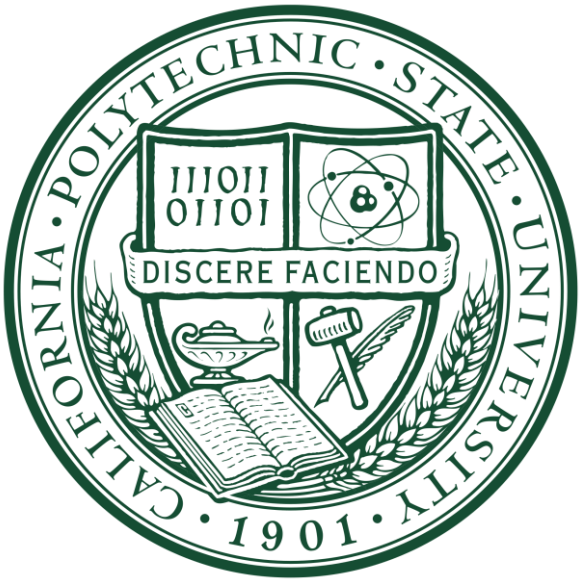
SEL-311L OVERREACHING IMPEDANCE PILOT PROTECTION LABORATORY



BRANDON VAN LOON

SENIOR PROJECT

ELECTRICAL ENGINEERING DEPARTMENT

CALIFORNIA POLYTECHNIC STATE UNIVERSITY

SAN LUIS OBISPO

2015

ACKNOWLEDGEMENTS

I would like to thank Dr. Shaban and Dr. Nafisi for giving me a solid foundation in power systems analysis and protection. Their knowledge and ability to teach has been unparalleled. Thanks to Jaime and the other support staff for the work they do to support the lab equipment and students in their projects.

ABSTRACT

The objective of this senior project is to protect a three terminal transmission line during fault conditions using the SEL-311L microprocessor based relay and communication assisted permissive over-reaching transfer trip protection. The SEL-311L's directional distance elements are programmed to trip on internal faults while faults external to the zones of protection are ignored. Upon sensing a fault condition, the relay issues a trip command to the local breaker and a permissive key for tripping to the remote relay via fiber optic communication. When a permissive key is received and all other permissive conditions have been satisfied, the remote relay issues a trip command to its breaker. Included in this senior project are lab materials for students who wish to complete the lab or for integration into a power protection laboratory in the future. The lab introduces Over-reach concepts and Zone 2 protection. Students gain experience in programming SEL relays, testing protection functionality, and protective relay logic.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION AND BACKGROUND

Implementation of a Permissive Overreaching Transfer Trip protection (POTT) scheme relies on the application of at least two directional distance (21) units. Distance units require monitoring of both current and voltage to determine the impedance of the connected circuit. During low impedance conditions, the relay is programmed to trip the breaker to prevent over-current conditions from damaging the transmission line and connected equipment. To achieve POTT protection, the directional distance units or relays are connected via a communications channel. When either relay detects a fault condition internal to the line, a distance element bit is asserted and the relay waits for a permissive trip signal from the opposite relay. In order to receive the trip signal, the other relay must sense the fault condition, issue the trip signal, and send it via the communications channel. Once both of the distance elements have asserted and the permissive trip or key bits have been asserted, the relays close their respective trip contacts. The trip signal is then sent to the trip coil of the breaker causing the breaker to operate and open. Once both breakers have opened, any fault condition that existed in the protected region of the line is now electrically isolated.

1.1 PROJECT DEVELOPMENT

Dr.Shaban originally developed the idea and gave it to me for further development and implementation. The experiment will hopefully be included in the EE444 or a Power Protection laboratory class and executed by students interested in power systems protection and SEL relays. The project requirements and specifications were developed over a series of conversations with Dr.Shaban. Upon completion of the lab, students will be able to implement POTT and PUTT impedance protection schemes on a tapped multi-source transmission line using the SEL-311L relays and fiber optic communication. In the future, the power faculty hopes to establish an operational micro-grid with the intent of integrating protection and analyzing system functionality when fault conditions appear at different locations in the system. This project represents one piece of that system. The lab's delivery date is June 2015, at which time the lab will be fully documented and operational.

The transmission line consists of 100mH inductors in series with 10Ω power resistors. The line connects to a tapped load comprised of three wye connected power resistors. System breakers were available and chosen based on past student design. The breaker boxes consist of manual trip/close contacts and a three-pole contactor which simulates the fast operation of a high-voltage circuit breaker. The circuit breaker can be automatically operated by connecting the SEL relay to the appropriate coil contacts. The source(s) are three-phase at 208VLL which is available at all of the lab benches in the power labs.

My knowledge of power protection was minimal at the beginning of this project and required me to rely on the SEL-311L instruction manuals provided by Schweitzer Engineering Laboratories (SEL). SEL produces thorough documentation for their relays including application notes on advanced configurations such as POTT and PUTT. SEL allows students to enroll in a Computer Based Training (CBT 101) to gain basic familiarity with their relaying system. The CBT allowed me to understand the fundamentals of communicating and programming the relay. The department was able to purchase CBT 104 which further introduced relay logic programming. Dr. Shaban's EE518 class notes, and *Protective Relaying Principles, and Applications 4th Edition*, by J. L. Blackburn, and T. J. Domin, were heavily utilized as resources for this project [1].

1.2 THEORY OF OPERATION

Distance protection requires measurement of both current and voltage to determine the impedance of a line and connected load at a given time. The impedance for a transmission line network is determined during design phase and is used as a starting point for the design of the distance protection system. The transmission line impedance is a physical quantity that remains generally constant under normal operating conditions. Any impedance detected by the relay lower than 100% of the line impedance indicates a fault condition on that line. The non-directional distance relay zone of protection is represented graphically by Figure 1-1. The diagram consists of a circle centered at zero. The circle's radius represents the complex impedance value at which the relay will pick up and issue a trip. The non-directional nature of this configuration poses a problem for protection engineers because of limitations it poses for coordination. Regardless of whether the low impedance condition is caused by a fault internal to the line or external to the line, the relay will see a low impedance and pickup. This becomes an issue when designing non radial systems, commonly

referred to as loop systems, because the low impedance condition could cause the relay to pick-up and the breaker to open a non-faulted zone. Adding directional capabilities to the relay allows the engineer to design the system so that fault conditions are cleared by the most appropriate protection devices. The appropriate device is that which causes the least amount of system to be disconnected while maintaining system stability. The graphical representation below in figure 1-2 depicts the opening of a non-faulted transmission line.

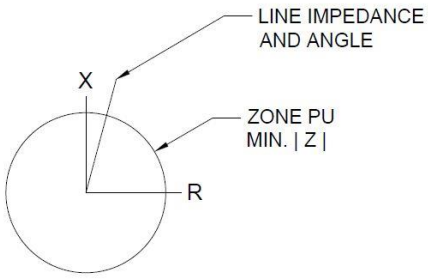


FIGURE 1-1 NON-DIRECTIONAL R-X DIAGRAM

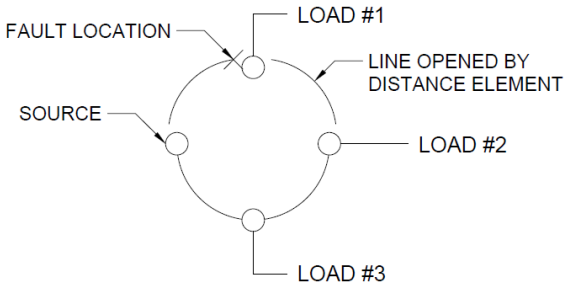


FIGURE 1-2 RING TOPOLOGY

For loop systems (ring topology) and other non-radial systems, adding a directional unit and communication to the distance relay allows the protection engineer to create zones of protection that do not necessarily extend into other devices areas of protection. Multiple zones with varying impedances and time delay settings can be used to create backup protection for other devices close to the line if necessary. Protection for a line is accomplished with two relays who both look towards opposite ends of the transmission line as shown in figure 1-3. Each relay's zone of protection

overlaps. During internal Zone 2 fault conditions, the relays should detect the fault, issue a trip key command to the relay at the opposite end of the line, and assert its own zone 2 element.

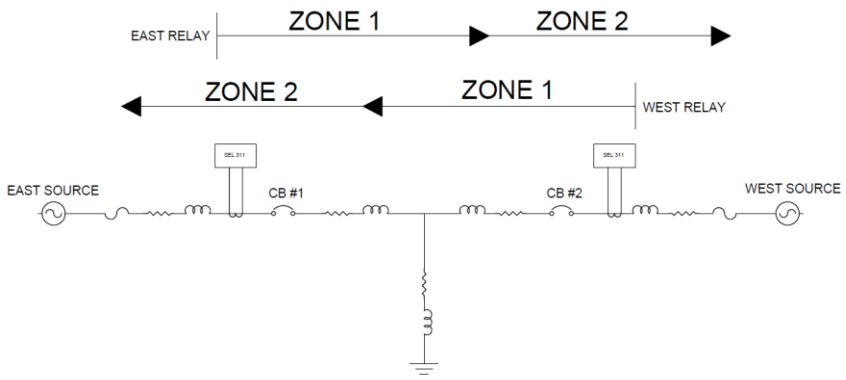


FIGURE 1-3 RELAY ZONES OF PROTECTION

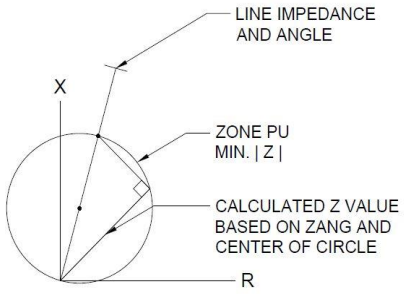


FIGURE 1-4 DIRECTIONAL DISTANCE MHO DIAGRAM

The two most popular schemes for communication assisted distance relaying are POTT and PUTT protection. Permissive Overreaching Transfer Trip requires the distance element (impedance element) to assert as well as receive a trip key command from the relay at the remote end of the line as shown in the logic diagram below. Permissive Under-reaching Transfer Trip scheme is beyone the scope of this project.

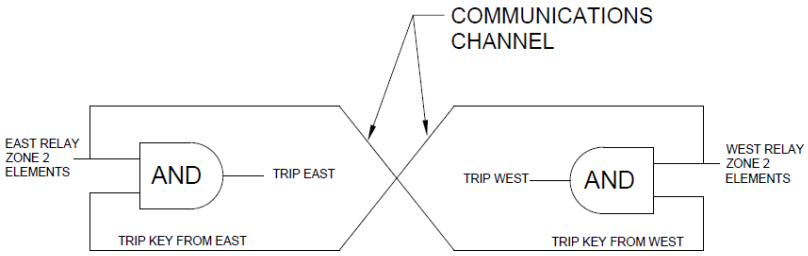


FIGURE 1-5 POTT LOGIC

2 REQUIREMENTS, SPECIFICATIONS, AND BLOCK DIAGRAM

2.1 CUSTOMER REQUIREMENTS

Two separate meetings with Dr. Shaban early this year identified his needs and requirements. The system's main objective is to protect a transmission line using the permissive overreaching transfer trip scheme (POTT). Two SEL311-L relays connected via fiber optic communication protect a transmission line fed from two independent sources. At the center of the line, a third terminal is connected which feeds a wye connected load. The sources will both feed the load under normal load conditions. Fault conditions are then introduced into the system at different nodes internal and external to the transmission line system. Single line to ground (SLG), double line to ground (DLG), line to line (LL), and line to line to line (LLL) fault conditions are applied to the system at the locations specified in Figure 3-1. Faults internal to the transmission line will result in a trip while external faults at the load and beyond the transmission line are ignored. The relays detect Zone 2 faults. All Zone 2 trips will require a permissive trip key from each relay to trip the circuit breakers.

The associated lab materials found in the appendix introduce distance relays and basic relay programming concepts to senior level electrical engineering students. The laboratory allows students to gain hands-on experience with the SEL 311-L relay and implement an operational POTT protection scheme.

The requirements and specifications found below in Table 2-1 are based on the customer needs assessment and follow the IEEE1233 standard for requirements development [3]. Marketing requirements were developed through analyzing the 'Customer Needs Assessment' (1.2). The requirements analyzed and Engineering Specifications developed satisfy marketing and customer requirements. The engineering specifications developed using the IEEE1233-6.2 'Properties of a Requirement' (p.12) [3].

2.2 ENGINEERING SPECIFICATIONS

TABLE 2-1 REQUIREMENTS AND SPECIFICATIONS

Customer Requirements	Engineering Specifications	Justification
2	2.2.1.1 Use Schweitzer Engineering Laboratories relay SEL-311L.	Teaching SEL 311-L is the main objective of the laboratory.
1	2.2.1.2 Use copper wire rated for at least 15 A continuous current or greater.	Minimum gauge of wire provides margin of safety.
1	2.2.1.3 All components have 600V insulation rating or greater.	All lab voltages below 600V. Safety
1	2.2.1.4 Transmission Line model connection points labeled and referenced in accompanying lab manual.	Labeling increases safety and decrease lab setup time. Lab manual reference conveys added information and increases learning efficacy.
1	2.2.1.5 Transmission Line model capable of accepting banana type connectors.	Speeds lab setup. Increases safety through recessing and guarding live parts.
1	2.2.2.1 SEL 311-L relays shall be programmed via Desktop PC over existing serial connection.	Required by equipment manufacturer for connectivity and programming.
1	2.2.2.2 SEL 311-L relays achieves pilot communication via fiber optic communication.	Enables POTT protection. Teaches students about pilot protection and relay communication.
2	2.2.2.3 Laboratory capable of SCADA via SEL-2032 RTAC.	Allows me to further my knowledge about SEL SCADA. Teaches students about relay communication.
2	2.2.2.4 Relay programmed using distance protection.	Enables POTT protection scheme.
2	2.2.2.5 Transmission line ends sourced separately.	Facilitates students learning: over-reach, under-reach, and zone protection.
2, 3	2.2.2.6 Manual fault propagation. Student controlled fault condition and location.	Provides student control. Allows for internal and external fault locations.
2	2.2.2.7 Zone 1 and Zone 2 protection.	Satisfies zone protection requirement
1, 2, 3	2.2.2.8 Low Current (less than 5 A) relay inputs.	Provides margin of safety and prevents relay damage.

2, 3, 4	2.2.4.1 The Laboratory costs less than $500 (not including SEL relays).	Low cost increases lab feasibility decreases EE department economic burden.
1	2.2.5.1 Laboratory designed February 20, 2015.	Milestone facilitates timely graduation.
1	2.2.5.2 Laboratory building begins March 1, 2015.	Milestone facilitates timely graduation.
5, 7	2.2.5.3 Laboratory testing and programming begins April 1, 2015.	Milestone facilitates timely graduation.
8	2.2.5.4 Supporting documentation completed June 12, 2015.	Milestone facilitates timely graduation.
8	2.2.6.1 Student laboratory manual. 2.2.6.2 Instructor laboratory manual.	Facilitates learning and meets customer requirements.

Customer Requirements

1. Senior-level power students build and operate system safely.
2. Teaches students programming concepts related to SEL-311L POTT protection and communication.
3. Introduces over-reach and under-reach concepts.
4. Pilot & zone protection concepts introduced.
5. Completed during three hour lab period.
6. Accompanying lab documentation.
7. Low Cost.
8. Senior Project completed before graduation June 2015.

2.3 BLOCK DIAGRAM LEVEL 0

The level 0 block diagram in Figure 2-1 consists of a single block and describes the basic inputs and outputs from the SEL311-L relay system, breaker, transmission line, and communication system. The left side of the block diagram describes the inputs and outputs from the West end of the Line and the right side describes the inputs and outputs from the East side of the Line. The left and right sides of the diagram contain both voltage and current inputs from the line. These measurements are used to calculate the perceived impedance of the line to determine if fault conditions are present. The top of the block represents relay and device power and communication connections. Relay equipment is powered via 120V AC. Breaker control and contactor voltage is 125V DC. The bottom of the block describes inputs and outputs from the relays and breakers to remote annunciator panels typically found in control rooms and on medium voltage switch gear. Figure 2-2 provides a level two-block diagram view of the system and provides more insight into the physical connection of the

equipment. A fiber optic connection provides a communications path between the relays. Serial connections provide SCADA throughput to peripheral devices.

TABLE 2-2 LEVEL 0 BLOCK DIAGRAM INPUT / OUTPUT FUNCTIONALITY

Input / Output	Functionality
1. West Line Current Input From CT (Ia, Ib, Ic)	Current inputs processed by relay microprocessor and analyzed for presence of fault conditions. (I)
2. West Line Voltage Input From PT (Va, Vb, Vc)	Voltage used in conjunction with current determines line impedance and presence of fault conditions. (I)
3. West Pilot Communication (Tx, Rx)	Communication via fiber optics, ensures high speed tripping and establishes pilot communication capabilities. (IO)
4. West SCADA (Serial)	Establishes information channel and data aggregation for HMI and remote control. (IO)
5. West Trip Alarm Breaker	Provides relay with breaker trip confirmation. (I)
6. West Alarm Breaker	Provides relay with breaker status. (I)
7. East Line Current Input From CT (Ia, Ib, Ic)	Current inputs processed by relay microprocessor and analyzed for presence of fault conditions. (I)
8. East Line Voltage Input From PT (Va, Vb, Vc)	Voltage used in conjunction with current determines line impedance and presence of fault conditions. (I)
9. East Pilot Communication (Tx, Rx)	Communication via fiber optics, ensures high speed tripping and establishes pilot communication capabilities. (IO)
10. East SCADA (Serial)	Establishes information channel and data aggregation for HMI and remote control. (IO)
11. East Trip Alarm Breaker	Provides relay with breaker trip confirmation. (I)
12. East Alarm Breaker	Provides relay with breaker status. (I)
13. Power 120V AC	Power for relay equipment. (I)
14. Station Battery 125VDC	Power for simulate breaker equipment. (I)
15. PC Communication	Provides user serial access programming capabilities. (I)

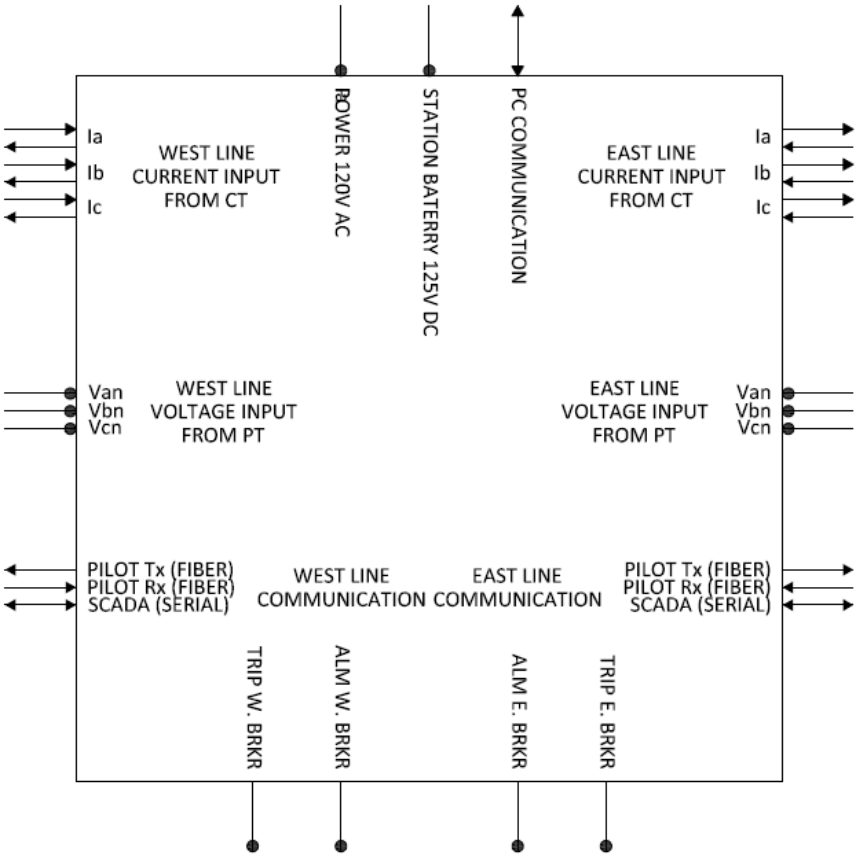


FIGURE 2-1 LEVEL 0 BLOCK DIAGRAM

2.4 BLOCK DIAGRAM LEVEL 1

TABLE 2-3 LEVEL 1 BLOCK DIAGRAM INPUT / OUTPUT FUNCTIONALITY

Input / Output	Functionality
1. West Line Current Input From CT (Ia, Ib, Ic)	Current inputs processed by relay microprocessor and analyzed for presence of fault conditions. (I)
2. West Line Voltage Input From PT (Va, Vb, Vc)	Voltage used in conjunction with current determines line impedance and presence of fault conditions. (I)
3. West Pilot Communication (Tx, Rx)	Communication via fiber optics, ensures high speed tripping and establishes pilot communication capabilities. (IO)
4. West SCADA (Serial)	Establishes information channel and data aggregation for HMI and remote control. (IO)
5. West Trip Alarm Breaker	Provides relay with breaker trip confirmation. (I)
6. West Alarm Breaker	Provides relay with breaker status. (I)
7. East Line Current Input From CT (Ia, Ib, Ic)	Current inputs processed by relay microprocessor and analyzed for presence of fault conditions. (I)
8. East Line Voltage Input From PT (Va, Vb, Vc)	Voltage used in conjunction with current determines line impedance and presence of fault conditions. (I)
9. East Pilot Communication (Tx, Rx)	Communication via fiber optics, ensures high speed tripping and establishes pilot communication capabilities. (IO)
10. East SCADA (Serial)	Establishes information channel and data aggregation for HMI and remote control. (IO)
11. East Trip Alarm Breaker	Provides relay with breaker trip confirmation. (I)
12. East Alarm Breaker	Provides relay with breaker status. (I)
13. Power 120V AC	Power for relay equipment. (I)
14. Station Battery 125VDC	Power for simulate breaker equipment. (I)
15. PC Communication	Provides user serial access programming capabilities. (I)
16. Manual Open / Close (TYP)	Manually opens and closes breaker contactor.
17. Trip / Close (TYP)	Relay Issued trip/close command

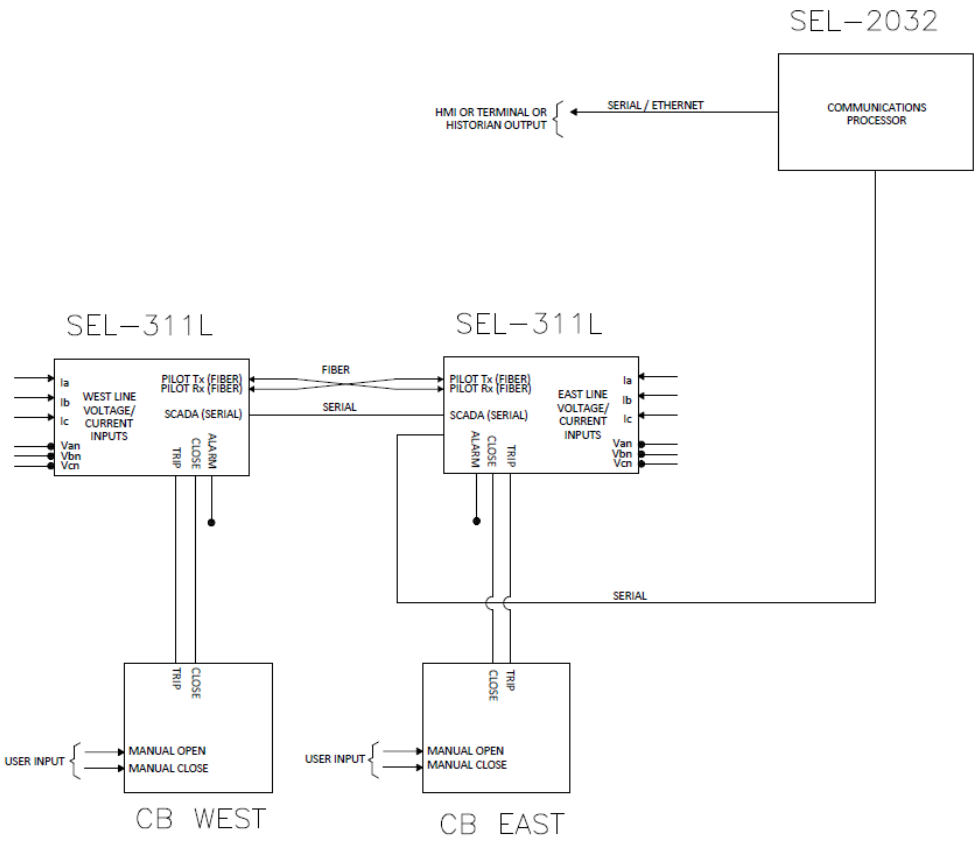


FIGURE 2-2 LEVEL 1 BLOCK DIAGRAM

3 DESIGN

The design began with the development of a single line diagram of the system as shown in Figure 3-1. The single-line diagram identifies the systems main components shows how they are electrically connected.

