Generator Interconnection Request # GI-2016-26
Feasibility Study

50 MW Solar Photovoltaic (PV) Generation
Tapping the Poncha Jct. – Sargent 115 kV line

Saguache County, Colorado

Public Service Company of Colorado
Transmission Planning
February 24, 2017

A. Executive Summary

On October 11, 2016 Public Service Company of Colorado (PSCo) received an interconnection request (GI-2016-26) for a 50 MW solar photovoltaic (PV) generation facility in Saguache County, Colorado. The proposed Point of Interconnection (POI) is a tap of the PSCo-owned Poncha Jct. – Sargent 115 kV line (see Figure 1).

The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2018 and accordingly the approximate target backfeed date is assumed to be six months prior to the COD - June 30, 2018.

The proposed solar photovoltaic generating facility would consist of 20 TMEIC dc/ac inverters, each rated 2.7MW. 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 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 a new tap point (new substation) along the Poncha Jct. – Sargent 115 kV line via an overhead 115kV transmission line owned by the Interconnection Customer.

The GI-2016-26 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).

The Feasibility Study consisted of power flow (steady-state) contingency analysis and short-circuit analysis. The power flow contingency analysis identified a thermal overload as a result of the 50 MW injection from GI-2016-26, but did not identify any voltage violations. Network Upgrades are required to accommodate the 50 MW of generation for NRIS. Therefore, no generation may be injected in the SLV and considered as Network Resource Interconnection Service (NRIS) until additional transmission lines are built. The short circuit analysis did not identify any over-dutied circuit breakers.

Study Conclusion

Based on the Feasibility Study results, it is concluded that new Network Upgrades are required for the 50 MW rated output of GI-2016-26 interconnection to qualify for Network Resource Interconnection Service (NRIS). Without these Network Upgrades, GI-2016-26 would only qualify for Energy Resource Interconnection Service (ERIS) to deliver up to 50 MW output using the existing system on a non-firm capacity and as available basis.

Without Network Upgrades:	NRIS = 0 MW ERIS = 0 – 50 MW on an as-available basis
With Network Upgrades:	NRIS = 50 MW

Cost Estimates

The total estimated cost of the required Interconnection Facilities and Network Upgrades at PSCo's Midway Station (in 2016 dollars) is **$253.066 million** and includes:

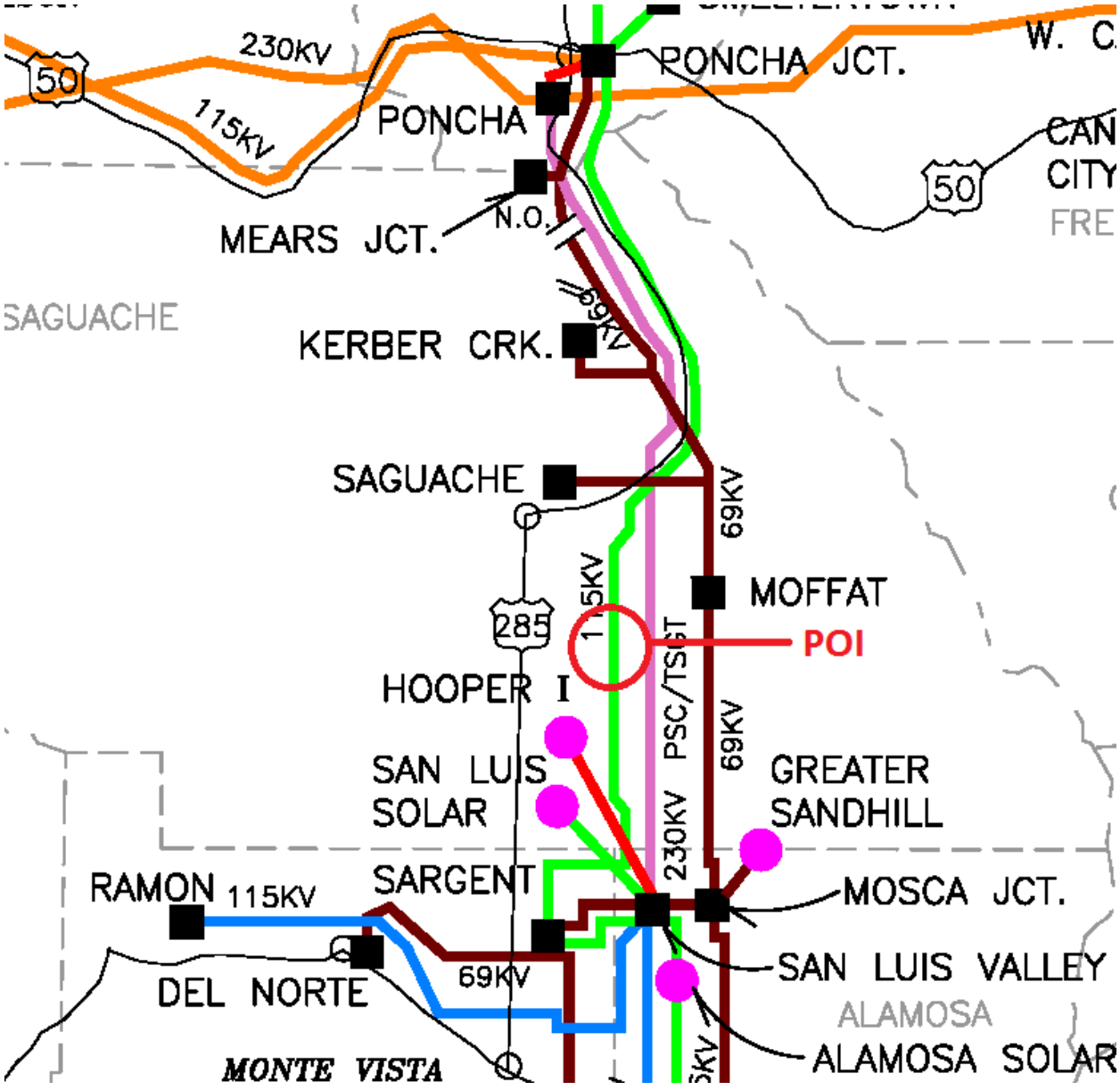
- $ 0.860 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- $ 6.056 million for PSCo-Owned, PSCo-Funded Interconnection Facilities
- $ 246.150 million for PSCo Network Upgrades for Delivery[1]

