Pikes Peak BESS

SISIS Study Report

08/24/2023

Xcel Energy℠

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1.0 Summary

This Surplus Interconnection System Impact Study (SISIS) will consist of verifying acceptable grid performance of the Pikes Peak Battery Energy Storage System (BESS) resulting from the modification of the existing solar generating facilities proposed in the Surplus Interconnection request. The proposed modification consists of installing a 115 MW Battery Energy Storage System (BESS) to the existing 200 MW Sun Mountain solar generation facility. The POI for the proposed BESS is Comanche 230 kV substation.

The expected operating modes of the BESS are:

i. 200 MW rated output at the POI from a combination of solar generation and BESS
ii. 115 MW rated output at the POI from BESS only
iii. 115 MW rated charging capacity from the grid
iv. 200 MW rated output at the POI from solar generation only (existing operating mode)

The BESS will be grid-charging via the new provisional Large Generator Interconnection Agreement (LGIA). Reactive power adequacy analysis was performed and verified that the BESS meets the same +/- 0.95 power factor range requirement at the POI that is applicable to the existing solar generating facility.

Pikes Peak BESS SISIS was studied under the Southern Colorado study pocket. The study was performed using a 2026 Heavy Summer loading profile. An Off-Peak loading profile was not analyzed.

The Interconnection Service determined for GIRs in this report in and of itself does not convey any transmission service.

1.1 Pikes Peak BESS Results

The study did not find any impact to the stability or short-circuit analysis performed due to the addition of the 115 MW BESS as Surplus Interconnection Service to Pikes Peak.

Surplus Interconnection Service = 115 MW

2.0 Introduction

The SISIS will consist of verifying acceptable grid performance of the Pikes Peak BESS Generating Facility resulting from the modification of existing solar generating facilities proposed in the Surplus Interconnection request. The proposed modification consists of installing a 115 MW BESS generating facility to the existing 200 MW Sun Mountain solar generation facility.

The POI for the proposed BESS is Comanche 230 kV.

The expected operating modes of the BESS are:

i. 200 MW rated output at the POI from a combination of solar generation and BESS
ii. 115 MW rated output at the POI from BESS only
iii. 115 MW rated charging capacity from the grid
iv. 200 MW rated output at the POI from solar generation only (existing operating mode)

Pikes Peak BESS requested Energy Resource Interconnection Service (ERIS)[1].

Table 1 – Summary of Pikes Peak BESS

Resource Type	Interconnection Service	COD	POI	Location	Service Type
Solar + BESS	200 MW	12/16/2025	Comanche 230 kV	Pueblo County, CO	ERIS

The approximate geographical locations of the POI within the Transmission System are shown in Figure 1 below.

[1] 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.

