Colorado
Transmission Planning
January 25, 2017

A. Executive Summary

On September 14, 2016 Public Service Company of Colorado (PSCo) received a generation interconnection (GI) request (GI-2016-22) for a 100 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 Customer is December 31, 2019 and accordingly the approximate target Backfeed Date is assumed to be six months prior to the COD on June 30, 2019.

The proposed solar photovoltaic generating facility would consist of 40 TMEIC dc/ac inverters, each rated 2.7MVA. Each inverter would be connected to a pad-mounted step-up transformer (SUT) which provides voltage transformation for integration of the inverter and its associated PV source circuits with the medium voltage (15, 25 or 35 kV class) power collection system within the generating plant. One main generator step-up transformer (GSUT) 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. This physical interconnection is in addition to and separate from the physical interconnection of GI-2016-5 which is considered to be in-service as explained below.

The 100 MW electrical output of GI-2016-22 interconnection request was studied as a stand-alone project. That is, the study did not include any prior-queued GI requests existing in PSCo's or any affected party's GI queue except those which are: (a) considered to be PSCo planned resources in recognition of their signed Power Purchase Agreements, or (b) assumed in-service as per the agreed-upon study assumptions with the Interconnection Customer. As requested by the Interconnection Customer, the GI-2016-22 interconnection request was studied by assuming the prior-queued GI-2016-5 is in-service at 200 MW electrical output. Since both GI



requests have the same POI, this study effectively determines the feasibility of 300 MW aggregate electrical output injected at the Midway 115kV bus.

The Feasibility Study consisted of power flow (steady-state) contingency analysis and short-circuit analysis. The power flow contingency analysis identified thermal overloads as a result of the 100 MW injection from GI-2016-22, but did not identify any voltage violations. The short circuit analysis did not identify any over-dutied circuit breakers.

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

B. Study Conclusion

For the 100 MW rated output of GI-2016-22 interconnection to qualify for Network Resource Interconnection Service (NRIS) no new PSCo Network Upgrades are required provided the Network Upgrades identified for GI-2016-5 are in-service prior to the COD of GI-2016-22. Without the GI-2016-5 Network Upgrades, GI-2016-22 would only qualify for Energy Resource Interconnection Service (ERIS) to deliver up to 100 MW output using the existing firm or non-firm capacity on an as-available basis.

Without GI-2016-5 Network Upgrades: NRIS = 0 MW
ERIS = 0 – 100 MW on an as-available basis

With GI-2016-5 Network Upgrades: NRIS = 100 MW

Cost Estimates

The total estimated cost of the required Interconnection Facilities and Network Upgrades at PSCo's Midway Station (in 2016 dollars) is **\$2.575 million** and includes:

- \$ 0.875 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- \$ 1.700 million for PSCo-Owned, PSCo-Funded Interconnection Facilities
- \$ 0.000 million for PSCo Network Upgrades for Delivery

Siting and Land Rights activities required for Transmission Provider's Interconnection Facilities are not included in the estimates.