The estimated time frame to site, design, procure and construct these Interconnection Facilities and Network Upgrades is 60 months.

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

[1] Some of the Network Upgrade cost estimates were taken from the CCPG San Luis Valley Phase 2 report dated January 13, 2017: https://doc.westconnect.com/Documents.aspx?NID=17368

Figure 1 - POI Surrounding Transmission System (2016)



B. Introduction

On October 11, 2016 Public Service Company of Colorado (PSCo) received an interconnection request (GI-2016-26) for a 50 MW solar photovoltaic (PV) generation facility in Saguache County, Colorado. The proposed Point of Interconnection (POI) is tapping the PSCo-owned Poncha Jct. – Sargent 115 kV line (see Figure 1).

The Commercial Operation Date (COD) requested by the Interconnection Customer is December 31, 2018 and accordingly the approximate target backfeed date is assumed to be six months prior to the COD - June 30, 2018.

The proposed solar photovoltaic generating facility would consist of 20 TMEIC dc/ac inverters, each rated 2.7MW. 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 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 tap point (new substation) along the Poncha Jct. – Sargent 115 kV line via an overhead 115kV transmission line owned by the Interconnection Customer.

The GI-2016-26 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.

For this interconnection request, the potential Affected Parties are Western Area Power Administration (WAPA), 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)[2] and Energy Resource Interconnection Service (ERIS)[3].

[2] 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.

[3] 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 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 50 MW rated output of the proposed generation to load for both NRIS and ERIS.

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

D. Power Flow Study Models

Four power flow cases were created for evaluating the system impact of the proposed generator interconnection. Two WECC bases cases, a WECC 2018 light autumn case and a WECC 2022 heavy summer case, were used to create the four cases. The four cases were:

- Benchmark Case: A WECC 2018 light autumn case with the load in the San Luis Valley scaled to 45 MW which did not include GI-2016-26.
- Study Case: A WECC 2018 light autumn case with the load in the San Luis Valley scared to 45 MW and the GI-2016-26 project added.
- Benchmark Case: A WECC 2022 heavy summer case with the load in the San Luis Valley scaled to 140 MW which did not include GI-2016-26
- Study Case: A WECC 2022 heavy summer case with the load in the San Luis Valley scaled to 140 MW and the GI-2016-26 project added.

A generation dispatch was adopted 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. The resulting PSCo Area 70 generation dispatch can be found in Appendix B.

E. Power Flow Study Process

The study area was defined as Zones 710 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 – 1.05 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 is the seasonal continuous rating of the transmission facility – but PSCo allows 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.

F. Power Flow Contingency Analysis Results

Light Load Case

Thermal Analysis: A new thermal overload occurred as a result of the GI-2016-26 interconnection and is shown in Table A.1 in Appendix A.