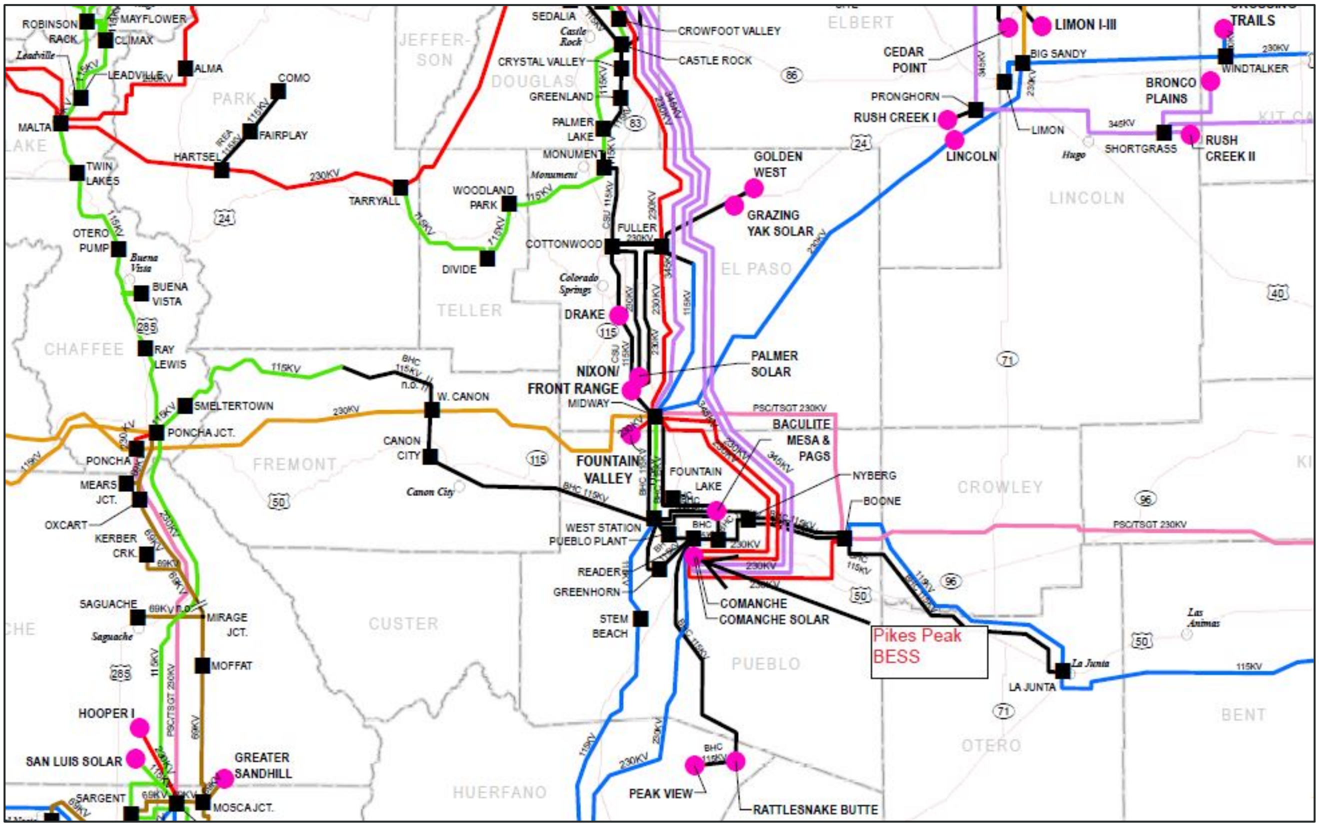

Figure 1 – Approximate Location of Pikes Peak BESS POI

3.0 Project Description

3.1 Pikes Peak BESS

Pikes Peak BESS consists of a 115 MW_{ac} BESS Generating Facility to the existing 200 MW Sun Mountain Solar Generating Facilities located in Pueblo County, Colorado. The hybrid facility will be AC-coupled with the net output at the POI limited to, at most, 200 MW_{ac} using a Power Plant Controller. The 121.7 MW BESS Generating Facility will consist of eighty-nine (89) EPC Power CAB1000/AC-3.2L 1.5 MVA, 1.0 PF inverters, each with their own 34.5/0.69 kV, 1.75 MVA Delta/Wye-grounded, Z=5.75% and X/R=10 pad-mount transformer. The 34.5 kV Collector System of the Pikes Peak BESS plant will connect to a 132/176/220 MVA, 230/34.5/13.8 kV Wye-grounded/Wye-grounded/Delta, Z=7.5% main step-up transformer. The main step-up transformer will connect to the PSCo transmission system via a 230 kV generation tie-line at the POI, Comanche 230 kV Substation.

The BESS has a maximum and minimum state of charge of 100% and 0%, respectively.

The proposed COD of Pikes Peak BESS is December 16, 2025. For the study purpose, the back-feed date is assumed to be June 16, 2025, approximately six (6) months before the COD.

4.0 Study Scope

The scope for the SISIS of Pikes Peak BESS consists of:

a. Reactive Power Adequacy analysis
b. Transient Stability analysis
c. Short-circuit analysis

4.1 Study Pockets

As shown in Figure 1, Pikes Peak BESS is located within the Southern Colorado study pocket.

4.2 Study Areas

The study area for the Southern Colorado study pocket includes the WECC base case zones 704, 710, 712, 751, 757, and 785.

4.3 Study Criteria

The following criteria is used for the reliability analysis of the PSCo system and Affected Systems.

The transient voltage stability criteria are as follows:

a. Following fault clearing, voltage shall recover to 80% of the pre-contingency voltage within 20 seconds of the initiating event for all P1 through P7 events for each applicable Bulk Electric System (BES) bus serving load.
b. Following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds, for all P1 through P7 events.
c. For contingencies without a fault (P2.1 category event), voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.
d. Note generator bus frequency plots are included, however, PSCo does not have criteria for frequency events.

