Limon I and II BESS

SISIS Study Report

07/21/2023

Table of Contents

List of Figures

List of Tables

1.0 Summary

The Surplus Interconnection System Impact Study (SISIS) will consist of verifying acceptable grid performance of the Hybrid Wind plus Energy Storage (HWES) Generating Facility resulting from the modification of the existing Limon wind generating facilities proposed in the Surplus Interconnection request. The proposed modification consists of installing a 100 MW Battery Energy Storage System (BESS) within each of the existing 200 MW Limon I and Limon II wind generation facilities. The POI for the proposed HWES is Missile Site 345 kV.

The expected operating modes of the Generating Facility are:

i. 400 MW rated output at the POI from a combination of wind generation and BESS
ii. 200 MW rated output at the POI from BESS only
iii. 400 MW rated output at the POI from wind generation only (existing operating mode)

No power flow analysis is required in the SISIS since (i) the surplus interconnection request would not result in any change (increase) in the 400 MW aggregate rated power output of the existing Limon I and II generating facilities allowed by their LGIA, and (ii) the BESS will charge only from the wind generating facility and not from the grid. No reactive power adequacy analysis is required since the resulting HWES generating facility must meet the same +/- 0.95 power factor range requirement at the POI that is applicable to the existing wind generating facility. The SISIS will consist of dynamic and short-circuit analyses to identify any mitigation(s) needed in the resulting HWES generating facility to achieve acceptable grid performance.

Limon I and II BESS SISIS was studied under the Eastern 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 Limon I and II BESS Results

The study did not find any impact from the stability or short-circuit analysis performed due to the addition of the 200 MW BESS as Surplus Interconnection Service to Limon I and II generating facility. Surplus Interconnection Service = 200 MW

2.0 Introduction

The SISIS will consist of verifying acceptable grid performance of the HWES Generating Facility resulting from the modification of existing wind generating facilities proposed in the Surplus Interconnection request. The proposed modification consists of installing a 100 MW BESS generating facility within each of the existing 200 MW Limon I and Limon II wind generation facilities, for a total of 200 MW of Surplus Interconnection Service. The POI for the proposed HWES is Missile Site 345 kV.

The BESS shall only charge from the wind generating facility and not from the grid. Thus, no Grid Charging analysis was required.

The expected operating modes of the HWES are:

i. 400 MW rated output at the POI from a combination of wind generation and BESS
ii. 200 MW rated output at the POI from BESS only
iii. 400 MW rated output at the POI from wind generation only (existing operating mode)

Limon I and II BESS requested Energy Resource Interconnection Service (ERIS)[1].

Table 1 – Summary of Limon I and II BESS

Resource Type	Interconnection Service	COD	POI	Location	Service Type
Wind + BESS	400 MW	12/1/2025	Missile Site 345 kV	Arapahoe County, CO	ERIS
BESS	200 MW	12/1/2025	Missile Site 345 kV	Arapahoe County, CO	ERIS

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

[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.