Voltage Analysis: No new voltage violations occurred as a result of the GI-2016-26 interconnection.

Heavy Load Case

Thermal Analysis: No new thermal violations occurred as a result of the GI-2016-26 interconnection.

Voltage Analysis: No new voltage violations occurred as a result of the GI-2016-26 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 that will increase this path generation capacity are placed in-service (Table 4), the GI-2016-26 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-2016-26 rated output would be deliverable as Network Resource Interconnection Service (NRIS).

Joint transmission reliability studies have identified proposed transmission system improvements required to increase the generation export capability out of the San Luis Valley. These include:

- A 62-mile San Luis Valley-Poncha 230kV line #2 (including the conversion of nine miles of 69kV line to 230kV) with line terminations at the San Luis Valley and Poncha substations and

- 88-miles of a new Poncha-West Canon-Midway 230kV line (including 115kV transmission line additions) with line terminations at the Poncha, West Canyon, and Midway substations.

G. Voltage Regulation and Reactive Power Capability

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

- 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.

H. Short Circuit Analysis Results

The calculated short circuit levels and Thevenin system equivalent impedances for the POI tapping Poncha Jct. – Sargent 115 kV line are tabulated below. No circuit-breakers were found to be over-dutied due to the proposed interconnection. The breaker duty study determined that no breaker replacements are needed at neighboring substations.

Table 1 – Short Circuit Levels at the POI (tapping Poncha Jct. – Sargent 115 kV line)

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance R +j X (ohms)
Before GI-2016-26 Interconnection	2946	2269	Z1(pos) = 5.585 + j21.834 Z2(neg) = 5.587 + j21.835 Z0(zero) = 11.951 + j41.023
After GI-2016-26 Interconnection	2946	2492	Z1(pos) = 5.585 + j21.834 Z2(neg) = 5.587 + j21.835 Z0(zero) = 19.263 + j30.237

Assumptions

- All planned network changes through the end of 2018 were assumed to be in service.
- No gen-tie line was modelled, it was assumed that the impedance from the point of interconnection to the customer transformer will be negligible.
- The impedance to the tertiary windings of the proposed transformer was estimated based on the information provided.

I. Study Conclusion

Based on the Feasibility Study results, it is concluded that new Network Upgrades are required for the 50 MW rated output of GI-2016-26 interconnection to qualify for Network Resource Interconnection Service (NRIS). Without these Network Upgrades, GI-2016-26 would only qualify for Energy Resource Interconnection Service (ERIS) to deliver up to 50 MW output using the existing system on a non-firm capacity and as available basis.

Without Network Upgrades: NRIS = 0 MW
ERIS = 0 – 50 MW on an as-available basis

With Network Upgrades: NRIS = 50 MW

J. Cost Estimates and Assumptions

GI-2016-26 (Feasibility Study Report)
January 20, 2017

PSCo Engineering has developed Indicative level (IE) cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the proposed generation facility. Indicative Estimates are based upon typical construction costs for previously performed similar construction projects; however they have no specified level of accuracy. The cost estimates are in 2016 dollars with escalation and contingencies applied. AFUDC is not included. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new PSCo facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The estimated total cost for the required upgrades is **$253.066 million**

Figure 2 below is a conceptual one-line of the proposed interconnection. The Point of Interconnection (POI) will be a tap on the Sargent to Poncha Junction 115kV Transmission Line.

The following Tables 2-4 list the improvements required to accommodate the interconnection and the delivery of the customer's 50 MW solar facility generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to revision as a more detailed and refined design is produced.

Table 2: PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities Table

Element	Description	Cost Est. (Millions)
PSCo's Proposed 115kV Transmission Switching Station	Interconnect Customer to the 115kV bus at the Proposed Switching Station. The new equipment includes: • One (1) motor operated 115kV disconnect switch • Three (3) 115kV combination CT/PT metering units • Power Quality Metering (115kV line from Customer) • Three (3) surge arresters • Two (2) relay panels • Associated bus, wiring and equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$0.810**
	Transmission line tap into substation. Conductor, hardware, and installation labor.	**$0.050**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$0.860**
Time Frame	**Design, procure and construct**	**18 Months**

Table 3: PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Proposed 115kV Transmission Switching Station	Interconnect Customer to the 115kV bus at the Proposed 115kV Substation. The new equipment includes: • Three (3) 115kV circuit breaker • Eight (8) 115kV gang switches • One (1) 115kV CCVT • Associated communications, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, miscellaneous electrical equipment, cabling and wiring • Associated foundations and structures • Associated road and site development, fencing and grounding	**$5.648**
	In/Out Tap on the 9811 Sargent to Poncha Junction 115kV Line at the Proposed Switching Station.	**$0.323**
	Siting and Land Rights support for substation land acquisition and construction.	**$0.085**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$6.056**
Time Frame	**Site, design, procure and construct**	**18 Months**