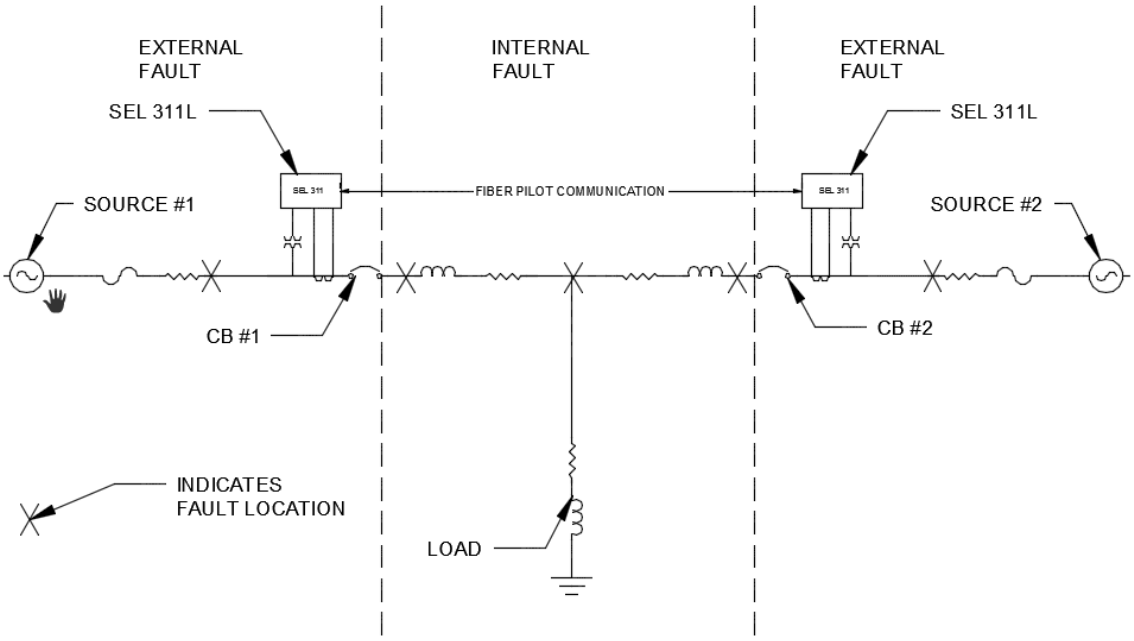


FIGURE 3-1 SINGLE LINE DIAGRAM

The three terminal transmission line network consists of a line and load tapped at the center of the line. The relays are located at the west and east ends and look towards opposite ends of the line. The relays monitor phase current and voltage. The load consists of three wye connected resistor-inductor pairs. Datasheets and instruction manuals for all the equipment in the system was gathered and the nominal system parameters are tabulated in Table 3-1.

TABLE 3-1 TRANSMISSION LINE & LOAD PARAMETERS

West	Resistance (Ω) / phase	Inductance (H) / phase	Inductive Reactance (Ω)
L1	21	200mH	75.698
L2	21	200mH	75.698
L3	21	200mH	75.698
Load	10.5		37.698
Source	10.5		

The impedance seen at a relay is affected by the load conditions on the system. Seven possible load flow states were identified and taken into consideration when designing the system. Figure 3-2 identifies the possible states the system can enter under normal operation. Figure 3-2-A (A) was implemented in the lab. Time did not permit for further in-depth study of the effect of load conditions found in Figure 3-2 on system functionality.

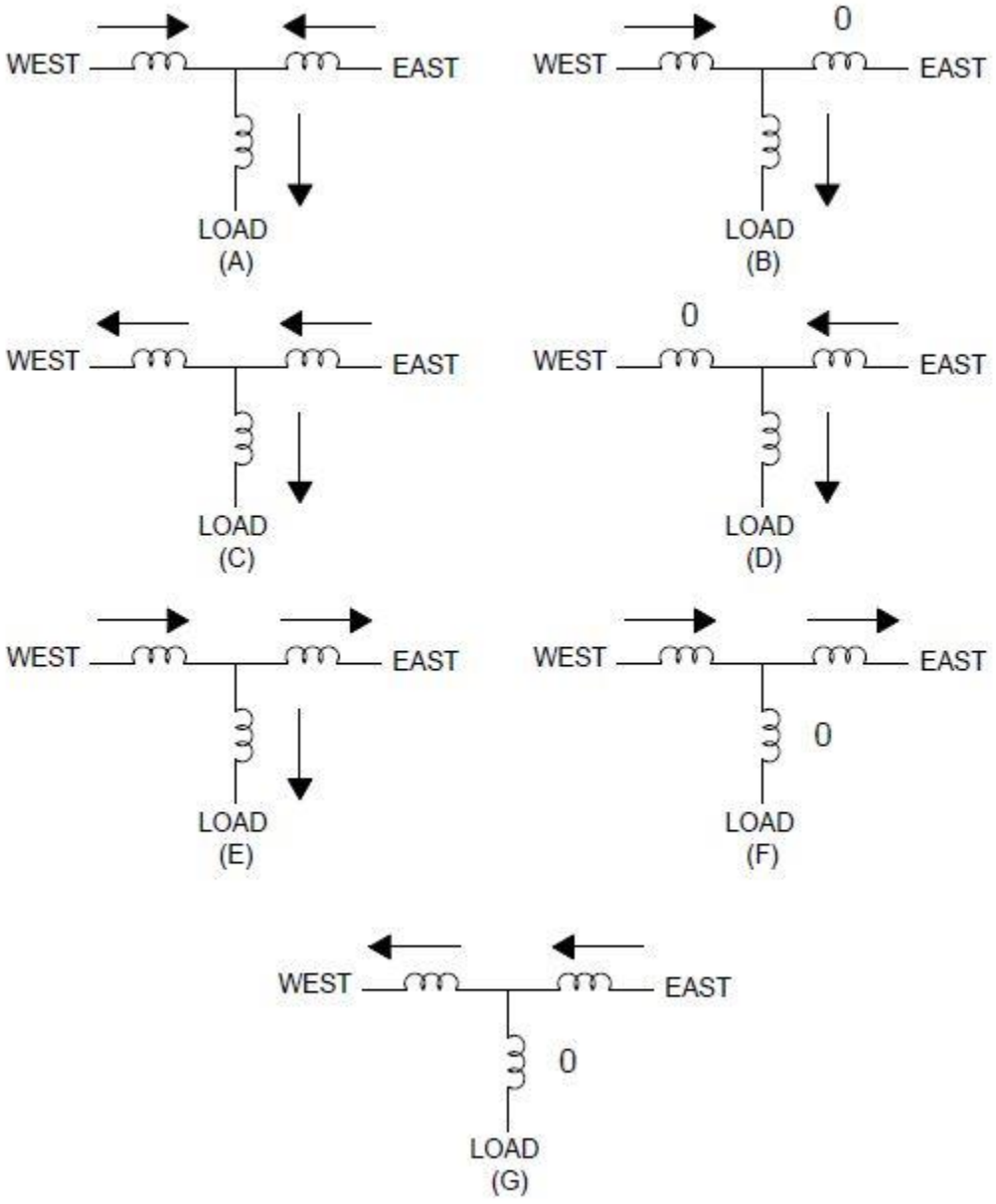


FIGURE 3-2 LOAD FLOW STATES

The design constraints for relay Zone 2 impedance protection require that the relays overreach the line by 120% of the line. Consideration of the load impedance magnitude with respect to each relay and source was taken into consideration in order to prevent overreaching into the load. Overreaching in to the load could cause false tripping during high load conditions and under-reaching the transmission line would result in non-operation during internal faults near the relays. To prevent non-operation and ensure overlapping Zone 2 protection the relay settings were chosen to be 120% of line impedance. To achieve tripping, the Zone 2 mho circles were overlapped and set to reach 120% of the impedance of the line. Since the load is fed by two sources, the perceived impedance increases because of load sharing. Under normal load conditions, the relays should see an impedance of 200% of the line. If load conditions change and current reverses direction, the relays should block operation further testing would be required to verify operation.

For faults near one of the relays, the effective impedance seen by the remote relay, shown in Equation 1. Will be one half the impedance of the line in parallel with connected load plus one half of the line. Equation 2 calculates the perceived impedance of the line when a fault condition exists at the remote relay. Equation 3 calculates 120% of the perceived impedance of the line when a fault condition exists at the remote relay.

$$Z_{FRR} = (\frac{Z_{LINE}}{2} || Z_{LOAD}) + \frac{Z_{LINE}}{2}\ \Omega \quad \text{Eq.1}$$

$$Z_{FRR} = (\frac{21 + 75.698j}{2}) || (10 + 37.698j)) + (\frac{21 + 75.698j}{2})\Omega$$

$$Z_{FRR} = 0.75 \times Z_{LINE}\ \Omega \quad \text{Eq.2}$$

$$Z_{FRR} = 58.918 \angle\ 74.5\ \Omega$$

$$1.2\ Z_{FRR} = 70.70 \angle\ 74.5\ \Omega \quad \text{Eq.3}$$

$$2Z_{LINE}\ = 157.11 \angle\ 74.5\ \Omega \quad \text{Eq.4}$$

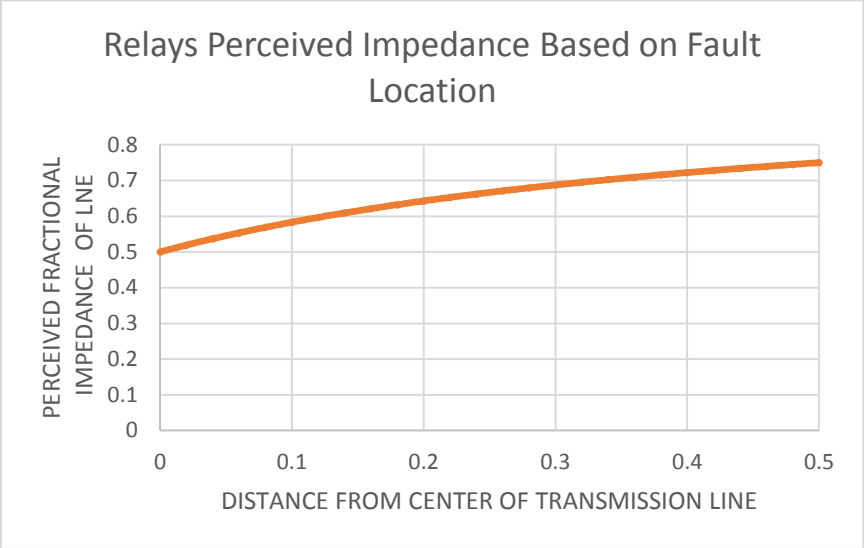


FIGURE 3-3 RELAYS PERCEIVED IMPEDANCE

DESIGN EQUATIONS:

$$Z2x = 1.2(21 + 75.698j) \qquad \text{Eq. 5}$$

$$Z2x = 94.268 \angle 75° \, \Omega$$

$$Z2P = \frac{94.268}{\cos(75° - 75.698°)} \Omega \qquad \text{Eq. 6}$$

$$Z2P \approx 94\Omega$$

Z2P represents the diameter of the Zone 2 Mho circle at 75 degrees. Equation 5 and Equation 6 calculate the appropriate diameter for the Mho circle based strictly on the physical impedance of the line. Consideration of the load conditions are not taken into account in these equations. Loads or faults whose impedances fall within the circle and seen by both relays, will operate the Zone 2 elements and trip the breakers.

For this project, loading and perceived impedance was taken into account. The settings applied to the relays allow for Zone 2 impedance overlapping based on the calculated Z_{FRR}. The SEL-311 maximum reach setting is 64Ω. Without additional equipment to reduce the secondary impedance to the relay, full 120% distance line protection is not possible.

POTT relies on communication between the relays for keying. Only when a relay receives a key signal and sees a fault on the line will the relay trip. In this configuration if communication is lost, the relay will still operate but must wait for the Zone timer to timeout before tripping. Waiting for the timer to timeout increases, the total energy released, and increases the probability of equipment damage and system instability. The timer allows for downstream device coordination and breaker tripping. Figure 3-3 depicts the systems MHO diagram.

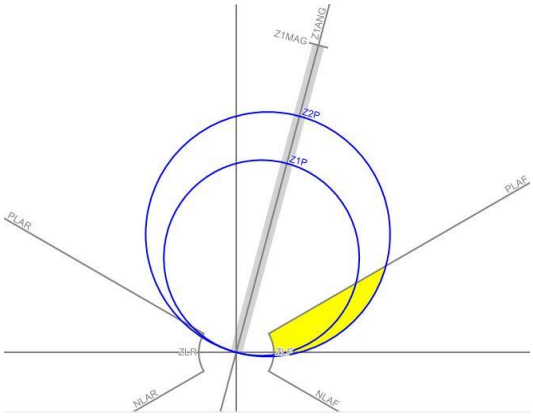


FIGURE 3-4 MHO DIAGRAM

4 DEVELOPMENT AND CONSTRUCTION

4.1 EQUIPMENT

The project required the following equipment:

(2) SEL-311L

(6) Power Resistor / Inductor combination unit (20+37j) Ω

(1) SEL-2924 Serial to Bluetooth Adapter

(100') #14 Wire

(50) #14 Fork Terminals

(1) Multi-meter

(2) Circuit Breakers

(1) Wire Strippers

(1) Terminal Crimper

(20) 3' Banana to Banana Leads

(10) Short Banana to Banana Leads

4.1.1 CIRCUIT BREAKER

The circuit breakers used in this project were built by Dr. Shaban's student. The circuit breaker includes automatic and manual trip/close capability. The SEL relay outputs can be wired to the breaker unit allowing remote trip/ close commands to be sent from the relay to operate the breaker automatically. For testing faults at a node, the built-in fault switch can be wired to introduce fault conditions into the test circuit. The line-side fault switch terminals are connected to the three phases of the node and the load side terminals of the fault switch are connected together in the desired fault condition.

4.1.2 SEL-311L

The SEL-311L is a differential current relay used to protect high voltage transmission lines. The relay includes 4 zone phase distance and ground distance capabilities. Differential and other communications assisted protection schemes, including POTT, utilize the relays fiber optic communications channel for data transfer between system IEDs.

4.1.3 LINE IMPEDANCE

Line impedance was achieved using available electrical engineering department resistor & reactor units built by the department's lab technicians. The unit consists of (2) 10 ohm power resistors rated at 160W and a 100mH 5A reactor all connected in series. Each electrical node is available for use via a banana type connector standoff.

Part Numbers:

(1) Hammond Manufacturing 195T5 Reactor

(2) Ohmite WFH160 Power Resistor

4.1.4 SEL-2924

EIA-232 to Bluetooth serial adapter allows communication between the relay and computer terminal. The adapter is useful when working with RS-232 devices in the field and is a wireless substituted for its wired counterpart. The adapter comes with a USB rechargeable lithium battery.

4.2 CONSTRUCTION

The lab required approximately 6 hours to wire and confirm the connections. Three-quarters of a standard power lab bench was needed to house the required equipment. Connections were made directly to the back of the relays and source using #14 wire and fork terminal connectors. Relay mimic panels are currently being manufactured by students to allow all lab connections to be made with banana to banana type cables and connectors. Once the mimic panels are completed, overall

wiring time should be reduced to under one hour. For this system, the same source was connected to each end of the system to model a loop system connection. For integration into the Cal Poly micro grid separate synchronized generation can be applied to the system with similar functionality obtained.

4.3 CONFIGURATION

The relays were programmed with the impedance settings calculated in the design section. Line parameters neglect the effect of the load and treat the line as a continuous line impedance from the local to remote relay terminal. The CT and VT settings were set to 1 because no PTs or VTs were used in the project and no ratio from primary to secondary exists. All voltage and current inputs to the relays are actual system values. Figure 4-1 & 4-2 show the line parameter settings and distance settings entered into the AcSELerator.

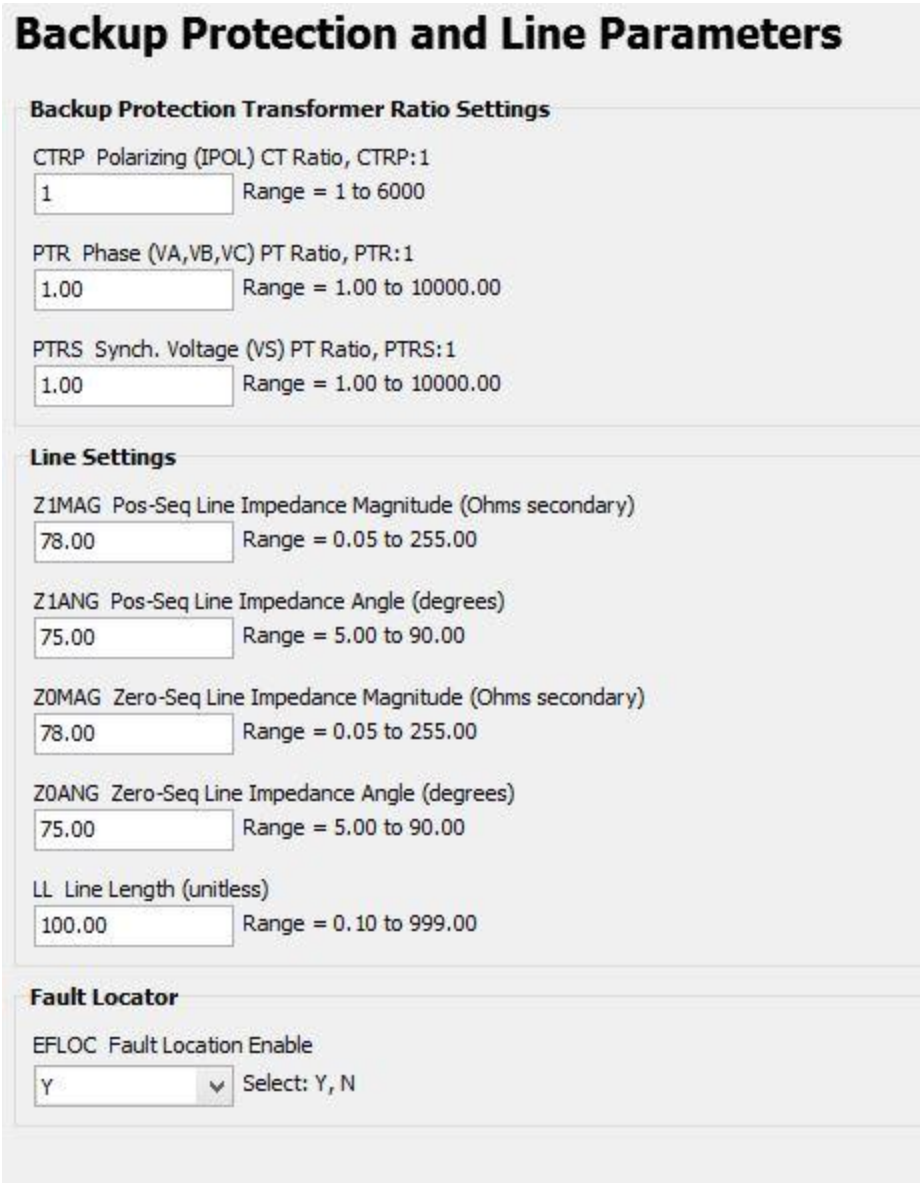


FIGURE 4-1 LINE PARAMETERS

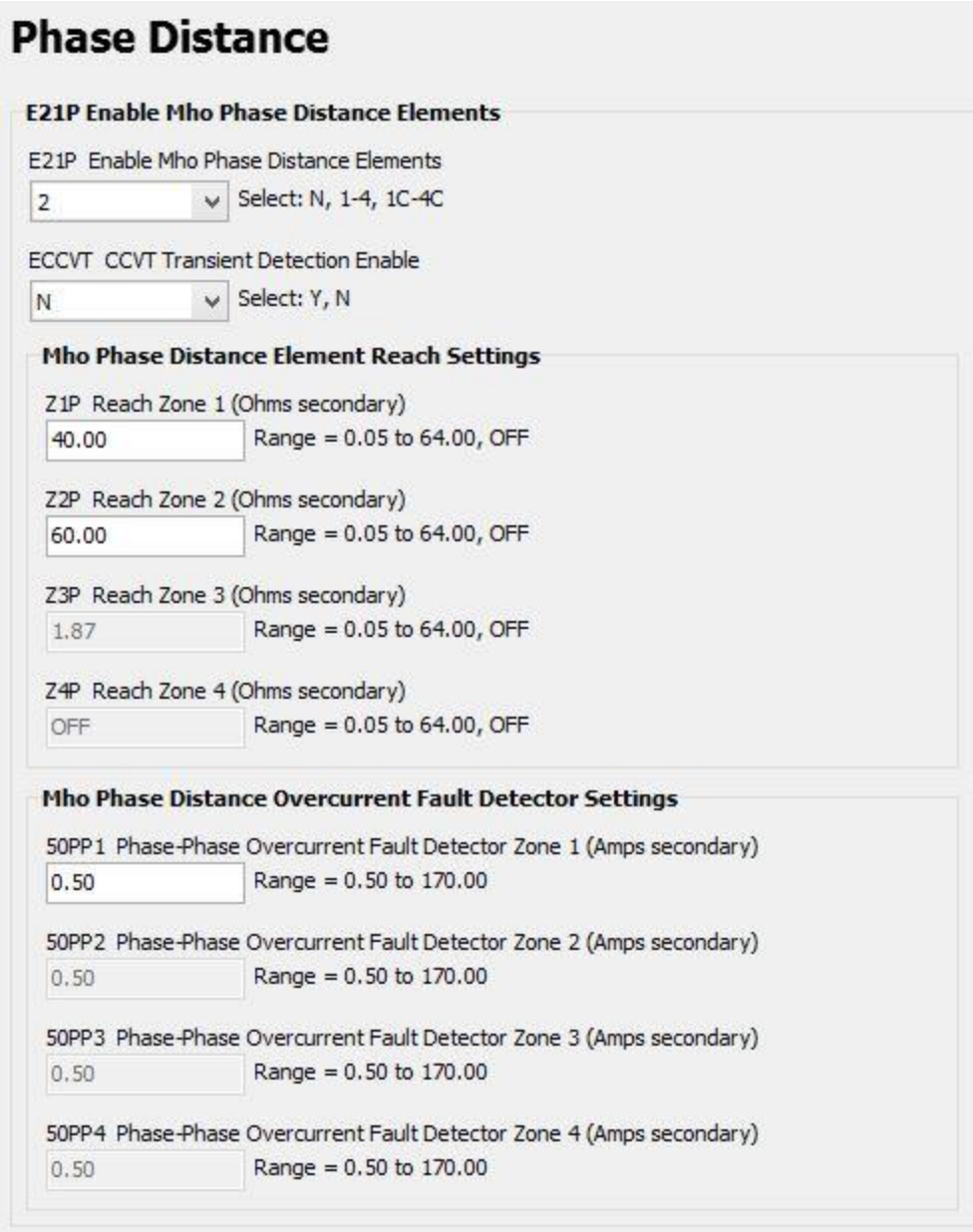


FIGURE 4-2 PHASE DISTANCE

The following settings (Figures 4-3 - 4-6) represent the trip logic equations, output contacts, and communication settings required to achieve POTT. Figure 4-3 shows the Words when asserted will close the output contacts on the relays. OUT103 when asserted will trip the circuit breaker and is asserted when word !TRIP*!OC are asserted. OUT102 is high when the Close command is asserted. The breaker requires a momentary close and will remain closed until the trip command has been issued. Although differential protection was not used in this project, the 87 differential settings were left active to allow for utilization of the 87 channel communication via the fiber optic connection.

