ENEL 482 Design Project

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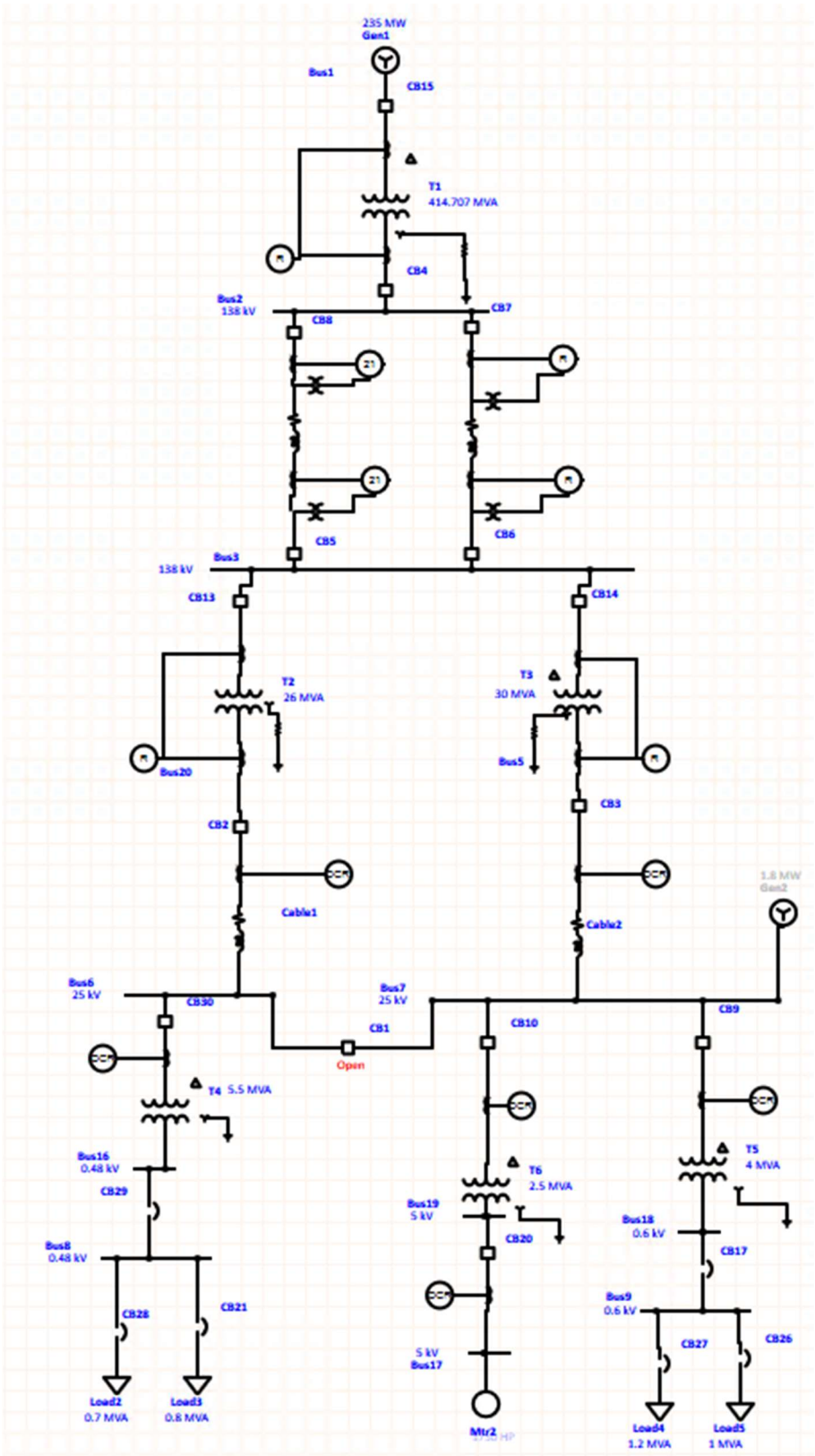
*Continuation of ENEL 472 Design Project

Updated Single Line Diagram:



*Refer to ETAP folder

Design Differential Protection T2 and T3:

Current transformers (CT) selected based on primary and secondary FLA of T2 and T3. If the FLA is 15 A, then pick 20 for CT (same method used for CT sizing for rest of the transformers). Both transformers have a Schweitzer 387A relay for differential protection. T2 primary circuit breaker is the Alstom FX12-145H, and secondary circuit breaker is the Powell 27AT25STD. T3 primary circuit breaker is the Alstom FX12-145L, and the secondary circuit breaker is the 27AT25STD.