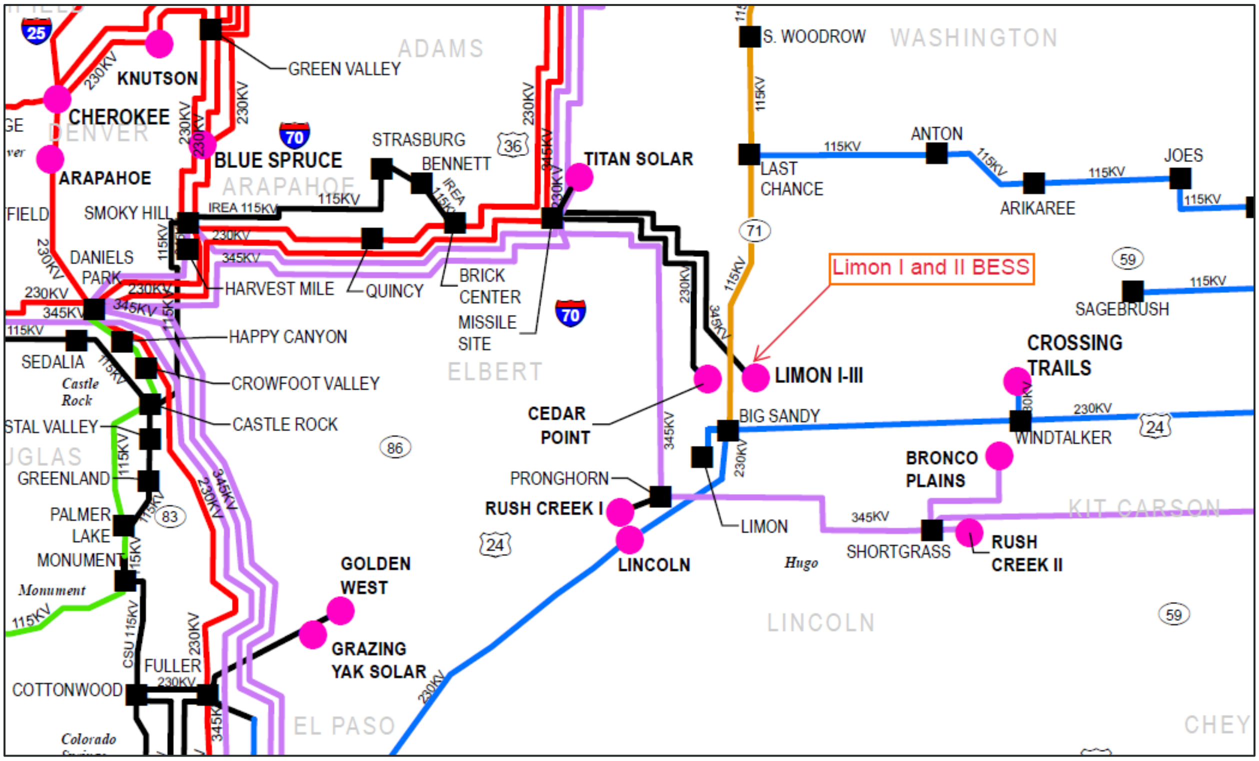

Figure 1 – Approximate Location of Limon I and II BESS POI

3.0 Project Description

3.1 Limon I and II BESS

Limon I and II BESS consists of a 100 MW_{ac} BESS Generating Facility within each of the 200 MW Limon I and II Wind Generating Facilities located in Lincoln County, Colorado. The hybrid facility will be AC-coupled with the net output at the POI limited to 400 MW_{ac} using a Power Plant Controller. Each of the 100 MW BESS Generating Facilities will consist of thirty-three (33) Power Electronics FP3430K 3.43 MVA, ±0.50 PF inverters, each with their own 34.5/0.645 kV, 3.51 MVA Delta/Wye-grounded, Z=8.5% and X/R=10 pad-mount transformer. The 34.5 kV collector system of the Limon I plant will connect to a 180/240/300 MVA, 345/34.5/13.8 kV Wye-grounded/Wye-grounded/Delta, Z=14.04% and X/R=40 main step-up transformer. The 34.5 kV collector system of the Limon II plant will connect to a 138/184/230 MVA, 345/34.5/13.8 kV Wye-grounded/Wye-grounded/Delta, Z=9.11% and X/R=40 main step-up transformer. These main step-up transformers will connect to the PSCo transmission system via a 40-mile, 345 kV generation tie-line at the POI, Missile Site 345 kV Substation.

The BESS has a maximum and minimum state of charge of 100% and 5%, respectively, per the REEC_C inverter data supplied by the customer.

The proposed COD of Limon I and II BESS is December 1, 2025. For the study purpose, the back-feed date is assumed to be June 1, 2025, approximately six (6) months before the COD.

4.0 Study Scope

The scope for the SISIS of Limon I and II BESS consists of:

a. Stability analysis and
b. Short-circuit analysis.

4.1 Study Pockets

As shown in Figure 1,

- Limon I and II BESS is located within the Eastern Colorado study pocket.