Table 4 – PSCo Network Upgrades for Delivery [4]

Element	Description	Cost Est. (Millions)
PSCo's San Luis Valley 115kV Sub.	Relay panel replacement and power line carrier communications upgrade.	**$0.500**
PSCo's Poncha Junction 115kV Sub.	Relay panel replacement and power line carrier communications upgrade.	**$0.650**
San Luis Valley – Poncha 230kv Line #2	Construct a new 62 mile, 230kV single circuit overhead transmission line.	**$75**
Poncha-West Canon-Midway 230kV/115kV OH Transmission Line	Construct approximately 88 miles of new single circuit 230kV and 115kV OH transmission line. Will require new easements/ROW. New line terminations and associated equipment at Poncha, West Canon and Midway Substations	**$170**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$246.150**
	Design, procure, permit and construct	**60 Months**
	Total Project Estimate	**$253.066**

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 applied).
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Solar Generation Facility is not in PSCo's retail service territory. The customer will need to work with the local electric distribution service provider to acquire station service for their facility.
- PSCo (or its Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- The estimated time to design, procure and construct the interconnection facilities is approximately 18 months after authorization to proceed has been obtained.
- This project is completely independent of other queued projects and their respective ISD's.
- A CPCN will not be required for the interconnection facilities construction.
- A CPCN will be required for the Network Upgrades for Delivery construction.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.

[4] Some of the Network Upgrade cost estimates were taken from the CCPG San Luis Valley Phase 2 report dated January 13, 2017: https://doc.westconnect.com/Documents.aspx?NID=17368

- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date due.
- Power Quality Metering (PQM) will be required on the Customer's 115 kV line terminating into Proposed Switching Station.

Appendix A - Power Flow Thermal Results

GI-2016-26 (50 MW) Interconnection tapping the Poncha Jct. – Sargent 115 kV Line

Light Load Conditions - WECC 2018 Light Autumn Scenario Case

- San Luis Valley loads scaled to 45 MW

Table A.1 – Thermal Violations before and after GI-2016-26

				Facility Contingency Loading Without GI-2016-26 (Benchmark Case)		Facility Contingency Loading With GI-2016-26 (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
GI-2016-26 tap – Poncha Jct. 115 kV	Line	PSCo	105 / 116	75.2	71.6 / 64.8	124	118 / 107	46.4 / 42.2	Poncha – San Luis Valley 230 kV Line

GI-2016-26 (50 MW) Interconnection tapping the Poncha Jct. – Sargent 115 kV Line

Heavy Load Conditions - WECC 2022 Heavy Summer Case

- San Luis Valley loads scaled to 140 MW

Table A.2 – Thermal Violations before and after GI-2016-26

				Facility Contingency Loading Without GI-2016-26 (Benchmark Case)		Facility Contingency Loading With GI-2016-26 (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
None	-	-	-	-	-	-	-	-	-

Appendix B - Generation Dispatch

Case Description: WECC 2018 Light Autumn Scenario Case with loads scaled to 45 MW for the San Luis Valley

Benchmark Case – Before GI-2016-26

Bus	ID	MW
Alamosa	G1	0
Alamosa	G2	0
Comanche2	C2	357.6
GE Solar	S1	25.5
Greater Sandhill	S1	13.6
Cogentrix	S1	25.5
Sunpower	S1	44.2

Study Case – With GI-2016-26

Bus	ID	MW
GI-2016-26	S1	50 (+50)
Comanche 2	C2	357.9 (+0.3)
Pawnee	C1	320 (-50)

Case Description: WECC 2022 Heavy Summer Case with loads scaled to 140 MW for the San Luis Valley

Benchmark Case – Before GI-2016-26

Bus	ID	MW
Alamosa	G1	0
Alamosa	G2	0
Comanche2	C2	359
GE Solar	S1	25.5
Greater Sandhill	S1	13.6
Cogentrix	S1	25.5
Sunpower	S1	44.2

Study Case – With GI-2016-26

Bus	ID	MW
GI-2016-26	S1	50 (+50)
Comanche 2	C2	359.2 (+0.2)
Manchief	G1	100 (-20)
Manchief	G2	100 (-20)
St. Vrain	G1	265 (-10)

Appendix C – Engineering Drawings

Figure 2: One-Line of Proposed GI-2016-26 New Interconnection Substation tapping Poncha Jct.-Sargent 115 kV line