The transient angular stability criteria are as follows:

a. P1 – No generating unit shall pull out of synchronism. A generator being disconnected from the system by fault clearing action or by a special Protection

System is not considered an angular instability.

b. P2-P7 – One or more generators may pull out of synchronism, provided the resulting apparent impedance swings shall not result in the tripping of any other generation facilities.

c. P1-P7 – The relative rotor angle (power) oscillations are characterized by positive damping (i.e., amplitude reduction of successive peaks) > 5% within 30 seconds.

The breaker duty analysis criterion is fault current after GIR(s) addition shall not exceed 100% of the breaker duty rating.

4.4 Study Methodology

The SISIS shall consist of only reactive power adequacy analysis, transient stability analysis and short-circuit analysis to identify any mitigation(s) needed in the resulting BESS generating facility to achieve acceptable grid performance.

No power flow analysis is required in the SISIS since (i) the surplus interconnection request would not result in any change (increase) in the 200 MW aggregate rated power output of the existing solar generating facility allowed by their LGIA, and (ii) the BESS will be grid-charging via new provisional LGIA. Reactive power adequacy analysis will be performed and verified that the BESS meets the same +/- 0.95 power factor range requirement at the POI that is applicable to the existing solar generating facility.

4.4.1 Transient Stability Study Methodology

All generators in the study pocket shall meet the transient stability criteria. If any violations are found, the contributing GIR(s) will be identified for performance violations and mitigations will be attributed to the contributing generator(s). The stability analysis is conducted by performing select single and multiple contingencies in the study pocket.

4.4.2 Short-Circuit and Breaker-Duty Study Methodology

The study was performed using the short-circuit model maintained for the PSCo owned system. This model includes only a small portion of Affected System(s) at the seams, and breaker duty on Affected System(s) was not evaluated in this study. The Affected Systems may choose to perform their own study to identify potential for breaker duty violations on their system.

GIRs are modeled on a per-machine basis, using the impedance and configuration information provided in the Interconnection Request. If tie-line length was not specified, gen-tie lines were assumed to have a length of 0.25 miles, with estimated impedance appropriate for the voltage. All inverter-based generation, including generator step-up transformers, were modeled on an aggregate basis using appropriately scaled generic models at the low side of the main power transformer(s).

All generating facilities, regardless of NRIS or ERIS, were modeled on-line at rated capacity and assumed capable of producing maximum fault current. Hybrid generating facilities (e.g., solar with battery storage) were modeled with each technology modeled as a separate generating resource at its rated capacity, regardless of any limitations to the combined output imposed otherwise.

Breaker duty studies are performed for the Benchmark Case for the entire system. Circuit breakers identified as overstressed (0% margin) in the Benchmark Case study are not included in the analysis. However, these are identified as Contingent Facilities to the Pikes Peak BESS plant if there is an increase in fault current contribution to these breakers from the Study Case evaluation.

Breaker duty studies are conducted using a sub-transient fault analysis. Single and three-phase faults are placed at each substation in the system. Each breaker is modeled by the manufacturer and model number with the catalog characteristics for that breaker and its application, i.e., the relevant standard applying to that breaker's date of manufacture, kA interrupting rating, voltage rating, relay operate time, breaker interrupting time, proximity to generation, etc. The reclosing scheme is not considered in the analysis. The aforementioned factors are used to calculate an XR factor according to ANSI C37.010-1999, ANSI C37.5-1979, or C37.6-1971. For evaluation of breaker opening by C37.010-1999, applicable to all breakers identified in this study, and with no reclosing and no additional derating, the equivalent current the breaker is required to interrupt is simply the fault current multiplied by the XR factor ($I_{breaking}$). This is compared against that breaker's rated interrupting capacity to determine whether the breaker is overstressed. If it is greater than the breaker's interrupting capacity, it is considered to be overstressed (0% margin).

Breaker duty studies are re-performed while excluding each individual interconnection and corresponding network upgrade, one at a time. Fault currents at the location of each identified overdutied breaker are compared to determine the relative contribution of each interconnection and corresponding network upgrade.