Test Differential Protection T2 or T3:
We were not able to test our own system's differential protection but we did learn about programming for the testing differential protection (See Lab 6 pdf).

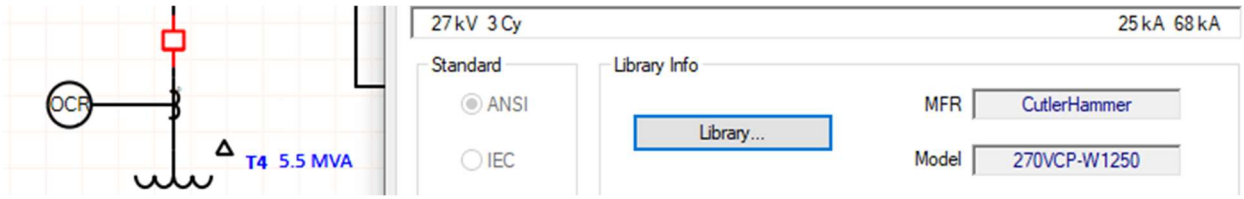
Specify Protection:
All HV (high voltage) transformers have a differential protection with the 387A relays, and HV CBs (circuit breakers) on the primary and secondary of the transformers.

Review of Fault currents and topology:
The tie breaker that is placed in between Bus 6 and Bus 7 is used for backing up the systems in case of no power from T2 or T3. This will affect coordination because of different fault values that may occur when switching on/off the tie breaker. Generator 2 will also come into play for back up power if faults occur on the T2 and T3 transformers, and will also affect the coordination of protection.

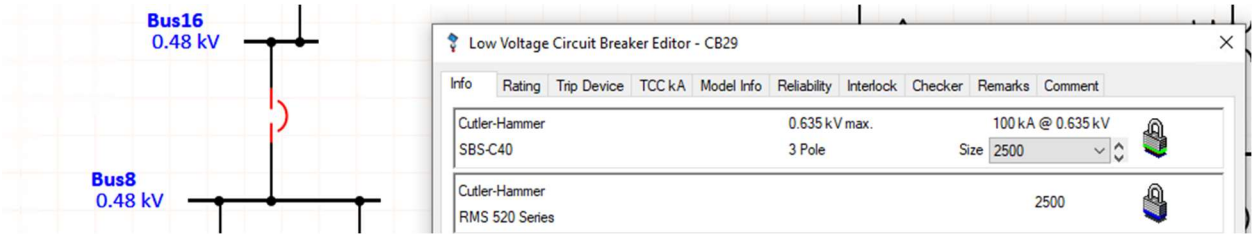
Transmission Line protection design:
From the discussion with Doug, we would use distance protection relay Schweitzer 321. We have not implemented this in our ETAP but ideally there would be two relays per transmission line. A CT would be placed on the primary of the transmission line with a CB above that CT. There should also be a CT on the secondary of the transmission line with a CB on after that CT.

Breaker and protection component design:
The LV (low voltage) transformers have an OCR (overcurrent) protection with the 751A relays and a HV CB on the primary on the transformer. The HV CBs are selected by their interrupting current, rated voltage, and continuous amps. Busses 6 and 7 are protected with OCR 751A relays that operate HV CBs (same CBs used for differential protection of secondary of T2 and T3).