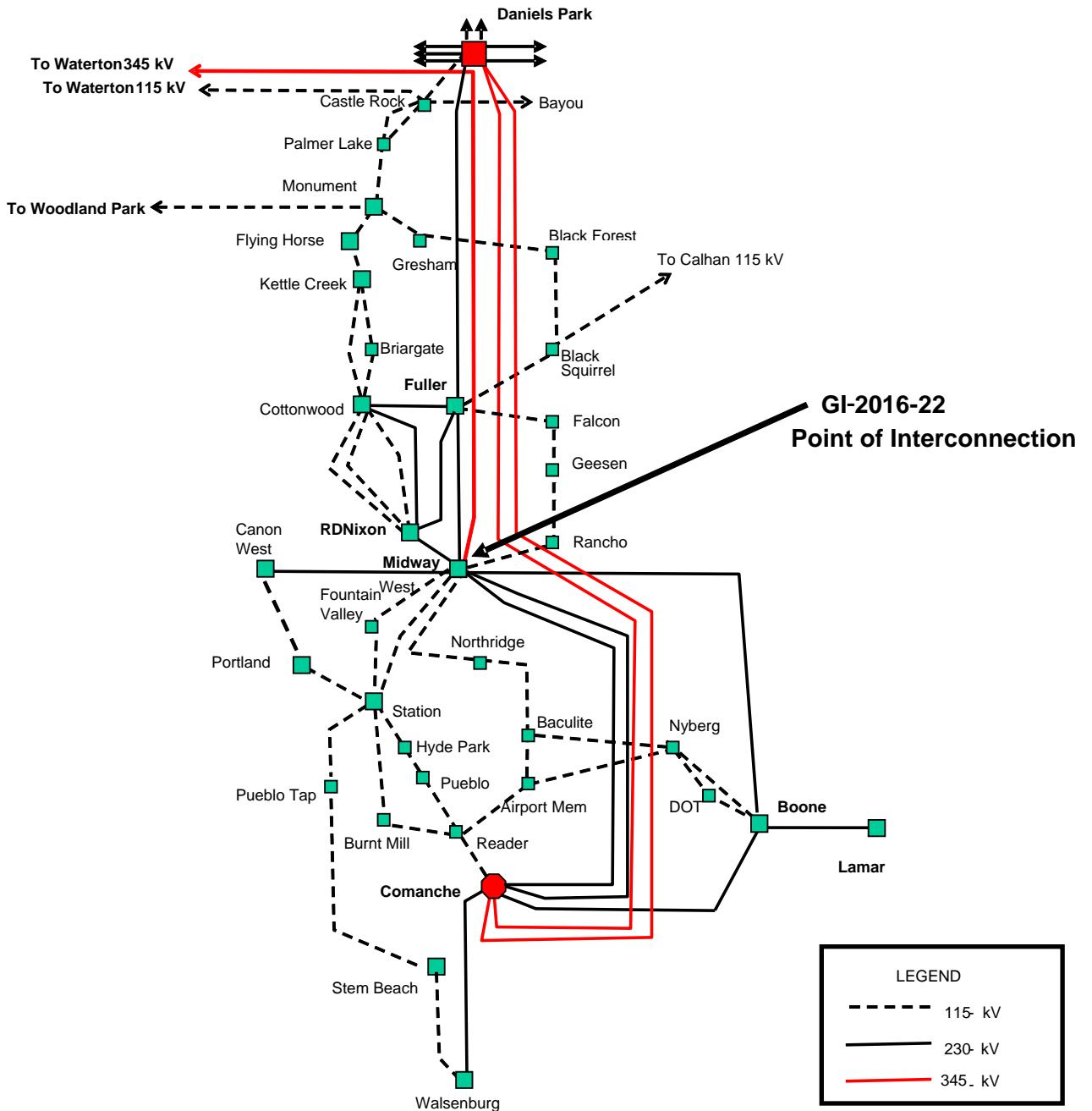
The estimated time frame to site, design, procure and construct these Interconnection Facilities and Network Upgrades is 24 months.

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 and GI-2016-22 (Appendix A) to determine the estimated cost and timeframe for Network Upgrades needed on their transmission system.

Figure 1 Midway Station and Surrounding Transmission System (2016)





C. Introduction

On September 14, 2016 Public Service Company of Colorado (PSCo) received a generation interconnection (GI) request (GI-2016-22) for a 100 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).

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The 100 MW electrical output of GI-2016-22 interconnection request was studied as a stand-alone project. That is, the study did not include any prior-queued GI requests existing in PSCo's or any affected party's GI queue except those which are: (a) considered to be PSCo planned resources in recognition of their signed Power Purchase Agreements, or (b) assumed in-service as per the agreed-upon study assumptions with the Interconnection Customer. As requested by the Interconnection Customer, the GI-2016-22 interconnection request was studied by assuming the prior-queued GI-2016-5 is in-service at 200 MW electrical output. Since both GI requests have the same POI, this study effectively determines the feasibility of 300 MW aggregate electrical output injected at the Midway 115kV bus.