4.5 Study Analyses

Short-circuit analyses in SISIS studies were performed using Siemens PSS®CAPE short-circuit analysis software (CAPE). All connected generating facilities were assumed capable of producing maximum fault current. As such, all generations were modeled at full capacity, whether NRIS or ERIS is requested. In addition, where hybrid facilities are included (e.g., solar with battery storage), each technology is modeled as a separate generating resource in CAPE and included at full capacity in the short circuit study, regardless of any limitations to the combined output that would be imposed otherwise.

Transient stability analyses for SISIS were performed using a transient stability Study Case developed in GE PSLF corresponding to the steady-state PSLF Study Case.

Select single and multiple disturbance events were simulated in this SISIS stability analysis. The disturbance events are simulated using three-phase bolted faults.

4.6 Case Development

The Benchmark Case created for this SISIS study started from the latest available working case created from the outcome of the DISIS Fall 2020 Phase 3 analysis. Additionally, the latest 2023 FAC-008 rating upgrades were included. The Benchmark Case included the existing operating mode of the solar generating plant outputting 200 MW at the POI. The Study Cases were created from the Benchmark Case per the operating modes shown in the list below.

The expected operating modes are:

i. 200 MW rated output at the POI from a combination of solar generation and BESS
ii. 115 MW rated output at the POI from BESS only
iii. 115 MW rated charging capacity from the grid

The Benchmark Case generation dispatch is shown in Table 2 to reflect a heavy generation in the Eastern Colorado study pocket.

Table 2 – Generation Dispatch Southern Colorado Benchmark Case (MW is Gross Capacity)

Bus Number	Bus Name	ID	Status	Pgen (MW)	Pmax (MW)
70577	FTNVL1&2	G1	1	36.00	40.00
70577	FTNVL1&2	G2	1	38.30	42.60
70578	FTNVL3&4	G3	1	36.00	40.00
70578	FTNVL3&4	G4	1	36.50	40.60
70579	FTNVL5&6	G5	1	36.00	40.00
70579	FTNVL5&6	G6	1	36.50	40.60
70701	CO_GRN_E	W1	1	65.80	82.00
70702	CO_GRN_W	W2	1	65.80	82.00
70703	TWNBUTTE	W1	1	42.40	41.80
70777	COMAN_3	C3	1	853.30	869.00
70934	COMAN_S1	S1	1	102.00	125.00
70017	SI_GEN	1	1	25.60	30.00
70010	TBII_GEN	W	1	79.20	78.00
70665	GLDNWST_W1	W1	1	100.90	125.90
70666	GLDNWST_W2	W2	1	100.90	125.90
70994	SP_GEN	PV	1	69.90	100.20
70758	CEP6_S1	S1	1	212.50	300.00
70763	CEP5_S1	S1	1	170.00	200.00
970285	GI-2014-6	S1	1	85.20	152.20
70120	COMAN_2	C2	1	360.40	390.20
70125	COMAN_1	C1	1	365.00	395.20

Bus Number	Bus Name	ID	Status	Pgen (MW)	Pmax (MW)
70725	SPANPKS2_GEN	PV	1	27.90	40.00
97016	LV PV1	1	1	102.00	121.50
97017	LV PV2	2	1	102.00	121.50
Total				**3150.10**	**3624.20**

4.7 Voltage and Reactive Power Capability Evaluation

The following voltage regulation and reactive power capability requirements are applicable to non-synchronous generators:

- Xcel Energy's OATT requires all non-synchronous generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the high side of the generator substation. Furthermore, Xcel Energy requires every Generating Facility to have dynamic voltage control capability to assist in maintaining the POI voltage schedule specified by the Transmission Operator.
- It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (Mvar), and the locations (on the Interconnection Customer's facility) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/- 0.95 power factor at the high side of the main step-up transformer.
- It is the responsibility of the Interconnection Customer to compensate their generation tie-line to ensure minimal reactive power flow under no load conditions.

The following voltage regulation and reactive power capability requirements are applicable to synchronous generators:

- Xcel Energy's OATT requires all synchronous Generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the POI.
- The reactive power analysis performed in this report is an indicator of the reactive power requirements at the POI and the capability of the generator to meet those requirements. The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and the regulating voltage of the POI.

All proposed reactive devices in customer provided models are switched favorably to provide appropriate reactive compensation in each test, therefore identified deficiencies are in addition to any proposed reactive compensation.

