Arc Flash and Short Circuit Studies

Technical Documentation for Ames BESS

Iowa State Senior Design Team: SDDEC24-18

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Executive Summary

To validate the choices made in the initial design phase of the Ames Battery Energy Storage System (BESS), including protective device and equipment parameters, and to evaluate the safety of the system, we ran arc flash and short circuit studies using ETAP software. The system built in ETAP mirrored the one-line diagram of the system. The device parameters and cable sizes were selected based on the calculations from creating our one-line diagram and cable schedule. This model allowed us to test our system's performance under several worst-case scenario conditions.

Short circuit analysis examines how our system behaves during a fault, including line-to-line, line-to-ground, and three-phase faults. It determines the fault current levels throughout the system. These values are used to determine proper protective equipment. The fuses and breakers must be sized to handle the maximum fault current to prevent damage to equipment. Based on the results from this analysis, we can ensure that system components, including our fuses, breakers, cables, and equipment, can withstand and isolate faults.

An arc flash is a rapid release of energy due to an electrical fault, causing a high-temperature explosion that can severely damage equipment and pose serious safety risks to personnel. Compared with the short circuit study, arc flash analysis is focused on protecting personnel near the equipment rather than the equipment itself. It determines the arc flash boundary; the minimum safe distance personnel should maintain to avoid injury from an arc flash event. It also provides guidance on appropriate PPE for personnel working within the arc flash boundary. For a utility-scale BESS, this typically involves protective clothing, gloves, face shields, and other safety gear.

The protective devices in our system must be coordinated to operate effectively. Coordination means the protective device closest to the fault operates first, leaving upstream devices unaffected. This prevents unnecessary disconnection of the entire system and minimizes downtime. It may also reduce arc flash incident energy because the faults can be cleared faster. Time current curves (TCC) are used to visualize the coordination of a system graphically by representing the relationship between the operating time of a protective device and the magnitude of current passing through it. By analyzing the positions of the curves relative to one another, we can ensure that the downstream devices operate faster than the upstream devices.

The results of these tests indicate that our BESS meets the standards expected, considering the scope of our project. The short circuit tests show that the fault currents are well below the short circuit withstand ratings and the cable fault current ratings of the conductors. However, the arc flash tests show several parts of our system have a very high incident energy, well above 40 $\mathrm{cal/cm^2}$. This is due to poor coordination of the protective devices. Due to time constraints, we did not go beyond a surface level analysis of the TCC curves. A more in-depth analysis of the protective device ratings would yield better results. Overall, while our BESS is clearly not construction-ready, these tests verify our design decisions and provide recommendations for future work.

Standards

AC Arc Flash - IEEE 1584-2018

This standard was used for the arc flash tests on the low voltage side of our system.

AC Arc Fault – High Voltage

This standard is built into the ETAP library and was used for the arc flash tests on the medium voltage side of our system.

Short circuit - ANSI/IEEE-C37 & UL 489

This standard is used for both low and medium voltage short circuit analysis.

Methodology

Short Circuit Analysis

In our short circuit analysis, we focused on 3 phase faults. We faulted the medium voltage buses (34.5 kV), and the low voltage buses (480 V and 760V) separately. To perform a short circuit analysis, we sized the transformers, cables, inverters, and batteries based on the work we did last semester. Setting up the short circuit study in ETAP involved configuring the settings for the test four cases. To do this we needed to edit the study case details and update the faulted buses, standards used, and pre-fault voltage. Details on the parameters used can be found in Appendix A.

We concluded whether our system passed the short circuit test cases by comparing the fault currents at each bus to a maximum value. Based on industry standards, the maximum allowable short circuit current is 25 kA for medium voltage buses and 65 kA for low voltage buses. We also found the maximum allowable short circuit currents for each of our medium voltage cables, including both home runs and the cables connecting the PCS skids. The equation for insulated aluminum conductors rated for 105° C continuous operation is given as follows:

Equation 1: $\left(\frac{I}{A}\right)^2 t = 0.0125 \log\left(\frac{T_2+228}{T_1+228}\right)$

Where:

I = short circuit current (amperes)

A = conductor area (circular mils)

t = time of short circuit (seconds) - 0.25 seconds

T_1 = maximum operating temperature - 105° C

T_2 = maximum short circuit temperature - 250° C

This equation can be used to find the minimum conductor for a given short circuit current or the maximum short circuit current a given conductor can withstand. We also used this equation to verify our cable sizing after completing the short circuit studies.

Arc Flash Analysis

To run the arc flash study, we used the fault current values from short circuit analysis as inputs. It is also essential to have adequately sized fuses. The current limiting fuses are particularly important here because of their ability to rapidly interrupt fault currents and minimize incident energy levels. To set up arc fault study in ETAP, we needed to set up two high voltage cases, a 95% and 105% load, and two low voltage cases, a 95% and 105% load. These use different standards, so they are evaluated differently in the ETAP software. When setting up the cases we had to set the correct buses, arc flash method, standards, FCT (fuse clearing time), and pre-fault voltage. Details on the parameters used can be found in Appendix A.

The ETAP results include the incident energy, measured in calories per square centimeter (cal/cm^2), and the arc flash boundary distance, the area within which PPE is required. We ran a 3-phase fault because this typically produces the highest fault current. Additionally, running analyses at two different power factors makes our testing more robust. The highest current, at the higher power factor, does not necessarily result in the highest incident energy. This is because incident energy also increases with the duration of the fault and is a product of $\mathrm{I}^2\mathrm{t}$, which, depending on the settings and coordination of the fuses and breakers, may be faster at a higher current. With these four tests, we can ensure that we are analyzing the worst-case arc flash scenario.

Time Current Curve (TCC) Graph Analysis

These graphs display the amount of time it takes to activate a protective device depending on the amount of current flowing through them. They also show similar curves for the time and current that cables and equipment can withstand before being damaged. By selecting several devices in series on the ETAP model, we can generate a graph containing all their time current curves.

To evaluate the coordination of our equipment using these graphs, we compared the positions of the curves for the protective devices relative to the damage curves for equipment they protect. The graphs axes are on a logarithmic scale and are read from bottom to top and left to right. The curves of the protective devices should be to the left of and below the curves of the equipment they protect to ensure they are activated before the equipment is damaged by the fault.

System Data

The input data for our system in ETAP was obtained from

- One line diagram (Appendix D)
- Cable schedule (Appendix E)
- Short circuit results from ETAP (Appendix B)
- Arc flash results from ETAP (Appendix C)

Assumptions

Protective device libraries: used to choose the types of fuses and breakers

Utility data: the power and voltage levels at the point of interconnection was assumed to be

Parameters	Utility Max Contribution (Case 1)	Utility Min Contribution N-1 (Case 2)
3Φ Fault (kA)	20.874	20.874
3Φ X/R (kA)	7.97	7.97
SLG Fault (kA)	21.878	21.878
SLG X/R (kA)	8.99	8.99
%R	0.49904	0.49904
%X	3.97734	3.97734
MPT Impedance	8%	13%

Human reaction time: 2 seconds according to IEEE 1584

Study Cases

For both the arc flash and short circuit studies, we ran four separate cases. We did this to supersede the maximum and minimum voltages and simulate all worst-case scenarios. This was necessary because when voltage is higher there is more energy in the system, which can cause damage to equipment or people. When the voltage is low there is a slower tripping time for fuses, leaving more time for the fault to go unnoticed and cause damage to equipment or people.

MV 1.05: performed on the 34.5 kV buses and uses the high voltage AC arc fault and ANSI/IEEE-C37 & UL 489 standards

MV 0.95: performed on the 34.5 kV buses and uses the high voltage AC arc fault and ANSI/IEEE-C37 & UL 489 standards

LV 1.05: performed on the 480 and 760 V buses and uses the IEEE 1584-2018 and ANSI/IEEE-C37 & UL 489 standards

LV 0.95: performed on the 480 and 760 V buses and uses the IEEE 1584-2018 and ANSI/IEEE-C37 & UL 489 standards

Results

Short Circuit Studies

Table 1 shows the three phase, line-to-ground, and line-to-line fault currents and the short circuit withstand ratings for each category of bus in our system. Table 2 shows the worst-case fault current withstand ratings for the medium voltage cables in our system. The cable fault current withstand rating was calculated using equation 1. Detailed results can be found in Appendix B.

Table 1: Worst Case Short Circuit Current Value for AC Terminals

Equipment (1.05 PF)	3-Phase (kA)	L-G (kA)	L-L-G (kA)	SC Withstand Ratings (kA)
Home Run Bus (34.5 kV)	5.744	5.897	5.061	25
PCS Skid High Side Terminals (34.5 kV)	5.682	5.797	4.986	25
PCS Skid Low Side Terminals (760 V)	47.071	49.715	41.256	65
Aux Power System High Side Terminal (34.5 kV)	5.662	5.784	4.979	25
Aux Power System Low Side Terminal (480 V)	28.604	28.995	24.772	65

Table 2: Short Circuit Withstand of Aluminum Conductors

Worst case MV Cable ID	Conductor Size	Clearing Time (cycles)	Calculated Cable Fault Current Rating (kA)	System 3P Fault (kA)
Homerun (Cable ID:4)	350 KCMil	15	31.01	5.74
PCS 1-2 (Cable ID: 2)	1/0 AWG	15	9.39	5.67

The results from the short circuit studies indicate that our system is properly protected in the event of a fault. The short circuit current values for buses in our system are below the industry standard withstand ratings, as seen in table 1 above. The medium voltage bus fault currents were around 5-6 kA, compared to the maximum rating of 25kA. The 760 V bus fault currents were at most 49.7 kA, and the 480 V bus currents were at most 28.9 kA. Both of these values are lower that the maximum rating of 65 kA as well.

The results were also below the calculated cable fault current ratings, as seen in table 2. The three phase fault current in the 350 KCMil home run cable was 5.74 kA, below the fault current rating of 31.01 kA. Additionally, the smallest cable connecting the PCS skids, at 1/0 AWG, had a three-phase fault current of 5.67 kA, below its fault current rating of 9.39 kA.

Arc Flash Studies

Table 3 and 4 show the duration of the arc faults, the incident energy, and the recommended working distance for the worst case of each bus voltage in our system. Detailed results for every bus in our system can be found in Appendix C.

Table 3: Worst Case 3-Phase AC Arc Flash Results at 1.05 PF

Arc Flash Fault Locations (1.05 PF)	Voltage	Bus $\mathbf{I_a}$ (kA)	Duration (cycles)	Working Distance (in)	Incident Energy $(\mathbf{cal/cm^2})$
MV Buses 1.05 PF	34.5 kV	5.738 kA	120*	15	220.6
LV Buses 1.05 PF	760 V	47.071	120*	18	38
LV Buses 1.05 PF	480 V	26.945	1.8	18	1.3

Table 3: Worst Case 3-Phase AC Arc Flash Results at 0.95 PF

Arc Flash Fault Locations (0.95 PF)	Voltage	Bus $\mathbf{I_a}$ (kA)	Duration (cycles)	Working Distance (in)	Incident Energy $(\mathbf{cal/cm^2})$
MV Buses 0.95 PF	34.5 kV	5.16	120*	15	197.5
LV Buses 0.95 PF	760 V	38.2	120*	18	42.8
LV Buses 0.95 PF	480 V	22.8	1.8	18	13.5

**Arc flash durations over the human reaction time of 2 seconds (120 cycles) are not considered as in IEEE 1584*

The results from the arc flash studies reveal very high incident energies, greater than 40 $\mathrm{cal/cm^2}$, in some parts of the system. This means that these sections must be de-energized before performing maintenance on them. The buses with the highest incident energies (MV Buses 1.05 PF) are the points where our PCS skids connect on the medium voltage side.

The AUX power system low voltage buses have incident energy ratings well below 40 $\mathrm{cal/cm^2}$, meaning they are safe to work on while energized, with proper PPE and safety precautions.

TCC Graph Analysis

These graphs show the time current curves for fuses, breakers, cables, transformers, and other devices with current on the x-axis and time on the y-axis. Both axes are logarithmically scaled. More details on these graphs can be found in Appendix F.