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

D. Study Scope and Analysis

This interconnection request was studied both as Network Resource Interconnection Service (NRIS)¹ and Energy Resource Interconnection Service (ERIS)².

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



The Feasibility 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 Feasibility 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 100 MW rated output of the proposed generation to load, for both NRIS and ERIS.

PSCo adheres to NERC & WECC System Performance Criteria, as well as internal system performance criteria for transmission system planning studies. Operationally, PSCo attempts to maintain a transmission system voltage profile ranging from ≥ 1.02 per unit at regulating (generation) buses to ≥ 1.0 per unit at transmission load buses.

E. Power Flow Study Models

The power flow study was performed by developing a Benchmark Case (without GI-2016-22) and a Study Case (with GI-2016-22). The Benchmark Case was developed by updating the GI-2016-5 Study Case to include the PSCo Network Upgrade identified for GI-2016-5 – that is, the Midway 230/115 kV transformer rated 280 MVA. The Study Case was developed by adding the 100 MW generator for GI-2016-22 in the Benchmark Case. Another pair of Benchmark and Study Cases were developed wherein the Palmer Lake-Monument line was opened to reflect an existing operating procedure to mitigate thermal overloads on CSU 115kV transmission facilities. In total, four power flow cases were used for evaluating the feasibility of the proposed generator interconnection using power flow analysis. (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 sunk the aggregate 300 MW generation into the Denver Metro area. The resulting PSCo Area 70 generation dispatch can be found in Appendix B.

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.



F. Power Flow Study Process

Contingency power flow studies were completed on the Benchmark Case and the Study Case using PTI's PSSE Ver.33.6.0 program and PSSE Ver. 33.6.0 ACCC contingency analysis. The study area was defined as Zones 700, 703, 704, 705, 709, 710, 712, 754 and 757. Results from the two cases were compared and notable results were analyzed. The following outages were performed for the entirety of Areas 70 and 73:

- Single branch outages for each line and transformer
- Tie line outages
- Single machine unit outages

G. Power Flow Contingency Analysis Results

Thermal Analysis: New thermal overloads did occur as a result of the GI-2016-22 interconnection and are shown in Tables A.1 and A.2 in Appendix A.

Voltage Analysis: No new voltage violations occurred as a result of the GI-2016-22 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 and GI-2016-22 are placed in-service, the GI-2016-22 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-2016-22 rated output would be deliverable as Network Resource Interconnection Service (NRIS).



H. 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 should adhere to the Rocky Mountain Area Voltage Coordination Guidelines. Accordingly, since the POI for this interconnection request is located within Southeast Colorado Region 4; the applicable ideal transmission system voltage profile range is 1.02 – 1.03 per unit at regulated buses and 1.0 – 1.03 per unit at non-regulated buses.
- The Interconnection Customer shall design their Generating Facility to maintain a composite power delivery at continuous rated power output at the Point of Interconnection at a power factor within the range of 0.95 leading to 0.95 lagging.
- 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 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-024-1.
- 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.



I. 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-2016-22 Interconnection	12,055	11,905	Z1(pos) = 0.736+j5.458 ohms Z2(neg) = 0.762+j5.457 ohms Z0(zero) = 0.285+j5.721 ohms
After GI-2016-22 Interconnection	12,055	11,971	Z1(pos) = 0.736+j5.458 ohms Z2(neg) = 0.762+j5.457 ohms Z0(zero) = 0.891+j5.551 ohms

Assumptions:

- The “Without Proposed Generation” column includes all expected transmission buildout through year-end 2019, and also includes the proposed generation from GI-2016-5.
- The additional generation under this project was modelled as being connected to the Midway 115kV bus via a 115kV line separate from the GI-2016-5 interconnection with the parameters indicated in the documentation provided by the customer.
- Transformer tertiary impedances were estimated based on the information provided by the customer.