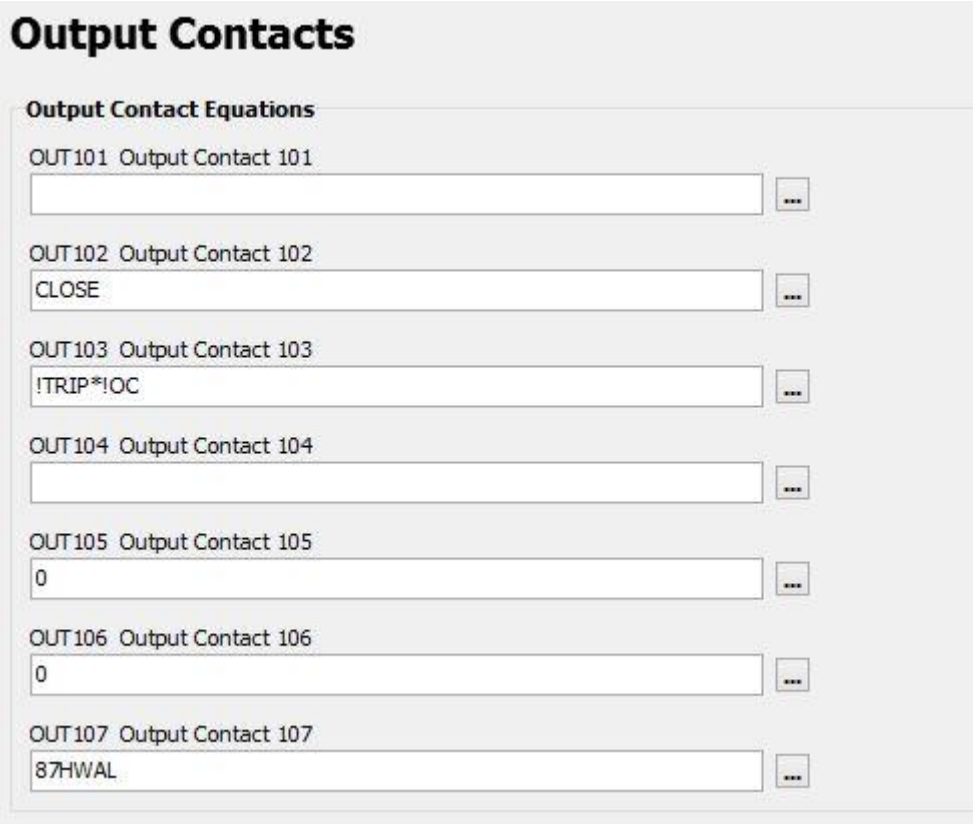


FIGURE 4-3 OUTPUT CONTACTS

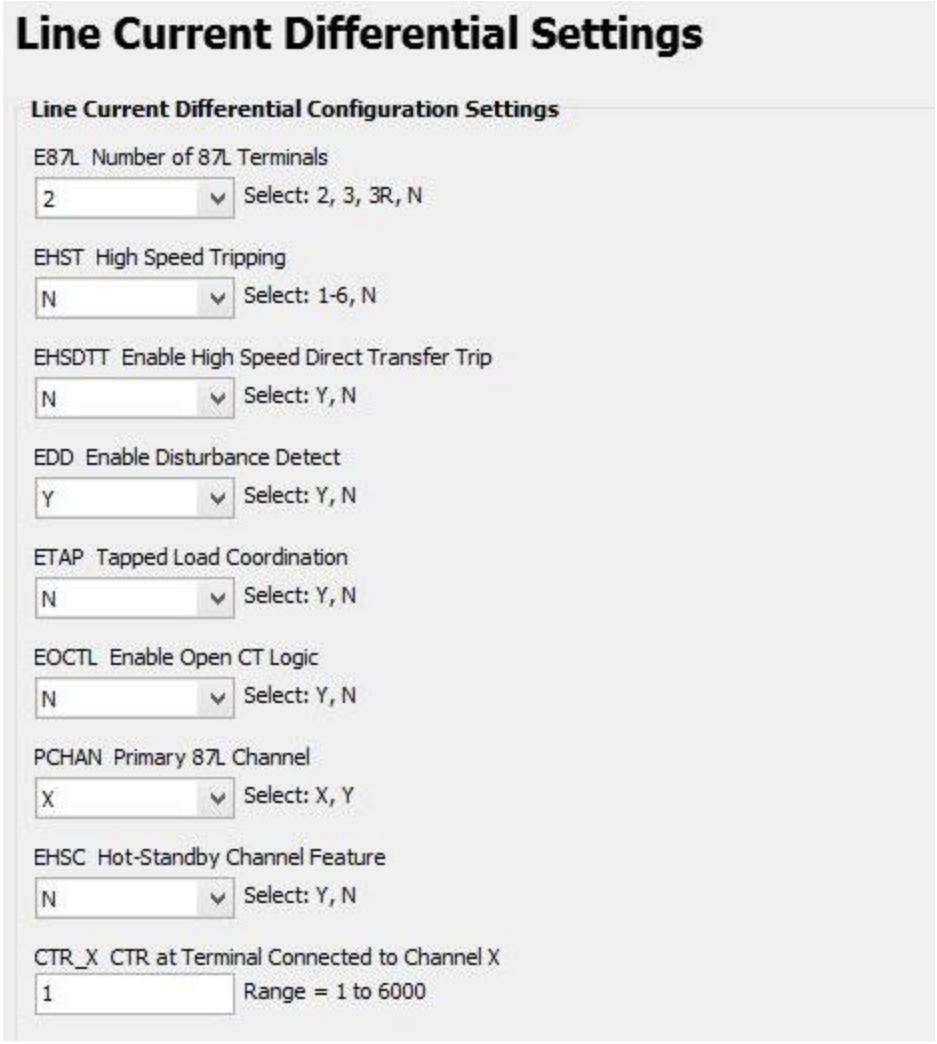


FIGURE 4-4 LINE CURRENT DIFFERENTIAL SETTINGS

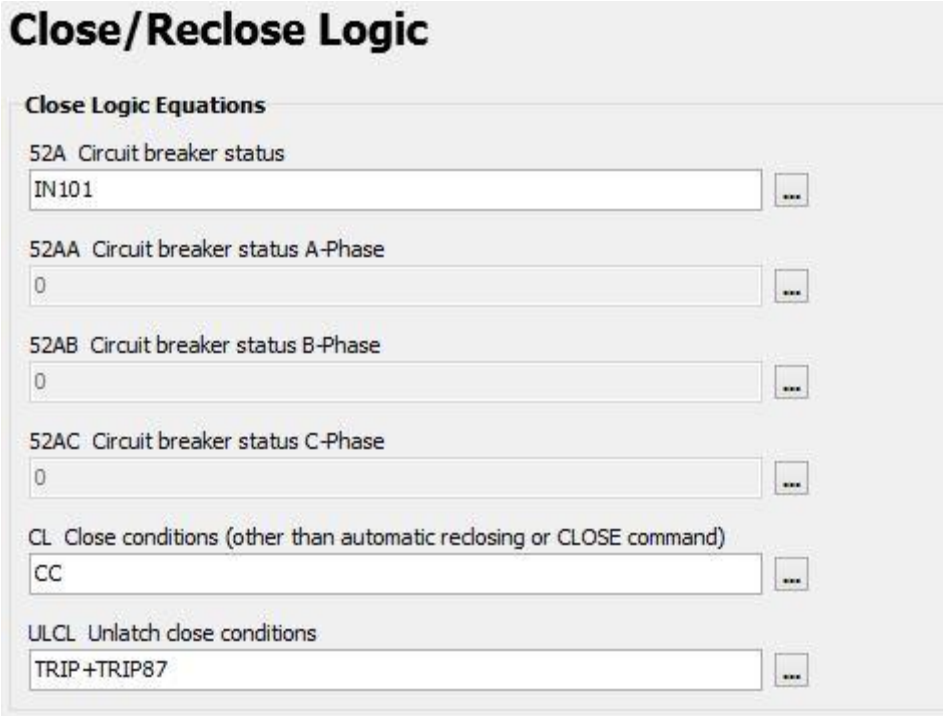


FIGURE 4-5 CLOSE & RECLOSE LOGIC

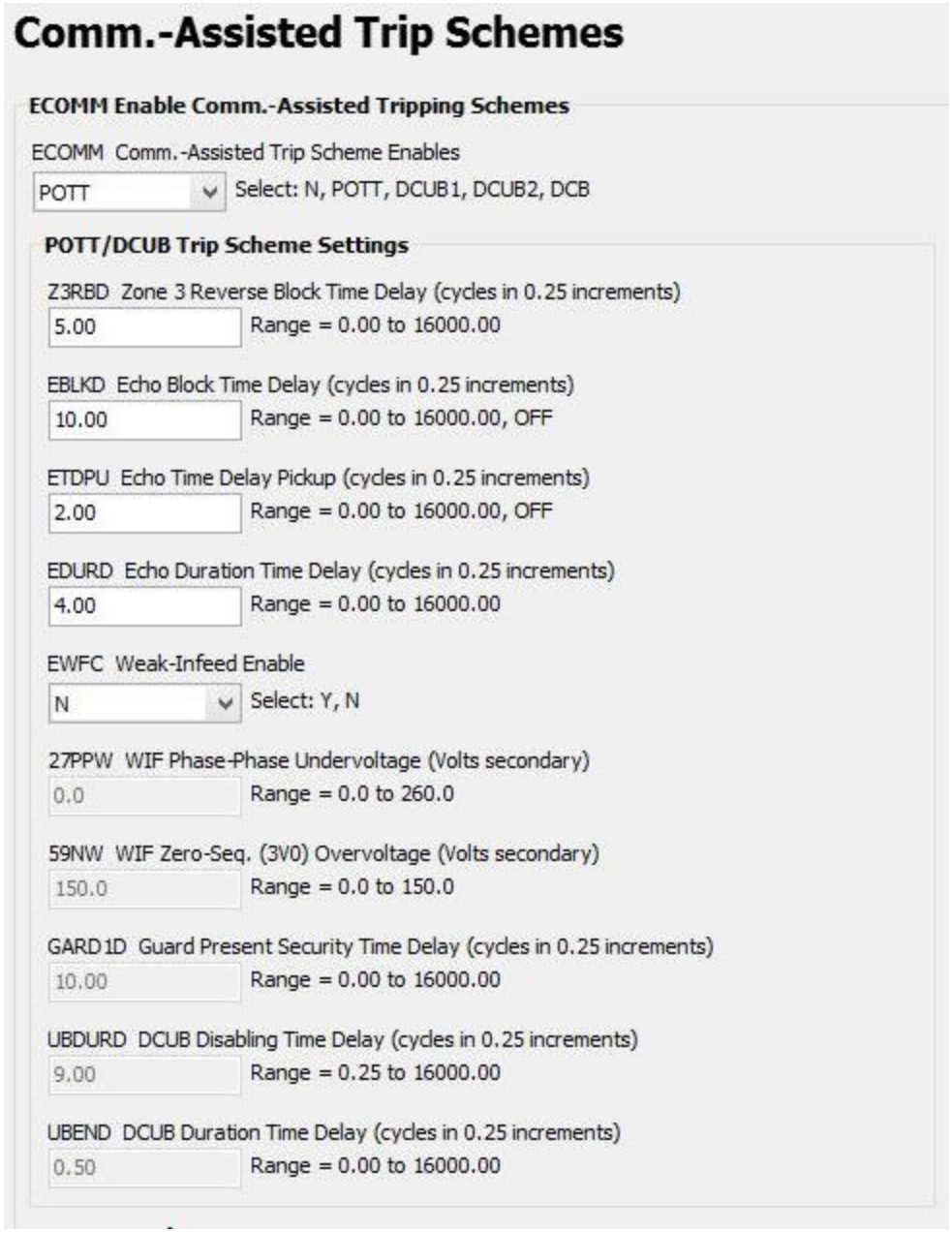


FIGURE 4-6 COMMUNICATIONS ASSISTED TRIPPING

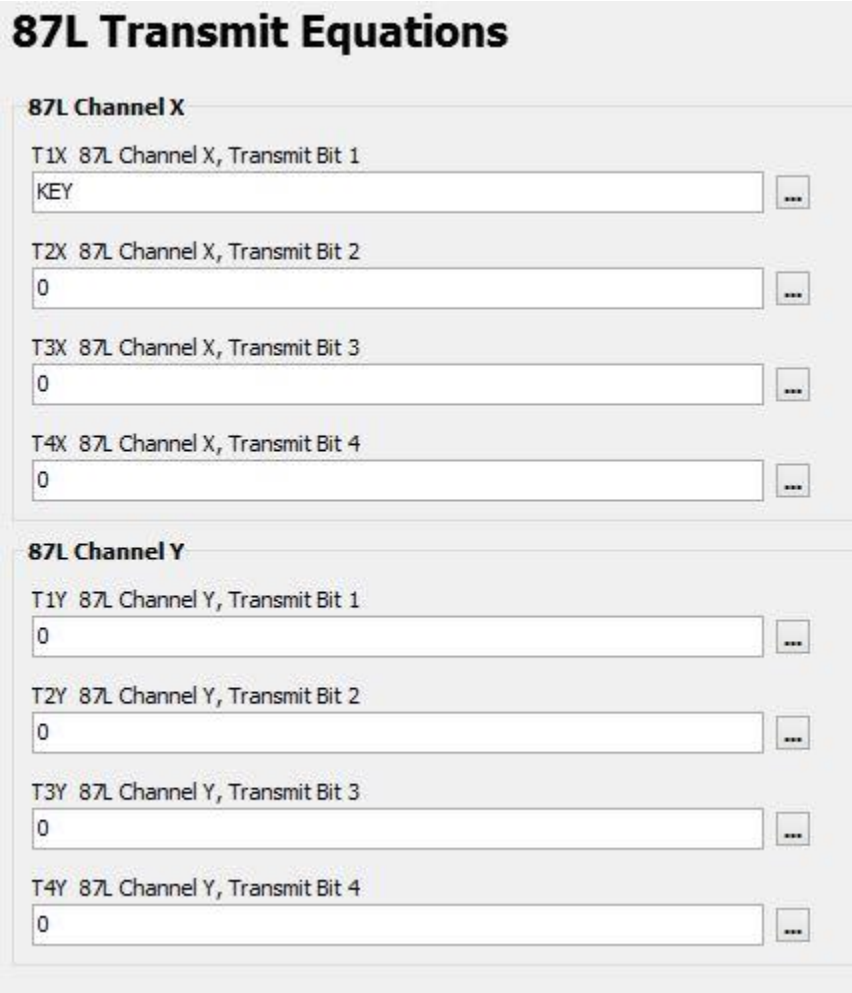


FIGURE 4-7 87L TRANSMIT EQUATIONS

4.4 OPERATION

After wiring and system functionality has been verified, the sources can be applied and breakers closed. Special care was taken to ensure that the power resistors were not being overheated by the power dissipated through them. Fault conditions are then applied to the nodes specified on the single line construction drawing located in the appendix. The system is energized and fault switched on momentarily. If the relays are functioning as designed, they should immediately operate and open both breakers, which can be confirmed by the red breaker closed lights transition to two green

breaker open lights located on the circuit breaker boxes. In addition, the relays targets displayed on the front panel should light up when a fault condition is sensed. All wiring changes including moving the fault nodes to a different location should be performed with the system de-energized.

5 TESTING

5.1 TEST PROCEDURES

The following are test procedures for verifying the circuit's electrical and mechanical connections prior to energizing the circuit. Verifying the circuit's electrical and mechanical connections are imperative to protect both the student and equipment from inadvertent damage.

POINT TO POINT AND MECHANICAL CHECK

The mechanical connections should be checked. With the circuit de-energized, gently pull on the wires and look for wire movement or displacement at the mechanical connection. If the wire connections move, further steps need to be taken to secure the connection. A point to point check using the construction drawings should be done to verify that all connections have been appropriately made. These tests should help eliminate wiring errors and decrease the likely hood a loose or misplaced wire.

WIRING CONTINUITY CHECK

With the load open-circuited and sources de-energized and open-circuited, a continuity / resistance check should be made from the source to the load using a standard multi-meter. All three phases from both sides of the line should be recorded and verified for consistency across all 6 of test points. If any of the test points show a low resistance, resistance difference of 25% or more, or infinite resistance the circuit should not be energized and all connections should be verified. Do not energize the circuit until resistances are equal and approximately 35 ohms from source to load.

5.1.1 BREAKER CONTROL VERIFICATION

With the three phase ac source de-energized, energize the DC control voltage and test manual open close breaker functionality prior to energizing the circuit. Verify that the trip and close commands can be issued from the serial terminal within the AcSELerator terminal and that the breaker responds accordingly.

5.1.2 MULTI-SOURCE SYSTEM

If utilizing multiple sources, care must be taken to ensure the systems are synchronized and have proper phasing prior to closing the breaker. Failing to properly synchronize and phase independent sources can result in equipment damage and injury. Procedures for synchronizing and phasing are beyond the scope of this senior project.

6 ANALYSIS

Internal line to line faults were selected for analysis because they result in the lowest fault current. By analyzing relay functionality at the lowest fault current magnitude possible, we can deduce that the relay will operate under more extreme fault current conditions.

6.1 INTERNAL LL

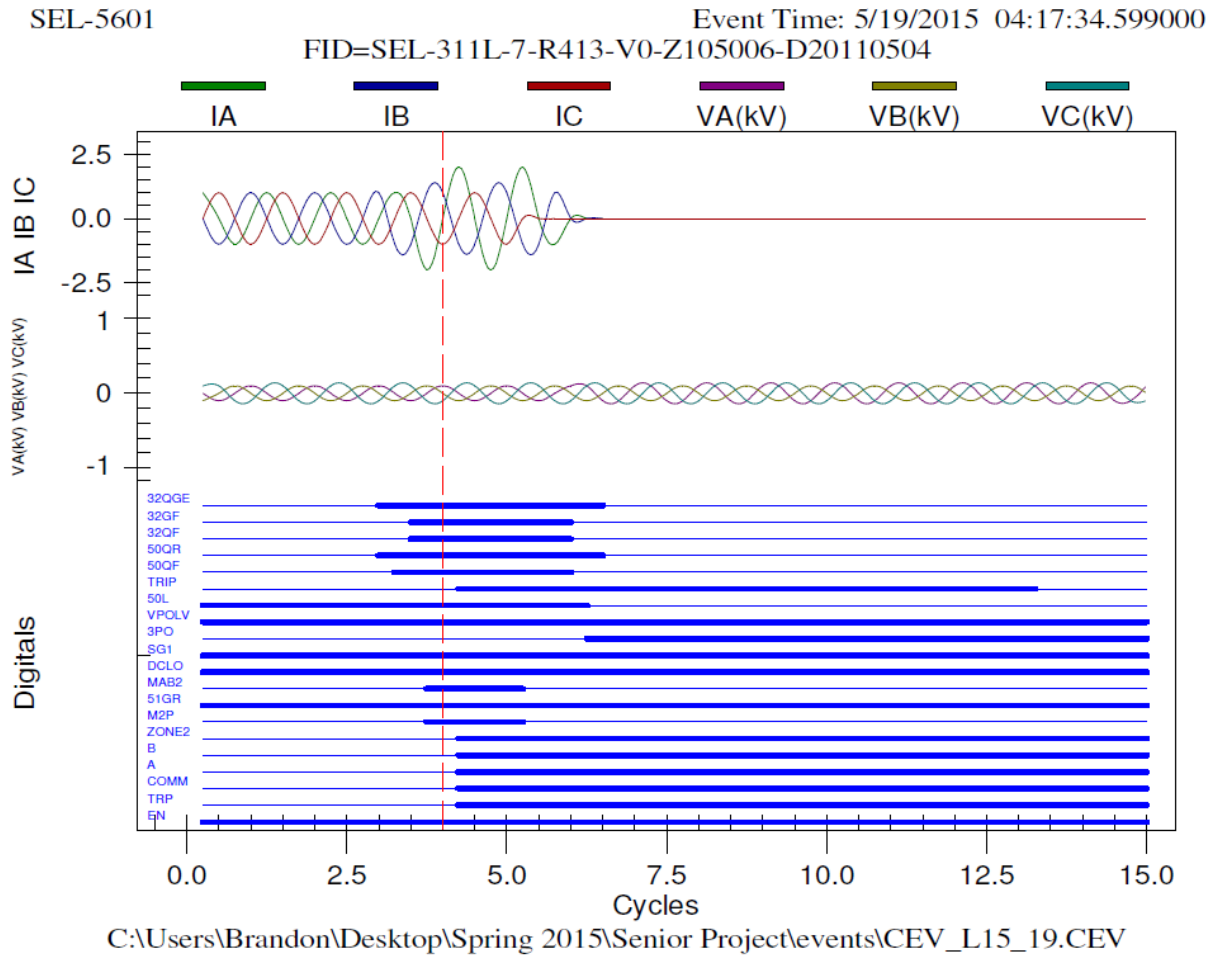


FIGURE 6-1 LINE TO LINE FAULT WEST

In Figure 6-1 and Figure 6-2 Phases A & B have been faulted. Figure 6-1 the system is faulted at the West node as shown on the single line diagram. Figure 6-2 the system is faulted at the Center node

as shown on the single line diagram. As seen in the event diagram the fault causes increases in current and decreases in the voltages seen on those phases. The relay word bit M2P picks up indicating that a Zone 2 fault has been detected similarly M1P has not picked up indicating the fault impedance is higher and outside the zone 1 impedance circle. Shortly after the M2P word bit goes high, a permissive key is received shown as the COMM signal and the trip command issued. Both breakers opened successfully.

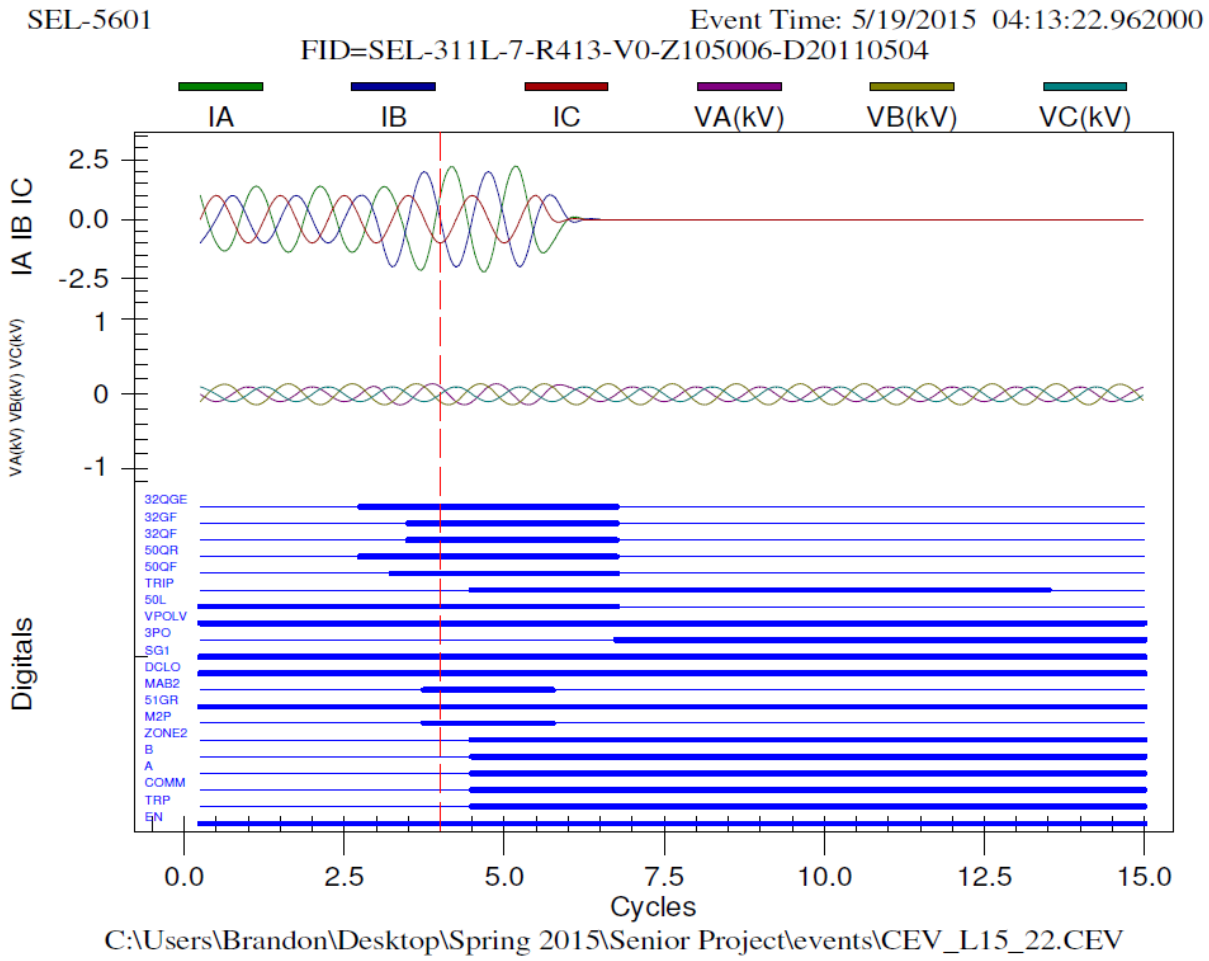


FIGURE 6-2 LINE TO LINE FAULT CENTER

When fault conditions external to the relays were applied, the relays blocked the trip and did not operate. Blocking trips for faults external to the line allow protection engineers to better coordinate protection and predict system operation after a fault condition has been cleared.