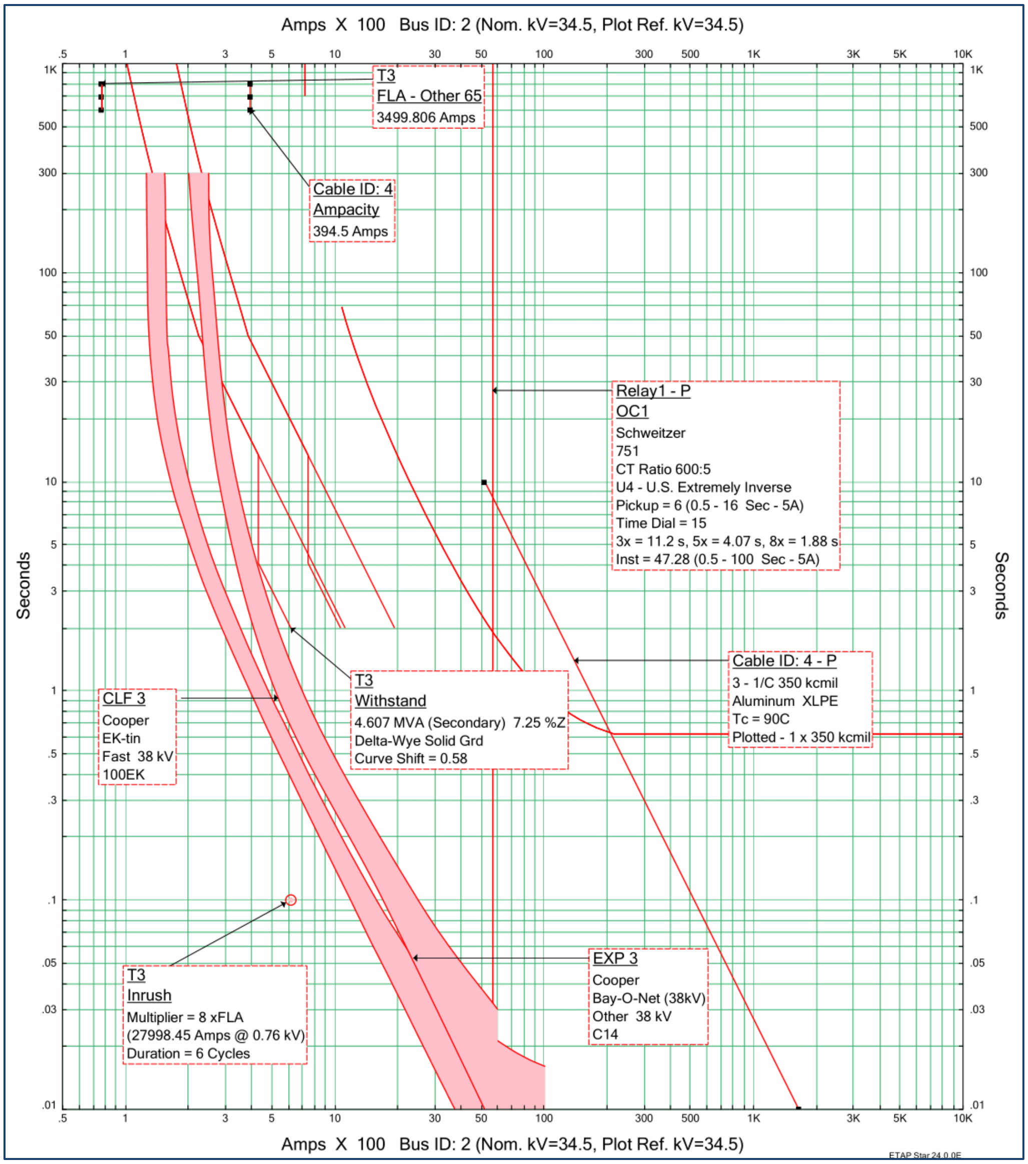


Figure 1: HR to PCS TCC Graph

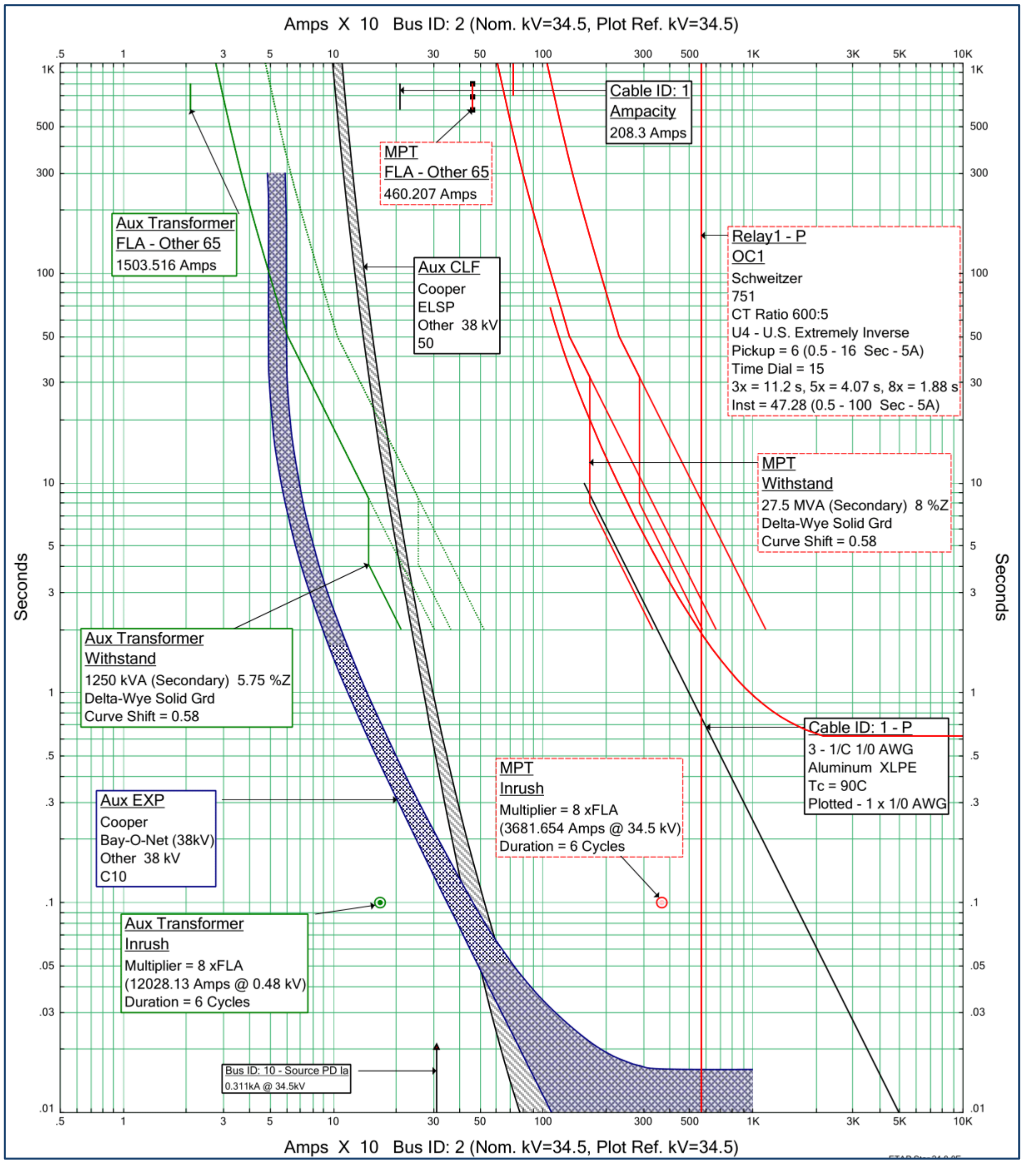


Figure 2: AUX Pad TCC Graph

The graphs show the limits breakers and fuses as thick lines because they take time to fully trigger. The thin curves correspond to the equipment that needs to be protected. In a well coordinated system, these lines should be fully above and to the right of the thicker lines corresponding to the protective devices.

Initially, the TCC graphs revealed several weaknesses in our system. Resizing certain fuses and breakers based on which curves were right of the equipment curves improved coordination. However, there are still some contingencies that our system is not prepared for. This can be seen in the top left part of both graphs, where the damage curves for the AUX transformer (figure 2) and PCS transformer (figure 1) are left of the fuse and breaker curves. However, further analysis of the graphs was out of the scope of our project.

Recommendations

Further work is needed related to the device coordination and arc flash studies for this battery energy storage system. This work should consist of a more in death analysis of the TTCs of the fuses and breakers, and then performing additional arc flash studies. Additionally, a load flow study should be performed to analyze the voltage drop and current flow profile. This study would also confirm whether our system meets power requirements at the POI.

Conclusion

The tests described in this report simulated worst-case real-world scenarios to evaluate the safety and reliability of the BESS. The results of our tests indicate that our system meets the standards expected, considering the scope of our project.

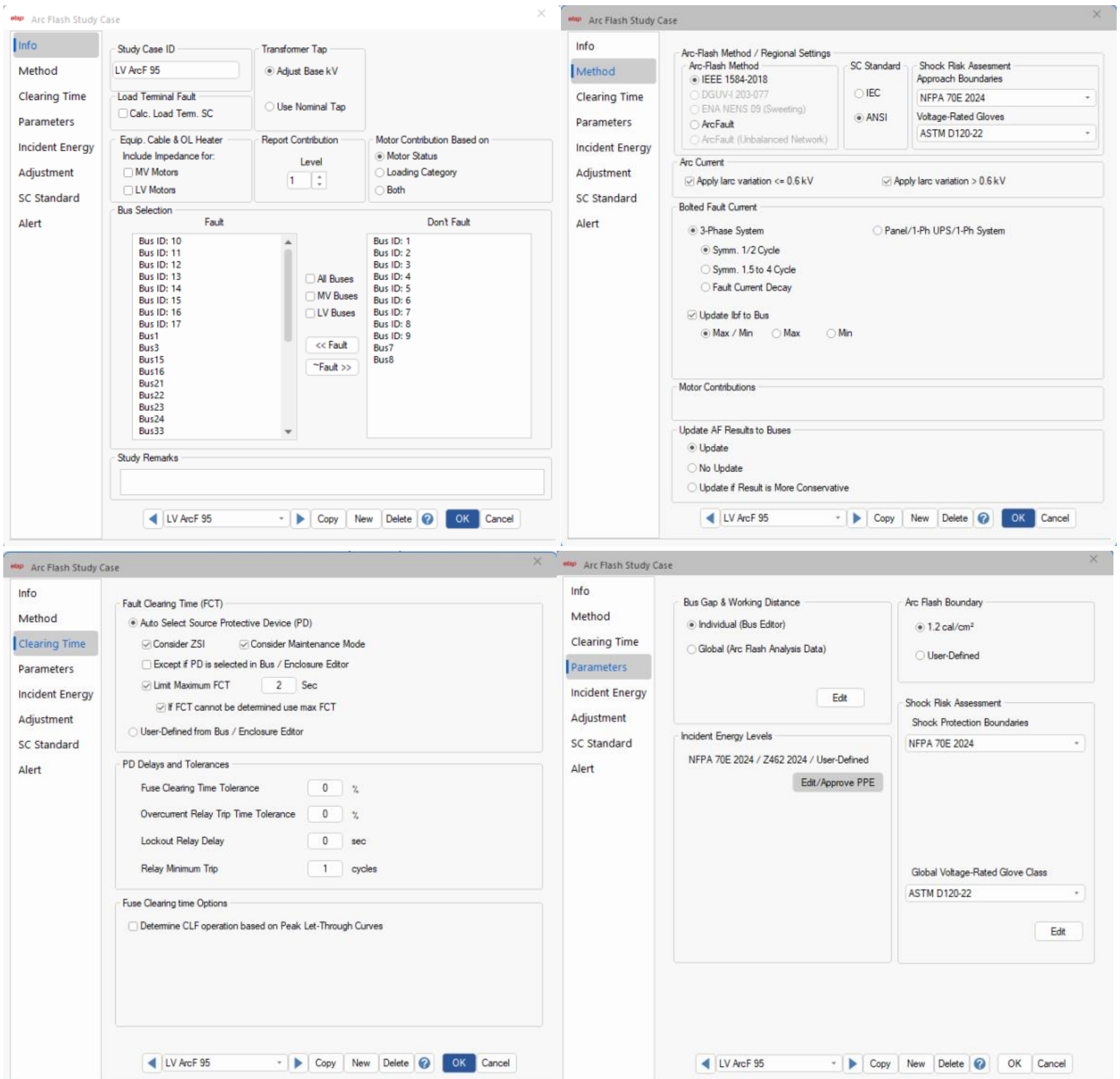
The short circuit tests show that the fault currents are well below the short circuit withstand ratings and the cable fault current ratings of the conductors. However, the arc flash tests show several parts of our system have a very high incident energy, well above 40 $\mathrm{cal/cm^2}$. The parts of our system with an incident energy greater than 40 $\mathrm{cal/cm^2}$ need to be completely deenergized before performing maintenance on them, according to IEEE 1584. This is not ideal for the reliability of our BESS. The results from the TCC graphs show poor coordination of the protective devices. Due to time constraints, we did not go beyond a surface level analysis of the TCC curves. A more in-depth analysis of the protective device ratings would improve device coordination and decrease incident energies.

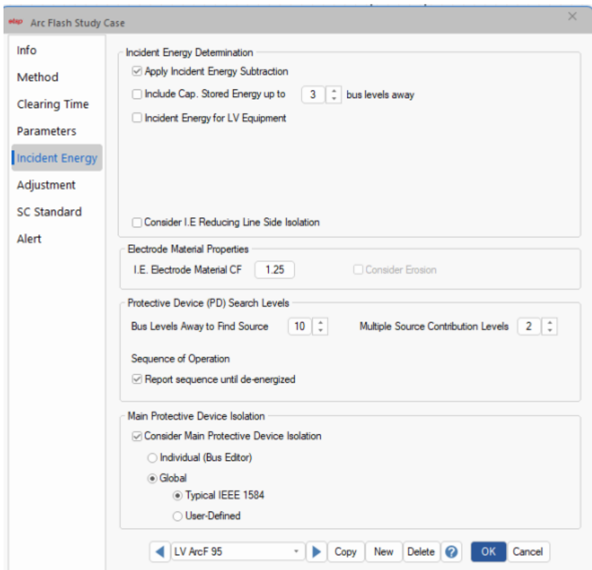
Appendix

Appendix A: Study Cases Settings:

Arc Flash Study ETAP Settings

Arc Flash Low Voltage 95%

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Incident Energy for LV Equipment
Consider I.E Reducing Line Side Isolation
Electrode Material Properties
I.E. Electrode Material CF 1.25
Consider Erosion
Protective Device (PD) Search Levels
Bus Levels Away to Find Source 10
Multiple Source Contribution Levels 2
Sequence of Operation
Report sequence until de-energized
Main Protective Device Isolation
Consider Main Protective Device Isolation
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Typical IEEE 1584
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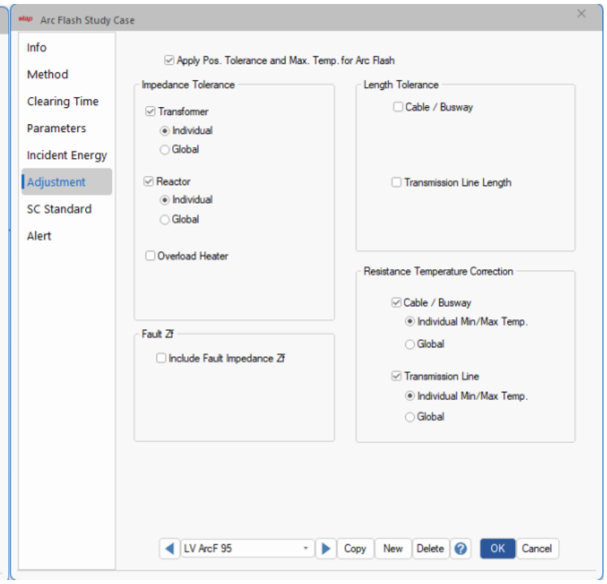
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Global
Reactor
Individual
Global
Overload Heater
Length Tolerance
Cable / Busway
Transmission Line Length
Resistance Temperature Correction
Cable / Busway
Individual Min/Max Temp.
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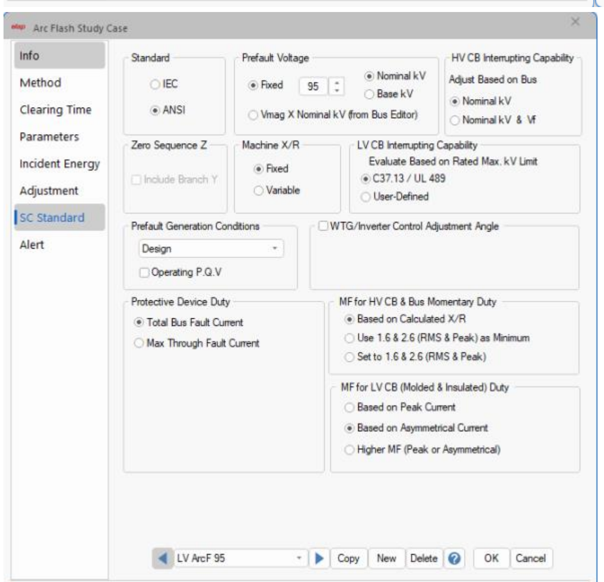
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Base kV
Vmag X Nominal kV (from Bus Editor)
HV CB Interrupting Capability
Adjust Based on Bus
Nominal kV
Nominal kV & Vf
Zero Sequence Z
Include Branch Y
Machine X/R
Fixed
Variable
LV CB Interrupting Capability
Evaluate Based on Rated Max. kV Limit
C37.13 / UL 489
User-Defined
Prefault Generation Conditions
Design
Operating P,Q,V
WTG/Inverter Control Adjustment Angle
Protective Device Duty
Total Bus Fault Current
Max Through Fault Current
MF for HV CB & Bus Momentary Duty
Based on Calculated X/R
Use 1.6 & 2.6 (RMS & Peak) as Minimum
Set to 1.6 & 2.6 (RMS & Peak)
MF for LV CB (Molded & Insulated) Duty
Based on Peak Current
Based on Asymmetrical Current
Higher MF (Peak or Asymmetrical)
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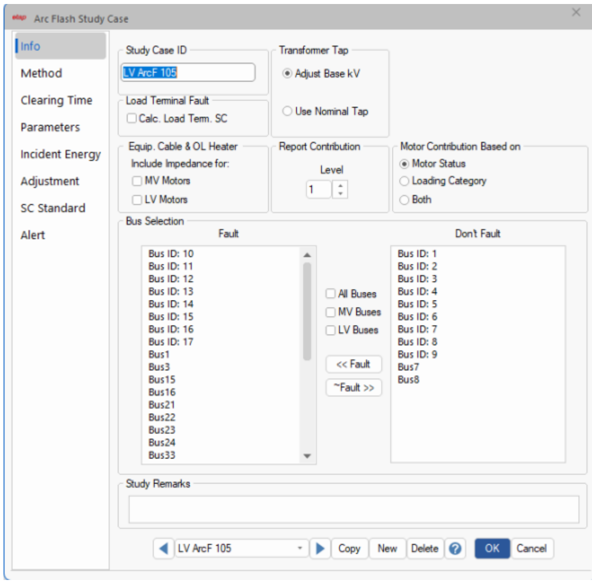
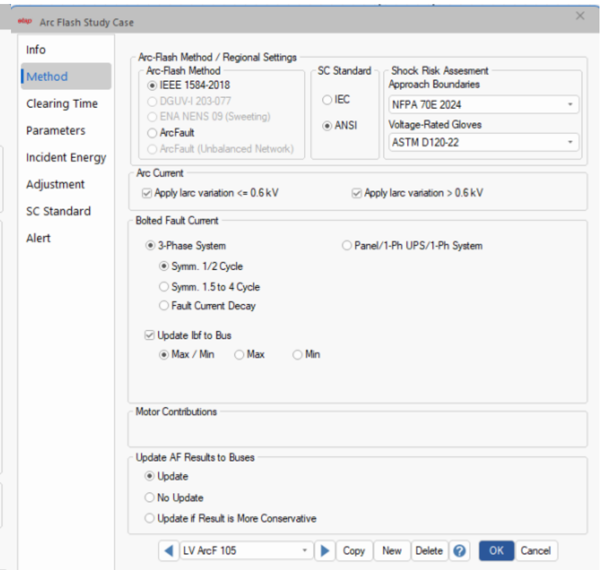
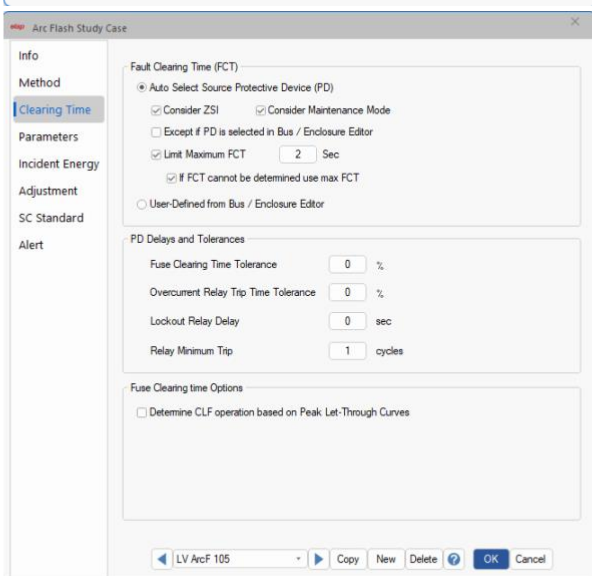
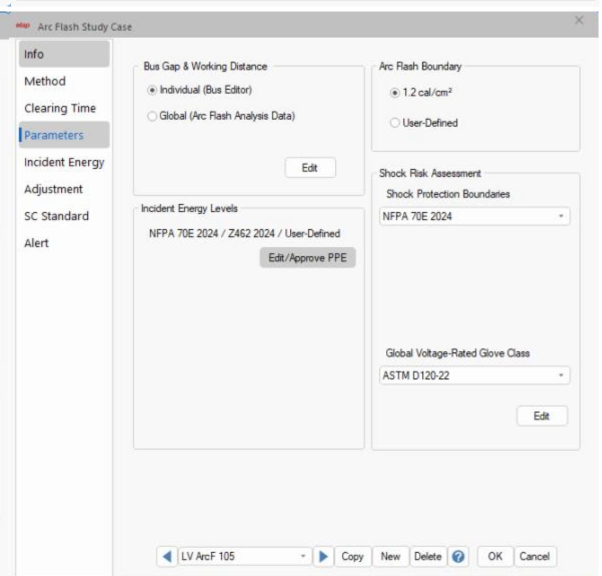
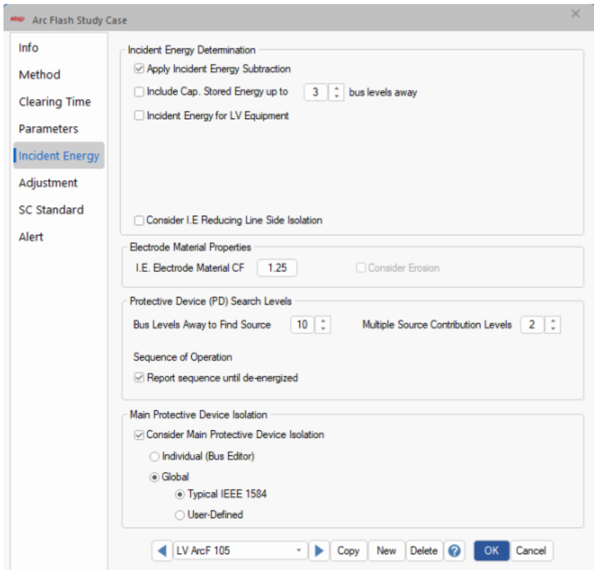
Arc Flash Low Voltage 105%