4.2 Study Areas

The study area for the Eastern Colorado study pocket includes the WECC base case zone 706.

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 dynamic and short-circuit analyses to identify any mitigation(s) needed in the resulting HWES 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 400 MW aggregate rated power output of the existing Limon I and II generating facilities allowed by their LGIA, and (ii) the BESS shall charge only from the wind generating facility and not from the grid. No reactive power adequacy analysis is required since the resulting HWES generating facility must meet the same +/- 0.95 power factor range requirement at the POI that is applicable to the existing wind 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. The analysis was performed using Siemens PSS®CAPE short-circuit analysis software (CAPE). 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 Limon I and II 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 over-dutied breaker are compared to determine the relative contribution of each interconnection and corresponding network upgrade.

4.5 Study Analyses

Short-circuit analysis for the SISIS request was performed using 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 2023 FAC-008 rating upgrades were included. The Benchmark Case included the existing operating mode of the Limon I and II wind generating plants each 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 of the HWES are:

i. 400 MW rated output at the POI from a combination of wind generation and BESS
ii. 200 MW rated output at the POI from BESS only

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 Eastern Colorado Benchmark Case (MW is Gross Capacity)

Bus Number	Bus Name	ID	Status	Pgen (MW)	Pmax (MW)
70314	MANCHEF1	G1	1	136.1	150.8
70315	MANCHEF2	G2	1	136.1	150.8
70562	SPRUCE1	G1	1	163.4	181.5
70563	SPRUCE2	G2	1	128.3	142.5
70310	PAWNEE	C1	1	537.2	567.2
70593	SPNDLE1	G1	1	141.3	157
70594	SPNDLE2	G2	1	141.3	157
70710	PTZLOGN1	W1	1	161.44	201.8
70712	PTZLOGN2	W2	1	96.44	120.8
70713	PTZLOGN3	W3	1	64.24	80.3
70714	PTZLOGN4	W4	1	140	175
70635	LIMON1_W	W1	1	202.4	202.4
70636	LIMON2_W	W2	1	202.4	202.4
70637	LIMON3_W	W3	1	161.9	202.4
70670	CEDARPT_W1	W1	1	100.8	126
70671	CEDARPT_W2	W2	1	100.8	126
70733	CHEYRGE_W1	W1	1	99.6	125
70736	CHEYRGE_W2	W2	1	100.4	126
70739	CHEYRGW_W1	W1	1	99.6	125
70742	CHEYRGW_W2	W2	1	100.4	126
70753	BRONCO_W1	W1	1	240	300

Bus Number	Bus Name	ID	Status	Pgen (MW)	Pmax (MW)
70616	TITAN_S1	S1	1	44.6	50
70767	RUSHCK1_W1	W1	1	168	202
70770	RUSHCK1_W2	W2	1	148	178
70771	RUSHCK2_W3	W3	1	168	202
999001	GI-2016-4	G1	1	240	300
Total				4022.4	4677.9

4.7 Eastern Colorado Study Pocket Analysis

The Study Cases modeled Limon I and II BESS at the Missile Site 345 kV Substation. The SISIS report consists of a transient stability analysis and short-circuit analysis.

4.7.1 Transient Stability Analysis

The transient stability analysis was performed in the east pocket using the generation dispatch scenario determined by dispatch criteria described in the Business Practice Manual under section 3.4.3. Table 3 is a summary of the contingencies studied and the corresponding stability results.

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.