7 CONCLUSION

Permissive over-reaching transfer trip protection is a useful way to provide security to vital transmission line infrastructure. By overreaching the transmission line and requiring both relays to sense a fault internal to the line, false trips on faults external to the line become unlikely. The SEL-311L offers a robust set of protection elements and fiber optic connections for high speed reliable communication between relays. For long distance transmission lines, POTT is a more secure alternative to phase distance and overcurrent alone. The multi-source and tapped load system forced me to think about how system operating and load conditions affect the perceived impedance at the relays. Careful consideration of system conditions need to be part of a protection analysis to avoid false trips and non-operation.

8 APPENDICES

8.1 WBS, COST ESTIMATE, AND GANTT CHART

TABLE 8-1 WBS

				Time (a)	Time (m)	Time (b)	
1	SEL 311 Transmission Line Differential Protection Project						
1.1	Concept & Preliminary Design						
1.1.1	Customer Requirements Development						
	1.1.1.1	Customer Requirements Elicitation		1.5	2	4	2.25
	1.1.1.2	Requirements Document Development		3	4	8	4.5
	1.1.1.3	Literature Research		6	8	16	9
	1.1.1.4	Communications Architecture		1.5	2	4	2.25
	1.1.1.5	Customer Review & Acceptance		3	4	8	4.5
1.3.1	Engineering Specifications Development						
	1.3.1.1	Specification Document Development		3	4	8	4.5
	1.3.1.2	Customer Review & Acceptance		0.75	1	2	1.125
	1.3.1.3	Specification Verification & Traceability		4.5	6	12	6.75
2.1	Detailed Design						
	2.1.1	Protection Scheme Design					
		2.1.1.1	Protection Specification & Engineering	15	20	40	22.5
		2.1.1.2	ETAP Model	4.5	6	12	6.75
		2.1.1.3	Fault Analysis	1.5	2	4	2.25
		2.1.1.4	Preliminary Test Plan Development	2.25	3	6	3.375
		2.1.1.5	Customer Review	0.75	1	2	1.125
	2.1.2	Programming Design					
		~~2.1.2.1~~	~~Differential Trip Pickup~~	~~3.75~~	~~5~~	~~10~~	~~5.625~~
		2.1.2.2	Protection Functionality	3.75	5	10	5.625
		2.1.2.3	Calibration & Parameters	3.75	5	10	5.625
		2.1.2.4	PILOT Protection	3.75	5	10	5.625
		2.1.1.5	Customer Review	0.75	1	2	1.125
	2.1.3	Design Documentation Development					
		2.1.4.1	Wiring Diagrams	2.25	3	6	3.375
		2.1.4.2	Communications Diagrams	2.25	3	6	3.375
		2.1.4.3	Bill of Materials	3	4	8	4.5
		2.1.4.4	Customer Review	0.75	1	2	1.125
	2.1.4	Customer Design Final Review and Acceptance					
		2.1.4.1	Document Review	0.75	1	2	1.125

		2.1.4.2	Program review	0.75	1	2	1.125
		2.1.4.3	Engineering Review	0.75	1	2	1.125
3.1	Procurement						
	3.1.1	Locate Available Equipment		1.5	2	4	2.25
	3.1.2	Vendor Qualification		1.5	2	4	2.25
	3.1.3	Quotation		1.5	2	4	2.25
	3.1.4	Purchase		3	4	8	4.5
4.1	Construct						
	4.1.1	Initial Setup		1.5	2	4	2.25
	4.1.2	Wire		5.25	7	14	7.875
	4.1.3	Programming		6	8	16	9
	4.1.4	Communication Wiring		3	4	8	4.5
	4.1.5	Communication Programming		6	8	16	9
	4.1.6	Systems Integration		6	8	16	9
5.1	Test						
	5.1.1	Finalize Test Plan Development		2.25	3	6	3.375
	5.1.2	Test Plan Customer Acceptance		0.75	1	2	1.125
	5.1.3	Fault Testing		6	8	16	9
	5.1.4	Communications Testing		3.75	5	10	5.625
	5.1.5	Factory Acceptance Test		1.5	2	4	2.25
6.1	Project Deliverable						
	6.1.1	Customer Delivery		0.75	1	2	1.125
7.1	Report Deliverables						
	7.1.1	Functional Specification		3.75	5	10	5.625
	7.1.2	Lab Student Material		6	8	16	9
	7.1.3	Lab Instructor Materials		6	8	16	9
	7.1.4	Customer Review & Acceptance		1.5	2	4	2.25

Time (a)	Time (m)	Time (b)	Estimated Labor Hours
141	188	376	211.5

* Time (a) x.75 multiplier
* Time (m) x1.0 multiplier
* Time (b) x2.0 multiplier

MATERIAL COST ESTIMATE

Items Provided by Student

Item #	QTY:	Item:	Unit Cost	Total Cost
1	3	500' #14 Stranded	$60.00	$180.00
2	1	100 fork terminations	$25.00	$25.00
3	1	Misc. Electrical Parts	$50.00	$50.00
4	1	Misc. Admin	$50.00	$50.00
			Subtotal	$305.00

	Sale Tax	9.00%	Tax	$27.45
			Total	$332.45

Items Provided by Dr. Shaban

Item #	QTY:	Item:	Unit Cost	Total Cost
5	6	Transformers	$50.00	$300.00
6	2	SEL 311-L	$5,000.00	$10,000.00
7	1	SEL 2042	$2,840.00	$2,840.00
8	2	Fiber Optic Cables	$20.00	$40.00
9	4	Circuit Breaker Simulators	$200.00	$800.00
			Subtotal	$13,980.00
	Sale Tax	9.00%	Tax	$1,258.20
			Total	$15,238.20
	Total Material Cost			$15,570.65
	Total Estimated Labor Hours			211.50
		Labor Rate	$125	Hourly
		Total Labor Cost		$26,375.00
		Total Project Cost		$41,945.65

Project estimates developed using previous project experience and a Work Breakdown Structure further identifying work tasks. The total cost estimates how much the project would cost if contracted to organizations for implementation and engineering for development of a differential impedance protection system using the SEL-311L.

TABLE 8-2 GANTT CHART

SEL 311-L Differential Impedance Pilot Protection Laboratory

Brandon Van Loon

Today's Date: 2/6/2015 Friday

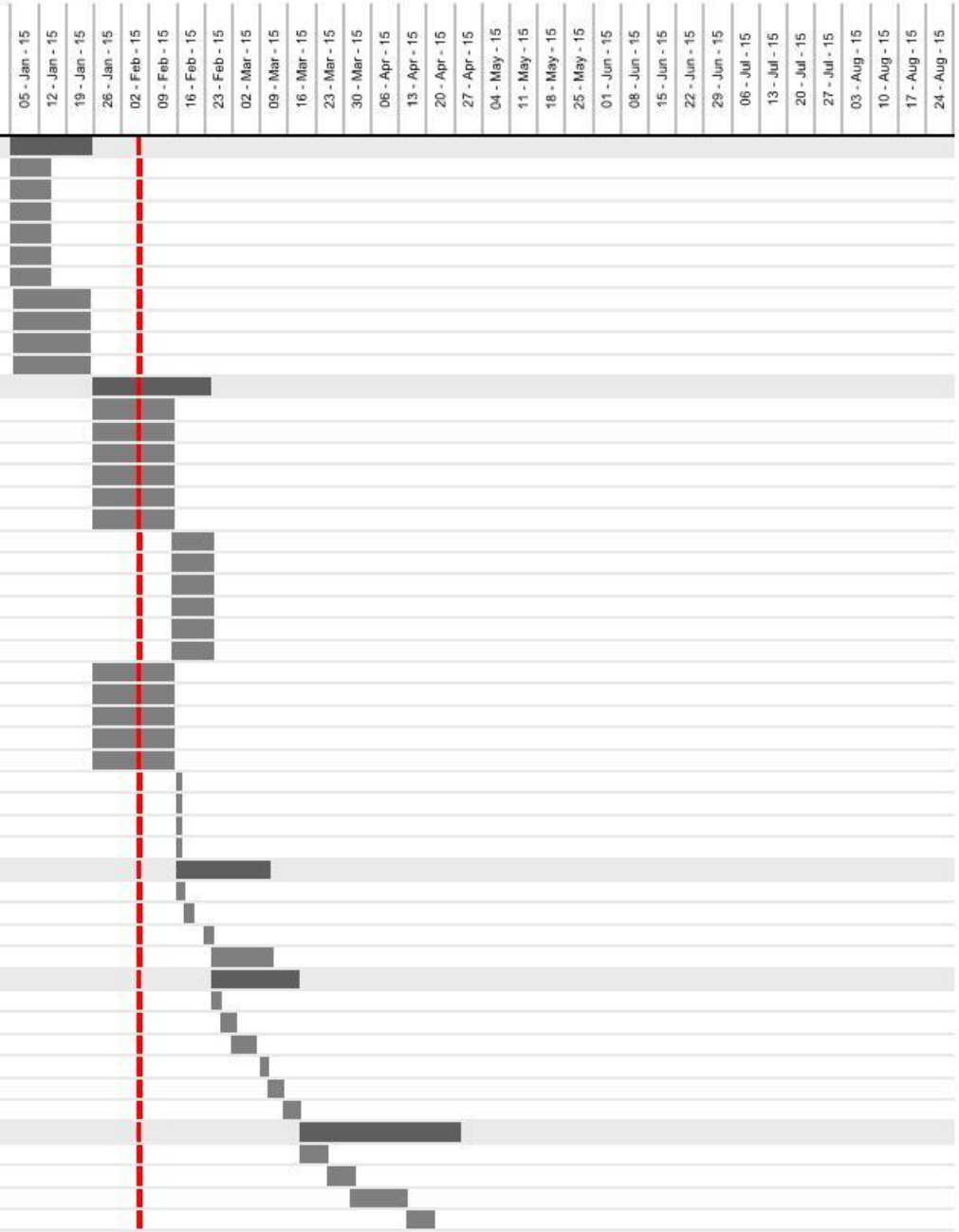
(vertical red line)

Project Lead: Brandon Van Loon

Start Date: 1/5/2015 Monday

First Day of Week (Mon=2): 2

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
1	**Concept & Preliminary Design**	BVL	1/5/15	1/25/15	21	0%	15	0	21
1.1	**Customer Requirements Development**		1/5/15	1/14/15	10	0%	8	0	10
1.1.1	Customer Requirements Elicitation		1/5/15	1/14/15	10	0%	8	0	10
1.1.2	Requirements Document Development		1/5/15	1/14/15	10	0%	8	0	10
1.1.3	Literature Research		1/5/15	1/14/15	10	0%	8	0	10
1.1.4	Communications Architecture		1/5/15	1/14/15	10	0%	8	0	10
1.1.5	Customer Review & Acceptance		1/5/15	1/14/15	10	0%	8	0	10
1.2	**Engineering Specifications Development**		1/6/15	1/24/15	19	0%	14	0	19
1.2.1	Specification Document Development		1/6/15	1/24/15	19	0%	14	0	19
1.2.2	Customer Review & Acceptance		1/6/15	1/24/15	19	0%	14	0	19
1.2.3	Specification Verification & Traceability		1/6/15	1/24/15	19	0%	14	0	19
2	**Detailed Design**	BVL	1/26/15	2/24/15	30	0%	22	0	30
2.1	**Protection Scheme Design**		1/26/15	2/14/15	20	0%	15	0	20
2.1.1	Protection Specification & Engineering		1/26/15	2/14/15	20	0%	15	0	20
2.1.2	ETAP Model		1/26/15	2/14/15	20	0%	15	0	20
2.1.3	Fault Analysis		1/26/15	2/14/15	20	0%	15	0	20
2.1.4	Preliminary Test Plan Development		1/26/15	2/14/15	20	0%	15	0	20
2.1.5	Customer Review & Iteration		1/26/15	2/14/15	20	0%	15	0	20
2.2	**Programming Design**		2/15/15	2/24/15	10	0%	7	0	10
2.2.1	Differential Trip Pickup		2/15/15	2/24/15	10	0%	7	0	10
2.2.2	Protection Functionality		2/15/15	2/24/15	10	0%	7	0	10
2.2.3	Calibration & Parameters		2/15/15	2/24/15	10	0%	7	0	10
2.2.4	PILOT Protection		2/15/15	2/24/15	10	0%	7	0	10
2.2.5	Customer Review & Iteration		2/15/15	2/24/15	10	0%	7	0	10
2.3	**Design Documentation Development**		1/26/15	2/14/15	20	0%	15	0	20
2.3.1	Wiring Diagrams		1/26/15	2/14/15	20	0%	15	0	20
2.3.2	Communications Diagrams		1/26/15	2/14/15	20	0%	15	0	20
2.3.3	Bill of Materials		1/26/15	2/14/15	20	0%	15	0	20
2.3.4	Customer Review & Iteration		1/26/15	2/14/15	20	0%	15	0	20
2.4	**Customer Design Final Review and Acceptance**		2/16/15	2/16/15	1	0%	1	0	1
2.4.1	Document Review		2/16/15	2/16/15	1	0%	1	0	1
2.4.2	Program review		2/16/15	2/16/15	1	0%	1	0	1
2.4.3	Engineering Review		2/16/15	2/16/15	1	0%	1	0	1
3	**Procurement**	BVL	2/16/15	3/11/15	24	0%	18	0	24
3.1	Locate Available Equipment		2/16/15	2/17/15	2	0%	2	0	2
3.2	Vendor Qualification		2/18/15	2/19/15	2	0%	2	0	2
3.3	Quotation		2/23/15	2/24/15	2	0%	2	0	2
3.4	Purchase		2/25/15	3/11/15	15	0%	11	0	15
4	**Construct**	BVL	2/25/15	3/18/15	22	0%	16	0	22
4.1	Initial Setup		2/25/15	2/26/15	2	0%	2	0	2
4.2	Wire		2/27/15	3/2/15	4	0%	2	0	4
4.3	Program		3/2/15	3/7/15	6	0%	5	0	6
4.4	Communication Wiring		3/9/15	3/10/15	2	0%	2	0	2
4.5	Communication Programming		3/11/15	3/14/15	4	0%	3	0	4
4.6	Systems Integration		3/15/15	3/18/15	4	0%	3	0	4
5	**Test**	BVL	3/19/15	4/28/15	41	0%	29	0	41
5.1	Finalize Test Plan Development		3/19/15	3/25/15	7	0%	5	0	7
5.2	Test Plan Customer Acceptance		3/26/15	4/1/15	7	0%	5	0	7
5.3	Fault Testing		4/1/15	4/14/15	14	0%	10	0	14
5.4	Communications Testing		4/15/15	4/21/15	7	0%	5	0	7



SEL 311-L Differential Impedance Pilot Protection Laboratory

Brandon Van Loon

Today's Date: 2/6/2015 Friday

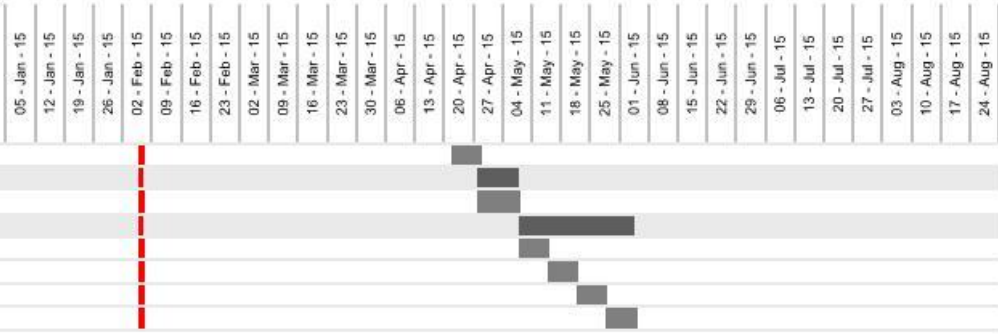
(vertical red line)

Project Lead: Brandon Van Loon

Start Date: 1/5/2015 Monday

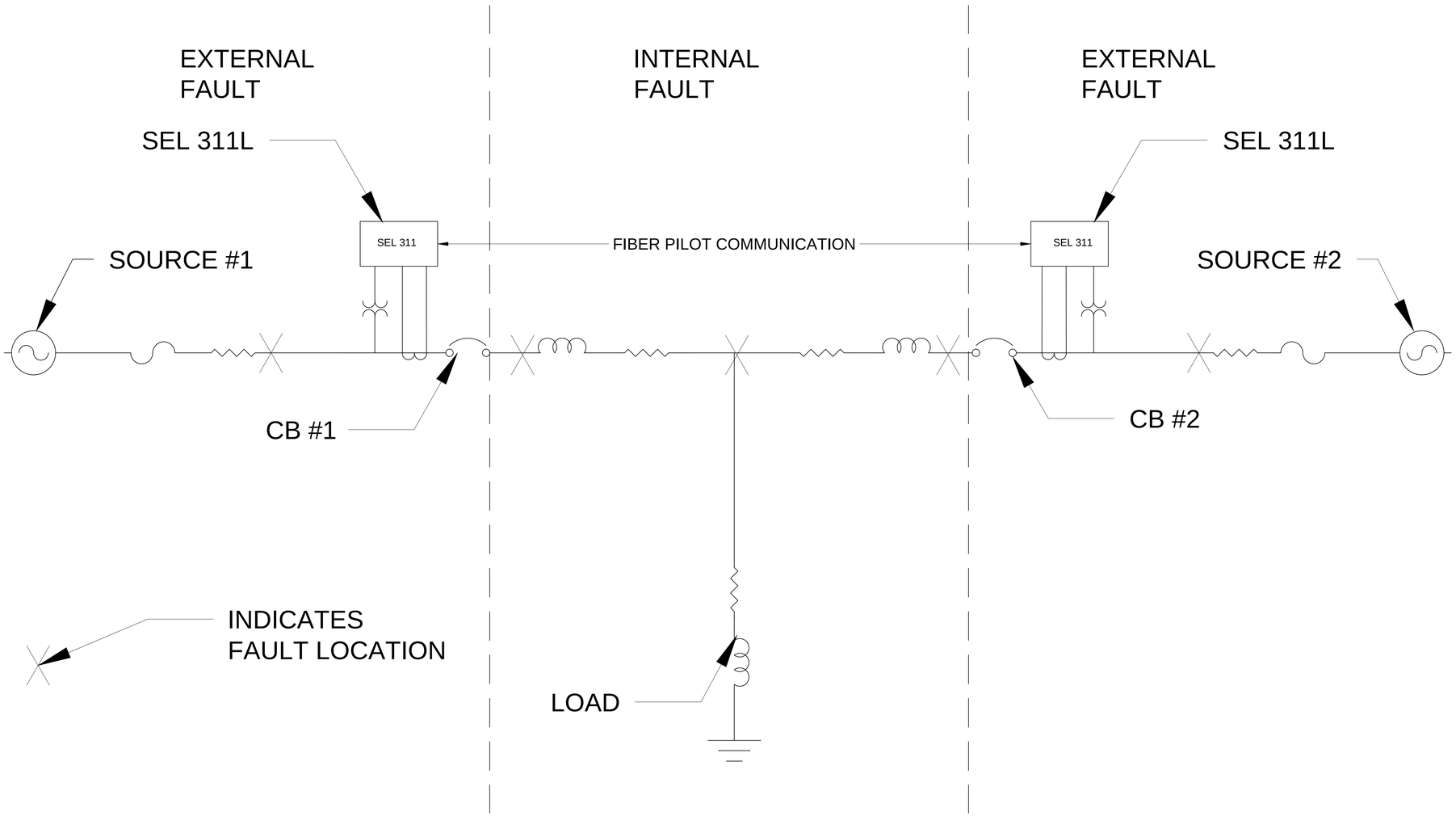
First Day of Week (Mon=2): 2

WBS	Tasks	Task Lead	Start	End	Duration (Days)	% Complete	Working Days	Days Complete	Days Remaining
5.5	Factory Acceptance Test		4/22/15	4/28/15	7	0%	5	0	7
6	**Project Deliverable**	BVL	4/28/15	5/7/15	10	0%	8	0	10
6.1	Customer Delivery		4/28/15	5/7/15	10	0%	8	0	10
7	**Report Deliverables**	BVL	5/8/15	6/4/15	28	0%	20	0	28
7.1	Functional Specification		5/8/15	5/14/15	7	0%	5	0	7
7.2	Lab Student Material		5/15/15	5/21/15	7	0%	5	0	7
7.3	Lab Instructor Materials		5/22/15	5/28/15	7	0%	5	0	7
7.4	Customer Review & Acceptance		5/29/15	6/4/15	7	0%	5	0	7



8.2 CONSTRUCTION DRAWING

PAGE INTENTIONALLY LEFT BLANK



POTT SINGLE LINE DIAGRAM

SCALE: NONE

NOTES:

REVISIONS

NO	DATE	DESCRIPTION	BY

DRAWN BY	BVL	DATE	4/22/15
ENGINEERED BY	BVL	DATE	4/22/15
CHECKED BY	BVL	DATE	4/22/15
APPROVED BY	BVL	DATE	4/22/15

CUSTOMER

CALPOLY EE

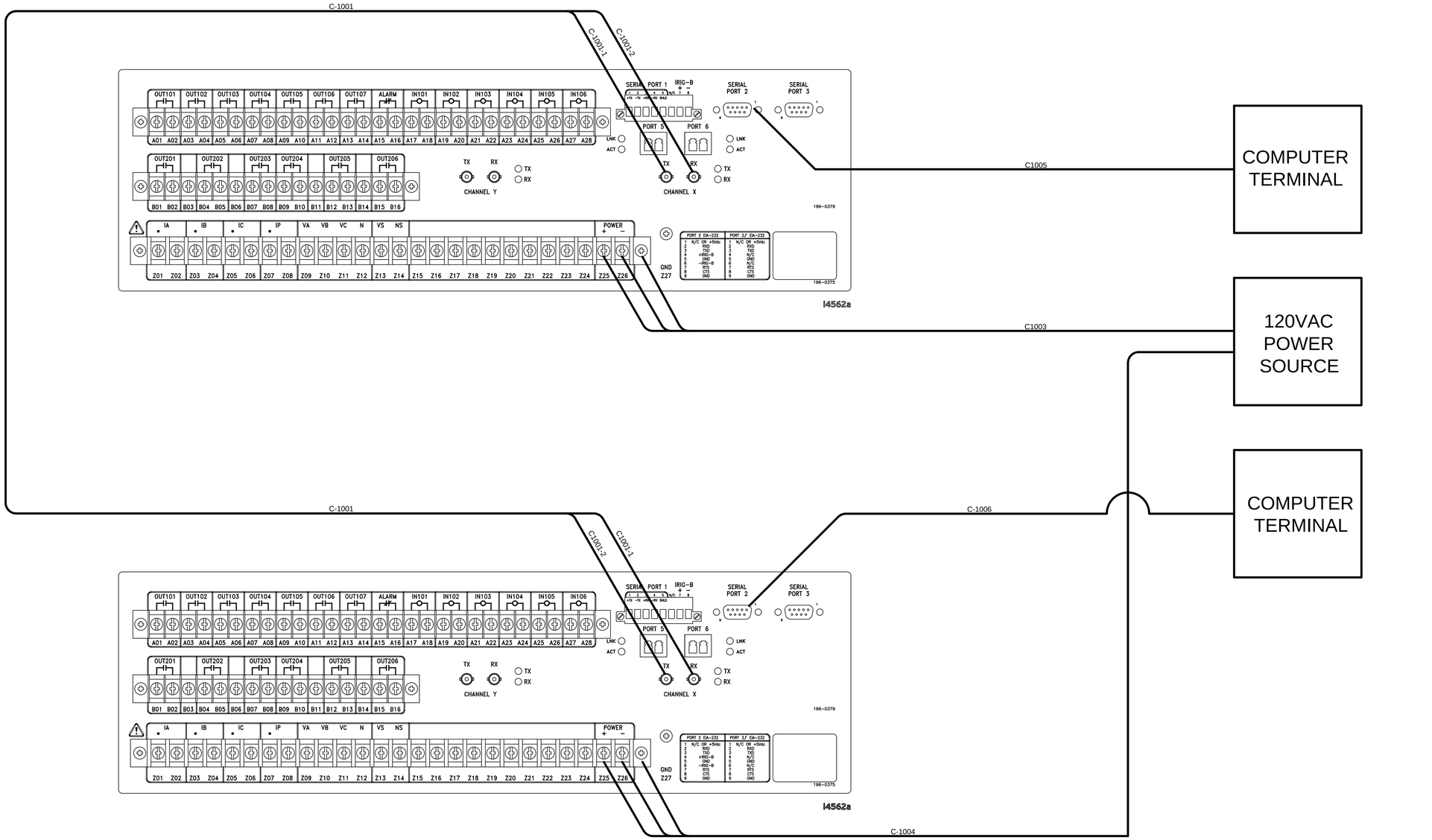
TITLE

POTT CIRCUIT
SINGLE LINE DIAGRAM

PROJECT NUMBER	POTT001		
CAD FILE NAME	POTT_001_01.DWG	SCALE	NONE
DRAWING NUMBER	E1.0	CONTROL	A
		REVISION	0

WIRE / CABLE SCHEDULE

WIRE / CABLE NUMBER:	TERMINATION #1 LOCATION:	TERMINATION #2 LOCATION:	TYPE:	DESCRIPTION:	NOTES:
C-1001-1	RELAY EAST CHANNEL X (TX)	RELAY WEST CHANNEL X (RX)	930 NM FIBER OPTIC	87 CHANNEL COMMUNICATIONS	NOTICE RX-TX ROLLOVER BETWEEN RELAYS
C-1001-2	RELAY EAST CHANNEL X (RX)	RELAY WEST CHANNEL X (TX)	930 NM FIBER OPTIC	87 CHANNEL COMMUNICATIONS	NOTICE RX-TX ROLLOVER BETWEEN RELAYS
C-1003	Z25, Z26, Z27 RELAY EAST	WALL OUTLET (120VAC)	POWER CORD 16/2	RELAY POWER CONNECTION	
C-1004	Z25, Z26, Z27 RELAY WEST	WALL OUTLET (120VAC)	POWER CORD 16/2	RELAY POWER CONNECTION	
C-1005	RELAY EAST SERIAL PORT 2	PC SERIAL PORT	DB-9 CONNECTOR FM-FM	SERIAL COMMUNICATIONS FOR RELAY PROGRAMMING AND TERMINAL ACCESS	ONLY CONNECTED WHEN RELAY IS LOCALLY ACCESSED BY PERSONELL
C-1006	RELAY WEST SERIAL PORT 2	PC SERIAL PORT	DB-9 CONNECTOR FM-FM	SERIAL COMMUNICATIONS FOR RELAY PROGRAMMING AND TERMINAL ACCESS	ONLY CONNECTED WHEN RELAY IS LOCALLY ACCESSED BY PERSONELL



COMMUNICATIONS WIRING DIAGRAM

SCALE: NONE

THIS DRAWING IS PROPRIETARY INFORMATION AND IS NOT TO BE USED IN ANY WAY THAT WILL BE DAMAGING TO THE INTERESTS OF THE ORIGINAL ENGINEER

NOTES:

REVISIONS

NO	DATE	DESCRIPTION	BY

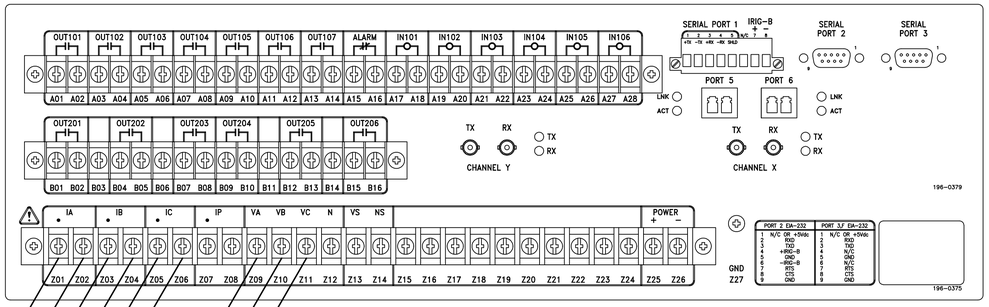
DRAWN BY: BVL	DATE: 4/22/15
ENGINEERED BY: BVL	DATE: 4/22/15
CHECKED BY: BVL	DATE: 4/22/15
APPROVED BY: BVL	DATE: 4/22/15

CUSTOMER: CALPOLY EE

TITLE: POTT COMMUNICATIONS WIRING DIAGRAM

PROJECT NUMBER: POTT001		
CAD FILE NAME: POTT_001_02.DWG	SCALE: NONE	
DRAWING NUMBER: E2.0	CONTROL: A	REVISION: 0

SEL- 311L - EAST LINE



I4562a

SOURCE #1 ΦA CURRENT
REFER TO DRAWING
POTT_0151-05.DWG

W-1121

W-1124

SOURCE #1 ΦB CURRENT
REFER TO DRAWING
POTT_0151-05.DWG

W-1122

W-1125

SOURCE #1 ΦC CURRENT
REFER TO DRAWING
POTT_0151-05.DWG

W-1123

W-1126

REFER TO DRAWING
POTT_0151-05.DWG

SOURCE #1 ΦA VOLTAGE — W-1133

SOURCE #1 ΦB VOLTAGE — W-1134

SOURCE #1 ΦC VOLTAGE — W-1135

SOURCE #2 ΦA CURRENT
REFER TO DRAWING
POTT_0151-05.DWG

W-1127

W-1130

SOURCE #2 ΦB CURRENT
REFER TO DRAWING
POTT_0151-05.DWG

W-1128

W-1131

SOURCE #2 ΦC CURRENT
REFER TO DRAWING
POTT_0151-05.DWG

W-1129

W-1132

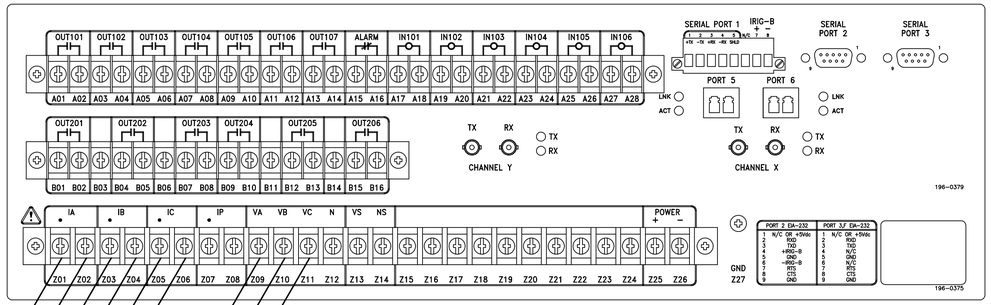
REFER TO DRAWING
POTT_0151-05.DWG

SOURCE #2 ΦA VOLTAGE — W-1136

SOURCE #2 ΦB VOLTAGE — W-1137

SOURCE #2 ΦC VOLTAGE — W-1138

SEL- 311L - WEST LINE



I4562a

WIRE / CABLE SCHEDULE

WIRE / CABLE NUMBER:	TERMINATION #1 LOCATION:	TERMINATION #2 LOCATION:	TYPE:		
W-1121	SOURCE #1 IMPEDANCE PHASE A	EAST LINE RELAY CURRENT PHASE A DOTTED	#14 THHN (BLK)		
W-1122	SOURCE #1 IMPEDANCE PHASE B	EAST LINE RELAY CURRENT PHASE B DOTTED	#14 THHN (RED)		
W-1123	SOURCE #1 IMPEDANCE PHASE C	EAST LINE RELAY CURRENT PHASE C DOTTED	#14 THHN (BLUE)		
W-1124	EAST LINE RELAY CURRENT PHASE A	EAST LINE INDUCTANCE PHASE A	#14 THHN (BLK)		
W-1125	EAST LINE RELAY CURRENT PHASE B	EAST LINE INDUCTANCE PHASE B	#14 THHN (RED)		
W-1126	EAST LINE RELAY CURRENT PHASE C	EAST LINE INDUCTANCE PHASE C	#14 THHN (BLUE)		
W-1127	SOURCE #2 IMPEDANCE PHASE A	WEST LINE RELAY CURRENT PHASE A DOTTED	#14 THHN (BLK)		
W-1128	SOURCE #2 IMPEDANCE PHASE B	WEST LINE RELAY CURRENT PHASE B DOTTED	#14 THHN (RED)		
W-1129	SOURCE #2 IMPEDANCE PHASE C	WEST LINE RELAY CURRENT PHASE C DOTTED	#14 THHN (BLUE)		
W-1130	WEST LINE RELAY CURRENT PHASE A	WEST LINE INDUCTANCE PHASE A	#14 THHN (BLK)		
W-1131	WEST LINE RELAY CURRENT PHASE B	WEST LINE INDUCTANCE PHASE B	#14 THHN (RED)		
W-1132	WEST LINE RELAY CURRENT PHASE C	WEST LINE INDUCTANCE PHASE C	#14 THHN (BLUE)		
W-1133	SOURCE #1 PHASE A	EAST LINE RELAY VOLTAGE PHASE A	#14 THHN (BLK)		
W-1134	SOURCE #1 PHASE B	EAST LINE RELAY VOLTAGE PHASE B	#14 THHN (RED)		
W-1135	SOURCE #1 PHASE C	EAST LINE RELAY VOLTAGE PHASE C	#14 THHN (BLUE)		
W-1136	SOURCE #2 PHASE A	WEST LINE RELAY VOLTAGE PHASE A	#14 THHN (BLK)		
W-1137	SOURCE #2 PHASE B	WEST LINE RELAY VOLTAGE PHASE B	#14 THHN (RED)		
W-1138	SOURCE #2 PHASE C	WEST LINE RELAY VOLTAGE PHASE C	#14 THHN (BLUE)		

INSTRUMENTATION WIRING DIAGRAM

SCALE: NONE

NOTES:

REVISIONS

NO	DATE	DESCRIPTION	BY

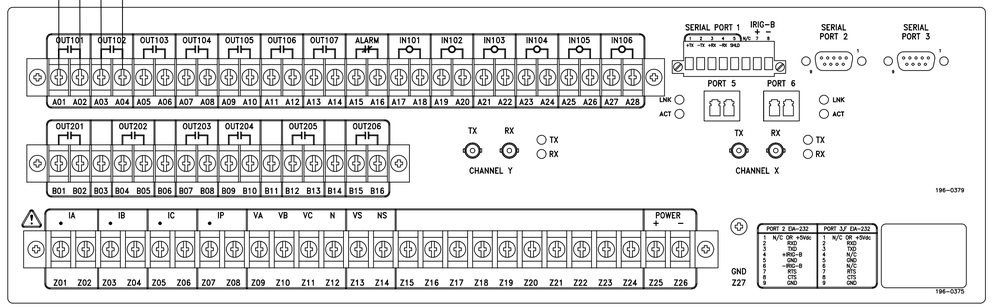
DRAWN BY: BVL	DATE: 4/22/15
ENGINEERED BY: BVL	DATE: 4/22/15
CHECKED BY: BVL	DATE: 4/22/15
APPROVED BY: BVL	DATE: 4/22/15

CUSTOMER: CALPOLY EE

TITLE: POTT INSTRUMENTATION WIRING DIAGRAM

PROJECT NUMBER: POTT001		
CAD FILE NAME: POTT_001_03.DWG	SCALE: NONE	
DRAWING NUMBER: E3.0	CONTROL: A	REVISION: 0

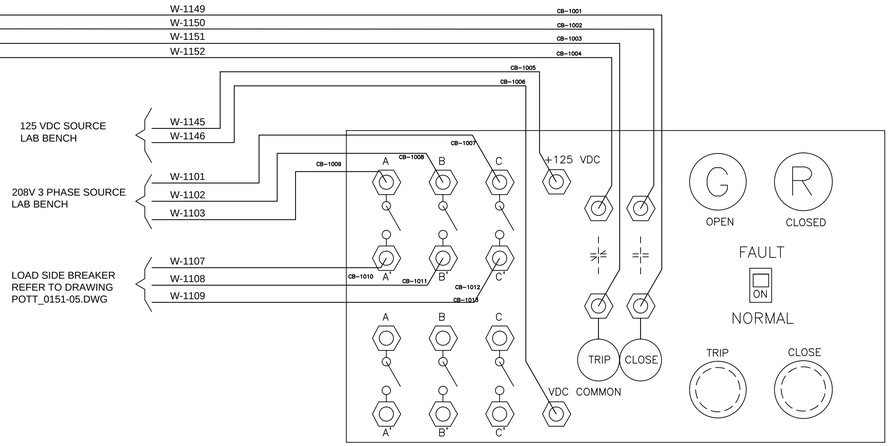
SEL- 311L - EAST LINE



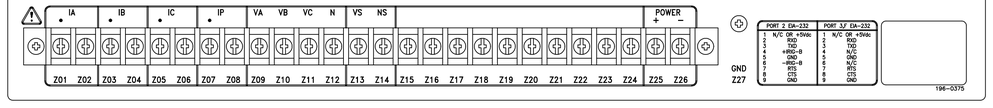
I4562a

W-1149
W-1150
W-1151
W-1152

CIRCUIT BREAKER - EAST LINE



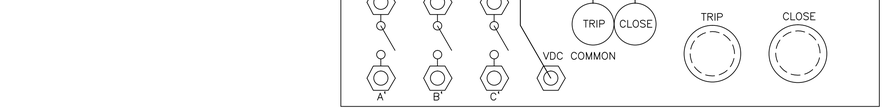
SEL- 311L - WEST LINE



I4562a

W-1153
W-1154
W-1155
W-1156

CIRCUIT BREAKER - WEST LINE



WIRE / CABLE SCHEDULE

WIRE / CABLE NUMBER:	TERMINATION #1 LOCATION:	TERMINATION #2 LOCATION:	TYPE:	DESCRIPTION:	NOTES:
W-1101	SOURCE #1 PHASE A	CB EAST LINE PHASE A	#14 THHN (BLK)	SOURCE TO LINE SIDE CB CONNECTION	
W-1102	SOURCE #1PHASE B	CB EAST LINE PHASE B	#14 THHN (RED)	SOURCE TO LINE SIDE CB CONNECTION	
W-1103	SOURCE #1 PHASE C	CB EAST LINE PHASE C	#14 THHN (BLUE)	SOURCE TO LINE SIDE CB CONNECTION	
W-1104	SOURCE #2 PHASE A	CB WEST LINE PHASE A	#14 THHN (BLK)	SOURCE TO LINE SIDE CB CONNECTION	
W-1105	SOURCE #2PHASE B	CB WEST LINE PHASE B	#14 THHN (RED)	SOURCE TO LINE SIDE CB CONNECTION	
W-1106	SOURCE #2 PHASE C	CB WEST LINE PHASE C	#14 THHN (BLUE)	SOURCE TO LINE SIDE CB CONNECTION	
W-1107	CB EAST LOAD PHASE A	EAST LINE IMPEDANCE PHASE A	#14 THHN (BLK)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1108	CB EAST LOAD PHASE B	EAST LINE IMPEDANCE PHASE B	#14 THHN (RED)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1109	CB EAST LOAD PHASE C	EAST LINE IMPEDANCE PHASE C	#14 THHN (BLUE)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1110	CB WEST LOAD PHASE A	WEST LINE IMPEDANCE PHASE A	#14 THHN (BLK)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1111	CB WEST LOAD PHASE B	WEST LINE IMPEDANCE PHASE B	#14 THHN (RED)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1112	CB WEST LOAD PHASE C	WEST LINE IMPEDANCE PHASE C	#14 THHN (BLUE)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1145	125VDC SOURCE	EAST LINE CB +125VDC	#14 THHN (BLK)		
W-1146	125VDC COMMON SOURCE	EAST LINE CB 125DC COMMON	#14 THHN (WHT)		
W-1147	125VDC SOURCE	WEST LINE CB +125VDC	#14 THHN (BLK)		
W-1148	125VDC COMMON SOURCE	WEST LINE CB 125DC COMMON	#14 THHN (WHT)		
W-1149	EAST LINE RELAY OUT101-1	EAST LINE CB OPEN (CB-1001)	#14 THHN (BLUE)		
W-1150	EAST LINE RELAY OUT101-2	EAST LINE CB OPEN (CB-1002)	#14 THHN (BLUE)		
W-1151	EAST LINE RELAY OUT102-1	EAST LINE CB TRIP (CB-1003)	#14 THHN (RED)		
W-1152	EAST LINE RELAY OUT102-2	EAST LINE CB TRIP (CB-1004)	#14 THHN (RED)		
W-1153	WEST LINE RELAY OUT101-1	WEST LINE CB OPEN (CB-1001)	#14 THHN (BLUE)		
W-1154	WEST LINE RELAY OUT101-2	WEST LINE CB OPEN (CB-1002)	#14 THHN (BLUE)		
W-1155	WEST LINE RELAY OUT102-1	WEST LINE CB TRIP (CB-1003)	#14 THHN (RED)		
W-1156	WEST LINE RELAY OUT102-2	WEST LINE CB TRIP (CB-1004)	#14 THHN (RED)		

CIRCUIT BREAKER CONTROL WIRING DIAGRAM

SCALE: NONE

NOTES:

REVISIONS

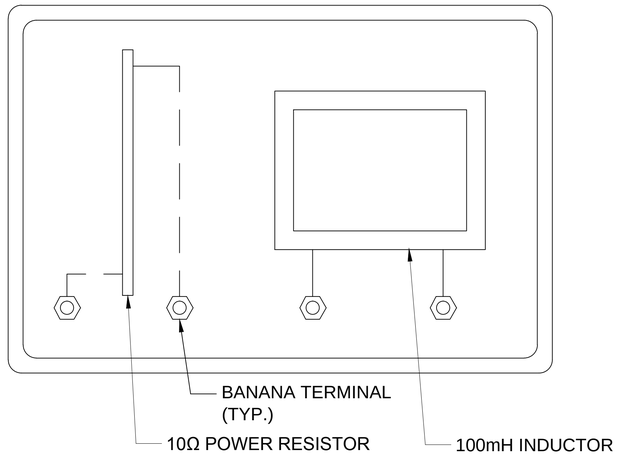
NO	DATE	DESCRIPTION	BY

DRAWN BY: BVL	DATE: 4/22/15
ENGINEERED BY: BVL	DATE: 4/22/15
CHECKED BY: BVL	DATE: 4/22/15
APPROVED BY: BVL	DATE: 4/22/15