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Incident Energy for LV Equipment
Consider I.E Reducing Line Side Isolation
Electrode Material Properties
I.E. Electrode Material CF 1.25
Consider Erosion
Protective Device (PD) Search Levels
Bus Levels Away to Find Source 10
Multiple Source Contribution Levels 2
Sequence of Operation
Report sequence until de-energized
Main Protective Device Isolation
Consider Main Protective Device Isolation
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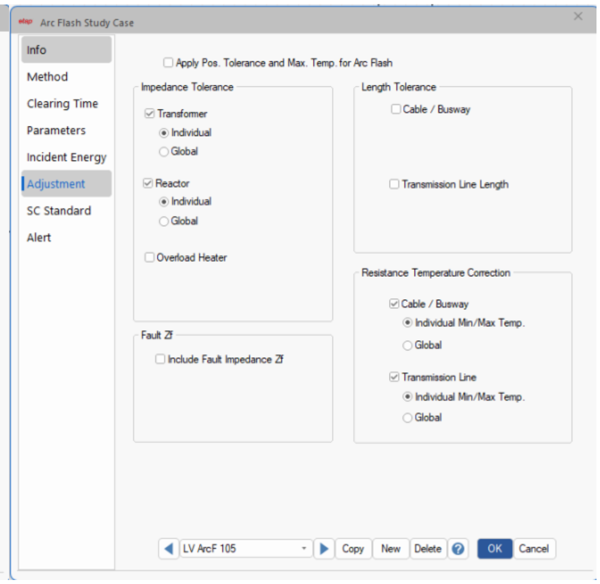
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Cable / Busway
Transmission Line Length
Resistance Temperature Correction
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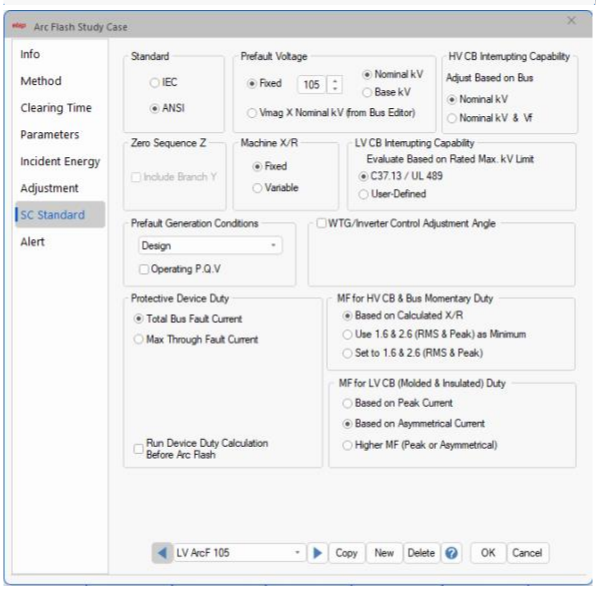
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Total Bus Fault Current
Max Through Fault Current
Run Device Duty Calculation Before Arc Flash
MF for HV CB & Bus Momentary Duty
Based on Calculated X/R
Use 1.6 & 2.6 (RMS & Peak) as Minimum
Set to 1.6 & 2.6 (RMS & Peak)
MF for LV CB (Molded & Insulated) Duty
Based on Peak Current
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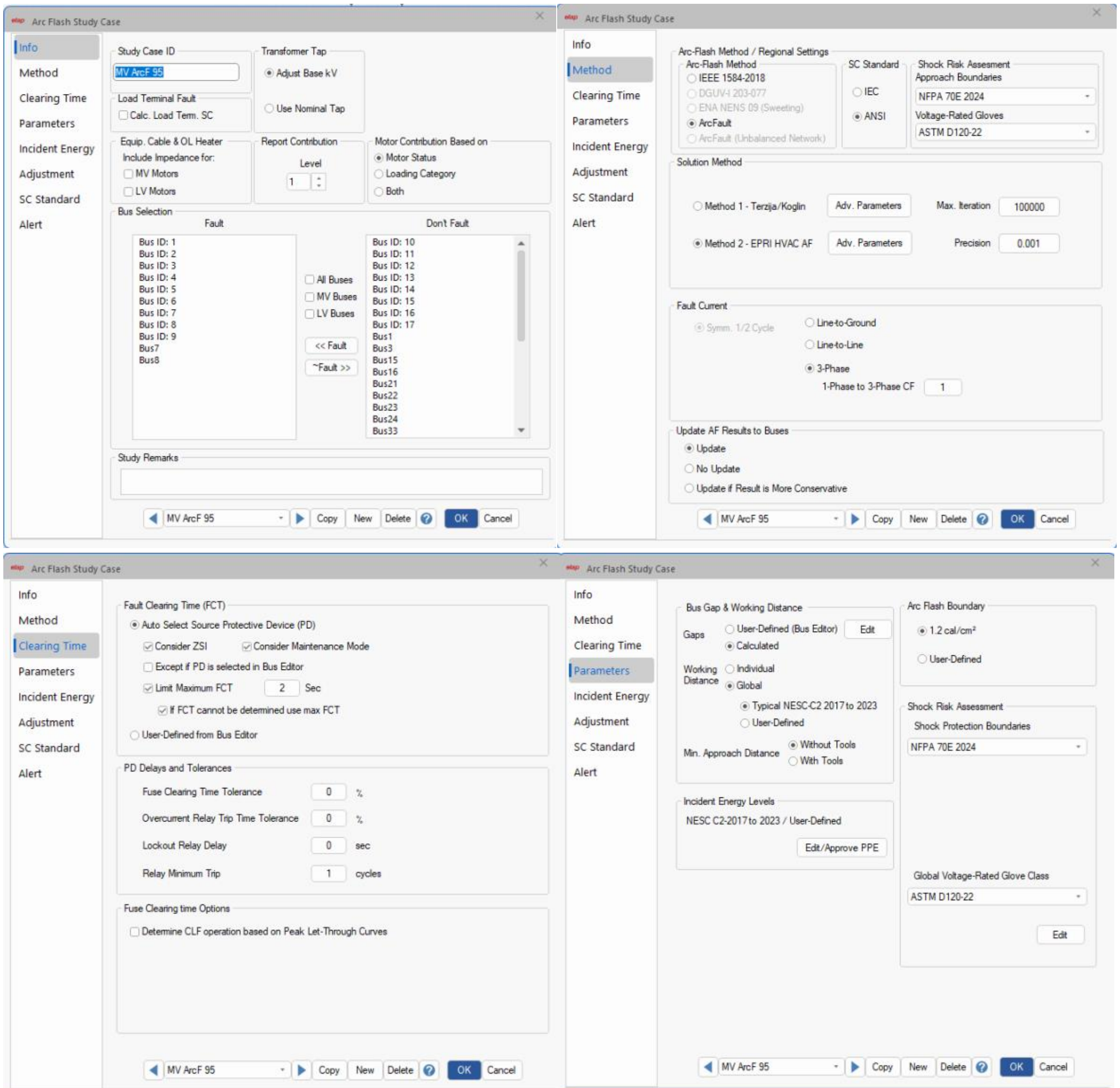
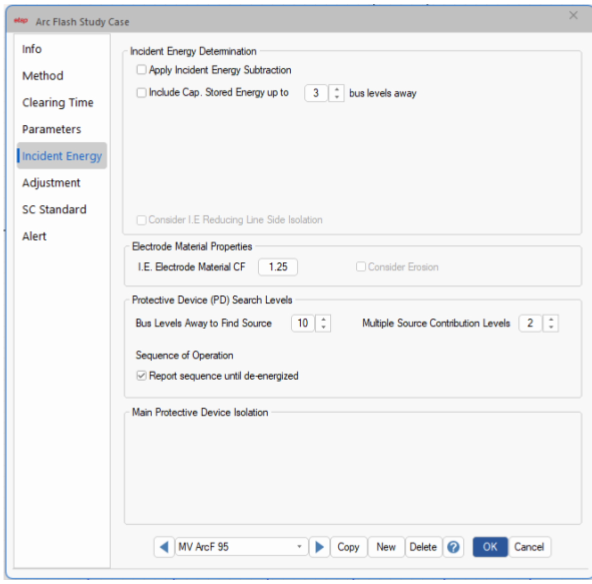
Arc Flash Medium Voltage 95%

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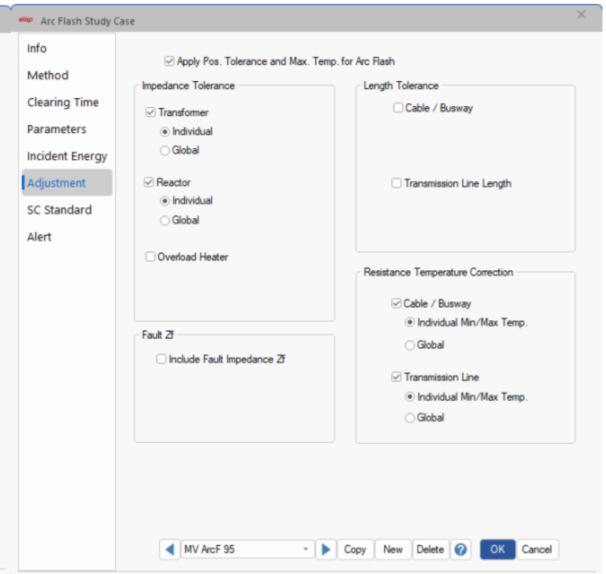
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Overload Heater
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Transmission Line Length
Resistance Temperature Correction
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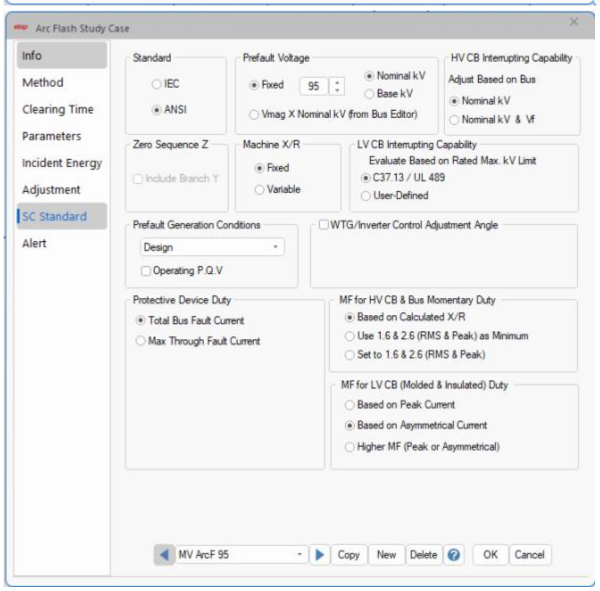
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Base kV
Vmag X Nominal kV (from Bus Editor)
HV CB Interrupting Capability
Adjust Based on Bus
Nominal kV
Nominal kV & Vf
Zero Sequence Z
Include Branch Y
Machine X/R
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LV CB Interrupting Capability
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C37.13 / UL 489
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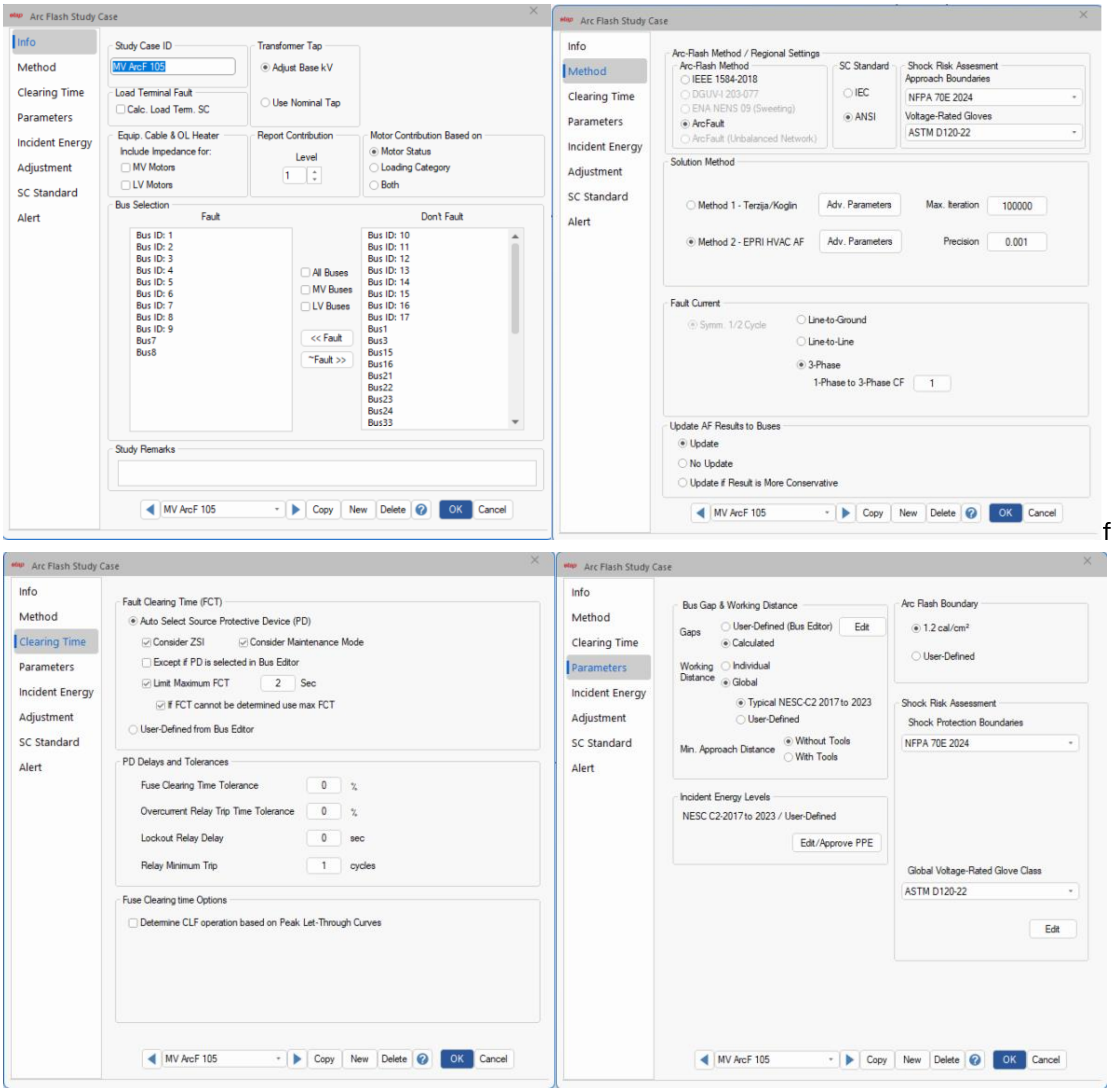
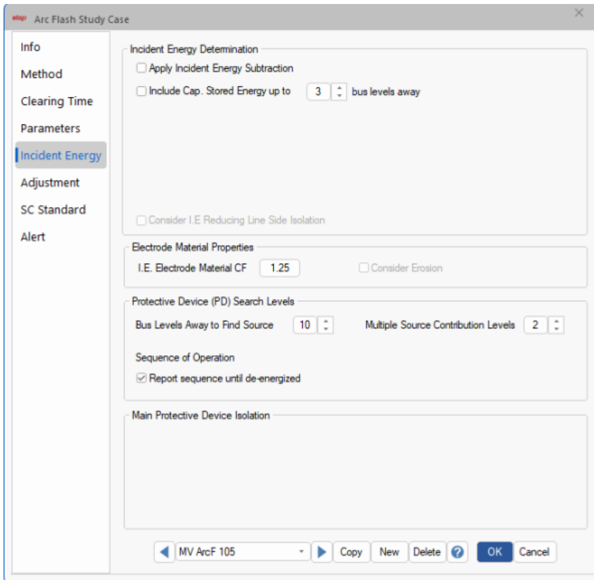
Arc Flash Medium voltage 105%