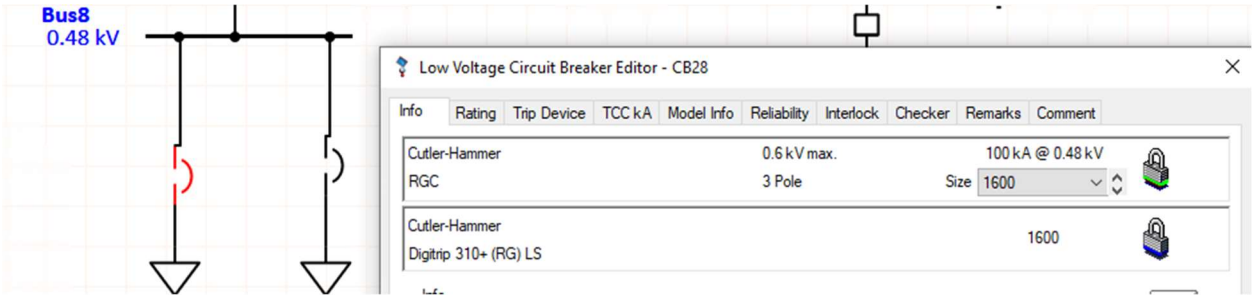
HV CB for T4:



LV Insulated CB for Bus 8:



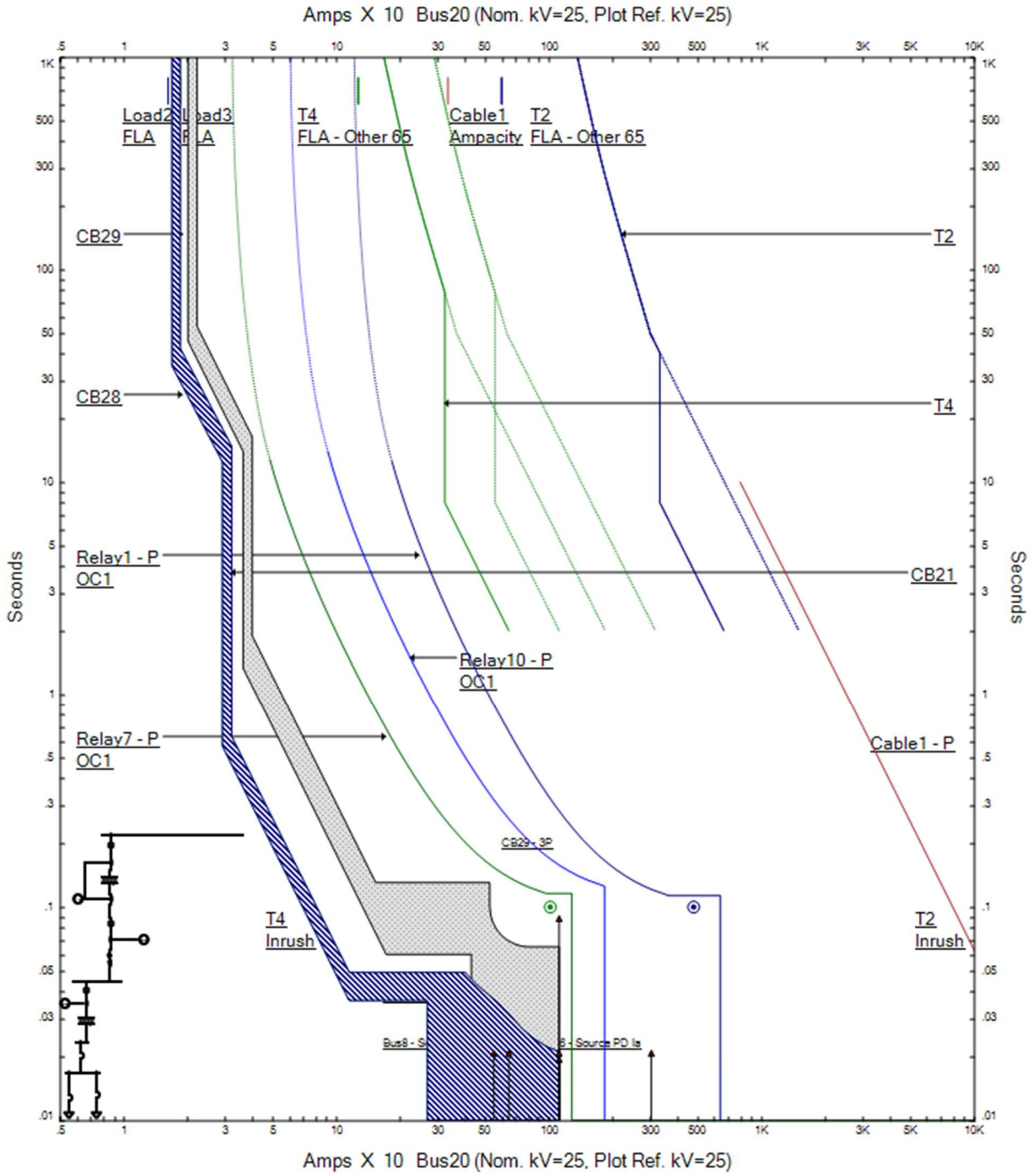
LV Molded Case CB for Load 2:

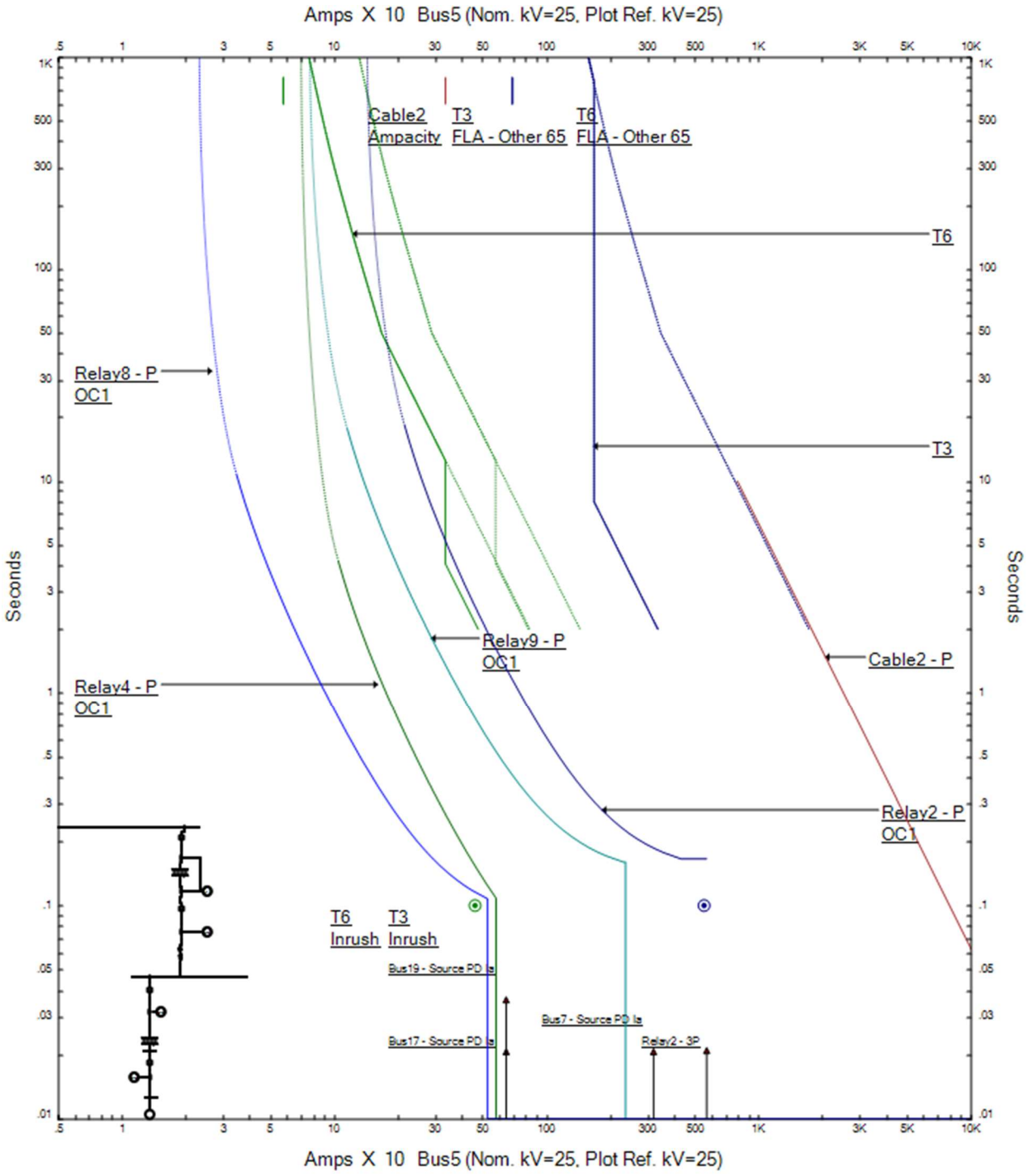


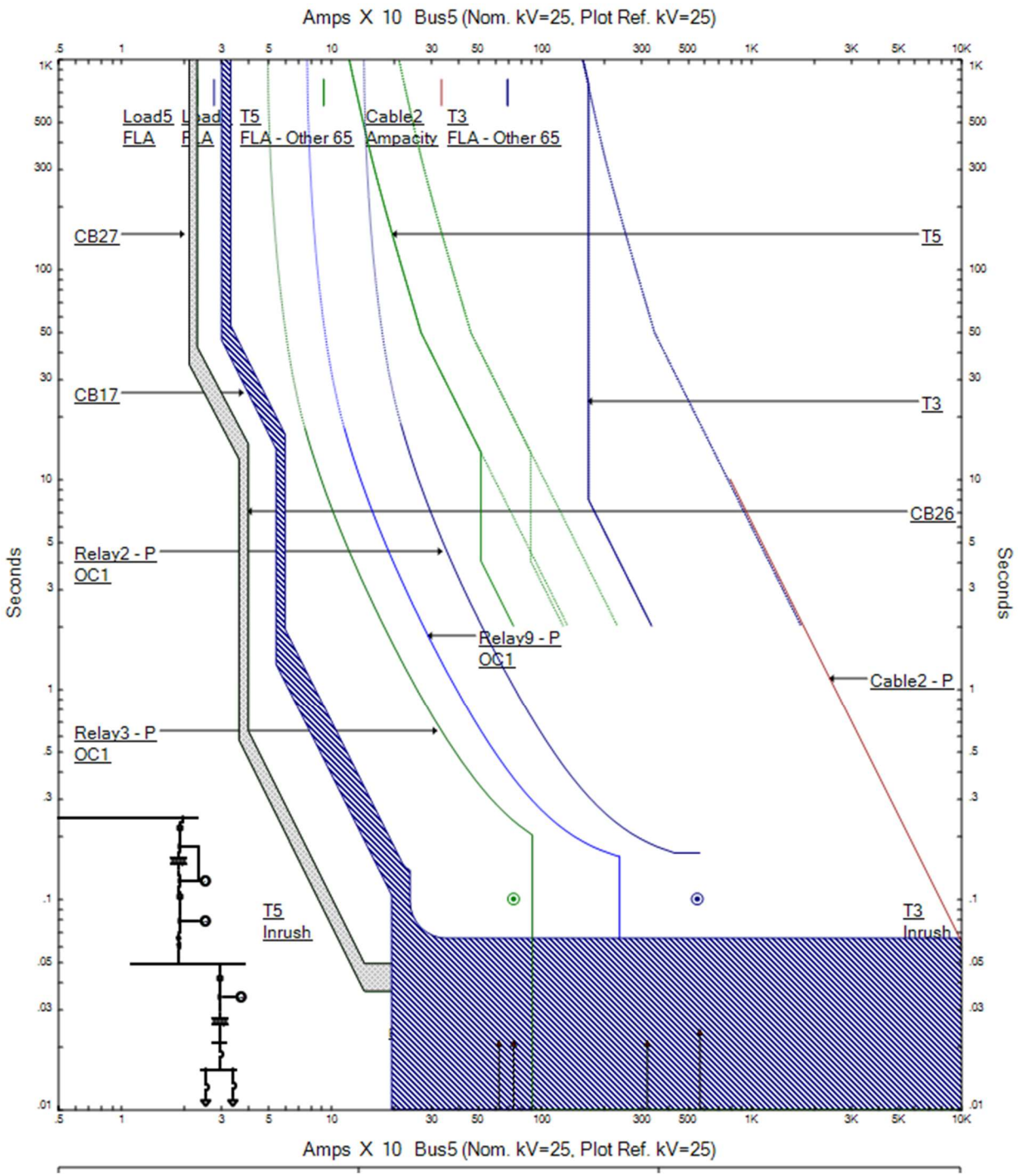
These protections were also implemented for the rest of the loads and busses that are connected to the LV transformers. The breaker sizing was 1.25x the operating current of the load/bus. Example, Bus 8 has a load flow of 1812.9 Amps and the CB that is protecting it is 1.25x that current. Insulated CBs are used for the protection of the bus that power the loads, and Molded Case CBs are used for the protection of the loads. Motor load should have a motor protection relay.