The summary table representing facility's Voltage and Reactive Power Capability tests adhere to the following color formatting representing the different aspects of the tests:

- Values highlighted in red indicate a failed reactive power requirement.
- Voltages outside the range of 0.95 p.u. to 1.05 p.u. are highlighted in yellow to provide additional information.

4.7.1 Sun Mountain Solar and Pikes Peak BESS

The Sun Mountain Solar and Pikes Peak BESS plant is modeled as follows:

PV Generator: Pmax = 202.9 MW, Pmin = 0.0 MW, Qmax = 86.2 Mvar, Qmin= -86.2 Mvar

BESS: Pmax = 121.7 MW, Pmin = -115 MW, Qmax = 54.8 Mvar, Qmin= -54.8 Mvar

The summary for the Voltage and Reactive Power Capability Evaluation

- The facility is capable of meeting ±0.95 pf at the high side of the main step-up transformer while maintaining a normal operating voltage at the POI.
- The facility is capable of meeting ±0.95 pf at its terminals while meeting the interconnection service request.
- The reactive power exchange and voltage change across the gen-tie are acceptable under no load conditions.

The Voltage and Reactive Power Capability tests performed for Sun Mountain Solar and Pikes Peak BESS facility are summarized in Table 3.

Table 3 – Reactive Capability Evaluation for Sun Mountain Solar plus BESS Plant

PV Generator Terminals					BESS Generator Terminals					High Side of Main Transformer				POI			
Pgen (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)	V (p.u.)	Pgen (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)	V (p.u.)	P (MW)	Q (Mvar)	V (p.u.)	PF	P (MW)	Q (Mvar)	V (p.u.)	PF
129.9	42.6	86.2	-86.2	1.05	77.8	42.6	54.8	-54.8	1.06	200.4	66.7	1.01	0.9488	200.0	64.1	1.00	0.9523
129.9	-24.1	86.2	-86.2	0.98	77.8	-24.1	54.8	-54.8	0.99	200.4	-67.4	0.99	-0.9478	199.9	-70.1	1.00	-0.9437
202.9	84.9	86.2	-86.2	1.05	OFFLINE					200.4	66.7	1.01	0.9488	200.0	64.1	1.00	0.9523
OFFLINE					121.7	54.8	54.8	-54.8	1.05	115.2	44.6	1.01	0.9326	115.0	-44.0	1.00	0.9340
202.9	-48.3	86.2	-86.2	0.98	OFFLINE					200.3	-67.4	0.99	-0.9478	199.8	-70.1	1.00	-0.9436
OFFLINE					121.7	-36.6	54.8	-54.8	0.97	115.2	-47.4	1.00	-0.9248	115.0	-48.1	1.00	-0.9226
0.0	-9.6	86.2	-86.2	0.99	0.0	-9.6	54.8	-54.8	0.99	-0.2	-0.2	1.00	-0.7071	0.0	-17.8	1.00	0.0000

4.8 Southern Colorado Study Pocket Analysis

The Study Cases modeled Pikes Peak BESS at the Comanche 230 kV Substation. The SISIS report consists of reactive power adequacy analysis, transient stability analysis and short-circuit analysis.

4.8.1 Transient Stability Analysis

The transient stability analysis was performed in the southern Colorado study pocket using the generation dispatch scenario determined by dispatch criteria described in the Business Practice Manual under section 3.4.3.

Table 4 is a summary of the contingencies studied and the corresponding stability results, which applies to all operating modes unless otherwise stated.

The following results were obtained for the disturbances analysis:

- ✓ No machines lost synchronism with the system.
- ✓ No transient voltage drop violations were observed.
- ✓ Machine rotor angles displayed positive damping.

The transient stability plots are shown in Section 7.0 of this report.

Note: The Generating Facility, when in PV+BESS operating mode, did not recover to the pre-fault generation output for the fault studied in Reference 3a within

Table 4. Small, sustained oscillations occurred during this fault, while not unstable, may require further model tuning by the Xcel PSCo Modeling Team at a later time. A sensitivity was run by applying the fault as shown in Reference 3b within

Table 4. This sensitivity resolved the oscillatory behavior observed. Plots of this sensitivity are shown in Section 7.0 of this report.