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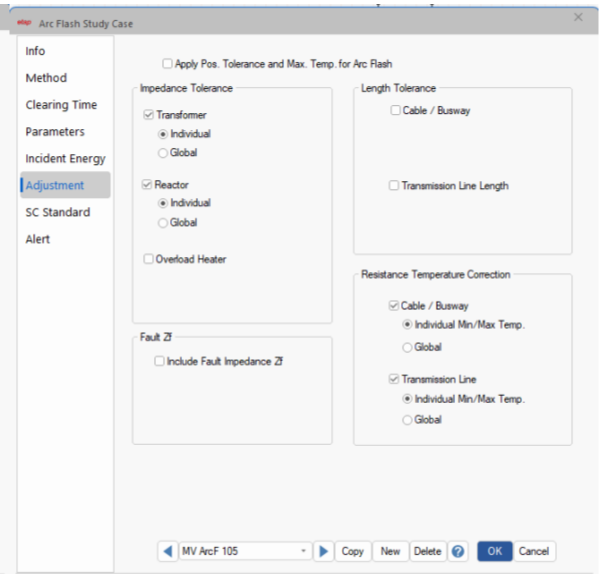
Apply Incident Energy Subtraction
Include Cap. Stored Energy up to 3 bus levels away
Consider I.E Reducing Line Side Isolation
Electrode Material Properties
I.E. Electrode Material CF 1.25
Consider Erosion
Protective Device (PD) Search Levels
Bus Levels Away to Find Source 10
Multiple Source Contribution Levels 2
Sequence of Operation
Report sequence until de-energized
Main Protective Device Isolation
MV ArcF 105
Copy
New
Delete
OK
Cancel


Arc Flash Study Case
Info
Method
Clearing Time
Parameters
Incident Energy
Adjustment
SC Standard
Alert
Apply Pos. Tolerance and Max. Temp. for Arc Flash
Impedance Tolerance
Transformer
Individual
Global
Reactor
Individual
Global
Overload Heater
Length Tolerance
Cable / Busway
Transmission Line Length
Fault Zf
Include Fault Impedance Zf
Resistance Temperature Correction
Cable / Busway
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Individual Min/Max Temp.
Global
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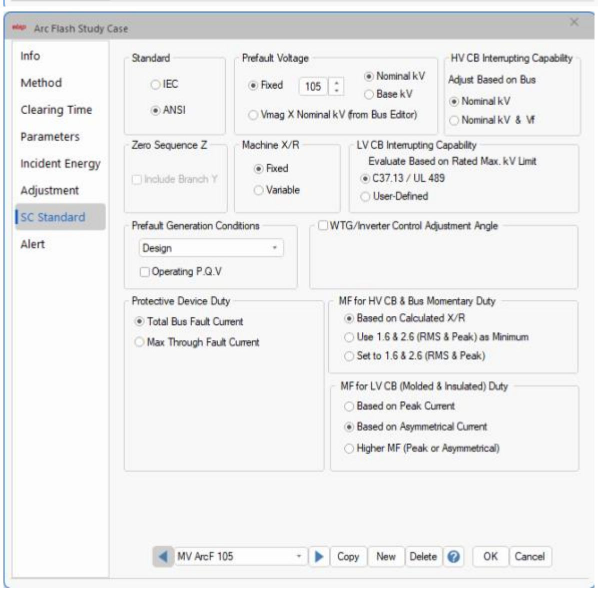
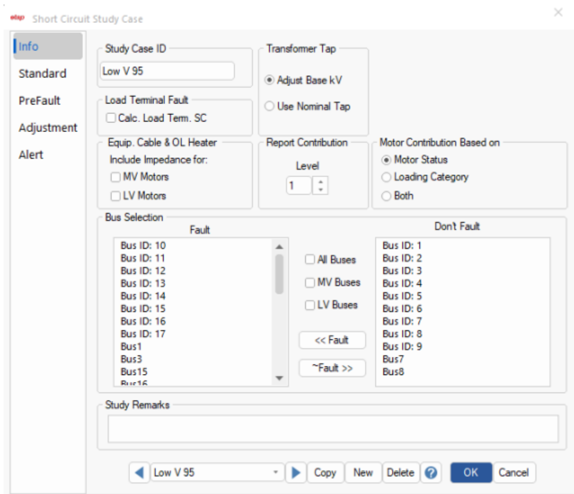
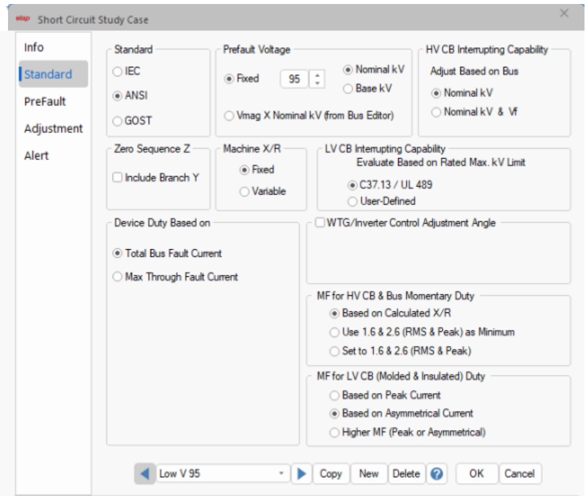
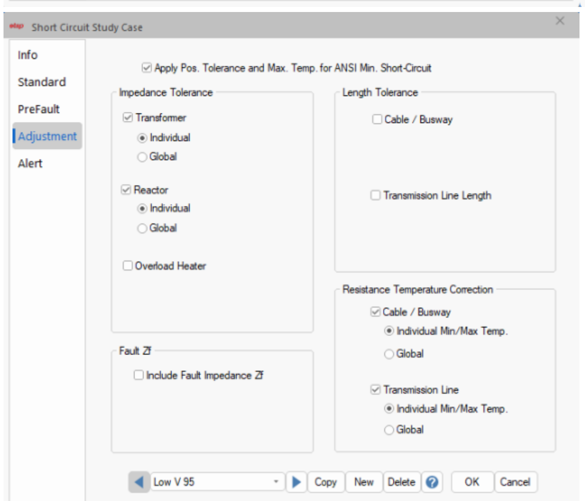

Arc Flash Study Case
Info
Method
Clearing Time
Parameters
Incident Energy
Adjustment
SC Standard
Alert
Standard
IEC
ANSI
Prefault Voltage
Fixed 105
Nominal kV
Base kV
Vmag X Nominal kV (from Bus Editor)
HV CB Interrupting Capability
Adjust Based on Bus
Nominal kV
Nominal kV & Vf
Zero Sequence Z
Include Branch Y
Machine X/R
Fixed
Variable
LV CB Interrupting Capability
Evaluate Based on Rated Max. kV Limit
C37.13 / UL 489
User-Defined
Prefault Generation Conditions
Design
Operating P,Q,V
WTG/Inverter Control Adjustment Angle
Protective Device Duty
Total Bus Fault Current
Max Through Fault Current
MF for HV CB & Bus Momentary Duty
Based on Calculated X/R
Use 1.6 & 2.6 (RMS & Peak) as Minimum
Set to 1.6 & 2.6 (RMS & Peak)
MF for LV CB (Molded & Insulated) Duty
Based on Peak Current
Based on Asymmetrical Current
Higher MF (Peak or Asymmetrical)
MV ArcF 105
Copy
New
Delete
OK
Cancel

Short Circuit Study ETAP Setting

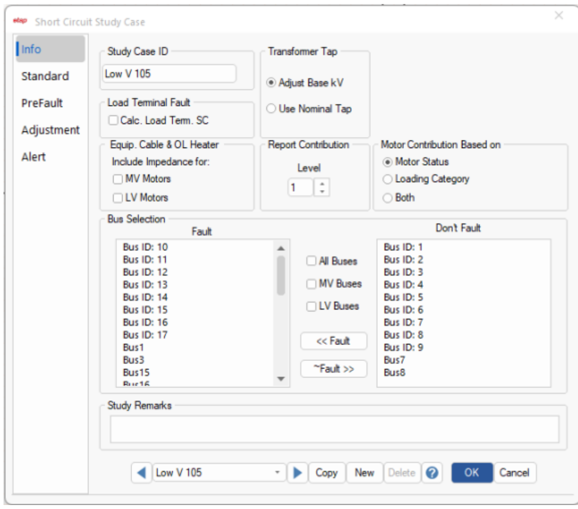
Short Circuit Low Voltage 95%

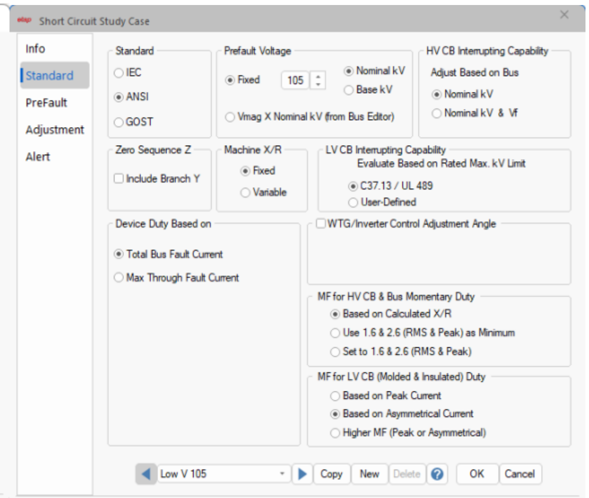


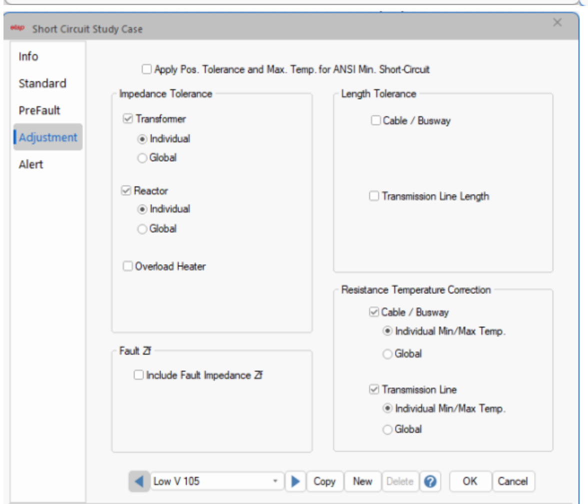




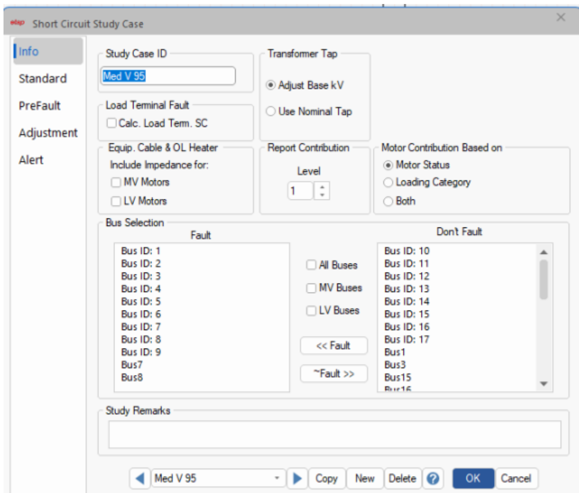
Short Circuit LV 105%

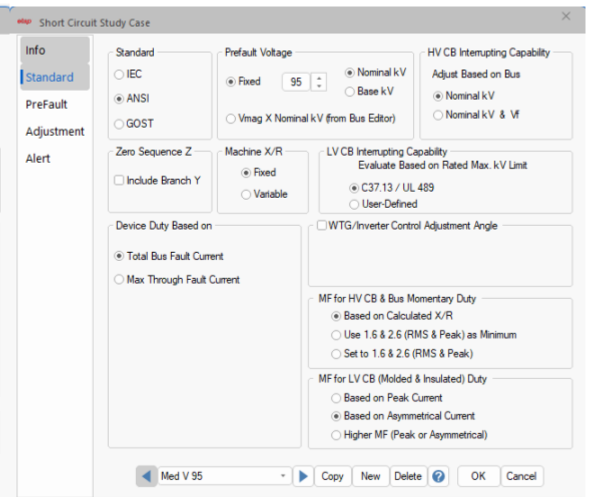


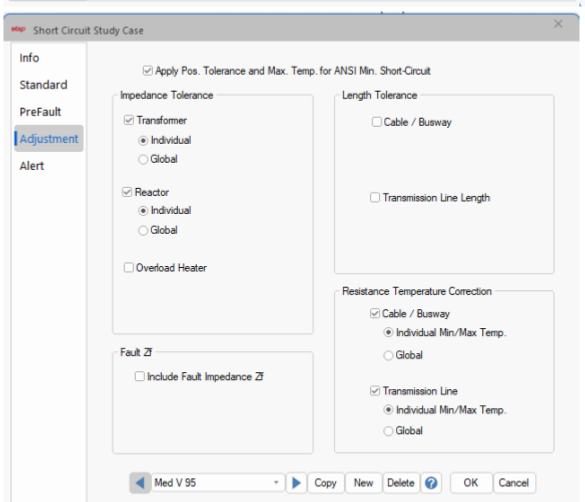




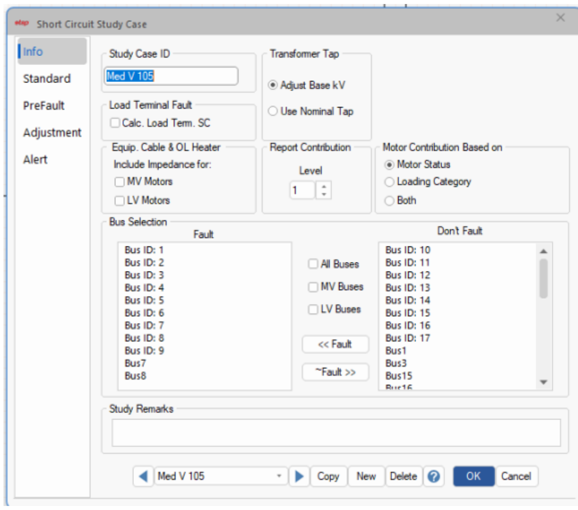
Short Circuit MV 95%

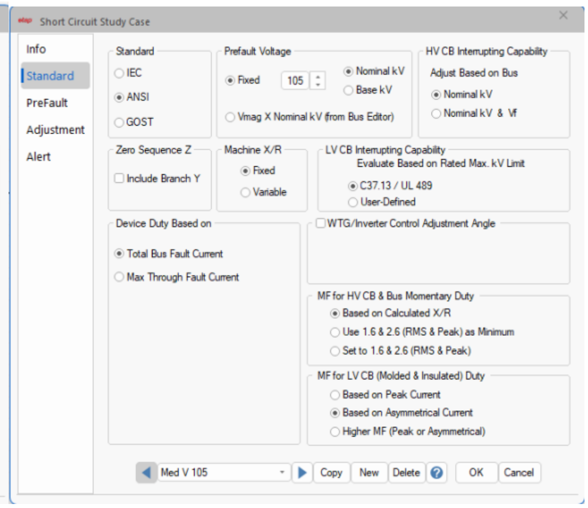


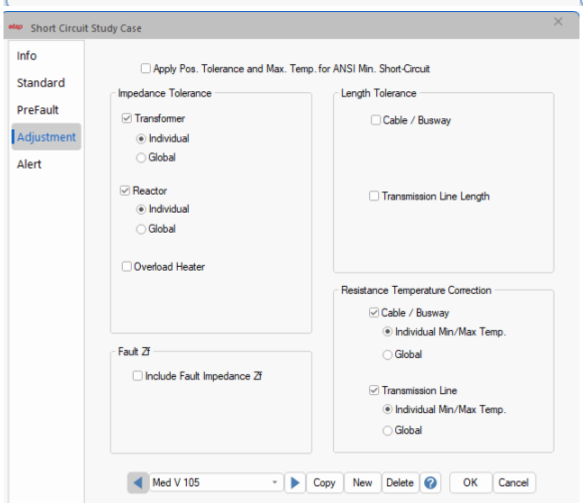




Short Circuit Medium Voltage 105%







Appendix B: Short circuit results

Low Voltage 95% Power Factor Test Case

Project:		**ETAP**	Page:	1
Location:		24.0.0E	Date:	11-20-2024
Contract:			SN:	IASTATEPL
Engineer:		Study Case: Low V 95	Revision:	Base
Filename:	AMES_BESS		Config.:	Normal