J. Study Conclusion

For the 100 MW rated output of GI-2016-22 interconnection to qualify for Network Resource Interconnection Service (NRIS) no new PSCo Network Upgrades are required provided the Network Upgrades identified for GI-2016-5 are in-service prior to the COD of GI-2016-22. Without the GI-2016-5 Network Upgrades, GI-2016-22 would only qualify for Energy Resource Interconnection Service (ERIS) to deliver up to 100 MW output using the existing firm or non-firm capacity on an as-available basis.

Without GI-2016-5 Network Upgrades: NRIS = 0 MW
ERIS = 0 – 100 MW on an as-available basis

With GI-2016-5 Network Upgrades: NRIS = 100 MW



K. Cost Estimates and Assumptions

GI-2016-22 (Feasibility Study Report)
January 25, 2017

PSCo Engineering has developed Indicative level cost estimates (IE) for Interconnection Facilities and Network/Infrastructure Upgrades required for Delivery of the Interconnection Customer's proposed 100MW solar generation facility. The cost estimates are in 2016 dollars with escalation and contingency applied (AFUDC is not included). Indicative Estimates are based upon typical construction costs for previously performed similar construction projects; however they have no specified 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 Customer owned equipment and associated design and engineering.

The estimated total cost of the facilities and upgrades for the interconnection is **\$2,575,000**. The Study and Estimates assume that the Customer's 200MW generating facility (GI-2016-5) and the associated Network Upgrades are in-service. Figure 2 below is a conceptual one-line of the proposed interconnection of the Customer's 100MW Solar Photovoltaic (PV) Generation. The Point of Interconnection (POI) is at the Midway Substation 115 kV bus.

The following tables (Tables 2, 3 and 4) list the improvements required to accommodate the interconnection and the delivery of the Project generation output on the PSCo system. 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.

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 and GI-2016-22 (Appendix A) to determine the estimated cost and timeframe for Network Upgrades needed on their transmission system.



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: <ul style="list-style-type: none"> • One 115kV, 3000 amp gang switch • Three 115kV CT/PT metering units • Three 115kV lightning arresters • Primary metering for Load Frequency/Automated Generation Control • Power Quality Metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing 	\$0.800
	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	\$0.875
Time Frame	Design, procure and construct	24 Months

Table 3: Transmission Provider’s Interconnection Facilities – PSCo Transmission 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: <ul style="list-style-type: none"> • Two (2) 115kV, 3000 amp circuit breakers • Four (4) 115kV, 3000 amp gang switches • Three 115kV CCVTs • Associated station controls, • Associated foundations and structures • Associated equipment and system testing • Associated fence and yard improvements 	\$1.700
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	\$1.700
Time Frame	Site, design, procure and construct	24 months



Table 4 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
	None identified at this time	0
	Total Cost Estimate for PSCo Network Upgrades for Delivery	0
	Design, procure and construct	N/A
	Total Project Estimate	\$2.575

Cost Estimate Assumptions

- Indicative level project cost estimates (IE) for Interconnection Facilities were developed by PSCo Engineering. No level of accuracy is specified for IE’s.
- Estimates are based on 2016 dollars (appropriate contingency and escalation included).
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The 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.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.



Appendix A - Power Flow Thermal Results

**GI-2016-22 (100 MW) Interconnection at Midway 115 kV POI (assuming GI-2016-5 200 MW in service)
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

GI-2016-5 assumed in-service = 200 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-2016-22 with Palmer Lake – Monument 115 kV line closed (normal operation)