Table 3 – Eastern Colorado Transient Stability Analysis Results

Ref No.	Fault Location	Fault Category	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Missile Site 345 kV	P4	3 Ph	Missile Site - Daniel Park 345 kV CKT #1 & Daniel Park 345/230 kV T5	12	Stable	Stable
2	Missile Site 345 kV	P4	3 Ph	Missile Site 345/230/13.8 kV T1 & Missile Site - Pawnee 230 CKT #1	12	Stable	Stable
3	Missile Site 345 kV	P4	3 Ph	Missile Site - Pawnee 345 kV CKT #1 & Pawnee 345/230/13.8 kV T3	12	Stable	Stable
4	Missile Site 345 kV	P4	3 Ph	Missile Site - Pawnee 345 kV CKT #2 & Pawnee 345/230/13.8 kV T3	12	Stable	Stable
5	Missile Site 345 kV	P4	3 Ph	Missile Site - Pawnee 345 kV CKT #2 & Pawnee 345/230/13.8 kV T2	12	Stable	Stable
6	Missile Site 345 kV	P4	3 Ph	Missile Site - Pawnee 345 kV CKT #1 & Pawnee 345/230/13.8 kV T2	12	Stable	Stable
7	Missile Site 345 kV	P4	3 Ph	Missile site - Limon 1 345 kV CKT #1, Missile Site 345/230/13.8 kV T1 & Limon Generation	12	Stable	Stable
8	Missile Site 345 kV	P4	3 Ph	Missile Site - Pronghorn 345 kV CKT #1, Missile Site 345 kV Capacitor Bank, Rush Creek Generation, Bronco Plains Generation, & Cheyenne Ridge Generation	12	Stable	Stable

Ref No.	Fault Location	Fault Category	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
9	Missile Site 345 kV	P4	3 Ph	Missile Site - Pawnee 345 kV CKT #2 & Missile Site - Daniel Park 345 kV CKT #1	12	Stable	Stable
10	Missile Site 345 kV	P4	3 Ph	Missile Site - Smoky Hill 345 kV CKT #1 & Missile Site - Pawnee 345 kV CKT #1	12	Stable	Stable
11	Missile Site 345 kV	P7	3 Ph	Missile Site - Pawnee 345 kV CKT #1 & Pawnee - Brickctr 230 kV CKT #1	4	Stable	Stable
12	Missile Site 345 kV	P7	3 Ph	Missile Site - Smoky Hill 345 kV CKT #1 & Missile Site - Daniel Park 230 kV CKT #1	4	Stable	Stable

4.7.2 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 4 below, along with the Thevenin impedance at the POI. Both the base case and the case with the GI added are shown.

Table 4 – Short Circuit Parameters at GI-2011-2,7 POI (Missile Site 345kV Substation)

	Before the Cluster addition	**After the Cluster Addition**
Three Phase		
Three Phase Current	20985A	21648A
Positive Sequence Impedance	0.75695+ j9.48524 ohms	0.75695 + j9.48524 ohms
Negative Sequence Impedance	0.79906+ j9.48691 ohms	0.79906 + j9.48691 ohms
Zero Sequence Impedance	3.44005 + j16.3020 ohms	3.44005 + j16.3020 ohms
Phase-to-Ground		
Single Line to Ground Current	16833A	17146A
Positive Sequence Impedance	0.21780 + j3.10344 ohms	0.75695 + j9.48524 ohms
Negative Sequence Impedance	0.25164 + j3.09294 ohms	0.79906 + j9.48691 ohms
Zero Sequence Impedance	0.30528 + j2.71817 ohms	3.44005 + j16.3020 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.

4.7.3 Summary of Eastern 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 200 MW BESS as Surplus Interconnection Service to existing Limon I & II Wind Generating Facilities.
- The study did not identify any transmission network upgrades due to the addition of the 200 MW BESS as Surplus Interconnection Service to existing Limon I & II Wind Generating Facilities..
- The study did not identify any impacts to the Affected Systems due to the addition of the 200 MW BESS as Surplus Interconnection Service to existing Limon I & II Wind Generating Facilities..

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 Limon I and II wind 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 Limon I & II plus BESS, at all times, not to exceed 400 MW. The output shall also be monitored by PSCo Operations.