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 95 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus ID: 10	0.480	3.751	-25.897	26.168	3.737	-25.929	26.197	-22.179	-3.231	22.413	20.308	16.360	26.077
Bus ID: 11	0.760	3.242	-43.032	43.154	3.467	-45.887	46.018	-38.169	-2.787	38.271	-40.224	22.410	46.045
Bus ID: 12	0.760	3.220	-43.046	43.166	3.451	-45.868	45.998	-38.092	-2.767	38.192	-40.231	22.432	46.062
Bus ID: 13	0.760	3.207	-43.057	43.176	3.441	-45.847	45.976	-38.123	-2.756	38.223	-40.238	22.446	46.075
Bus ID: 14	0.760	3.208	-43.055	43.174	3.440	-45.820	45.949	-38.142	-2.758	38.242	-40.237	22.445	46.073
Bus ID: 15	0.760	3.224	-43.043	43.164	3.452	-45.788	45.918	-38.153	-2.772	38.254	-40.230	22.428	46.059
Bus ID: 16	0.760	3.246	-43.029	43.152	3.468	-45.749	45.880	-38.167	-2.791	38.269	-40.222	22.406	46.042
Bus ID: 17	0.480	3.723	-24.431	24.713	3.299	-23.202	23.435	-20.868	-3.202	21.112	19.394	14.385	24.147
Bus1	0.480	9.100	-13.929	16.638	4.730	-11.024	11.996	-12.063	-7.880	14.409	10.655	12.290	16.266
Bus3	0.480	9.025	-11.412	14.549	4.199	-8.979	9.912	-9.883	-7.816	12.600	8.721	11.310	14.282
Bus15	0.480	8.910	-10.641	13.879	4.012	-8.389	9.299	-9.216	-7.716	12.019	8.129	10.955	13.642
Bus16	0.480	9.122	-12.774	15.696	4.502	-10.060	11.021	-11.062	-7.900	13.594	9.768	11.872	15.373
Bus21	0.480	8.912	-10.656	13.892	4.016	-8.400	9.311	-9.228	-7.718	12.030	8.141	10.962	13.654
Bus22	0.480	8.490	-8.927	12.319	3.562	-7.119	7.961	-7.731	-7.353	10.669	6.811	10.054	12.144
Bus23	0.480	8.312	-8.395	11.814	3.412	-6.734	7.549	-7.271	-7.198	10.231	6.402	9.740	11.656
Bus24	0.480	8.748	-9.863	13.183	3.814	-7.807	8.688	-8.542	-7.576	11.417	7.531	10.566	12.975
Bus33	0.480	8.315	-8.406	11.824	3.415	-6.742	7.557	-7.279	-7.201	10.240	6.410	9.746	11.665
Bus34	0.480	7.636	-6.822	10.239	2.939	-5.606	6.329	-5.908	-6.613	8.867	5.192	8.694	10.127
Bus35	0.480	8.105	-7.855	11.287	3.255	-6.345	7.131	-6.802	-7.019	9.775	5.986	9.401	11.145
Bus36	0.480	8.179	-8.040	11.469	3.309	-6.478	7.275	-6.963	-7.083	9.933	6.129	9.519	11.322
Bus37	0.480	7.709	-6.969	10.392	2.985	-5.711	6.444	-6.035	-6.676	9.000	5.305	8.800	10.275
Bus38	0.480	7.620	-6.790	10.206	2.928	-5.583	6.305	-5.880	-6.599	8.839	5.167	8.671	10.094
Bus39	0.480	7.504	-6.568	9.973	2.858	-5.424	6.131	-5.688	-6.499	8.636	4.997	8.508	9.867
Bus40	0.480	8.117	-7.884	11.316	3.263	-6.366	7.154	-6.828	-7.030	9.800	6.009	9.420	11.173
Bus54	0.480	7.819	-7.198	10.627	3.056	-5.875	6.622	-6.233	-6.771	9.203	5.481	8.961	10.505
Bus61	0.480	7.060	-5.792	9.132	2.602	-4.869	5.520	-5.016	-6.115	7.909	4.401	7.902	9.045
Bus63	0.480	6.978	-5.661	8.986	2.557	-4.774	5.416	-4.902	-6.043	7.782	4.300	7.794	8.901
Bus64	0.480	7.444	-6.456	9.854	2.822	-5.344	6.044	-5.591	-6.447	8.534	4.911	8.424	9.751
Bus65	0.480	6.879	-5.506	8.811	2.504	-4.662	5.292	-4.768	-5.957	7.630	4.181	7.663	8.729
Bus66	0.480	6.476	-4.920	8.133	2.297	-4.237	4.819	-4.260	-5.608	7.043	3.731	7.148	8.063
Bus67	0.480	6.403	-4.820	8.015	2.261	-4.164	4.738	-4.175	-5.545	6.941	3.655	7.057	7.947

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 95 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus69	0.480	6.819	-5.415	8.708	2.472	-4.597	5.219	-4.690	-5.906	7.541	4.111	7.586	8.628

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus ID: 10	0.480	0.00147	0.01007	0.01017	0.00147	0.01007	0.01017	0.00137	0.00971	0.00980	0.00000	0.00000	0.00000
Bus ID: 11	0.760	0.00082	0.01024	0.01028	0.00082	0.01024	0.01028	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 12	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 13	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 14	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 15	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 16	0.760	0.00082	0.01024	0.01028	0.00082	0.01024	0.01028	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 17	0.480	0.00164	0.01067	0.01080	0.00164	0.01067	0.01080	0.00147	0.01202	0.01211	0.00000	0.00000	0.00000
Bus1	0.480	0.00865	0.01325	0.01582	0.00865	0.01325	0.01582	0.00865	0.03401	0.03509	0.00000	0.00000	0.00000
Bus3	0.480	0.01122	0.01419	0.01810	0.01122	0.01419	0.01810	0.01130	0.04380	0.04523	0.00000	0.00000	0.00000
Bus15	0.480	0.01218	0.01454	0.01897	0.01218	0.01454	0.01897	0.01229	0.04753	0.04909	0.00000	0.00000	0.00000
Bus16	0.480	0.00975	0.01365	0.01677	0.00975	0.01365	0.01677	0.00978	0.03812	0.03935	0.00000	0.00000	0.00000
Bus21	0.480	0.01216	0.01454	0.01895	0.01216	0.01454	0.01895	0.01227	0.04746	0.04902	0.00000	0.00000	0.00000
Bus22	0.480	0.01473	0.01549	0.02137	0.01473	0.01549	0.02137	0.01494	0.05776	0.05966	0.00000	0.00000	0.00000
Bus23	0.480	0.01568	0.01584	0.02228	0.01568	0.01584	0.02228	0.01593	0.06165	0.06367	0.00000	0.00000	0.00000
Bus24	0.480	0.01325	0.01494	0.01997	0.01325	0.01494	0.01997	0.01340	0.05180	0.05350	0.00000	0.00000	0.00000
Bus33	0.480	0.01566	0.01583	0.02227	0.01566	0.01583	0.02227	0.01591	0.06157	0.06359	0.00000	0.00000	0.00000
Bus34	0.480	0.01917	0.01713	0.02571	0.01917	0.01713	0.02571	0.01958	0.07626	0.07873	0.00000	0.00000	0.00000
Bus35	0.480	0.01675	0.01623	0.02333	0.01675	0.01623	0.02333	0.01705	0.06608	0.06825	0.00000	0.00000	0.00000
Bus36	0.480	0.01637	0.01609	0.02295	0.01637	0.01609	0.02295	0.01665	0.06450	0.06662	0.00000	0.00000	0.00000
Bus37	0.480	0.01879	0.01699	0.02533	0.01879	0.01699	0.02533	0.01918	0.07465	0.07707	0.00000	0.00000	0.00000
Bus38	0.480	0.01926	0.01716	0.02580	0.01926	0.01716	0.02580	0.01967	0.07662	0.07910	0.00000	0.00000	0.00000
Bus39	0.480	0.01987	0.01739	0.02640	0.01987	0.01739	0.02640	0.02031	0.07920	0.08176	0.00000	0.00000	0.00000
Bus40	0.480	0.01669	0.01621	0.02327	0.01669	0.01621	0.02327	0.01698	0.06582	0.06798	0.00000	0.00000	0.00000
Bus54	0.480	0.01823	0.01678	0.02477	0.01823	0.01678	0.02477	0.01859	0.07225	0.07461	0.00000	0.00000	0.00000
Bus61	0.480	0.02229	0.01828	0.02883	0.02229	0.01828	0.02883	0.02286	0.08962	0.09248	0.00000	0.00000	0.00000
Bus63	0.480	0.02275	0.01846	0.02930	0.02275	0.01846	0.02930	0.02335	0.09164	0.09457	0.00000	0.00000	0.00000
Bus64	0.480	0.02018	0.01750	0.02672	0.02018	0.01750	0.02672	0.02064	0.08056	0.08316	0.00000	0.00000	0.00000
Bus65	0.480	0.02333	0.01867	0.02988	0.02333	0.01867	0.02988	0.02396	0.09415	0.09715	0.00000	0.00000	0.00000
Bus66	0.480	0.02578	0.01958	0.03237	0.02578	0.01958	0.03237	0.02655	0.10491	0.10822	0.00000	0.00000	0.00000
Bus67	0.480	0.02624	0.01976	0.03285	0.02624	0.01976	0.03285	0.02704	0.10698	0.11034	0.00000	0.00000	0.00000
Bus69	0.480	0.02368	0.01880	0.03023	0.02368	0.01880	0.03023	0.02432	0.09567	0.09871	0.00000	0.00000	0.00000

Low Voltage 105% Power Factor

Project:		ETAP 24.0.0E	Page:	1
Location:			Date:	11-20-2024
Contract:			SN:	IASTATEPL
Engineer:		Study Case: Low V 105	Revision:	Base
Filename:	AMES_BESS		Config.:	Normal

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 105 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus ID: 10	0.480	4.124	-28.306	28.604	4.130	-28.659	28.955	-24.513	-3.571	24.772	22.445	18.082	28.822
Bus ID: 11	0.760	3.578	-46.910	47.047	3.827	-49.550	49.698	-41.120	-3.078	41.236	-43.495	24.145	49.747
Bus ID: 12	0.760	3.554	-46.925	47.060	3.809	-49.561	49.707	-41.133	-3.057	41.247	-43.503	24.169	49.766
Bus ID: 13	0.760	3.539	-46.938	47.071	3.798	-49.570	49.715	-41.144	-3.045	41.256	-43.510	24.185	49.780
Bus ID: 14	0.760	3.540	-46.936	47.069	3.799	-49.568	49.714	-41.142	-3.046	41.255	-43.509	24.183	49.778
Bus ID: 15	0.760	3.558	-46.922	47.057	3.813	-49.559	49.705	-41.131	-3.061	41.244	-43.501	24.164	49.762
Bus ID: 16	0.760	3.582	-46.908	47.044	3.830	-49.548	49.696	-41.118	-3.082	41.233	-43.493	24.141	49.744
Bus ID: 17	0.480	4.087	-26.633	26.945	3.646	-25.644	25.902	-23.065	-3.539	23.335	21.436	15.900	26.689
Bus1	0.480	10.057	-15.395	18.389	5.228	-12.185	13.259	-13.333	-8.710	15.926	11.776	13.584	17.978
Bus3	0.480	9.975	-12.613	16.081	4.641	-9.924	10.955	-10.923	-8.639	13.926	9.639	12.500	15.785
Bus15	0.480	9.848	-11.761	15.340	4.435	-9.272	10.278	-10.186	-8.528	13.284	8.985	12.108	15.078
Bus16	0.480	10.082	-14.118	17.349	4.975	-11.118	12.181	-12.227	-8.732	15.024	10.796	13.121	16.992
Bus21	0.480	9.850	-11.777	15.354	4.439	-9.285	10.291	-10.200	-8.531	13.297	8.998	12.116	15.091
Bus22	0.480	9.384	-9.866	13.616	3.937	-7.869	8.798	-8.544	-8.127	11.792	7.528	11.112	13.422
Bus23	0.480	9.187	-9.279	13.057	3.771	-7.443	8.344	-8.036	-7.956	11.308	7.076	10.765	12.882
Bus24	0.480	9.669	-10.901	14.571	4.216	-8.628	9.603	-9.441	-8.373	12.619	8.324	11.678	14.341
Bus33	0.480	9.191	-9.290	13.068	3.775	-7.451	8.353	-8.046	-7.959	11.317	7.085	10.772	12.893
Bus34	0.480	8.440	-7.540	11.317	3.248	-6.196	6.996	-6.530	-7.309	9.801	5.738	9.610	11.193
Bus35	0.480	8.958	-8.681	12.475	3.597	-7.013	7.882	-7.518	-7.758	10.803	6.616	10.390	12.318
Bus36	0.480	9.040	-8.887	12.676	3.658	-7.160	8.041	-7.696	-7.829	10.978	6.774	10.522	12.514
Bus37	0.480	8.520	-7.702	11.486	3.299	-6.312	7.122	-6.670	-7.379	9.947	5.863	9.726	11.357
Bus38	0.480	8.422	-7.504	11.280	3.237	-6.171	6.968	-6.499	-7.293	9.769	5.711	9.584	11.157
Bus39	0.480	8.294	-7.259	11.022	3.158	-5.995	6.776	-6.287	-7.183	9.546	5.523	9.403	10.905
Bus40	0.480	8.972	-8.714	12.507	3.607	-7.037	7.907	-7.547	-7.770	10.831	6.642	10.412	12.350
Bus54	0.480	8.642	-7.955	11.746	3.378	-6.493	7.319	-6.890	-7.484	10.172	6.058	9.904	11.610
Bus61	0.480	7.804	-6.402	10.094	2.876	-5.381	6.101	-5.544	-6.758	8.741	4.864	8.734	9.997
Bus63	0.480	7.713	-6.257	9.932	2.826	-5.277	5.986	-5.419	-6.680	8.601	4.753	8.614	9.838
Bus64	0.480	8.228	-7.135	10.891	3.119	-5.907	6.680	-6.179	-7.126	9.432	5.428	9.310	10.777
Bus65	0.480	7.603	-6.085	9.738	2.767	-5.153	5.849	-5.270	-6.584	8.433	4.621	8.470	9.648
Bus66	0.480	7.158	-5.437	8.989	2.538	-4.683	5.327	-4.709	-6.199	7.784	4.124	7.900	8.912
Bus67	0.480	7.077	-5.328	8.859	2.499	-4.603	5.237	-4.614	-6.129	7.672	4.040	7.799	8.784

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 105 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus69	0.480	7.537	-5.985	9.624	2.733	-5.081	5.769	-5.183	-6.527	8.335	4.544	8.385	9.537