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Table 4 – Southern Colorado Transient Stability Analysis Results

Ref. No.	Fault Location	Fault Category	Fault Type	Facility Tripped	Post-Fault Voltage Recovery	Angular Stability
1	Comanche 345 kV	P4	SLG	Comanche 230-345 Transformer 3 Comanche 115-230 Transformer 2	Stable	Stable
2	Comanche 345 kV	P4	SLG	Comanche GSU #2 Comanche 230-345 Transformer 4 Comanche Generator #2	Stable	Stable
3a	Comanche-CF&I 230 kV	P4	SLG	Comanche-Midway (Mirasol) 230 kV CKT #1 Comanche-CF&I 230 kV CKT #1	Stable	Stable
3b	Comanche-Midway (Mirasol) 230 kV	P4	SLG	Comanche – Midway (Mirasol) 230 kV CKT #1 Comanche - CF&I 230 kV CKT #1	Stable	Stable
4	Comanche-Boone 230 kV	P4	SLG	Comanche - Boone 230 kV CKT #1 Comanche - Walsenburg 230 kV CKT #1	Stable	Stable
5	Comanche 230 kV	P1	3PH	Comanche - Walsenberg 230 kV CKT #1 Walsenberg - Valent 230 kV CKT #1 Valent - Goldstone 230 kV CKT #1 Goldstone PS Rosebud Generation, HESSBDW Generation, Spanish Peaks Generation	Stable	Stable
6	Comanche 230 kV	P7	SLG	Comanche - Boone 230 kV CKT #1 Boone - Midway 230 kV CKT #1	Stable	Stable

4.8.2 Short-Circuit Analysis Results

There were no breakers identified requiring upgrades as a result of a short-circuit analysis performed by Xcel Energy System Protection Engineering. The fault currents at the POI for three-phase and phase-to-ground faults can be found in the Table 5 below, along with the Thevenin impedance at the POI. Both the base case and the case with the GI added are shown.

Table 5 – Short Circuit Parameters at Sun Mountain (GI-2021-1) POI (Comanche 230 kV Substation)

	Before the Surplus Addition	After the Surplus Addition
Three Phase		
Three Phase Current	22731 A	23140 A
Positive Sequence Impedance	0.45463+ j6.22463 ohms	0.45463+ j6.22463 ohms
Negative Sequence Impedance	0.47438+ j6.25060 ohms	0.47438+ j6.25060 ohms
Zero Sequence Impedance	0.21911+ j3.19644 ohms	0.21911+ j3.19644 ohms
Phase-to-Ground		
Single Line to Ground Current	25069 A	25330 A
Positive Sequence Impedance	0.45463+ j6.22463 ohms	0.45463+ j6.22463 ohms
Negative Sequence Impedance	0.47438+ j6.25060 ohms	0.47438+ j6.25060 ohms
Zero Sequence Impedance	0.21911+ j3.19644 ohms	0.21911+ j3.19644 ohms

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied because of adding the Surplus Interconnection.

4.8.3 Summary of Southern Colorado Study Pocket Analysis

- The study did not identify any impacts to the stability or short-circuit analysis performed due to the addition of the 115 MW BESS as Surplus Interconnection Service to existing Sun Mountain Solar at Comanche 230 kV Substation.
- The study did not identify any system network upgrades due to the addition of the 115 MW BESS as Surplus Interconnection Service to existing Sun Mountain Solar at Comanche 230 kV Substation.

- The study did not identify any impacts to the Affected Systems due to the addition of the 115 MW BESS as Surplus Interconnection Service to existing Sun Mountain Solar at Comanche 230 kV Substation.

5.0 Summary of Surplus Interconnection Service

The Surplus Interconnection Service will be made available 24/7, all days of the year, for as long as: 1) the LGIA associated with Sun Mountain Solar is in effect, and 2) the battery energy storage system is in operation and adheres to the terms of its future Surplus agreement. The Interconnection Customer is required to design and build the Generating Facility to mitigate for any potential inverter interactions with the neighboring inverter-based Generating Facilities and/or the inverters of the hybrid Generating Facility. The Interconnection Customer shall use the Plant Controller to limit the output of Sun Mountain Solar plus Pikes Peak BESS, at all times, not to exceed 200 MW. The output shall also be monitored by PSCo Operations.