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6.0 Conceptual POI One-Line Diagram of Limon I and II BESS

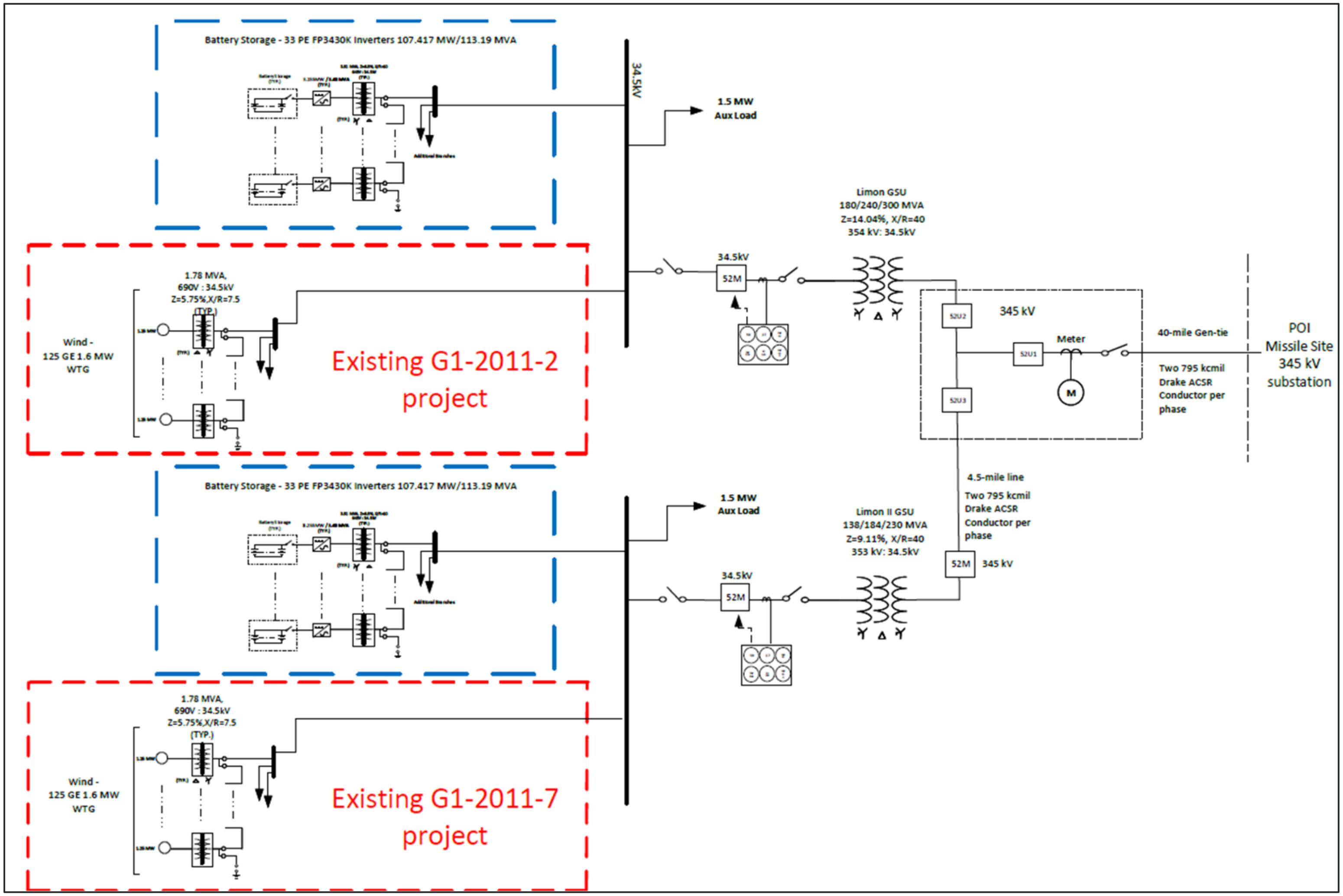

Figure 2 – Preliminary One-line of the Limon I and II BESS POI at Missile Site 345 kV

7.0 Appendices

Appendix A: Transient Stability Wind Plots	Limon Wind plots.pdf
Appendix B: Transient Stability BESS Plots	Limon Bess Plots.pdf
Appendix C: Transient Stability Wind and BESS Plots	Limon Wind and BESS plots.pdf