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus ID: 10	0.480	0.00147	0.01007	0.01017	0.00147	0.01007	0.01017	0.00137	0.00971	0.00980	0.00000	0.00000	0.00000
Bus ID: 11	0.760	0.00082	0.01024	0.01028	0.00082	0.01024	0.01028	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 12	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 13	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 14	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 15	0.760	0.00081	0.01024	0.01027	0.00081	0.01024	0.01027	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 16	0.760	0.00082	0.01024	0.01028	0.00082	0.01024	0.01028	0.00069	0.00838	0.00841	0.00000	0.00000	0.00000
Bus ID: 17	0.480	0.00164	0.01067	0.01080	0.00164	0.01067	0.01080	0.00147	0.01202	0.01211	0.00000	0.00000	0.00000
Bus1	0.480	0.00865	0.01325	0.01582	0.00865	0.01325	0.01582	0.00865	0.03401	0.03509	0.00000	0.00000	0.00000
Bus3	0.480	0.01122	0.01419	0.01810	0.01122	0.01419	0.01810	0.01130	0.04380	0.04523	0.00000	0.00000	0.00000
Bus15	0.480	0.01218	0.01454	0.01897	0.01218	0.01454	0.01897	0.01229	0.04753	0.04909	0.00000	0.00000	0.00000
Bus16	0.480	0.00975	0.01365	0.01677	0.00975	0.01365	0.01677	0.00978	0.03812	0.03935	0.00000	0.00000	0.00000
Bus21	0.480	0.01216	0.01454	0.01895	0.01216	0.01454	0.01895	0.01227	0.04746	0.04902	0.00000	0.00000	0.00000
Bus22	0.480	0.01473	0.01549	0.02137	0.01473	0.01549	0.02137	0.01494	0.05776	0.05966	0.00000	0.00000	0.00000
Bus23	0.480	0.01568	0.01584	0.02228	0.01568	0.01584	0.02228	0.01593	0.06165	0.06367	0.00000	0.00000	0.00000
Bus24	0.480	0.01325	0.01494	0.01997	0.01325	0.01494	0.01997	0.01340	0.05180	0.05350	0.00000	0.00000	0.00000
Bus33	0.480	0.01566	0.01583	0.02227	0.01566	0.01583	0.02227	0.01591	0.06157	0.06359	0.00000	0.00000	0.00000
Bus34	0.480	0.01917	0.01713	0.02571	0.01917	0.01713	0.02571	0.01958	0.07626	0.07873	0.00000	0.00000	0.00000
Bus35	0.480	0.01675	0.01623	0.02333	0.01675	0.01623	0.02333	0.01705	0.06608	0.06825	0.00000	0.00000	0.00000
Bus36	0.480	0.01637	0.01609	0.02295	0.01637	0.01609	0.02295	0.01665	0.06450	0.06662	0.00000	0.00000	0.00000
Bus37	0.480	0.01879	0.01699	0.02533	0.01879	0.01699	0.02533	0.01918	0.07465	0.07707	0.00000	0.00000	0.00000
Bus38	0.480	0.01926	0.01716	0.02580	0.01926	0.01716	0.02580	0.01967	0.07662	0.07910	0.00000	0.00000	0.00000
Bus39	0.480	0.01987	0.01739	0.02640	0.01987	0.01739	0.02640	0.02031	0.07920	0.08176	0.00000	0.00000	0.00000
Bus40	0.480	0.01669	0.01621	0.02327	0.01669	0.01621	0.02327	0.01698	0.06582	0.06798	0.00000	0.00000	0.00000
Bus54	0.480	0.01823	0.01678	0.02477	0.01823	0.01678	0.02477	0.01859	0.07225	0.07461	0.00000	0.00000	0.00000
Bus61	0.480	0.02229	0.01828	0.02883	0.02229	0.01828	0.02883	0.02286	0.08962	0.09248	0.00000	0.00000	0.00000
Bus63	0.480	0.02275	0.01846	0.02930	0.02275	0.01846	0.02930	0.02335	0.09164	0.09457	0.00000	0.00000	0.00000
Bus64	0.480	0.02018	0.01750	0.02672	0.02018	0.01750	0.02672	0.02064	0.08056	0.08316	0.00000	0.00000	0.00000
Bus65	0.480	0.02333	0.01867	0.02988	0.02333	0.01867	0.02988	0.02396	0.09415	0.09715	0.00000	0.00000	0.00000
Bus66	0.480	0.02578	0.01958	0.03237	0.02578	0.01958	0.03237	0.02655	0.10491	0.10822	0.00000	0.00000	0.00000
Bus67	0.480	0.02624	0.01976	0.03285	0.02624	0.01976	0.03285	0.02704	0.10698	0.11034	0.00000	0.00000	0.00000
Bus69	0.480	0.02368	0.01880	0.03023	0.02368	0.01880	0.03023	0.02432	0.09567	0.09871	0.00000	0.00000	0.00000

Medium Voltage 95% Power Factor

Project:		**ETAP** 24.0.0E	Page: 1
Location:			Date: 11-20-2024
Contract:			SN: IASTATEPL
Engineer:		Study Case: Med V 95	Revision: Base
Filename:	AMES_BESS		Config.: Normal

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 95 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus ID: 1	138.000	1.972	-13.824	13.964	1.653	-11.767	11.882	-11.990	-1.707	12.111	11.295	6.850	13.210
Bus ID: 2	34.500	0.259	-5.212	5.219	0.249	-5.396	5.402	-4.631	-0.220	4.636	4.561	3.084	5.506
Bus ID: 3	34.500	0.351	-5.132	5.144	0.397	-5.284	5.299	-4.551	-0.297	4.561	-4.818	2.513	5.434
Bus ID: 4	34.500	0.338	-5.139	5.150	0.379	-5.297	5.311	-4.558	-0.286	4.567	-4.813	2.532	5.438
Bus ID: 5	34.500	0.322	-5.146	5.156	0.357	-5.313	5.325	-4.566	-0.274	4.575	-4.807	2.554	5.443
Bus ID: 6	34.500	0.313	-5.153	5.162	0.342	-5.324	5.335	-4.573	-0.266	4.581	-4.803	2.569	5.446
Bus ID: 7	34.500	0.314	-5.152	5.161	0.343	-5.322	5.333	-4.572	-0.266	4.580	-4.802	2.567	5.445
Bus ID: 8	34.500	0.325	-5.145	5.155	0.361	-5.309	5.322	-4.565	-0.276	4.573	-4.808	2.549	5.442
Bus ID: 9	34.500	0.341	-5.137	5.149	0.382	-5.294	5.308	-4.557	-0.289	4.566	-4.814	2.528	5.437
Bus7	138.000	1.972	-13.824	13.964	1.653	-11.767	11.882	-11.990	-1.707	12.111	11.295	6.850	13.210
Bus8	138.000	2.469	-19.676	19.830	2.588	-20.622	20.784	-17.040	-2.138	17.174	-18.399	8.694	20.350

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus ID: 1	138.000	0.77257	5.39040	5.44548	0.77257	5.39040	5.44548	1.13424	8.21192	8.28989	0.00000	0.00000	0.00000
Bus ID: 2	34.500	0.19703	3.78705	3.79217	0.19703	3.78705	3.79217	0.14597	3.45947	3.46255	0.00000	0.00000	0.00000
Bus ID: 3	34.500	0.27313	3.84415	3.85384	0.27313	3.84415	3.85384	0.34018	3.53420	3.55053	0.00000	0.00000	0.00000
Bus ID: 4	34.500	0.26258	3.83986	3.84882	0.26258	3.83986	3.84882	0.31691	3.52226	3.53648	0.00000	0.00000	0.00000
Bus ID: 5	34.500	0.25030	3.83486	3.84302	0.25030	3.83486	3.84302	0.28983	3.50836	3.52032	0.00000	0.00000	0.00000
Bus ID: 6	34.500	0.24255	3.83018	3.83785	0.24255	3.83018	3.83785	0.26957	3.49951	3.50988	0.00000	0.00000	0.00000
Bus ID: 7	34.500	0.24336	3.83109	3.83881	0.24336	3.83109	3.83881	0.27134	3.50008	3.51058	0.00000	0.00000	0.00000
Bus ID: 8	34.500	0.25283	3.83588	3.84420	0.25283	3.83588	3.84420	0.29464	3.51179	3.52413	0.00000	0.00000	0.00000
Bus ID: 9	34.500	0.26492	3.84082	3.84995	0.26492	3.84082	3.84995	0.32121	3.52542	3.54002	0.00000	0.00000	0.00000
Bus7	138.000	0.77257	5.39040	5.44548	0.77257	5.39040	5.44548	1.13424	8.21192	8.28989	0.00000	0.00000	0.00000
Bus8	138.000	0.47519	3.78722	3.81692	0.47519	3.78722	3.81692	0.40977	3.26582	3.29143	0.00000	0.00000	0.00000

Medium Voltage 105%

Project:		ETAP	Page:	1
Location:		24.0.0E	Date:	11-20-2024
Contract:			SN:	IASTATEPL
Engineer:		Study Case: Med V 105	Revision:	Base
Filename:	AMES_BESS		Config.:	Normal

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 105 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus ID: 1	138.000	2.180	-15.273	15.427	1.828	-12.991	13.119	-13.237	-1.887	13.371	12.470	7.565	14.585
Bus ID: 2	34.500	0.287	-5.737	5.744	0.276	-5.890	5.897	-5.055	-0.245	5.061	5.002	3.387	6.041
Bus ID: 3	34.500	0.388	-5.649	5.662	0.440	-5.768	5.784	-4.968	-0.330	4.979	-5.289	2.752	5.962
Bus ID: 4	34.500	0.373	-5.656	5.668	0.419	-5.782	5.797	-4.975	-0.318	4.986	-5.283	2.773	5.967
Bus ID: 5	34.500	0.356	-5.664	5.675	0.395	-5.799	5.812	-4.984	-0.304	4.993	-5.276	2.798	5.972
Bus ID: 6	34.500	0.346	-5.671	5.682	0.378	-5.811	5.823	-4.992	-0.295	5.000	-5.271	2.814	5.975
Bus ID: 7	34.500	0.347	-5.670	5.681	0.380	-5.809	5.822	-4.990	-0.296	4.999	-5.271	2.812	5.975
Bus ID: 8	34.500	0.360	-5.662	5.674	0.399	-5.795	5.809	-4.983	-0.307	4.992	-5.277	2.793	5.970
Bus ID: 9	34.500	0.376	-5.654	5.667	0.423	-5.779	5.794	-4.974	-0.321	4.984	-5.284	2.768	5.965
Bus7	138.000	2.180	-15.273	15.427	1.828	-12.991	13.119	-13.237	-1.887	13.371	12.470	7.565	14.585
Bus8	138.000	2.729	-21.747	21.918	2.860	-22.793	22.972	-18.834	-2.363	18.981	-20.336	9.609	22.492

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus ID: 1	138.000	0.77257	5.39040	5.44548	0.77257	5.39040	5.44548	1.13424	8.21192	8.28989	0.00000	0.00000	0.00000
Bus ID: 2	34.500	0.19703	3.78705	3.79217	0.19703	3.78705	3.79217	0.14597	3.45947	3.46255	0.00000	0.00000	0.00000
Bus ID: 3	34.500	0.27313	3.84415	3.85384	0.27313	3.84415	3.85384	0.34018	3.53420	3.55053	0.00000	0.00000	0.00000
Bus ID: 4	34.500	0.26258	3.83986	3.84882	0.26258	3.83986	3.84882	0.31691	3.52226	3.53648	0.00000	0.00000	0.00000
Bus ID: 5	34.500	0.25030	3.83486	3.84302	0.25030	3.83486	3.84302	0.28983	3.50836	3.52032	0.00000	0.00000	0.00000
Bus ID: 6	34.500	0.24255	3.83018	3.83785	0.24255	3.83018	3.83785	0.26957	3.49951	3.50988	0.00000	0.00000	0.00000
Bus ID: 7	34.500	0.24336	3.83109	3.83881	0.24336	3.83109	3.83881	0.27134	3.50008	3.51058	0.00000	0.00000	0.00000
Bus ID: 8	34.500	0.25283	3.83588	3.84420	0.25283	3.83588	3.84420	0.29464	3.51179	3.52413	0.00000	0.00000	0.00000
Bus ID: 9	34.500	0.26492	3.84082	3.84995	0.26492	3.84082	3.84995	0.32121	3.52542	3.54002	0.00000	0.00000	0.00000
Bus7	138.000	0.77257	5.39040	5.44548	0.77257	5.39040	5.44548	1.13424	8.21192	8.28989	0.00000	0.00000	0.00000
Bus8	138.000	0.47519	3.78722	3.81692	0.47519	3.78722	3.81692	0.40977	3.26582	3.29143	0.00000	0.00000	0.00000

Appendix C: Arc Flash Results

Low Voltage 95% Power Factor

Project:		ETAP	Page:	1
Location:		24.0.0E	Date:	12-05-2024
Contract:			SN:	IASTATEPL
Engineer:		Study Case: LV ArcF 95	Revision:	Base
Filename:	AMES_BESS~~		Config.:	Normal

Bus Arc Flash Hazard Analysis Summary

Faulted Bus				Fault Current			Trip Device							
				Bolted Fault (kA)							Arc Flash	Incident	Working	
ID	Nom. kV	Equipment Type	Gap (mm)	Bus	PD	PD Arc Fault (kA)	Source Trip Device ID	Trip (cycle)	Open (cycle)	FCT (cycle)	Boundary (ft)	Energy (cal/cm²)	Distance (in)	Energy Level
Bus ID: 10	0.480	Other	13	22.835	0.305	0.214	Aux EXP	25.83	0.00	25.83	6.8	13.5	18	Level D
Bus ID: 11	0.760	Other	13	38.186						120.00	14.1	42.8	18	Level F
Bus ID: 12	0.760	Other	13	38.195						120.00	14.1	42.8	18	Level F
Bus ID: 13	0.760	Other	13	38.203						120.00	14.1	42.8	18	Level F
Bus ID: 14	0.760	Other	13	38.202						120.00	14.1	42.8	18	Level F
Bus ID: 15	0.760	Other	13	38.193						120.00	14.1	42.8	18	Level F
Bus ID: 16	0.760	Other	13	38.184						120.00	14.1	42.8	18	Level F
Bus ID: 17	0.480	Other	13	22.078	21.149	17.038	Aux Breaker	1.80	0.00	1.80	1.4	1.0	18	Level A
Bus1	0.480	Other	13	15.473	14.802	12.083	Aux Breaker	1.80	0.00	1.80	1.1	0.7	18	Level A
Bus3	0.480	Other	13	13.685	13.087	10.675	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus15	0.480	Other	13	13.101	12.527	10.212	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus16	0.480	Other	13	14.673	14.034	11.455	Aux Breaker	1.80	0.00	1.80	1.0	0.7	18	Level A
Bus21	0.480	Other	13	13.112	12.538	10.221	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus22	0.480	Other	13	11.724	11.208	9.112	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus23	0.480	Other	13	11.273	10.775	8.749	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus24	0.480	Other	13	12.490	11.942	9.725	Aux Breaker	1.80	0.00	1.80	0.9	0.6	18	Level A
Bus33	0.480	Other	13	11.281	10.783	8.756	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus34	0.480	Other	13	9.847	9.409	7.602	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus35	0.480	Other	13	10.798	10.321	8.368	Aux Breaker	1.80	0.00	1.80	0.8	0.5	18	Level A
Bus36	0.480	Other	13	10.963	10.478	8.501	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus37	0.480	Other	13	9.987	9.543	7.715	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus38	0.480	Other	13	9.817	9.380	7.578	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus39	0.480	Other	13	9.603	9.175	7.406	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus40	0.480	Other	13	10.825	10.346	8.390	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus54	0.480	Other	13	10.201	9.748	7.887	Aux Breaker	1.80	0.00	1.80	0.8	0.5	18	Level A
Bus61	0.480	Other	13	8.830	8.434	6.782	Aux Breaker	1.80	0.00	1.80	0.7	0.4	18	Level A
Bus63	0.480	Other	13	8.694	8.304	6.673	Aux Breaker	1.80	0.00	1.80	0.7	0.4	18	Level A
Bus64	0.480	Other	13	9.495	9.071	7.318	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus65	0.480	Other	13	8.532	8.148	6.542	Aux Breaker	1.80	0.00	1.80	0.7	0.4	18	Level A
Bus66	0.480	Other	13	7.900	7.543	6.033	Aux Breaker	1.80	0.00	1.80	0.7	0.3	18	Level A
Bus67	0.480	Other	13	7.789	7.437	5.944	Aux Breaker	1.80	0.00	1.80	0.7	0.3	18	Level A
Bus69	0.480	Other	13	8.436	8.057	6.465	Aux Breaker	1.80	0.00	1.80	0.7	0.4	18	Level A