6.0 Conceptual POI One-Line Diagrams of Pikes Peak BESS

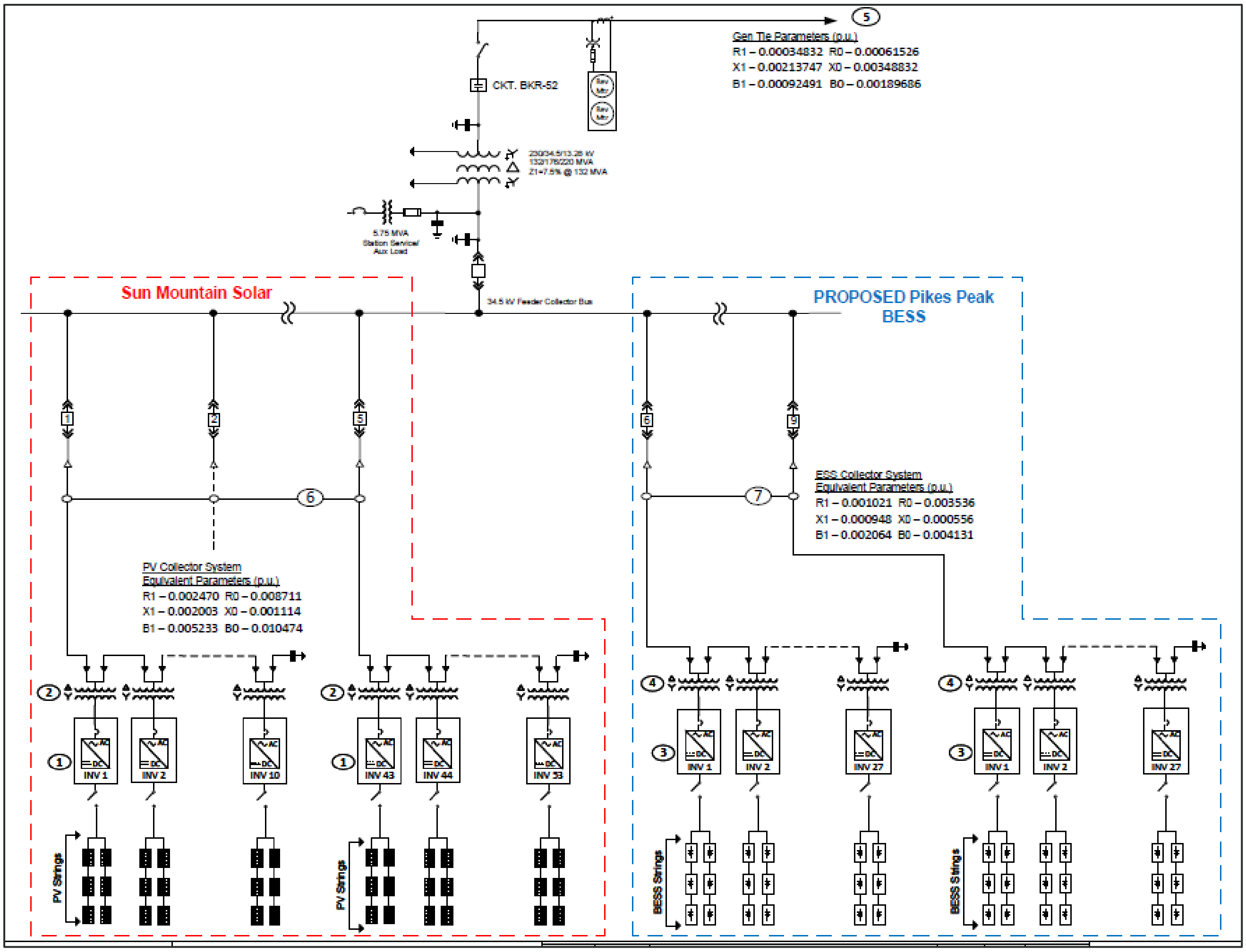

Figure 2 – Preliminary One-line of the Pikes Peak BESS POI

at Comanche 230 kV

7.0 Appendices

Appendix A: Transient Stability PV Plots	PikesPeak_PV_Plots
Appendix B: Transient Stability BESS Plots	PikesPeak_BESS_ Plots
Appendix C: Transient Stability PV and BESS Plots	PikesPeak_PVBESS_ Plots
Appendix D: Transient Stability BESS Grid Charging Plots	PikesPeak_BESSChrg _Plots
Appendix E: Sensitivity Test (Reference 3b, Table 4) Plots	3b_PikesPeak_PV+ BESS_Sens