				Facility Contingency Loading Without GI-2016-22 (Benchmark Case)		Facility Contingency Loading With GI-2016-22 (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 (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	63.9	79.9 / 79.9	92.3	115 / 115	35.1 / 35.1	None – System Intact
Briar Gate S – Cottonwood S 115 kV	Line	CSU	150 / 192	156	104 / 81.3	162	108 / 84.4	4.0 / 3.1	Cottonwood N – Kettle Creek S 115 kV
Cottonwood N – Kettle Creek S 115 kV	Line	CSU	162 / 180	168	104 / 93.3	175	108 / 97.2	4.0 / 3.9	Briar Gate S – Cottonwood S 115 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	138	173 / 173	198	247 / 247	74 / 74	Midway 115/230 kV

Note: Emergency Ratings are the Applicable Facility Ratings to determine acceptable post-contingency loading on CSU facilities.



**GI-2016-22 (100 MW) Interconnection at Midway 115 kV POI (assuming GI-2016-5 200 MW in service)
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
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Solar PV Gen: Comanche = 102 MW (dispatched @ 85% of Installed Capacity)

Table A.2 – GI-2016-22 with Palmer Lake – Monument 115 kV line open (as per Palmer Lake operating procedure)

				Facility Contingency Loading Without GI-2016-22		Facility Contingency Loading With GI-2016-22			
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 (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	64.4	80.5 / 80.5	92.3	115 / 115	34.5 / 34.5	None – System Intact
Briar Gate S – Cottonwood S 115 kV	Line	CSU	150 / 192	133	88.6 / 69.3	135	90.0 / 70.3	1.4 / 1.0	Cottonwood N – Kettle Creek S 115 kV
Cottonwood N – Kettle Creek S 115 kV	Line	CSU	162 / 180	139	85.8 / 77.2	141	87.1 / 78.3	1.3 / 1.1	Briar Gate S – Cottonwood S 115 kV
Midway (PSCo) – West Station 115 kV	Line	BHCE	80 / 80	138	173 / 173	198	247 / 247	74 / 74	Midway 115/230 kV

Note: Emergency Ratings are the Applicable Facility Ratings to determine acceptable post-contingency loading on CSU facilities.

Appendix B - Generation Dispatch

Case Description: GI-2016-5 case with GI-2016-5 200 MW generator (2020 HS, Colorado South to North Generation Flow Bias, based on CCPG 2020 HS case)

Benchmark Case – Before GI-2016-22

PSCo:

<u>Bus</u>	<u>ID</u>	<u>MW</u>
Comanche PV	S1	102
Comanche	C1	360
Comanche	C2	358
Comanche	C3	780
Lamar DC Tie	DC	0
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	0
Colorado Green	2	0
Twin Butte	1	15.8
Jackson Fuller	W1	50
Jackson Fuller	W2	50
RMEC 1	G1	130
RMEC 2	G2	130
RMEC 3	G3	275
GE Solar	S1	25.5
Greater Sandhill	S1	16.1
SLV Solar	S1	44.2
SLV Solar	S1	44.2
GI-2016-5	S1	200

BHCE:

<u>Bus</u>	<u>ID</u>	<u>MW</u>
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:

<u>Bus</u>	<u>ID</u>	<u>MW</u>
Birdsale1	1	0.0
Birdsale 2	1	0.0
Birdsale 3	1	0.0
RD Nixon	1	221.39
Tesla	1	13.2
Drake 5	1	49.65
Drake 6	1	81.19
Drake 7	1	138.03
Nixon CT 1	1	0.0
Nixon CT 2	1	0.0
Front Range CC 1	1	138.4
Front Range CC 2	1	138.8
Front Range CC 3	1	136.0

Study Case – With GI-2016-22

<u>Bus</u>	<u>ID</u>	<u>MW</u>
GI-2016-22	S1	100 (+100)
Comanche 2	C2	360 (+2)
Ft. Lupton	G1	15 (-15)
Ft. Lupton	G2	15 (-15)
Manchief	G1	95 (-35)
Manchief	G2	95 (-35)

Appendix C – Engineering Drawings

Figure 2: One-Line of Proposed GI-2016-22 Interconnection at Midway 115kV Station