CUSTOMER: CALPOLY EE

TITLE: POTT CONTROL WIRING DIAGRAM

PROJECT NUMBER: POTT001		
CAD FILE NAME: POTT_001_04.DWG	SCALE: NONE	
DRAWING NUMBER: E4.0	CONTROL: A	REVISION: 0

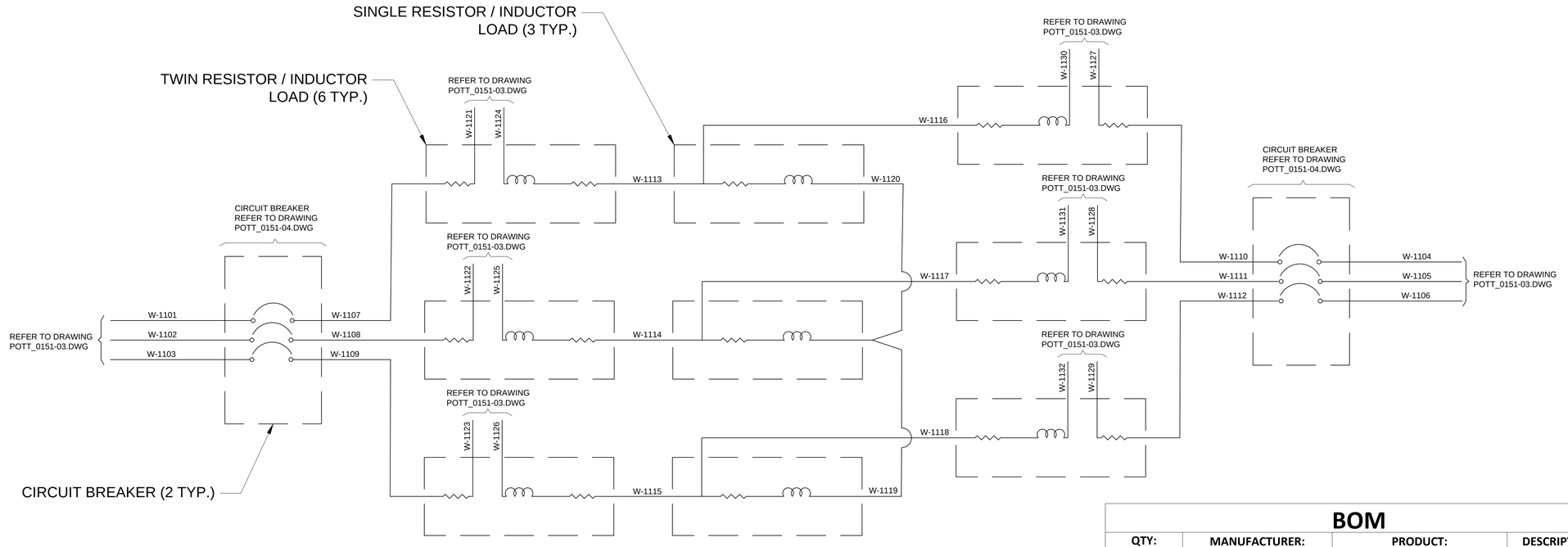


LINE IMPEDANCE DETAIL

SCALE: NONE

WIRE / CABLE SCHEDULE

WIRE / CABLE NUMBER:	TERMINATION #1 LOCATION:	TERMINATION #2 LOCATION:	TYPE:	DESCRIPTION:	NOTES:
W-1101	SOURCE #1 PHASE A	CB EAST LINE PHASE A	#14 THHN (BLK)	SOURCE TO LINE SIDE CB CONNECTION	
W-1102	SOURCE #1PHASE B	CB EAST LINE PHASE B	#14 THHN (RED)	SOURCE TO LINE SIDE CB CONNECTION	
W-1103	SOURCE #1 PHASE C	CB EAST LINE PHASE C	#14 THHN (BLUE)	SOURCE TO LINE SIDE CB CONNECTION	
W-1104	SOURCE #2 PHASE A	CB WEST LINE PHASE A	#14 THHN (BLK)	SOURCE TO LINE SIDE CB CONNECTION	
W-1105	SOURCE #2PHASE B	CB WEST LINE PHASE B	#14 THHN (RED)	SOURCE TO LINE SIDE CB CONNECTION	
W-1106	SOURCE #2 PHASE C	CB WEST LINE PHASE C	#14 THHN (BLUE)	SOURCE TO LINE SIDE CB CONNECTION	
W-1107	CB EAST LOAD PHASE A	EAST LINE IMPEDANCE PHASE A	#14 THHN (BLK)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1108	CB EAST LOAD PHASE B	EAST LINE IMPEDANCE PHASE B	#14 THHN (RED)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1109	CB EAST LOAD PHASE C	EAST LINE IMPEDANCE PHASE C	#14 THHN (BLUE)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1110	CB WEST LOAD PHASE A	WEST LINE IMPEDANCE PHASE A	#14 THHN (BLK)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1111	CB WEST LOAD PHASE B	WEST LINE IMPEDANCE PHASE B	#14 THHN (RED)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1112	CB WEST LOAD PHASE C	WEST LINE IMPEDANCE PHASE C	#14 THHN (BLUE)	LOAD SIDE CB TO LINE IMPEDANCE	
W-1113	EAST LINE IMPEDANCE PHASE A	LOAD IMPEDANCE PHASE A	#14 THHN (BLK)	LINE IMPEDANCE TO LOAD	
W-1114	EAST LINE IMPEDANCE PHASE B	LOAD IMPEDANCE PHASE B	#14 THHN (RED)	LINE IMPEDANCE TO LOAD	
W-1115	EAST LINE IMPEDANCE PHASE C	LOAD IMPEDANCE PHASE C	#14 THHN (BLUE)	LINE IMPEDANCE TO LOAD	
W-1116	WEST LINE IMPEDANCE PHASE A	LOAD IMPEDANCE PHASE A	#14 THHN (BLK)	LINE IMPEDANCE TO LOAD	
W-1117	WEST LINE IMPEDANCE PHASE B	LOAD IMPEDANCE PHASE B	#14 THHN (RED)	LINE IMPEDANCE TO LOAD	
W-1118	WEST LINE IMPEDANCE PHASE C	LOAD IMPEDANCE PHASE C	#14 THHN (BLUE)	LINE IMPEDANCE TO LOAD	
W-1119	LOAD PHASE A	LOAD PHASE B	#14 THHN (BLK)	WYE LOAD CONNECTION	
W-1120	LOAD PHASE B	LOAD PHASE C	#14 THHN (BLK)	WYE LOAD CONNECTION	
W-1121	SOURCE #1 IMPEDANCE PHASE A	EAST LINE RELAY CURRENT PHASE A DOTTED	#14 THHN (BLK)		DOTTED TERMINAL
W-1122	SOURCE #1 IMPEDANCE PHASE B	EAST LINE RELAY CURRENT PHASE B DOTTED	#14 THHN (RED)		DOTTED TERMINAL
W-1123	SOURCE #1 IMPEDANCE PHASE C	EAST LINE RELAY CURRENT PHASE C DOTTED	#14 THHN (BLUE)		DOTTED TERMINAL
W-1124	EAST LINE RELAY CURRENT PHASE A	EAST LINE INDUCTANCE PHASE A	#14 THHN (BLK)		
W-1125	EAST LINE RELAY CURRENT PHASE B	EAST LINE INDUCTANCE PHASE B	#14 THHN (RED)		
W-1126	EAST LINE RELAY CURRENT PHASE C	EAST LINE INDUCTANCE PHASE C	#14 THHN (BLUE)		
W-1127	SOURCE #2 IMPEDANCE PHASE A	WEST LINE RELAY CURRENT PHASE A DOTTED	#14 THHN (BLK)		DOTTED TERMINAL
W-1128	SOURCE #2 IMPEDANCE PHASE B	WEST LINE RELAY CURRENT PHASE B DOTTED	#14 THHN (RED)		DOTTED TERMINAL
W-1129	SOURCE #2 IMPEDANCE PHASE C	WEST LINE RELAY CURRENT PHASE C DOTTED	#14 THHN (BLUE)		DOTTED TERMINAL
W-1130	WEST LINE RELAY CURRENT PHASE A	WEST LINE INDUCTANCE PHASE A	#14 THHN (BLK)		
W-1131	WEST LINE RELAY CURRENT PHASE B	WEST LINE INDUCTANCE PHASE B	#14 THHN (RED)		
W-1132	WEST LINE RELAY CURRENT PHASE C	WEST LINE INDUCTANCE PHASE C	#14 THHN (BLUE)		



LABORATORY CIRCUIT WIRING DIAGRAM

SCALE: NONE

BOM

QTY:	MANUFACTURER:	PRODUCT:	DESCRIPTION:
6	LAB EQUIPMENT	TWIN RESISTOR & INDUCTOR LOAD	
3	LAB EQUIPMENT	SINGLE RESISTOR & INDUCTOR LOAD	
2	LAB EQUIPMENT	CIRCUIT BREAKER / FAULT BOXES	
50'	SOUTHWIRE	#14 THHN WIRE BLK, RED, BLUE	
AR	IDEAL	#14-#24 RED NARROW FORK TERMINAL	

NOTES:

REVISIONS

NO	DATE	DESCRIPTION	BY

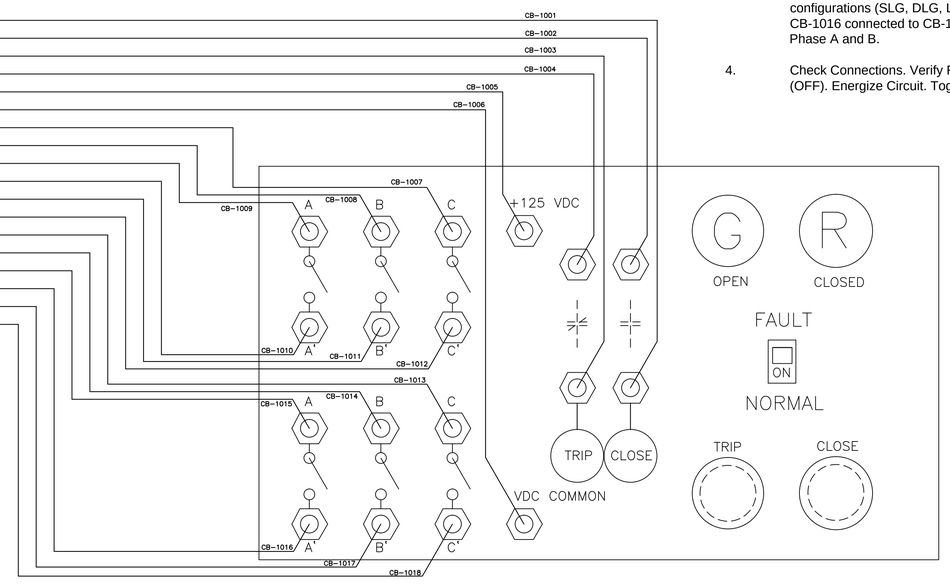
DRAWN BY: BVL	DATE: 4/22/15
ENGINEERED BY: BVL	DATE: 4/22/15
CHECKED BY: BVL	DATE: 4/22/15
APPROVED BY: BVL	DATE: 4/22/15

CUSTOMER: CALPOLY EE

TITLE: POTT CIRCUIT WIRING DIAGRAM

PROJECT NUMBER: POTT001		
CAD FILE NAME: POTT_001_05.DWG	SCALE: NONE	
DRAWING NUMBER: E5.0	CONTROL: A	REVISION: 0

DESCRIPTION:	WIRE NUMBER:
SEL OUTPUT NORMALLY OPEN (CLOSE CB)	CB-1001
SEL OUTPUT NORMALLY OPEN (CLOSE CB)	CB-1002
SEL OUTPUT NORMALLY CLOSED (TRIP CB)	CB-1003
SEL OUTPUT NORMALLY CLOSED (TRIP CB)	CB-1004
+125VDC STATION BATTERY	CB-1005
0VDC (COMMON TERMINAL) STATION BATTERY	CB-1006
CB LINE PHASE C	CB-1007
CB LINE PHASE B	CB-1008
CB LINE PHASE A	CB-1009
CB LOAD PHASE A	CB-1010
CB LOAD PHASE B	CB-1011
CB LOAD PHASE C	CB-1012
FAULT SW. LINE PHASE C	CB-1013
FAULT SW. LINE PHASE B	CB-1014
FAULT SW. LINE PHASE A	CB-1015
FAULT SW. LOAD PHASE A	CB-1016
FAULT SW. LOAD PHASE B	CB-1017
FAULT SW. LOAD PHASE C	CB-1018



CIRCUIT BREAKER WIRING DIAGRAM

SCALE: NONE

NOTES

CIRCUIT BREAKER INSTRUCTIONS:

1. From source, connect phases to 'CB Line' connections (CB-1007, CB-1008, and CB-1009.)
2. Connect the protected load to 'CB Load' connections (CB-1010, CB-1011, and CB-1012.)
3. Connect a 125VDC source to 'Station Battery' terminals (CB-1005, CB-1006.)
4. Connect protective relay output contacts (ex. SEL-311L OUT101 and OUT102) to Normally Open (NO) output contacts for 'CLOSE CB' (CB-1001, CB-1002) and Normally Closed (NC) output contacts for 'TRIP CB' (CB-1003, CB-1004.)
5. Check Connections.
6. Energize 125VDC control circuit.
7. Test Breaker Manual Trip / Close functionality.

FAULT SIMULATOR CONFIGURATION:

1. De-energize equipment.
2. Connect 'Fault SW. Line' terminals to circuit nodes that are to be faulted using banana leads.
3. Connect 'Fault SW. Load' terminals together in desired fault configurations (SLG, DLG, LL, LLL) using short leads. Example: CB-1016 connected to CB-1017 for Line-to-Line fault across Phase A and B.
4. Check Connections. Verify Fault Switch in Normal Position (OFF). Energize Circuit. Toggle Fault Switch.

NOTES:

REVISIONS

NO	DATE	DESCRIPTION	BY

DRAWN BY: BVL	DATE: 4/22/15
ENGINEERED BY: BVL	DATE: 4/22/15
CHECKED BY: BVL	DATE: 4/22/15
APPROVED BY: BVL	DATE: 4/22/15

CUSTOMER: CALPOLY EE

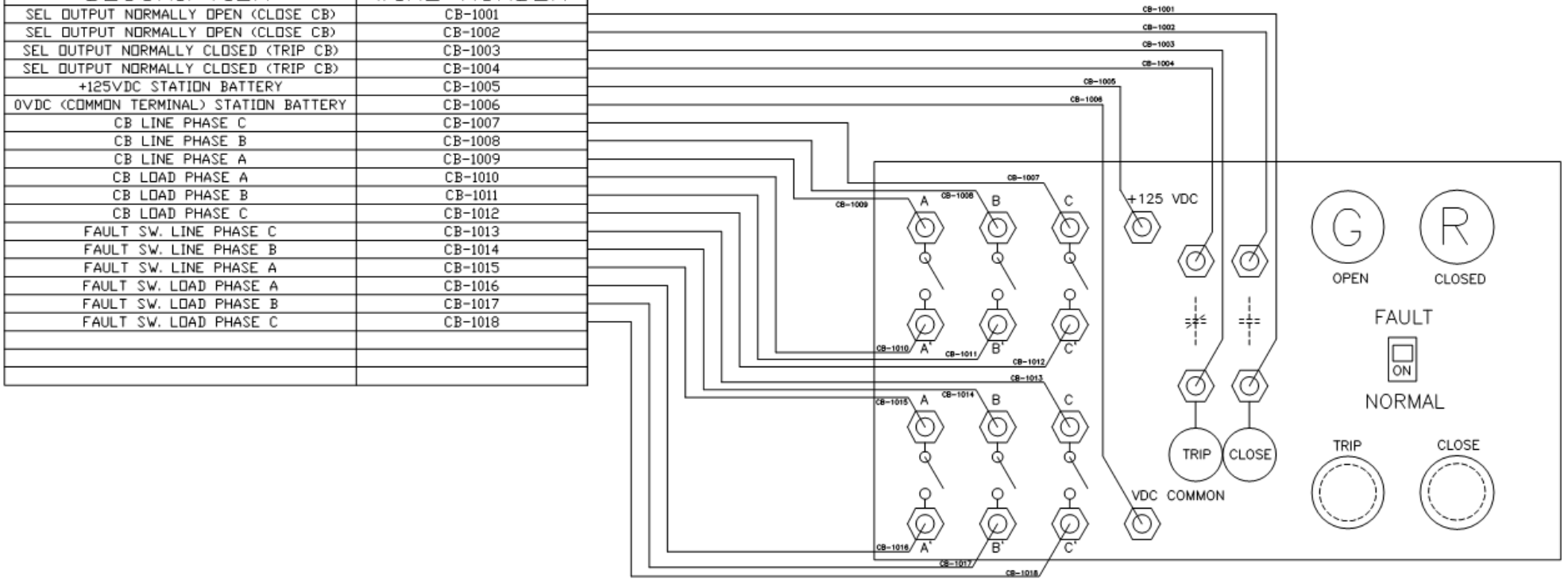
TITLE: POTT CIRCUIT BREAKER GENERIC WIRING DIAGRAM

PROJECT NUMBER: POTT001		
CAD FILE NAME: POTT_001_06.DWG	SCALE: NONE	
DRAWING NUMBER: E6.0	CONTROL: A	REVISION: 0

8.3 CIRCUIT BREAKER OPERATION

Circuit Breaker and Fault Simulator Connection Diagram

DESCRIPTION:	WIRE NUMBER:
SEL OUTPUT NORMALLY OPEN (CLOSE CB)	CB-1001
SEL OUTPUT NORMALLY OPEN (CLOSE CB)	CB-1002
SEL OUTPUT NORMALLY CLOSED (TRIP CB)	CB-1003
SEL OUTPUT NORMALLY CLOSED (TRIP CB)	CB-1004
+125VDC STATION BATTERY	CB-1005
0VDC (COMMON TERMINAL) STATION BATTERY	CB-1006
CB LINE PHASE C	CB-1007
CB LINE PHASE B	CB-1008
CB LINE PHASE A	CB-1009
CB LOAD PHASE A	CB-1010
CB LOAD PHASE B	CB-1011
CB LOAD PHASE C	CB-1012
FAULT SW. LINE PHASE C	CB-1013
FAULT SW. LINE PHASE B	CB-1014
FAULT SW. LINE PHASE A	CB-1015
FAULT SW. LOAD PHASE A	CB-1016
FAULT SW. LOAD PHASE B	CB-1017
FAULT SW. LOAD PHASE C	CB-1018



CIRCUIT BREAKER CONFIGURATION:

1. From source, connect phases to 'CB Line' connections (CB-1007, CB-1008, and CB-1009.)
2. Connect the protected load to 'CB Load' connections (CB-1010, CB-1011, and CB-1012.)
3. Connect a 125VDC source to 'Station Battery' terminals (CB-1005, CB-1006.)
4. Connect protective relay output contacts (ex. SEL-311L OUT101 and OUT102) to Normally Open (NO) output contacts for 'CLOSE CB' (CB-1001, CB-1002) and Normally Closed (NC) output contacts for 'TRIP CB' (CB-1003, CB-1004.)
5. Check Connections.
6. Energize 125VDC control circuit.
7. Test Breaker Manual Trip / Close functionality.

FAULT SIMULATOR CONFIGURATION:

1. De-energize equipment.
2. Connect 'Fault SW. Line' terminals to circuit nodes that are to be faulted using banana leads.
3. Connect 'Fault SW. Load' terminals together in desired fault configurations (SLG, DLG, LL, LLL) using short leads. Example: CB-1016 connected to CB-1017 for Line-to-Line fault across Phase A and B.
4. Check Connections. Verify Fault Switch in Normal Position (OFF). Energize Circuit. Toggle Fault Switch.

SEL-311L EAST TRANSMISSION LINE

Setting	Range	Value
Group : 1		
RID	Range = ASCII string with a maximum length of 30.	SEL-311
TID	Range = ASCII string with a maximum length of 30.	EXAMPLE: BUS B, BREAKER 3
CTR	Range = 1 to 6000	1
APP	Select: 87L, 87L21, 87L21P, 87LSP, 311L	311L
EADVS	Select: Y, N	N
E87L	Select: 2, 3, 3R, N	2
EHST	Select: 1-6, N	N
EHSDTT	Select: Y, N	N
EDD	Select: Y, N	Y
ETAP	Select: Y, N	N
EOCTL	Select: Y, N	N
PCHAN	Select: X, Y	X
EHSC	Select: Y, N	N
CTR_X	Range = 1 to 6000	1
TA_X	Select: 1-16	1
RA_X	Select: 1-16	2
CTR_Y	Range = 1 to 6000	200
TA_Y	Select: 1-16	3
RA_Y	Select: 1-16	4
87LPP	Range = 1.00 to 10.00, OFF	6.00
87L2P	Range = 0.50 to 5.00, OFF	0.50
87LGP	Range = 0.50 to 5.00, OFF	OFF
CTALRM	Range = 0.50 to 10.00	0.50
87LR	Range = 2.0 to 8.0	6.0
87LANG	Range = 90 to 270	195
ETP	Select: Y, N	N
T51PP	Range = 0.50 to 16.00, OFF	OFF
T51PC	Select: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	U3
T51PTD	Range = 0.50 to 15.00	2.00
T51PRS	Select: Y, N	N
T50PP	Range = 0.50 to 100.00, OFF	OFF
T50PD	Range = 0.00 to 16000.00, OFF	0.00
ETG	Select: Y, N	N
T51GP	Range = 0.50 to 16.00, OFF	0.75

<Filter is Empty>

Setting	Range	Value
T51GC	Select: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	U3
T51GTD	Range = 0.50 to 15.00	2.00
T51GRS	Select: Y, N	Y
T50GP	Range = 0.50 to 100.00, OFF	OFF
T50GD	Range = 0.00 to 16000.00, OFF	0.00
ETQ	Select: Y, N	N
T51QP	Range = 0.50 to 16.00, OFF	2.20
T51QC	Select: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	U3
T51QTD	Range = 0.50 to 15.00	2.00
T51QRS	Select: Y, N	N
T50QP	Range = 0.50 to 100.00, OFF	OFF
T50QD	Range = 0.00 to 16000.00, OFF	0.00
CTRP	Range = 1 to 6000	1
PTR	Range = 1.00 to 10000.00	1.00
PTRS	Range = 1.00 to 10000.00	1.00
Z1MAG	Range = 0.05 to 255.00	78.00
Z1ANG	Range = 5.00 to 90.00	75.00
Z0MAG	Range = 0.05 to 255.00	78.00
Z0ANG	Range = 5.00 to 90.00	75.00
LL	Range = 0.10 to 999.00	100.00
EFLOC	Select: Y, N	Y
E21P	Select: N, 1-4, 1C-4C	2
ECCVT	Select: Y, N	N
Z1P	Range = 0.05 to 64.00, OFF	40.00
Z2P	Range = 0.05 to 64.00, OFF	60.00
Z3P	Range = 0.05 to 64.00, OFF	1.87
Z4P	Range = 0.05 to 64.00, OFF	OFF
50PP1	Range = 0.50 to 170.00	0.50
50PP2	Range = 0.50 to 170.00	0.50
50PP3	Range = 0.50 to 170.00	0.50
50PP4	Range = 0.50 to 170.00	0.50
E21MG	Select: N, 1-4	3
Z1MG	Range = 0.05 to 64.00, OFF	40.00
Z2MG	Range = 0.05 to 64.00, OFF	60.00
Z3MG	Range = 0.05 to 64.00, OFF	60.00
Z4MG	Range = 0.05 to 64.00, OFF	OFF
E21XG	Select: N, 1-4	N

<Filter is Empty>

Setting	Range	Value
XG1	Range = 0.05 to 64.00, OFF	6.24
XG2	Range = 0.05 to 64.00, OFF	9.36
XG3	Range = 0.05 to 64.00, OFF	1.87
XG4	Range = 0.05 to 64.00, OFF	OFF
RG1	Range = 0.05 to 50.00	2.50
RG2	Range = 0.05 to 50.00	5.00
RG3	Range = 0.05 to 50.00	6.00
RG4	Range = 0.05 to 50.00	0.05
XGPOL	Select: I2, IG	I2
TANG	Range = -45.0 to 45.0	-3.0
50L1	Range = 0.50 to 100.00	0.50
50L2	Range = 0.50 to 100.00	0.50
50L3	Range = 0.50 to 100.00	0.50
50L4	Range = 0.50 to 100.00	0.50
50GZ1	Range = 0.50 to 100.00	0.50
50GZ2	Range = 0.50 to 100.00	0.50
50GZ3	Range = 0.50 to 100.00	0.50
50GZ4	Range = 0.50 to 100.00	0.50
k0M1	Range = 0.000 to 6.000	0.726
k0A1	Range = -180.00 to 180.00	-3.69
k0M	Range = 0.000 to 6.000	0.726
k0A	Range = -180.00 to 180.00	-3.69
Z1PD	Range = 0.00 to 16000.00, OFF	OFF
Z2PD	Range = 0.00 to 16000.00, OFF	20.00
Z3PD	Range = 0.00 to 16000.00, OFF	OFF
Z4PD	Range = 0.00 to 16000.00, OFF	OFF
Z1GD	Range = 0.00 to 16000.00, OFF	OFF
Z2GD	Range = 0.00 to 16000.00, OFF	20.00
Z3GD	Range = 0.00 to 16000.00, OFF	OFF
Z4GD	Range = 0.00 to 16000.00, OFF	OFF
Z1D	Range = 0.00 to 16000.00, OFF	OFF
Z2D	Range = 0.00 to 16000.00, OFF	OFF
Z3D	Range = 0.00 to 16000.00, OFF	OFF
Z4D	Range = 0.00 to 16000.00, OFF	OFF
E50P	Select: N, 1-3	1
50P1P	Range = 0.25 to 100.00, OFF	3.00
50P2P	Range = 0.25 to 100.00, OFF	OFF
50P3P	Range = 0.25 to 100.00, OFF	OFF
67P1D	Range = 0.00 to 16000.00	0.00
67P2D	Range = 0.00 to 16000.00	0.00
67P3D	Range = 0.00 to 16000.00	0.00

<Filter is Empty>

Setting	Range	Value
E50G	Select: N, 1-4	N
50G1P	Range = 0.25 to 100.00, OFF	OFF
50G2P	Range = 0.25 to 100.00, OFF	OFF
50G3P	Range = 0.25 to 100.00, OFF	OFF
50G4P	Range = 0.25 to 100.00, OFF	OFF
67G1D	Range = 0.00 to 16000.00	0.00
67G2D	Range = 0.00 to 16000.00	0.00
67G3D	Range = 0.00 to 16000.00	0.00
67G4D	Range = 0.00 to 16000.00	0.00
E50Q	Select: N, 1-4	N
50Q1P	Range = 0.25 to 100.00, OFF	OFF
50Q2P	Range = 0.25 to 100.00, OFF	OFF
50Q3P	Range = 0.25 to 100.00, OFF	OFF
50Q4P	Range = 0.25 to 100.00, OFF	OFF
67Q1D	Range = 0.00 to 16000.00	0.00
67Q2D	Range = 0.00 to 16000.00	0.00
67Q3D	Range = 0.00 to 16000.00	0.00
67Q4D	Range = 0.00 to 16000.00	0.00
E51P	Select: Y, N	N
51PP	Range = 0.25 to 16.00, OFF	OFF
51PC	Select: U1-U5, C1-C5	U3
51PTD	Range = 0.50 to 15.00	2.00
51PRS	Select: Y, N	N
E51G	Select: Y, N	Y
51GP	Range = 0.25 to 16.00, OFF	0.75
51GC	Select: U1-U5, C1-C5	U3
51GTD	Range = 0.50 to 15.00	2.00
51GRS	Select: Y, N	Y
E51Q	Select: Y, N	Y
51QP	Range = 0.25 to 16.00, OFF	2.20
51QC	Select: U1-U5, C1-C5	U3
51QTD	Range = 0.50 to 15.00	2.00
51QRS	Select: Y, N	N
EOOS	Select: Y, N	N
OOSB1	Select: Y, N	N
OOSB2	Select: Y, N	N
OOSB3	Select: Y, N	N
OOSB4	Select: Y, N	N
OSBD	Range = 0.50 to 8000.00	2.00
EOOST	Select: N, I, O	N
OSTD	Range = 0.50 to 8000.00	0.50