Protection Coordination:

Fault clearing starts from closest protection device to furthest device until fault is cleared. Since the distance relays, and the differential relay for T1 has not been implemented (only been designed) I have not included them in the time current curves below, otherwise those protections should be coordinated. Motor at Bus17 produces current back into the system when Bus19 is faulted, hence why Relay 8 actives CB20.


Amps X 10 Bus20 (Nom. kV=25, Plot Ref. kV=25)
Seconds
Load2 FLA
Load3 FLA
T4 FLA - Other 65
Cable1 Ampacity
T2 FLA - Other 65
CB29
CB28
Relay1 - P OC1
Relay7 - P OC1
Relay10 - P OC1
T2
T4
CB21
Cable1 - P
T4 Inrush
T2 Inrush
CB29 - 3P
Amps X 10 Bus20 (Nom. kV=25, Plot Ref. kV=25)


Amps X 10 Bus5 (Nom. kV=25, Plot Ref. kV=25)
Seconds
Cable2 Ampacity
T3 FLA - Other 65
T6 FLA - Other 65
T6
T3
Relay8 - P OC1
Relay9 - P OC1
Relay4 - P OC1
Cable2 - P
Relay2 - P OC1
T6 Inrush
T3 Inrush
Bus19 - Source PD Is
Bus17 - Source PD Is
Bus7 - Source PD Is
Relay2 - 3P
Amps X 10 Bus5 (Nom. kV=25, Plot Ref. kV=25)


Amps X 10 Bus5 (Nom. kV=25, Plot Ref. kV=25)
Load5 FLA
T5 FLA - Other 65
Cable2 Ampacity
T3 FLA - Other 65
CB27
T5
CB17
T3
CB26
Relay2 - P OC1
Relay9 - P OC1
Cable2 - P
Relay3 - P OC1
T5 Inrush
T3 Inrush
Seconds
Seconds
Amps X 10 Bus5 (Nom. kV=25, Plot Ref. kV=25)

Incident Energy Report:

See attached IncidentEnergy.pdf

Incident Energy:
Calculations were done during assignment 6 for the far bottom left transformer.
See Attached Calculations.pdf

The calculations show the incident energy of the blind side of the transformer and of the load bus. After re-coordination of the left side, the blind side incident energy decreased because of the new CB and OCR settings. The bus incident energy slightly increased but allowed for the entire left side to be coordinated properly. I reduced the incident energy by reducing fault clearing times but there are more methods that can be implemented such as, increasing working distances and grounding resistances (dependent on voltage of systems).

Mitigation Strategies:
Optimized Coordination: reducing operation time for protective devices with proper coordination. (Implemented in ETAP)

Differential Protection: Switch OCR with Differential protection on T4. This will reduce IE significantly compared to just optimizing coordination.

Maintenance Mode Operation: We implement this with molded case circuit breakers. Once the plant is running, a secondary setting on our LVCB lets us trip on a faster time with the exception of the transformer inrush current. (Lower TTC for CB29 for instantaneous trip)

Arc flash detection/relaying: Attaching a fiber optic cable to detect light additionally to arc current detection. We can use AND logic for the implementation (shown in lab 7 SEL751A Functional Diagram).

Equipment Selection & Equipment specification from suppliers:

See attached EquipmentSelection.xlsx

Relay and Controller Testing:
Due to time constraints and Covid-19 restrictions, we were unable to test our relay and controller. We were shown an example of SEL 387 Relay using Quickest in lab 6.