Bus Incident Energy Summary

Bus			Total Fault Current (kA)		Arc-Flash Analysis Results			
ID	Nom. kV	Type	Bolted	Arcing	FCT (cycles)	Incident E (cal/cm²)	AFB (ft)	Energy Level
Bus ID: 10	0.480	Other	28.604	23.159	1.699	1.296	1.57	Level A
Bus ID: 11	0.760	Other	47.047	32.937	120.000	38.020	13.09	Level E
Bus ID: 12	0.760	Other	47.060	32.944	120.000	38.013	13.09	Level E
Bus ID: 13	0.760	Other	47.071	32.950	120.000	38.008	13.09	Level E
Bus ID: 14	0.760	Other	47.069	32.949	120.000	38.009	13.09	Level E
Bus ID: 15	0.760	Other	47.057	32.943	120.000	38.015	13.09	Level E
Bus ID: 16	0.760	Other	47.044	32.936	120.000	38.021	13.09	Level E
Bus ID: 17	0.480	Other	26.945	21.999	1.783	1.286	1.57	Level A
Bus1	0.480	Other	18.389	15.446	1.800	0.886	1.24	Level A
Bus3	0.480	Other	16.081	13.540	1.800	0.769	1.13	Level A
Bus15	0.480	Other	15.340	12.919	1.800	0.731	1.10	Level A
Bus16	0.480	Other	17.349	14.593	1.800	0.833	1.19	Level A
Bus21	0.480	Other	15.354	12.931	1.800	0.732	1.10	Level A
Bus22	0.480	Other	13.616	11.459	1.800	0.643	1.01	Level A
Bus23	0.480	Other	13.057	10.983	1.800	0.615	0.99	Level A
Bus24	0.480	Other	14.571	12.271	1.800	0.692	1.06	Level A
Bus33	0.480	Other	13.068	10.992	1.800	0.615	0.99	Level A
Bus34	0.480	Other	11.317	9.488	1.800	0.526	0.89	Level A
Bus35	0.480	Other	12.475	10.484	1.800	0.585	0.96	Level A
Bus36	0.480	Other	12.676	10.657	1.800	0.595	0.97	Level A
Bus37	0.480	Other	11.486	9.634	1.800	0.534	0.90	Level A
Bus38	0.480	Other	11.280	9.457	1.800	0.524	0.89	Level A
Bus39	0.480	Other	11.022	9.234	1.800	0.511	0.88	Level A
Bus40	0.480	Other	12.507	10.512	1.800	0.586	0.96	Level A
Bus54	0.480	Other	11.746	9.858	1.800	0.548	0.92	Level A
Bus61	0.480	Other	10.094	8.433	1.800	0.464	0.83	Level A
Bus63	0.480	Other	9.932	8.292	1.800	0.455	0.82	Level A
Bus64	0.480	Other	10.891	9.121	1.800	0.504	0.87	Level A
Bus65	0.480	Other	9.738	8.125	1.800	0.446	0.81	Level A
Bus66	0.480	Other	8.989	7.477	1.800	0.408	0.76	Level A
Bus67	0.480	Other	8.859	7.364	1.800	0.401	0.76	Level A
Bus69	0.480	Other	9.624	8.027	1.800	0.440	0.80	Level A

Low Voltage 105% Power Factor

Project:		ETAP	Page:	1
Location:		24.0.0E	Date:	11-20-2024
Contract:			SN:	IASTATEPL
Engineer:		Study Case: LV ArcF 105	Revision:	Base
Filename:	AMES_BESS		Config.:	Normal

Bus Incident Energy Summary

Bus			Total Fault Current (kA)		Arc-Flash Analysis Results			
ID	Nom. kV	Type	Bolted	Arcing	FCT (cycles)	Incident E (cal/cm²)	AFB (ft)	Energy Level
Bus ID: 10	0.480	Other	28.604	23.159	1.699	1.296	1.57	Level A
Bus ID: 11	0.760	Other	47.047	32.937	120.000	38.020	13.09	Level E
Bus ID: 12	0.760	Other	47.060	32.944	120.000	38.013	13.09	Level E
Bus ID: 13	0.760	Other	47.071	32.950	120.000	38.008	13.09	Level E
Bus ID: 14	0.760	Other	47.069	32.949	120.000	38.009	13.09	Level E
Bus ID: 15	0.760	Other	47.057	32.943	120.000	38.015	13.09	Level E
Bus ID: 16	0.760	Other	47.044	32.936	120.000	38.021	13.09	Level E
Bus ID: 17	0.480	Other	26.945	21.999	1.783	1.286	1.57	Level A
Bus1	0.480	Other	18.389	15.446	1.800	0.886	1.24	Level A
Bus3	0.480	Other	16.081	13.540	1.800	0.769	1.13	Level A
Bus15	0.480	Other	15.340	12.919	1.800	0.731	1.10	Level A
Bus16	0.480	Other	17.349	14.593	1.800	0.833	1.19	Level A
Bus21	0.480	Other	15.354	12.931	1.800	0.732	1.10	Level A
Bus22	0.480	Other	13.616	11.459	1.800	0.643	1.01	Level A
Bus23	0.480	Other	13.057	10.983	1.800	0.615	0.99	Level A
Bus24	0.480	Other	14.571	12.271	1.800	0.692	1.06	Level A
Bus33	0.480	Other	13.068	10.992	1.800	0.615	0.99	Level A
Bus34	0.480	Other	11.317	9.488	1.800	0.526	0.89	Level A
Bus35	0.480	Other	12.475	10.484	1.800	0.585	0.96	Level A
Bus36	0.480	Other	12.676	10.657	1.800	0.595	0.97	Level A
Bus37	0.480	Other	11.486	9.634	1.800	0.534	0.90	Level A
Bus38	0.480	Other	11.280	9.457	1.800	0.524	0.89	Level A
Bus39	0.480	Other	11.022	9.234	1.800	0.511	0.88	Level A
Bus40	0.480	Other	12.507	10.512	1.800	0.586	0.96	Level A
Bus54	0.480	Other	11.746	9.858	1.800	0.548	0.92	Level A
Bus61	0.480	Other	10.094	8.433	1.800	0.464	0.83	Level A
Bus63	0.480	Other	9.932	8.292	1.800	0.455	0.82	Level A
Bus64	0.480	Other	10.891	9.121	1.800	0.504	0.87	Level A
Bus65	0.480	Other	9.738	8.125	1.800	0.446	0.81	Level A
Bus66	0.480	Other	8.989	7.477	1.800	0.408	0.76	Level A
Bus67	0.480	Other	8.859	7.364	1.800	0.401	0.76	Level A
Bus69	0.480	Other	9.624	8.027	1.800	0.440	0.80	Level A

Bus Arc Flash Hazard Analysis Summary

Faulted Bus				Fault Current			Trip Device							
ID	Nom. kV	Equipment Type	Gap (mm)	Bolted Fault (kA) Bus	Bolted Fault (kA) PD	PD Arc Fault (kA)	Source Trip Device ID	Trip (cycle)	Open (cycle)	FCT (cycle)	Arc Flash Boundary (ft)	Incident Energy (cal/cm²)	Working Distance (in)	Energy Level
Bus ID: 10	0.480	Other	13	28.604	0.384	0.311	Fuse24	1.70	0.00	1.70	1.6	1.3	18	Level A
Bus ID: 11	0.760	Other	13	47.047						120.00	13.1	38.0	18	Level E
Bus ID: 12	0.760	Other	13	47.060						120.00	13.1	38.0	18	Level E
Bus ID: 13	0.760	Other	13	47.071						120.00	13.1	38.0	18	Level E
Bus ID: 14	0.760	Other	13	47.069						120.00	13.1	38.0	18	Level E
Bus ID: 15	0.760	Other	13	47.057						120.00	13.1	38.0	18	Level E
Bus ID: 16	0.760	Other	13	47.044						120.00	13.1	38.0	18	Level E
Bus ID: 17	0.480	Other	13	26.945	0.361	0.294	Fuse24	1.78	0.00	1.78	1.6	1.3	18	Level A
Bus1	0.480	Other	13	18.389	17.675	14.846	Aux Breaker	1.80	0.00	1.80	1.2	0.9	18	Level A
Bus3	0.480	Other	13	16.081	15.452	13.010	Aux Breaker	1.80	0.00	1.80	1.1	0.8	18	Level A
Bus15	0.480	Other	13	15.340	14.738	12.412	Aux Breaker	1.80	0.00	1.80	1.1	0.7	18	Level A
Bus16	0.480	Other	13	17.349	16.673	14.025	Aux Breaker	1.80	0.00	1.80	1.2	0.8	18	Level A
Bus21	0.480	Other	13	15.354	14.752	12.424	Aux Breaker	1.80	0.00	1.80	1.1	0.7	18	Level A
Bus22	0.480	Other	13	13.616	13.078	11.007	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus23	0.480	Other	13	13.057	12.540	10.548	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus24	0.480	Other	13	14.571	13.998	11.788	Aux Breaker	1.80	0.00	1.80	1.1	0.7	18	Level A
Bus33	0.480	Other	13	13.068	12.551	10.557	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus34	0.480	Other	13	11.317	10.865	9.109	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus35	0.480	Other	13	12.475	11.979	10.068	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus36	0.480	Other	13	12.676	12.174	10.234	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus37	0.480	Other	13	11.486	11.027	9.249	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus38	0.480	Other	13	11.280	10.829	9.079	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus39	0.480	Other	13	11.022	10.581	8.865	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus40	0.480	Other	13	12.507	12.011	10.094	Aux Breaker	1.80	0.00	1.80	1.0	0.6	18	Level A
Bus54	0.480	Other	13	11.746	11.278	9.465	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus61	0.480	Other	13	10.094	9.687	8.093	Aux Breaker	1.80	0.00	1.80	0.8	0.5	18	Level A
Bus63	0.480	Other	13	9.932	9.531	7.958	Aux Breaker	1.80	0.00	1.80	0.8	0.5	18	Level A
Bus64	0.480	Other	13	10.891	10.455	8.756	Aux Breaker	1.80	0.00	1.80	0.9	0.5	18	Level A
Bus65	0.480	Other	13	9.738	9.345	7.797	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus66	0.480	Other	13	8.989	8.623	7.173	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus67	0.480	Other	13	8.859	8.498	7.065	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A
Bus69	0.480	Other	13	9.624	9.235	7.702	Aux Breaker	1.80	0.00	1.80	0.8	0.4	18	Level A

Medium Voltage 95% Power Factor

ID	kV	Location	Working Distance LL (in)	Total Energy (cal/cm²)	AFB (ft-in)
Bus ID: 1	138	Bus Arc Fault	37.4	70.95	28'2"
Bus ID: 2	34.5	Bus Arc Fault	15	199.84	22'6"
Bus ID: 3	34.5	Bus Arc Fault	15	196.78	22'4"
Bus ID: 4	34.5	Bus Arc Fault	15	197.02	22'4"
Bus ID: 5	34.5	Bus Arc Fault	15	197.29	22'5"
Bus ID: 6	34.5	Bus Arc Fault	15	197.55	22'5"
Bus ID: 7	34.5	Bus Arc Fault	15	197.45	22'5"
Bus ID: 8	34.5	Bus Arc Fault	15	197.19	22'4"
Bus ID: 9	34.5	Bus Arc Fault	15	196.93	22'4"
Bus7	138	Bus Arc Fault	37.4	70.95	28'2"
Bus8	138	Bus Arc Fault	37.4	103.97	34'7"

ETAP

Project :

Engineer :

Location :

Date :

Contract # :

Serial # : ETAP-OTI

Filename : C:\Users\cdustin\OneDrive - Iowa State University\Ames_BESS\BACKUP\AMES_BESS~~.oti

Energy Levels	Final FCT (sec)	FaultType	Total Ia'' (kA)	Total Ibf'' (kA)
Level F	2	3-Phase	13.956	13.965
> Level G	2	3-Phase	5.218	5.222
> Level G	2	3-Phase	5.141	5.148
> Level G	2	3-Phase	5.147	5.153
> Level G	2	3-Phase	5.154	5.16
> Level G	2	3-Phase	5.16	5.166
> Level G	2	3-Phase	5.158	5.165
> Level G	2	3-Phase	5.151	5.158
> Level G	2	3-Phase	5.144	5.152
Level F	2	3-Phase	13.956	13.965
Level G	2	3-Phase	19.816	19.83

Medium Voltage 105% Power Factor

ID	kV	Working Distance LL (in)	Total Energy (cal/cm²)	AFB (ft-in)	Energy Levels
Bus ID: 1	138	37.4	79.01	29'10"	Level F
Bus ID: 2	34.5	15	220.6	23'9"	> Level G
Bus ID: 3	34.5	15	217.31	23'7"	> Level G
Bus ID: 4	34.5	15	217.49	23'7"	> Level G
Bus ID: 5	34.5	15	217.84	23'7"	> Level G
Bus ID: 6	34.5	15	218.11	23'7"	> Level G
Bus ID: 7	34.5	15	218.02	23'7"	> Level G
Bus ID: 8	34.5	15	217.74	23'7"	> Level G
Bus ID: 9	34.5	15	217.46	23'7"	> Level G
Bus7	138	37.4	79.01	29'10"	Level F
Bus8	138	37.4	116.2	36'9"	Level G

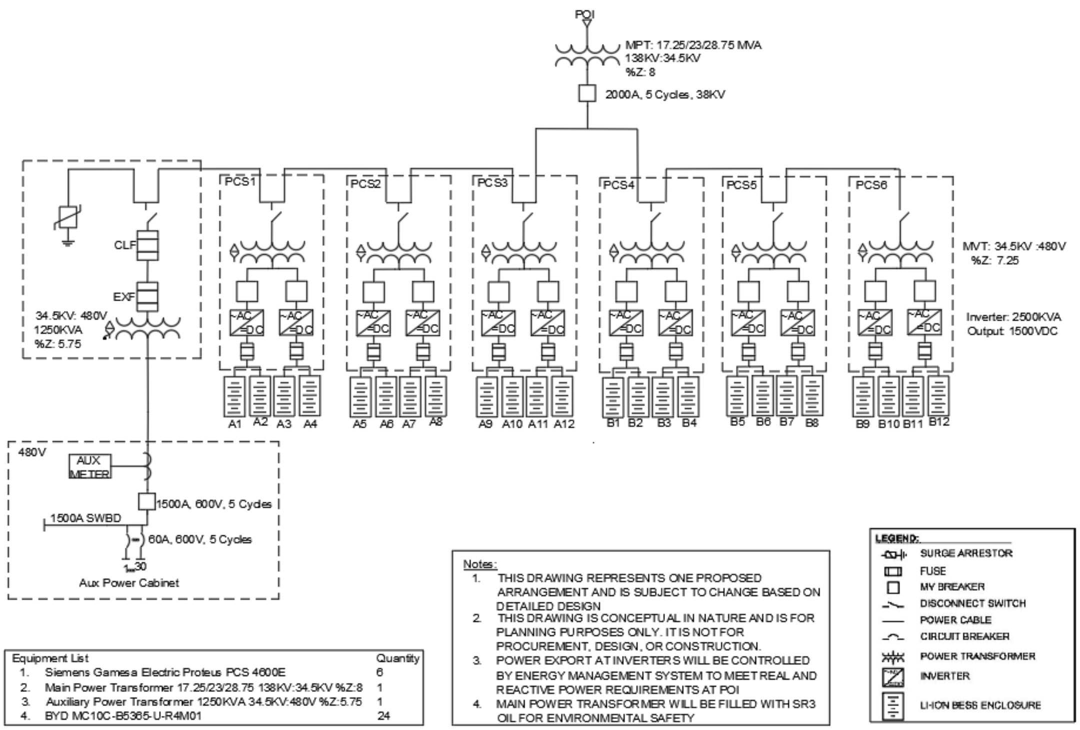
ETAP

Project :
Location :
Contract # :
Filename : C:\Users\cdustin\OneDrive - Iowa State University\Ames_BESS\BACKUP\AMES_BESS~~.oti

Engineer :
Date :
Serial # : ETAP-OTI

Final FCT (sec)	FaultType	Total Ia" (kA)	Total Ibf" (kA)	Output Rpt.	Configuration
2	3-Phase	15.416	15.427	MV ArcF 105	Normal
2	3-Phase	5.738	5.744	MV ArcF 105	Normal
2	3-Phase	5.656	5.662	MV ArcF 105	Normal
2	3-Phase	5.661	5.668	MV ArcF 105	Normal
2	3-Phase	5.669	5.675	MV ArcF 105	Normal
2	3-Phase	5.676	5.682	MV ArcF 105	Normal
2	3-Phase	5.674	5.681	MV ArcF 105	Normal
2	3-Phase	5.667	5.674	MV ArcF 105	Normal
2	3-Phase	5.66	5.667	MV ArcF 105	Normal
2	3-Phase	15.416	15.427	MV ArcF 105	Normal
2	3-Phase	21.903	21.918	MV ArcF 105	Normal

Appendix D: One-line diagram from AutoCAD


POI
MPT: 17.25/23/28.75 MVA
138KV:34.5KV
%Z: 8
2000A, 5 Cycles, 38KV
PCS1
PCS2
PCS3
PCS4
PCS5
PCS6
CLF
EXF
34.5KV: 480V
1250KVA
%Z: 5.75
MVT: 34.5KV :480V
%Z: 7.25
Inverter: 2500KVA
Output: 1500VDC
AC
DC
A1 A2 A3 A4
A5 A6 A7 A8
A9 A10 A11 A12
B1 B2 B3 B4
B5 B6 B7 B8
B9 B10 B11 B12
480V
AUX
METER
1500A, 600V, 5 Cycles
1500A SWBD
60A, 600V, 5 Cycles
1 30
Aux Power Cabinet
Equipment List
Quantity
1. Siemens Gamesa Electric Proteus PCS 4600E 6
2. Main Power Transformer 17.25/23/28.75 138KV:34.5KV %Z:8 1
3. Auxiliary Power Transformer 1250KVA 34.5KV:480V %Z:5.75 1
4. BYD MC10C-B5365-U-R4M01 24
Notes:
1. THIS DRAWING REPRESENTS ONE PROPOSED ARRANGEMENT AND IS SUBJECT TO CHANGE BASED ON DETAILED DESIGN
2. THIS DRAWING IS CONCEPTUAL IN NATURE AND IS FOR PLANNING PURPOSES ONLY. IT IS NOT FOR PROCUREMENT, DESIGN, OR CONSTRUCTION.
3. POWER EXPORT AT INVERTERS WILL BE CONTROLLED BY ENERGY MANAGEMENT SYSTEM TO MEET REAL AND REACTIVE POWER REQUIREMENTS AT POI
4. MAIN POWER TRANSFORMER WILL BE FILLED WITH SR3 OIL FOR ENVIRONMENTAL SAFETY
LEGEND:
SURGE ARRESTOR
FUSE
MV BREAKER
DISCONNECT SWITCH
POWER CABLE
CIRCUIT BREAKER
POWER TRANSFORMER
INVERTER
LI-ION BESS ENCLOSURE