<Filter is Empty>

Setting	Range	Value
X1T6	Range = 0.05 to 96.00	96.00
X1T5	Range = 0.05 to 96.00	90.00
R1R6	Range = 0.05 to 70.00	70.00
R1R5	Range = 0.05 to 70.00	65.00
X1B6	Range = -96.00 to -0.05	-96.00
X1B5	Range = -96.00 to -0.05	-90.00
R1L6	Range = -70.00 to -0.05	-70.00
R1L5	Range = -70.00 to -0.05	-65.00
50ABCP	Range = 1.00 to 100.00	1.00
UBD	Range = 0.50 to 120.00	0.50
UBOSBF	Range = 1.00 to 10.00	4.00
ELOAD	Select: Y, N	Y
ZLF	Range = 0.05 to 64.00	9.22
ZLR	Range = 0.05 to 64.00	9.22
PLAF	Range = -90.00 to 90.00	30.00
NLAF	Range = -90.00 to 90.00	-30.00
PLAR	Range = 90.00 to 270.00	150.00
NLAR	Range = 90.00 to 270.00	210.00
E32	Select: Y, AUTO	AUTO
ELOP	Select: Y, Y1, N	Y
EBBPT	Select: Y, N	N
DIR3	Select: F, R	R
DIR4	Select: F, R	F
ORDER	Select: I, Q, V, OFF	QVI
Z2F	Range = -64.00 to 64.00	39.00
Z2R	Range = -64.00 to 64.00	39.10
50QFP	Range = 0.25 to 5.00	0.50
50QRP	Range = 0.25 to 5.00	0.25
a2	Range = 0.02 to 0.50	0.10
k2	Range = 0.10 to 1.20	0.20
50GFP	Range = 0.25 to 5.00	0.50
50GRP	Range = 0.25 to 5.00	0.25
a0	Range = 0.02 to 0.50	0.10
Z0F	Range = -64.00 to 64.00	39.00
Z0R	Range = -64.00 to 64.00	39.10
EVOLT	Select: Y, N	N
27P	Range = 0.00 to 150.00, OFF	OFF
59P	Range = 0.00 to 150.00, OFF	OFF
59N1P	Range = 0.00 to 150.00, OFF	OFF
59N2P	Range = 0.00 to 150.00, OFF	OFF

<Filter is Empty>

Setting	Range	Value
59QP	Range = 0.00 to 100.00, OFF	OFF
59V1P	Range = 0.00 to 150.00, OFF	OFF
27SP	Range = 0.00 to 150.00, OFF	OFF
59SP	Range = 0.00 to 150.00, OFF	OFF
27PP	Range = 0.00 to 260.00, OFF	OFF
59PP	Range = 0.00 to 260.00, OFF	OFF
E25	Select: Y, N	N
25VLO	Range = 0.00 to 150.00	60.00
25VHI	Range = 0.00 to 150.00	75.00
25SF	Range = 0.005 to 0.500	0.042
25ANG1	Range = 0.00 to 80.00	25.00
25ANG2	Range = 0.00 to 80.00	40.00
SYNCP	Select: VA, VB, VC, VAB, VBC, VCA	VA
TCLOSD	Range = 1.00 to 60.00, OFF	3.00
E81	Select: N, 1-6	N
27B81P	Range = 20.00 to 150.00	20.00
81D1P	Range = 41.00 to 65.00, OFF	OFF
81D1D	Range = 2.00 to 16000.00	60.00
81D2P	Range = 41.00 to 65.00, OFF	OFF
81D2D	Range = 2.00 to 16000.00	60.00
81D3P	Range = 41.00 to 65.00, OFF	OFF
81D3D	Range = 2.00 to 16000.00	60.00
81D4P	Range = 41.00 to 65.00, OFF	OFF
81D4D	Range = 2.00 to 16000.00	60.00
81D5P	Range = 41.00 to 65.00, OFF	OFF
81D5D	Range = 2.00 to 16000.00	60.00
81D6P	Range = 41.00 to 65.00, OFF	OFF
81D6D	Range = 2.00 to 16000.00	60.00
E79	Select: N, 1-4	N
79OI1	Range = 0.00 to 999999.00	0.00
79OI2	Range = 0.00 to 999999.00	0.00
79OI3	Range = 0.00 to 999999.00	0.00
79OI4	Range = 0.00 to 999999.00	0.00
79RSD	Range = 0.00 to 999999.00	1800.00
79RSLD	Range = 0.00 to 999999.00	300.00
79CLSD	Range = 0.00 to 999999.00, OFF	OFF
ESOTF	Select: Y, N	Y

<Filter is Empty>

Setting	Range	Value
CLOEND	Range = 0.00 to 16000.00, OFF	OFF
52AEND	Range = 0.00 to 16000.00, OFF	10.00
SOTFD	Range = 0.50 to 16000.00	30.00
ECOMM	Select: N, POTT, DCUB1, DCUB2, DCB	POTT
Z3RBD	Range = 0.00 to 16000.00	5.00
EBLKD	Range = 0.00 to 16000.00, OFF	10.00
ETDPU	Range = 0.00 to 16000.00, OFF	2.00
EDURD	Range = 0.00 to 16000.00	4.00
EWFC	Select: Y, N	N
27PPW	Range = 0.0 to 260.0	0.0
59NW	Range = 0.0 to 150.0	150.0
GARD1D	Range = 0.00 to 16000.00	10.00
UBDURD	Range = 0.25 to 16000.00	9.00
UBEND	Range = 0.00 to 16000.00	0.50
Z3XPU	Range = 0.00 to 16000.00	1.00
Z3XD	Range = 0.00 to 16000.00	5.00
BTXD	Range = 0.00 to 16000.00	0.00
21SD	Range = 0.00 to 60.00	1.00
67SD	Range = 0.00 to 60.00	1.00
EMBA	Select: Y, N	N
RXIDA	Range = 1 to 4	1
TXIDA	Range = 1 to 4	2
EMBB	Select: Y, N	N
RXIDB	Range = 1 to 4	1
TXIDB	Range = 1 to 4	2
EZ1EXT	Select: Y, N	N
Z1EXTD	Range = 0.00 to 16000.00	180.00
Z1EXTM	Range = 1.00 to 4.00	1.30
EDEM	Select: THM, ROL	THM
DMTC	Select: 5, 10, 15, 30, 60	60
PDEMP	Range = 0.50 to 16.00, OFF	OFF
GDEMP	Range = 0.50 to 16.00, OFF	OFF
QDEMP	Range = 0.50 to 16.00, OFF	OFF
TDURD	Range = 2.00 to 16000.00	9.00
TOPD	Range = 2.00 to 8000.00	2.00
CFD	Range = 0.00 to 16000.00, OFF	60.00

<Filter is Empty>

Setting	Range	Value
3POD	Range = 0.00 to 60.00	0.50
OPO	Select: 27, 52	52
27PO	Range = 0.00 to 150.00	40.00
50LP	Range = 0.25 to 100.00, OFF	0.25
ELAT	Select: N, 1-16	16
EDP	Select: N, 1-16	16
ESV	Select: N, 1-16	N
SV1PU	Range = 0.00 to 999999.00	0.00
SV2PU	Range = 0.00 to 999999.00	0.00
SV3PU	Range = 0.00 to 999999.00	0.00
SV4PU	Range = 0.00 to 999999.00	0.00
SV5PU	Range = 0.00 to 999999.00	0.00
SV6PU	Range = 0.00 to 999999.00	0.00
SV7PU	Range = 0.00 to 16000.00	0.00
SV8PU	Range = 0.00 to 16000.00	0.00
SV9PU	Range = 0.00 to 16000.00	0.00
SV10PU	Range = 0.00 to 16000.00	0.00
SV11PU	Range = 0.00 to 16000.00	0.00
SV12PU	Range = 0.00 to 16000.00	0.00
SV13PU	Range = 0.00 to 16000.00	0.00
SV14PU	Range = 0.00 to 16000.00	0.00
SV15PU	Range = 0.00 to 16000.00	0.00
SV16PU	Range = 0.00 to 16000.00	0.00
SV1DO	Range = 0.00 to 999999.00	0.00
SV2DO	Range = 0.00 to 999999.00	0.00
SV3DO	Range = 0.00 to 999999.00	0.00
SV4DO	Range = 0.00 to 999999.00	0.00
SV5DO	Range = 0.00 to 999999.00	0.00
SV6DO	Range = 0.00 to 999999.00	0.00
SV7DO	Range = 0.00 to 16000.00	0.00
SV8DO	Range = 0.00 to 16000.00	0.00
SV9DO	Range = 0.00 to 16000.00	0.00
SV10DO	Range = 0.00 to 16000.00	0.00
SV11DO	Range = 0.00 to 16000.00	0.00
SV12DO	Range = 0.00 to 16000.00	0.00

<Filter is Empty>

Setting		Range	Value
	SV13DO	Range = 0.00 to 16000.00	0.00
	SV14DO	Range = 0.00 to 16000.00	0.00
	SV15DO	Range = 0.00 to 16000.00	0.00
	SV16DO	Range = 0.00 to 16000.00	0.00
⊞ Group : 2			
⊞ Group : 3			
⊞ Group : 4			
⊞ Group : 5			
⊞ Group : 6			
⊞ Group : DNPA			
⊞ Group : DNPB			
⊞ Group : G			
⊟ Group : L1			
	TR	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	87CHFAIL*(M1P+M2P+Z1G+Z2G)
	TRCOMM	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	M2P+Z2G
	TRSOTF	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	DTT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	E3PT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	ULTR	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	!(50L+51G)
	PT1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	R1X
	PT2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	LOG1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	LOG2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	BT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	52A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	IN101
	52AA	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	52AB	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	52AC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	CL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CC

<Filter is Empty>

Setting	Range	Value
ULCL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	TRIP+TRIP87
79RI	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79RIS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79DTL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79DLS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79SKP	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79STL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79BRS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79SEQ	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79CLS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
SET16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
67P1TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67P2TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67P3TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G1TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G2TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G3TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G4TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67Q1TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1

<Filter is Empty>

Setting	Range	Value
67Q2TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67Q3TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67Q4TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
51PTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
51GTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
51QTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T51PTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T51GTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T51QTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T50PTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T50GTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T50QTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
87LTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
SV1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
SV13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT101	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	
OUT102	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CLOSE
OUT103	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	!TRIP*!OC
OUT104	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	
OUT105	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT106	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT107	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	87HWAL
OUT201	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT202	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT203	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT204	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT205	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT206	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT301	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT302	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT303	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT304	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT305	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT306	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT307	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT308	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
OUT309	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT310	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT311	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT312	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	52A
DP2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CHXAL
DP3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CHYAL
DP4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
SS6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
ER	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	/B87L2+/M2P+/Z2G+/51G+/51Q+/50P1+/LOP
FAULT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	51G+51Q+M2P+Z2G
BSYNCH	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
CLMON	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
BKMON	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
E32IV	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
ESTUB	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB1A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB2A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB3A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB4A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB5A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB6A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB7A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB8A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB1B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB2B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB3B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB4B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB5B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB6B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB7B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB8B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
T1X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	KEY

<Filter is Empty>

Setting		Range	Value
	T2X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T3X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T4X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T1Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T2Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T3Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T4Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
⊞ Group : L2			
⊞ Group : L3			
⊞ Group : L4			
⊞ Group : L5			
⊞ Group : L6			
⊞ Group : P1			
⊞ Group : P2			
⊞ Group : P3			
⊞ Group : P4			
⊞ Group : P5			
⊞ Group : R			
⊞ Group : T			
⊟ Group : X			
	EADDCX	Select: Y, G, N	Y
	TA_X	Select: 1-16	1
	RA_X	Select: 1-16	2
	RBADXP	Range = 1 to 1000	10
	AVAXP	Range = 1 to 5000	10
	DBADXP	Range = 1 to 24	10
	RC422X	Select: R, F	R
	TC422X	Select: R, F	R
	TIMRX	Select: I, E	E
⊞ Group : Y			

<Filter is Empty>

SEL-311L WEST
TRANSMISSION LINE

Setting	Range	Value
Group : 1		
RID	Range = ASCII string with a maximum length of 30.	SEL-311
TID	Range = ASCII string with a maximum length of 30.	EXAMPLE: BUS B, BREAKER 3
CTR	Range = 1 to 6000	1
APP	Select: 87L, 87L21, 87L21P, 87LSP, 311L	311L
EADVS	Select: Y, N	N
E87L	Select: 2, 3, 3R, N	2
EHST	Select: 1-6, N	N
EHSDTT	Select: Y, N	N
EDD	Select: Y, N	Y
ETAP	Select: Y, N	N
EOCTL	Select: Y, N	N
PCHAN	Select: X, Y	X
EHSC	Select: Y, N	N
CTR_X	Range = 1 to 6000	1
TA_X	Select: 1-16	1
RA_X	Select: 1-16	2
CTR_Y	Range = 1 to 6000	200
TA_Y	Select: 1-16	3
RA_Y	Select: 1-16	4
87LPP	Range = 1.00 to 10.00, OFF	6.00
87L2P	Range = 0.50 to 5.00, OFF	0.50
87LGP	Range = 0.50 to 5.00, OFF	OFF
CTALRM	Range = 0.50 to 10.00	0.50
87LR	Range = 2.0 to 8.0	6.0
87LANG	Range = 90 to 270	195
ETP	Select: Y, N	N
T51PP	Range = 0.50 to 16.00, OFF	OFF
T51PC	Select: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	U3
T51PTD	Range = 0.50 to 15.00	2.00
T51PRS	Select: Y, N	N
T50PP	Range = 0.50 to 100.00, OFF	OFF
T50PD	Range = 0.00 to 16000.00, OFF	0.00
ETG	Select: Y, N	N

<Filter is Empty>

Setting	Range	Value
T51GP	Range = 0.50 to 16.00, OFF	0.75
T51GC	Select: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	U3
T51GTD	Range = 0.50 to 15.00	2.00
T51GRS	Select: Y, N	Y
T50GP	Range = 0.50 to 100.00, OFF	OFF
T50GD	Range = 0.00 to 16000.00, OFF	0.00
ETQ	Select: Y, N	N
T51QP	Range = 0.50 to 16.00, OFF	2.20
T51QC	Select: U1, U2, U3, U4, U5, C1, C2, C3, C4, C5	U3
T51QTD	Range = 0.50 to 15.00	2.00
T51QRS	Select: Y, N	N
T50QP	Range = 0.50 to 100.00, OFF	OFF
T50QD	Range = 0.00 to 16000.00, OFF	0.00
CTRP	Range = 1 to 6000	1
PTR	Range = 1.00 to 10000.00	1.00
PTRS	Range = 1.00 to 10000.00	1.00
Z1MAG	Range = 0.05 to 255.00	78.00
Z1ANG	Range = 5.00 to 90.00	75.00
Z0MAG	Range = 0.05 to 255.00	78.00
Z0ANG	Range = 5.00 to 90.00	75.00
LL	Range = 0.10 to 999.00	100.00
EFLOC	Select: Y, N	Y
E21P	Select: N, 1-4, 1C-4C	2
ECCVT	Select: Y, N	N
Z1P	Range = 0.05 to 64.00, OFF	40.00
Z2P	Range = 0.05 to 64.00, OFF	60.00
Z3P	Range = 0.05 to 64.00, OFF	1.87
Z4P	Range = 0.05 to 64.00, OFF	OFF
50PP1	Range = 0.50 to 170.00	0.50
50PP2	Range = 0.50 to 170.00	0.50
50PP3	Range = 0.50 to 170.00	0.50
50PP4	Range = 0.50 to 170.00	0.50
E21MG	Select: N, 1-4	3
Z1MG	Range = 0.05 to 64.00, OFF	40.00
Z2MG	Range = 0.05 to 64.00, OFF	60.00
Z3MG	Range = 0.05 to 64.00, OFF	60.00
Z4MG	Range = 0.05 to 64.00, OFF	OFF

<Filter is Empty>

Setting		Range	Value
	E21XG	Select: N, 1-4	N
	XG1	Range = 0.05 to 64.00, OFF	6.24
	XG2	Range = 0.05 to 64.00, OFF	9.36
	XG3	Range = 0.05 to 64.00, OFF	1.87
	XG4	Range = 0.05 to 64.00, OFF	OFF
	RG1	Range = 0.05 to 50.00	2.50
	RG2	Range = 0.05 to 50.00	5.00
	RG3	Range = 0.05 to 50.00	6.00
	RG4	Range = 0.05 to 50.00	0.05
	XGPOL	Select: I2, IG	I2
	TANG	Range = -45.0 to 45.0	-3.0
	50L1	Range = 0.50 to 100.00	0.50
	50L2	Range = 0.50 to 100.00	0.50
	50L3	Range = 0.50 to 100.00	0.50
	50L4	Range = 0.50 to 100.00	0.50
	50GZ1	Range = 0.50 to 100.00	0.50
	50GZ2	Range = 0.50 to 100.00	0.50
	50GZ3	Range = 0.50 to 100.00	0.50
	50GZ4	Range = 0.50 to 100.00	0.50
	k0M1	Range = 0.000 to 6.000	0.726
	k0A1	Range = -180.00 to 180.00	-3.69
	k0M	Range = 0.000 to 6.000	0.726
	k0A	Range = -180.00 to 180.00	-3.69
	Z1PD	Range = 0.00 to 16000.00, OFF	OFF
	Z2PD	Range = 0.00 to 16000.00, OFF	20.00
	Z3PD	Range = 0.00 to 16000.00, OFF	OFF
	Z4PD	Range = 0.00 to 16000.00, OFF	OFF
	Z1GD	Range = 0.00 to 16000.00, OFF	OFF
	Z2GD	Range = 0.00 to 16000.00, OFF	20.00
	Z3GD	Range = 0.00 to 16000.00, OFF	OFF
	Z4GD	Range = 0.00 to 16000.00, OFF	OFF
	Z1D	Range = 0.00 to 16000.00, OFF	OFF
	Z2D	Range = 0.00 to 16000.00, OFF	OFF
	Z3D	Range = 0.00 to 16000.00, OFF	OFF
	Z4D	Range = 0.00 to 16000.00, OFF	OFF
	E50P	Select: N, 1-3	1
	50P1P	Range = 0.25 to 100.00, OFF	3.00
	50P2P	Range = 0.25 to 100.00, OFF	OFF
	50P3P	Range = 0.25 to 100.00, OFF	OFF
	67P1D	Range = 0.00 to 16000.00	0.00
	67P2D	Range = 0.00 to 16000.00	0.00

<Filter is Empty>

Setting	Range	Value
67P3D	Range = 0.00 to 16000.00	0.00
E50G	Select: N, 1-4	N
50G1P	Range = 0.25 to 100.00, OFF	OFF
50G2P	Range = 0.25 to 100.00, OFF	OFF
50G3P	Range = 0.25 to 100.00, OFF	OFF
50G4P	Range = 0.25 to 100.00, OFF	OFF
67G1D	Range = 0.00 to 16000.00	0.00
67G2D	Range = 0.00 to 16000.00	0.00
67G3D	Range = 0.00 to 16000.00	0.00
67G4D	Range = 0.00 to 16000.00	0.00
E50Q	Select: N, 1-4	N
50Q1P	Range = 0.25 to 100.00, OFF	OFF
50Q2P	Range = 0.25 to 100.00, OFF	OFF
50Q3P	Range = 0.25 to 100.00, OFF	OFF
50Q4P	Range = 0.25 to 100.00, OFF	OFF
67Q1D	Range = 0.00 to 16000.00	0.00
67Q2D	Range = 0.00 to 16000.00	0.00
67Q3D	Range = 0.00 to 16000.00	0.00
67Q4D	Range = 0.00 to 16000.00	0.00
E51P	Select: Y, N	N
51PP	Range = 0.25 to 16.00, OFF	OFF
51PC	Select: U1-U5, C1-C5	U3
51PTD	Range = 0.50 to 15.00	2.00
51PRS	Select: Y, N	N
E51G	Select: Y, N	Y
51GP	Range = 0.25 to 16.00, OFF	0.75
51GC	Select: U1-U5, C1-C5	U3
51GTD	Range = 0.50 to 15.00	2.00
51GRS	Select: Y, N	Y
E51Q	Select: Y, N	Y
51QP	Range = 0.25 to 16.00, OFF	2.20
51QC	Select: U1-U5, C1-C5	U3
51QTD	Range = 0.50 to 15.00	2.00
51QRS	Select: Y, N	N
EOOS	Select: Y, N	N
OOSB1	Select: Y, N	N
OOSB2	Select: Y, N	N
OOSB3	Select: Y, N	N
OOSB4	Select: Y, N	N
OSBD	Range = 0.50 to 8000.00	2.00
EOOST	Select: N, I, O	N

<Filter is Empty>

Setting	Range	Value
OSTD	Range = 0.50 to 8000.00	0.50
X1T6	Range = 0.05 to 96.00	96.00
X1T5	Range = 0.05 to 96.00	90.00
R1R6	Range = 0.05 to 70.00	70.00
R1R5	Range = 0.05 to 70.00	65.00
X1B6	Range = -96.00 to -0.05	-96.00
X1B5	Range = -96.00 to -0.05	-90.00
R1L6	Range = -70.00 to -0.05	-70.00
R1L5	Range = -70.00 to -0.05	-65.00
50ABCP	Range = 1.00 to 100.00	1.00
UBD	Range = 0.50 to 120.00	0.50
UBOSBF	Range = 1.00 to 10.00	4.00
ELOAD	Select: Y, N	Y
ZLF	Range = 0.05 to 64.00	9.22
ZLR	Range = 0.05 to 64.00	9.22
PLAF	Range = -90.00 to 90.00	30.00
NLAF	Range = -90.00 to 90.00	-30.00
PLAR	Range = 90.00 to 270.00	150.00
NLAR	Range = 90.00 to 270.00	210.00
E32	Select: Y, AUTO	AUTO
ELOP	Select: Y, Y1, N	Y
EBBPT	Select: Y, N	N
DIR3	Select: F, R	R
DIR4	Select: F, R	F
ORDER	Select: I, Q, V, OFF	QVI
Z2F	Range = -64.00 to 64.00	39.00
Z2R	Range = -64.00 to 64.00	39.10
50QFP	Range = 0.25 to 5.00	0.50
50QRP	Range = 0.25 to 5.00	0.25
a2	Range = 0.02 to 0.50	0.10
k2	Range = 0.10 to 1.20	0.20
50GFP	Range = 0.25 to 5.00	0.50
50GRP	Range = 0.25 to 5.00	0.25
a0	Range = 0.02 to 0.50	0.10
Z0F	Range = -64.00 to 64.00	39.00
Z0R	Range = -64.00 to 64.00	39.10
EVOLT	Select: Y, N	N
27P	Range = 0.00 to 150.00, OFF	OFF
59P	Range = 0.00 to 150.00, OFF	OFF
59N1P	Range = 0.00 to 150.00, OFF	OFF