Appendix E: Input Data

Gamesa Electric Proteus Inverter Datasheet

Proteus PCS-E Battery Inverters	Gamesa Electric Proteus PCS 4180E	Gamesa Electric Proteus PCS 4360E	Gamesa Electric Proteus PCS 4600E	Gamesa Electric Proteus PCS 4910E	Gamesa Electric Proteus PCS 5150E
DC Input					
DC Minimum Voltage for grid tied mode[1]	976 V	1018 V	1075 V	1146 V	1202 V
DC Maximum Voltage	1500 V				
Number of Independent Power Modules per PCS	2, not galvanically isolated				
Max. DC Current	2 x 2227 A				
Number of Fused DC Inputs per Power Module/Total[2]	Up to 3+ & 3- / 6+ & 6-				
Max. DC short-circuit withstanding capability	2 x 250kA, 3ms Double DC bus configuration 1 x 250kA, 3ms Single DC bus configuration				
AC Output					
Number of Phases	Three-phase w/o neutral point				
Nominal AC Power Total @25°C [77°F], 1500VDC	4446 kVA	4639 kVA	4897 kVA	5219 kVA	5477 kVA
Nominal AC Power Total @40°C [104°F], 1500VDC	4183 kVA	4365 kVA	4607 kVA	4910 kVA	5153 kVA
Nominal AC Power Total @40°C [104°F], 1300VDC	4541 kVA	4739 kVA	5002 kVA	5331 kVA	5595 kVA
Nominal AC Voltage[2]	690 Vrms	720 Vrms	760 Vrms	810 Vrms	850 Vrms
Nominal Voltage Allowance Range[2]	+/-10%				
Frequency Range[2]	47.5-53 Hz // 57-63 Hz				
THD of AC Current	<1% @Sn				
Power Factor Range[3]	0 (lagging) - 1- 0 (leading)				
Performance					
Efficiency	99,00%				
Stand-by Power Consumption	< 200 W				
General Data					
Temperature Range - Operation	-20°C / +60°C [-4°F / +140°F]				
Maximum Altitude[4]	< 2,000 m [6,561 ft] (w/o derating)				
Cooling System	Liquid & forced air				
Relative Humidity	4% – 100% (w/o condensation)				
Seismic[2]	Zone 4 IBC 2012				
Max. wind speed[2]	288 km/h (179 mph)				
Snow load[2]	2,5 kN/m²				
Protection Class	IP55 class 1, NEMA3R				
Dimensions (W/H/D)	4,325 x 2,255 x 1,022 mm [170.3" x 88.5" x 40.2"]				
Weight	4,535 kg [10,000 lb]				
AC Protections					
AC Side Disconnection & Short-circuit Current Protection	Two motorized AC circuit breakers - one per each power module				
AC Overvoltage Protection	Type 1 + 2 SPD				
Anti-islanding	Included (SW)				
Grid Voltage Fluctuations (LVRT, HVRT)[2]	Included (SW)				
Frequency Failure	Included (SW)				
DC Protections					
DC Disconnections	Two motorized DC switches (on-load) - one per each power module				
DC Short-circuit Protection	DC fast fuses (optional)				
DC Over-voltage Protection	Type 1 + 2 SPD				
Reverse Polarity Detection	Included				
DC Ground Fault and Insulation Detection	Included				
Other Protections					
Over-temperature Protection	Included				
Emergency Push Button	Included				
Communications					
Control[2]	Modbus TCP/IP				
Monitoring[2]	Modbus TCP/IP				
Webserver	Included				

Optionals
Low Temperature Kit to up to -30°C [-22°F]
Factory-fitted DC fuses
Factory-fitted joint DC inputs
Enhanced corrosion protection

Standards/Directives[5]			
IEC 62109-1	IEC 62920	IEC 60529	NEC 2020
IEC 62109-2	UL 62109-1	IEC 61727	CEA 2007
IEC 61000-6-2/4	IEC 62116	NTS 631 v1.1 SENP, v2.1 SEPE	Rule 14, Rule 21
IEEE 1547	IEC 61683	UL 1741-SA	PRC 024
EN 55011	IEEE 519	CSA C22.2	

(1) At nominal AC voltage. Consult Gamesa Electric for other options
(2) Consult Gamesa Electric for a especific configuration
(3) Consult P-Q chart
(4) Up to 4,000m [13,123 ft] with derating as optional
(5) Consult Gamesa Electric for more details

GamesaElectric | Shaping New Energy

System Parameter

System Type	MC10C-B5365-U-R4M01	MC10C-B4659-U-R2M01
DC Data		
Cell type	LFP	LFP
Pack type	1P416S	1P416S
System configuration	10 × 1P416S	10 × 1P416S
Battery capacity (BOL)	5365kWh	4659kWh
DC usable energy (BOL)@FAT	5099kWh	4382kWh
DC usable energy (BOL)@SAT	4946kWh	4251kWh
Battery voltage range	1081.6 ~ 1497.6	1081.6 ~ 1497.6
Nominal power	1236kW	2125kW
General Data		
Dimensions (W×D×H)	6058×2438×2896mm	6058×2438×2896mm
Weight	≤42252kg	≤42252kg
IP rating	IP55	IP55
Ambient operating temperature range	-30℃ ~ +55℃【1】	-30℃ ~ +55℃【1】
Relative humidity	5% ~ 100%	5% ~ 100%
Max. working altitude	＜2000m【2】	＜2000m【2】
Cooling concept	Smart air cooling	Liquid cooling
Noise	≤75dBA	≤75dBA
Fire suppression system	With fire alarm system (Aerosol)	With fire alarm system (Aerosol)
Auxiliary power interface	AC480V/60Hz, 3 Phase 4 wire	AC480V/60Hz, 3 Phase 4 wire
Auxiliary system peak power requirement @45℃, PF0.8	38kVA	75kVA
Communication interfaces	Ethernet	Ethernet
Communication protocols	Modbus TCP/IP	Modbus TCP/IP
Standard color	RAL 9003	RAL 9003
Compliance	UN3536, UL9540A, UL9540	

Note:

【1】Power derating is performed when the ambient temperature is below -15℃ or above +45℃.

【2】Power derating is performed when the altitude is between 2000-3000m.

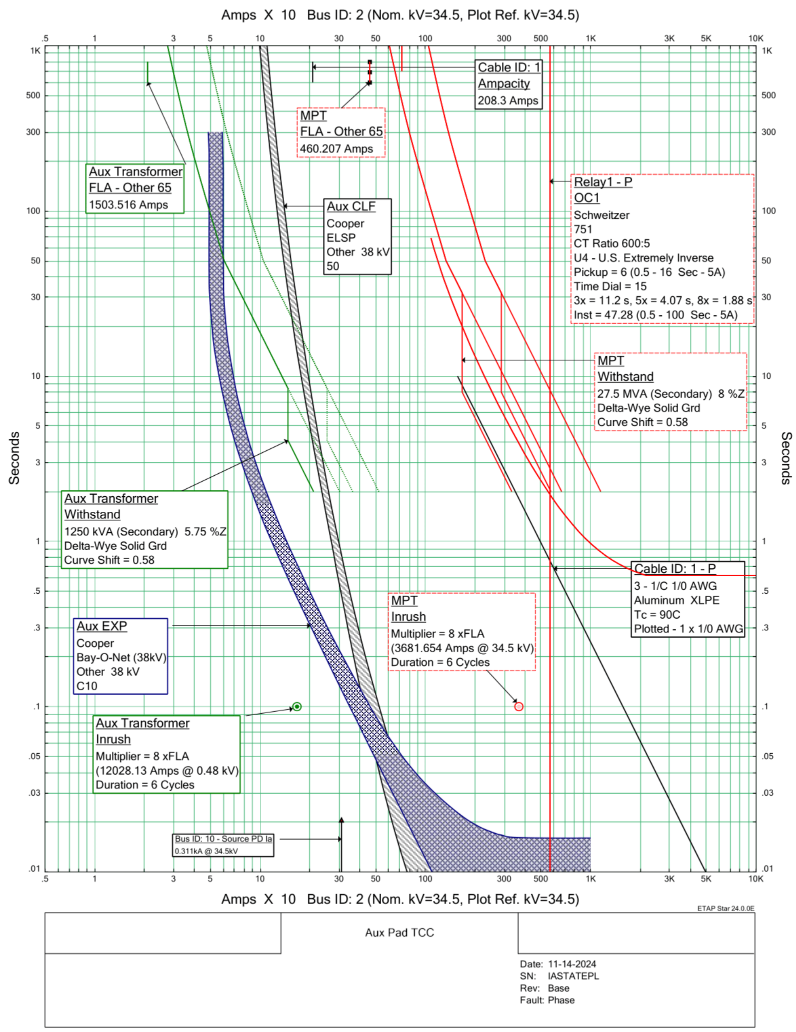
Cable Schedule

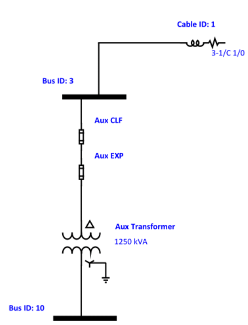
Cable ID	Current flow	From	To	Description	Conductor Size	Length	Conductors per phase	Qty	Raceway Length
1	20.918 A	Surge Arrestor	PCS1	Fuse/ Surge Arrestor	1/0	45.57 ft	1	3	29.57 ft
2	98.016 A	PCS1	PCS2	inveter cable	1/0	53.02 ft	1	3	37.02 ft
3	175.112 A	PCS2	PCS3	inverter cable	3/0	53.02 ft	1	3	37.02 ft
4	252.209 A	PCS3	Substation Breaker	Home Run 1	350 kcmil	563.99 ft	1	3	547.99 ft
5	231.291 A	Substaion Breaker	PCS 4	Home Run 2	350 kcmil	572.05 ft	1	3	556.05 ft
6	154.194 A	PCS4	PCS5	PCS4	2/0	53.02 ft	1	3	37.02 ft
7	77.097 A	PCS5	PCS6	PCS5	1/0	53.02 ft	1	3	37.02 ft
8	1274A	Inverter	Battery B12	DC Battery B12	500 Kcmil	30.86 ft	4	4	16.86 ft
9	1274A	Inverter	Battery B11	DC Battery B11	500 Kcmil	74.19 ft	4	4	60.19 ft
10	1274A	Inverter	Battery B10	DC Battery B10	500 Kcmil	72.62 ft	4	4	58.62 ft
11	1274A	Inverter	Battery B09	DC Battery B09	500 Kcmil	24.03 ft	4	4	10.03 ft
12	1274A	Inverter	Battery B08	DC Battery B08	500 Kcmil	30.86 ft	4	4	16.86 ft
13	1274A	Inverter	Battery B07	DC Battery B07	500 Kcmil	74.19 ft	4	4	60.19 ft
14	1274A	Inverter	Battery B06	DC Battery B06	500 Kcmil	72.62 ft	4	4	58.62 ft
15	1274A	Inverter	Battery B05	DC Battery B05	500 Kcmil	24.03 ft	4	4	10.03 ft
16	1274A	Inverter	Battery B04	DC Battery B04	500 Kcmil	30.86 ft	4	4	16.86 ft
17	1274A	Inverter	Battery B03	DC battery B03	500 Kcmil	74.19 ft	4	4	60.19 ft
18	1274A	Inverter	Battery B02	DC Battery B02	500 Kcmil	72.62 ft	4	4	58.62 ft
19	1274A	Inverter	Battery B01	DC Battery B01	500 Kcmil	24.03 ft	4	4	10.03 ft
20	1274A	Inverter	Battery A12	DC Battery A12	500 Kcmil	30.86 ft	4	4	16.86 ft
21	1274A	Inverter	Battery A11	DC Battery A11	500 Kcmil	74.19 ft	4	4	60.19 ft
22	1274A	Inverter	Battery A10	DC Battery A10	500 Kcmil	72.62 ft	4	4	58.62 ft
23	1274A	Inverter	Battery A09	DC Battery A09	500 Kcmil	24.03 ft	4	4	10.03 ft
24	1274A	Inverter	Battery A08	DC Battery A08	500 Kcmil	30.86 ft	4	4	16.86 ft
25	1274A	Inverter	Battery A07	DC Battery A07	500 Kcmil	74.19 ft	4	4	60.19 ft
26	1274A	Inverter	Battery A06	DC Battery A06	500 Kcmil	72.62 ft	4	4	58.62 ft
27	1274A	Inverter	Battery A05	DC Battery A05	500 Kcmil	24.03 ft	4	4	10.03 ft
28	1274A	Inverter	Battery A04	DC Battery A04	500 Kcmil	30.86 ft	4	4	16.86 ft
29	1274A	Inverter	Battery A03	DC Battery A03	500 Kcmil	74.19 ft	4	4	60.19 ft
30	1274A	Inverter	Battery A02	DC Battery A02	500 Kcmil	72.62 ft	4	4	58.62 ft
31	1274A	Inverter	Battery A01	DC Battery A01	500 Kcmil	24.03 ft	4	4	10.03 ft
32	1820A	Aux Transformer	Aux Equipment pad	Auxilary Equipment pad	1000 Kcmil	40 ft	4	4	24 ft
33	54.84A	Aux Cable C1	Battery A01	Aux Power Cabinet C1	1/0		4	1	
34	54.84A	Aux Cable C2	Battery A02	Aux Power Cabinet C2	1/0		1	1	
35	54.84A	Aux Cable C3	Battery A03	Aux Power Cabinet C3	1/0		1	1	
36	54.84A	Aux Cable C4	Battery A04	Aux Power Cabinet C4	1/0		1	1	
37	54.84A	Aux Cable C6	Battery A05	Aux Power Cabinet C6	1/0		1	1	
38	54.84A	Aux Cable C7	Battery A06	Aux Power Cabinet C7	1/0		1	1	
39	54.84A	Aux Cable C8	Battery A07	Aux Power Cabinet C8	1/0		1	1	
40	54.84A	Aux Cable C9	Battery A08	Aux Power Cabinet C9	1/0		1	1	
41	54.84A	Aux Cable C11	Battery A09	Aux Power Cabinet C11	1/0		1	1	
42	54.84A	Aux Cable C12	Battery A10	Aux Power Cabinet C12	1/0		1	1	
43	54.84A	Aux Cable C13	Battery A11	Aux Power Cabinet C13	1/0		1	1	
44	54.84A	Aux Cable C14	Battery A12	Aux Power Cabinet C14	1/0		1	1	
45	54.84A	Aux Cable C16	Battery B01	Aux Power Cabinet C15	1/0		1	1	
46	54.84A	Aux Cable C17	Battery B02	Aux Power Cabinet C17	1/0		1	1	
47	54.84A	Aux Cable C18	Battery B03	Aux Power Cabinet C18	1/0		1	1	
48	54.84A	Aux Cable C19	Battery B04	Aux Power Cabinet C19	1/0		1	1	
49	54.84A	Aux Cable C21	Battery B05	Aux Power Cabinet C21	1/0		1	1	
50	54.84A	Aux Cable C22	Battery B06	Aux Power Cabinet C22	1/0		1	1	
51	54.84A	Aux Cable C23	Battery B07	Aux Power Cabinet C23	1/0		1	1	
52	54.84A	Aux Cable C24	Battery B08	Aux Power Cabinet C24	1/0		1	1	
53	54.84A	Aux Cable C26	Battery B09	Aux Power Cabinet C26	1/0		1	1	
54	54.84A	Aux Cable C27	Battery B10	Aux Power Cabinet C27	1/0		1	1	
55	54.84A	Aux Cable C28	Battery B11	Aux Power Cabinet C28	1/0		1	1	
56	54.84A	Aux Cable C29	Battery B12	Aux Power Cabinet C29	1/0		1	1	

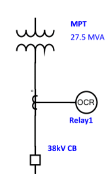
Appendix F: TCC Graphs

Phase and ground for aux and feeder

AUX Pad







Feeder to PCS Skid