<Filter is Empty>

Setting	Range	Value
59N2P	Range = 0.00 to 150.00, OFF	OFF
59QP	Range = 0.00 to 100.00, OFF	OFF
59V1P	Range = 0.00 to 150.00, OFF	OFF
27SP	Range = 0.00 to 150.00, OFF	OFF
59SP	Range = 0.00 to 150.00, OFF	OFF
27PP	Range = 0.00 to 260.00, OFF	OFF
59PP	Range = 0.00 to 260.00, OFF	OFF
E25	Select: Y, N	N
25VLO	Range = 0.00 to 150.00	60.00
25VHI	Range = 0.00 to 150.00	75.00
25SF	Range = 0.005 to 0.500	0.042
25ANG1	Range = 0.00 to 80.00	25.00
25ANG2	Range = 0.00 to 80.00	40.00
SYNCP	Select: VA, VB, VC, VAB, VBC, VCA	VA
TCLOSD	Range = 1.00 to 60.00, OFF	3.00
E81	Select: N, 1-6	N
27B81P	Range = 20.00 to 150.00	20.00
81D1P	Range = 41.00 to 65.00, OFF	OFF
81D1D	Range = 2.00 to 16000.00	60.00
81D2P	Range = 41.00 to 65.00, OFF	OFF
81D2D	Range = 2.00 to 16000.00	60.00
81D3P	Range = 41.00 to 65.00, OFF	OFF
81D3D	Range = 2.00 to 16000.00	60.00
81D4P	Range = 41.00 to 65.00, OFF	OFF
81D4D	Range = 2.00 to 16000.00	60.00
81D5P	Range = 41.00 to 65.00, OFF	OFF
81D5D	Range = 2.00 to 16000.00	60.00
81D6P	Range = 41.00 to 65.00, OFF	OFF
81D6D	Range = 2.00 to 16000.00	60.00
E79	Select: N, 1-4	N
79OI1	Range = 0.00 to 999999.00	0.00
79OI2	Range = 0.00 to 999999.00	0.00
79OI3	Range = 0.00 to 999999.00	0.00
79OI4	Range = 0.00 to 999999.00	0.00
79RSD	Range = 0.00 to 999999.00	1800.00
79RSLD	Range = 0.00 to 999999.00	300.00
79CLSD	Range = 0.00 to 999999.00, OFF	OFF

<Filter is Empty>

Setting	Range	Value
ESOTF	Select: Y, N	Y
CLOEND	Range = 0.00 to 16000.00, OFF	OFF
52AEND	Range = 0.00 to 16000.00, OFF	10.00
SOTFD	Range = 0.50 to 16000.00	30.00
ECOMM	Select: N, POTT, DCUB1, DCUB2, DCB	POTT
Z3RBD	Range = 0.00 to 16000.00	5.00
EBLKD	Range = 0.00 to 16000.00, OFF	10.00
ETDPU	Range = 0.00 to 16000.00, OFF	2.00
EDURD	Range = 0.00 to 16000.00	4.00
EWFC	Select: Y, N	N
27PPW	Range = 0.0 to 260.0	0.0
59NW	Range = 0.0 to 150.0	150.0
GARD1D	Range = 0.00 to 16000.00	10.00
UBDURD	Range = 0.25 to 16000.00	9.00
UBEND	Range = 0.00 to 16000.00	0.50
Z3XPU	Range = 0.00 to 16000.00	1.00
Z3XD	Range = 0.00 to 16000.00	5.00
BTXD	Range = 0.00 to 16000.00	0.00
21SD	Range = 0.00 to 60.00	1.00
67SD	Range = 0.00 to 60.00	1.00
EMBA	Select: Y, N	N
RXIDA	Range = 1 to 4	1
TXIDA	Range = 1 to 4	2
EMBB	Select: Y, N	N
RXIDB	Range = 1 to 4	1
TXIDB	Range = 1 to 4	2
EZ1EXT	Select: Y, N	N
Z1EXTD	Range = 0.00 to 16000.00	180.00
Z1EXTM	Range = 1.00 to 4.00	1.30
EDEM	Select: THM, ROL	THM
DMTC	Select: 5, 10, 15, 30, 60	60
PDEMP	Range = 0.50 to 16.00, OFF	OFF
GDEMP	Range = 0.50 to 16.00, OFF	OFF
QDEMP	Range = 0.50 to 16.00, OFF	OFF
TDURD	Range = 2.00 to 16000.00	9.00
TOPD	Range = 2.00 to 8000.00	2.00

<Filter is Empty>

Setting		Range	Value
	CFD	Range = 0.00 to 16000.00, OFF	60.00
	3POD	Range = 0.00 to 60.00	0.50
	OPO	Select: 27, 52	52
	27PO	Range = 0.00 to 150.00	40.00
	50LP	Range = 0.25 to 100.00, OFF	0.25
	ELAT	Select: N, 1-16	16
	EDP	Select: N, 1-16	16
	ESV	Select: N, 1-16	N
	SV1PU	Range = 0.00 to 999999.00	0.00
	SV2PU	Range = 0.00 to 999999.00	0.00
	SV3PU	Range = 0.00 to 999999.00	0.00
	SV4PU	Range = 0.00 to 999999.00	0.00
	SV5PU	Range = 0.00 to 999999.00	0.00
	SV6PU	Range = 0.00 to 999999.00	0.00
	SV7PU	Range = 0.00 to 16000.00	0.00
	SV8PU	Range = 0.00 to 16000.00	0.00
	SV9PU	Range = 0.00 to 16000.00	0.00
	SV10PU	Range = 0.00 to 16000.00	0.00
	SV11PU	Range = 0.00 to 16000.00	0.00
	SV12PU	Range = 0.00 to 16000.00	0.00
	SV13PU	Range = 0.00 to 16000.00	0.00
	SV14PU	Range = 0.00 to 16000.00	0.00
	SV15PU	Range = 0.00 to 16000.00	0.00
	SV16PU	Range = 0.00 to 16000.00	0.00
	SV1DO	Range = 0.00 to 999999.00	0.00
	SV2DO	Range = 0.00 to 999999.00	0.00
	SV3DO	Range = 0.00 to 999999.00	0.00
	SV4DO	Range = 0.00 to 999999.00	0.00
	SV5DO	Range = 0.00 to 999999.00	0.00
	SV6DO	Range = 0.00 to 999999.00	0.00
	SV7DO	Range = 0.00 to 16000.00	0.00
	SV8DO	Range = 0.00 to 16000.00	0.00
	SV9DO	Range = 0.00 to 16000.00	0.00
	SV10DO	Range = 0.00 to 16000.00	0.00
	SV11DO	Range = 0.00 to 16000.00	0.00

<Filter is Empty>

Setting		Range	Value
	SV12DO	Range = 0.00 to 16000.00	0.00
	SV13DO	Range = 0.00 to 16000.00	0.00
	SV14DO	Range = 0.00 to 16000.00	0.00
	SV15DO	Range = 0.00 to 16000.00	0.00
	SV16DO	Range = 0.00 to 16000.00	0.00
⊞ Group : 2			
⊞ Group : 3			
⊞ Group : 4			
⊞ Group : 5			
⊞ Group : 6			
⊞ Group : DNPA			
⊞ Group : DNPB			
⊞ Group : G			
⊟ Group : L1			
	TR	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	87CHFAIL*(M1P+M2P+Z1G+Z2G)
	TRCOMM	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	M2P+Z2G
	TRSOTF	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	M2P
	DTT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	E3PT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	ULTR	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	!(50L+51G)
	PT1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	R1X
	PT2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	LOG1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	LOG2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	BT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	52A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	IN101
	52AA	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	52AB	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	52AC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
CL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CC
ULCL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	TRIP+TRIP87
79RI	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79RIS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79DTL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79DLS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79SKP	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79STL	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79BRS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79SEQ	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
79CLS	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
SET15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SET16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
RST16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
67P1TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67P2TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67P3TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G1TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G2TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G3TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67G4TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1

<Filter is Empty>

Setting	Range	Value
67Q1TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67Q2TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67Q3TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
67Q4TC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
51PTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
51GTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
51QTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T51PTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T51GTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T51QTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T50PTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T50GTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
T50QTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
87LTC	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
SV1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
SV12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SV16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT101	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	
OUT102	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CLOSE
OUT103	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	!TRIP*!OC
OUT104	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	
OUT105	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT106	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT107	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	87HWAL
OUT201	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT202	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT203	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT204	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT205	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT206	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT301	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT302	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT303	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT304	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT305	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT306	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT307	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
OUT308	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT309	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT310	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT311	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
OUT312	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	52A
DP2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CHXAL
DP3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	CHYAL
DP4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP7	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP8	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP9	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP10	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP11	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP12	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP13	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP14	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP15	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
DP16	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS1	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS2	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS3	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS4	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting	Range	Value
SS5	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
SS6	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
ER	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	/B87L2+/M2P+/Z2G+/51G+/51Q+/50P1+/LOP
FAULT	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	51G+51Q+M2P+Z2G
BSYNCH	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
CLMON	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
BKMON	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
E32IV	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	1
ESTUB	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB1A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB2A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB3A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB4A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB5A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB6A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB7A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB8A	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB1B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB2B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB3B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB4B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB5B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB6B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB7B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
TMB8B	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0

<Filter is Empty>

Setting		Range	Value
	T1X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	KEY
	T2X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T3X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T4X	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T1Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T2Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T3Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
	T4Y	Valid range = Boolean equation using word bit elements and the legal operators: ! / \ ( ) * +	0
⊞ Group : L2			
⊞ Group : L3			
⊞ Group : L4			
⊞ Group : L5			
⊞ Group : L6			
⊞ Group : P1			
⊞ Group : P2			
⊞ Group : P3			
⊞ Group : P4			
⊞ Group : P5			
⊞ Group : R			
⊞ Group : T			
⊟ Group : X			
	EADDCX	Select: Y, G, N	Y
	TA_X	Select: 1-16	2
	RA_X	Select: 1-16	1
	RBADXP	Range = 1 to 1000	10
	AVAXP	Range = 1 to 5000	10
	DBADXP	Range = 1 to 24	10
	RC422X	Select: R, F	R
	TC422X	Select: R, F	R
	TIMRX	Select: I, E	I
⊞ Group : Y			

<Filter is Empty>

8.4 SEL 311-L PILOT PROTECTION LABORATORY MANUAL

PAGE INTENTIONALLY LEFT BLANK

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

EE 444 **Experiment #**

Permissive Over-reaching Transfer Trip Protection (POTT)

Introduction:

Permissive Over-reaching Transfer Trip Protection (POTT) is a communication based protection scheme that relies on phase distance protection elements. Protection of transmission lines in a non-radial systems is difficult to coordinate with other connected transmission lines and distribution because power flow is not static or in one direction all of the time. For the protection of transmission lines, differential protection is not possible because of the losses along the line ($I_{in} \neq I_{out}$). The basic topology of the system consists of a transmission line with a SEL-311L relay at each end connected via a fiber optic communications line. The relays phase distance Zone 2 elements are set to pick-up at 120% of the line. The difference between phase distance and POTT is in the trip logic and communications link. A trip will only be issued if both relays Zone 2 elements pick-up and both of the relays receive a "key" from the other acknowledging that they too could see the Zone 2 Fault. The logic can be better explained by referring to the logic diagram below in Figure 1.

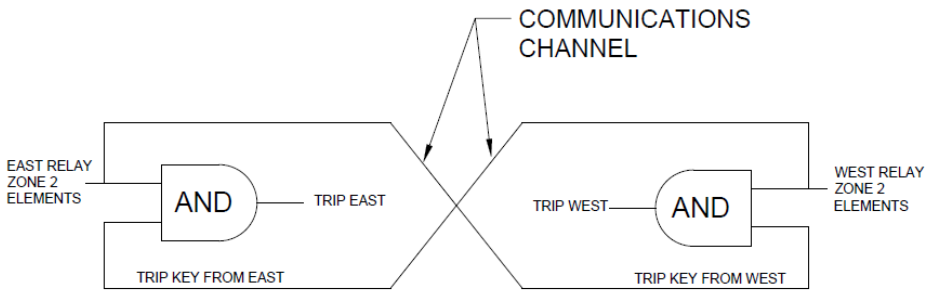


Figure 1. POTT Trip Logic

EQUIPMENT:

2 SEL 311-L relays

2 Circuit breakers

6 Inductor / double power resistors boards (100mH+ (2) 10Ω)

35 Long banana-to banana leads

1 Bag of short leads

1 Multi-meter

1 SEL serial data cable

3 High resistance / impedance load

PROCEDURE:

1. Download and print the construction document set.
2. Using banana to banana leads, wire the system according to the wiring diagrams in the construction drawing set.
3. With the power off, test the systems resistance of each phase to the center of the load wye connection. Resistance values should be 20 ohms + (load resistance / impedance) disconnected from the sources for resistance from each phase.
4. With the power off, verify the resistance between phases at the source is greater than 20 ohms.
    a. A to B
    b. B to C
    c. C to A
5. Wire Breaker and connect breaker to the SEL relay as shown in the construction drawing set.
6. Test manual breaker functionality by only energizing the 125VDC and pressing Open/ Close to verify breaker operation.
7. Program relay using settings found in the appendix of this document.
8. Upload the settings following the directions found in the appendix.
9. Based on the Single Line drawing in the construction drawing set. Connect the fault switch to the nodes internal to the transmission line zone of protection.
10. Apply fault conditions based on the procedure outlined in the "Breaker Operation" section. The **fault switch should only be turned on momentarily.** The switch should be returned to the off position within 5 seconds of being turned on to prevent equipment overheating and damage.
11. Apply SLG, LL, LLL faults for internal faults only. Download and view events to AcSELerator Analytic Assistant.

APPENDIX:

The relay settings below should be edited to provide proper system POTT protection.

Step 1. Open AcSELerator

Step 2. Click File new and choose SEL311-L. Based on the serial number of your relay enter the required information.

Step 3. Connect serial cable to the serial port located on the front of the relay and to the lab bench desktop

Step 4. Under the communications menu, select parameters. Confirm that the active connection type is set to serial and the settings in Figure 2 have been selected.

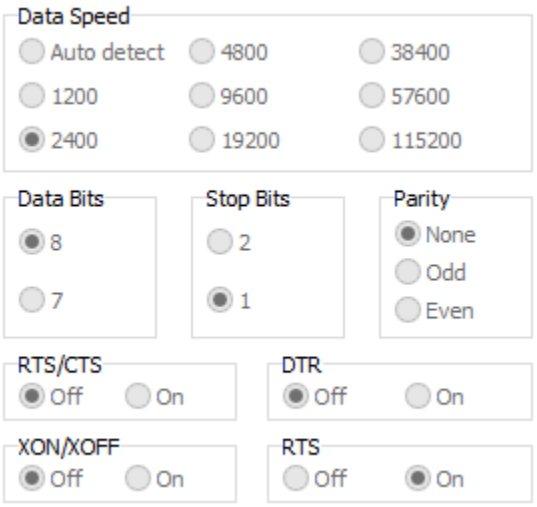


Figure 2. Communications Settings

Step 5. Click Connect. The bottom right hand corner of the window should display "Connected."

Step 6. Edit Settings.

Step 7. Click Send Active settings button. 

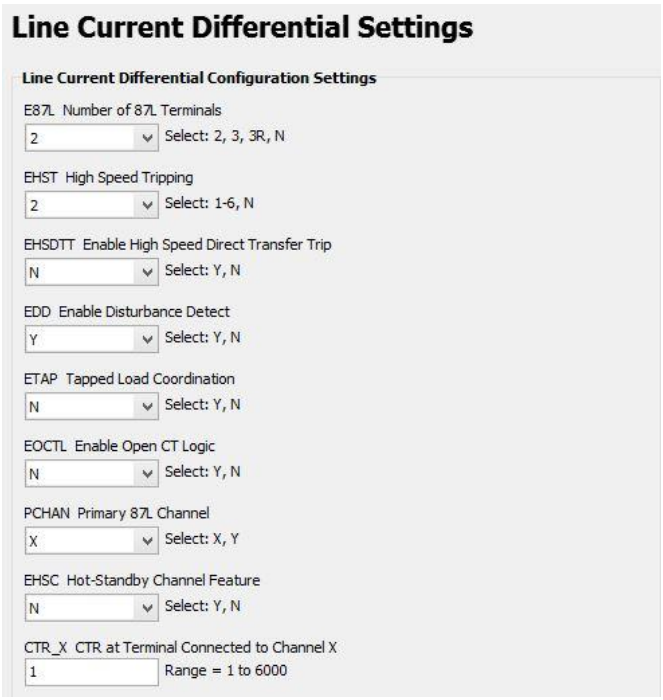


Figure 3. Line Current Differential Settings

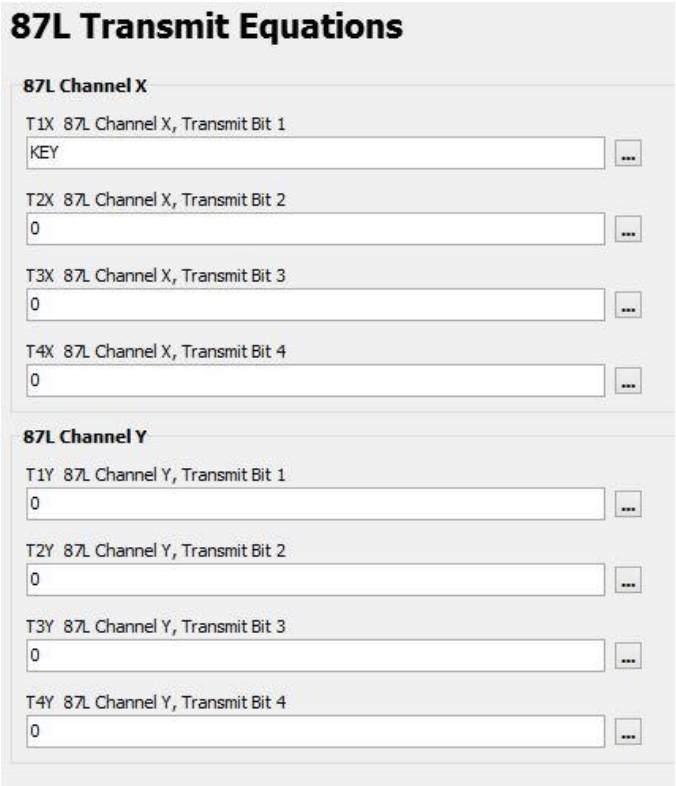


Figure 4. 87L Transmit Equations

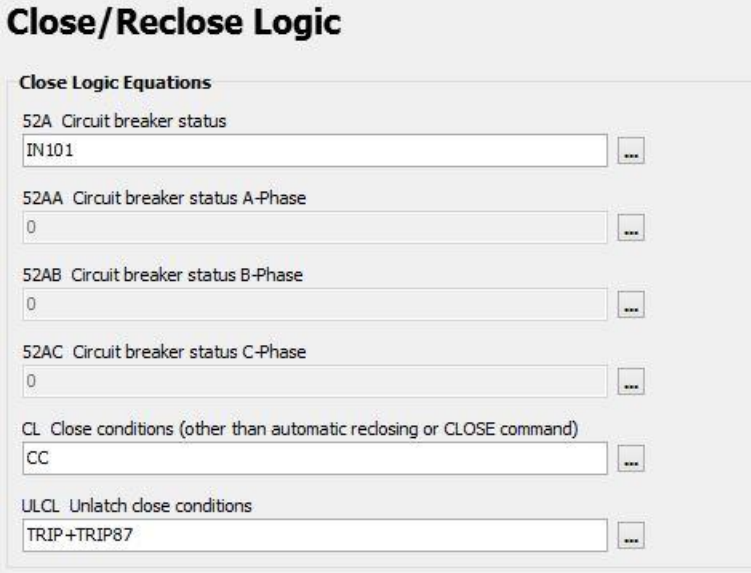


Figure 5. Close/Reclose Logic

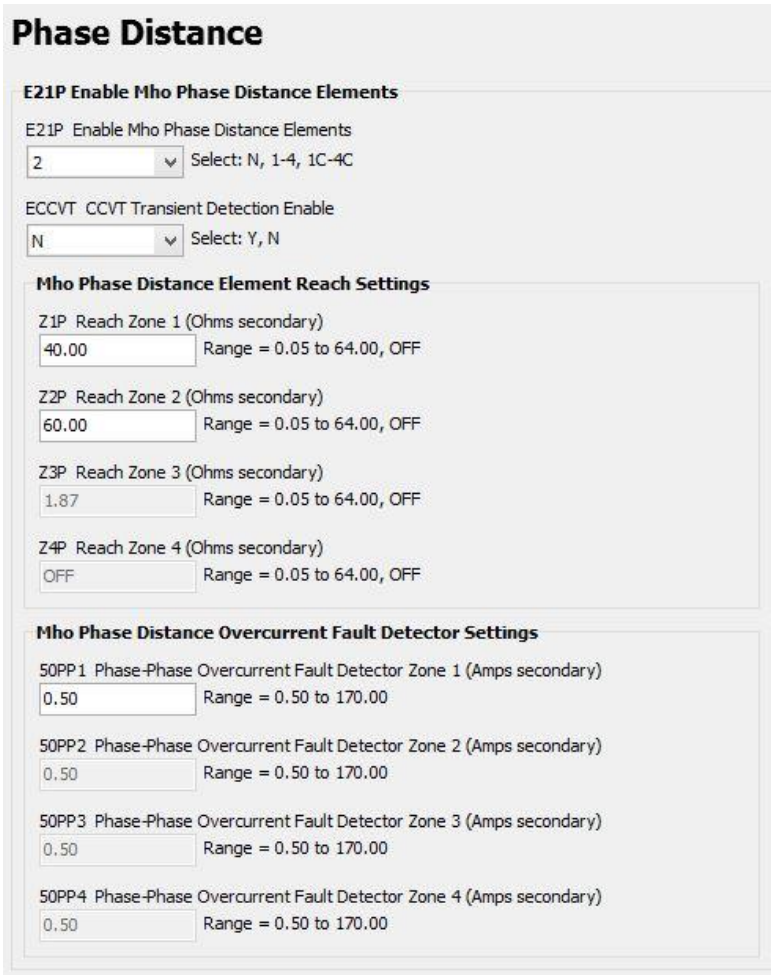


Figure 6. Phase Distance

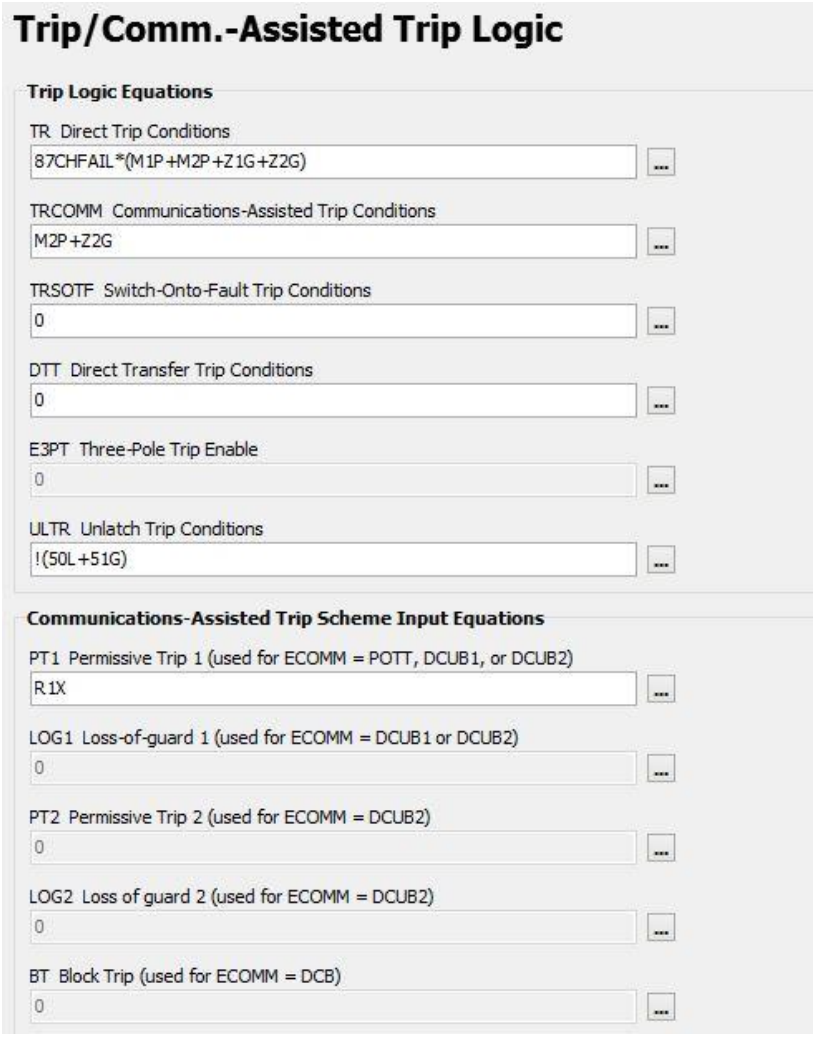


Figure 7. Trip/Comm – Assisted Trip Logic

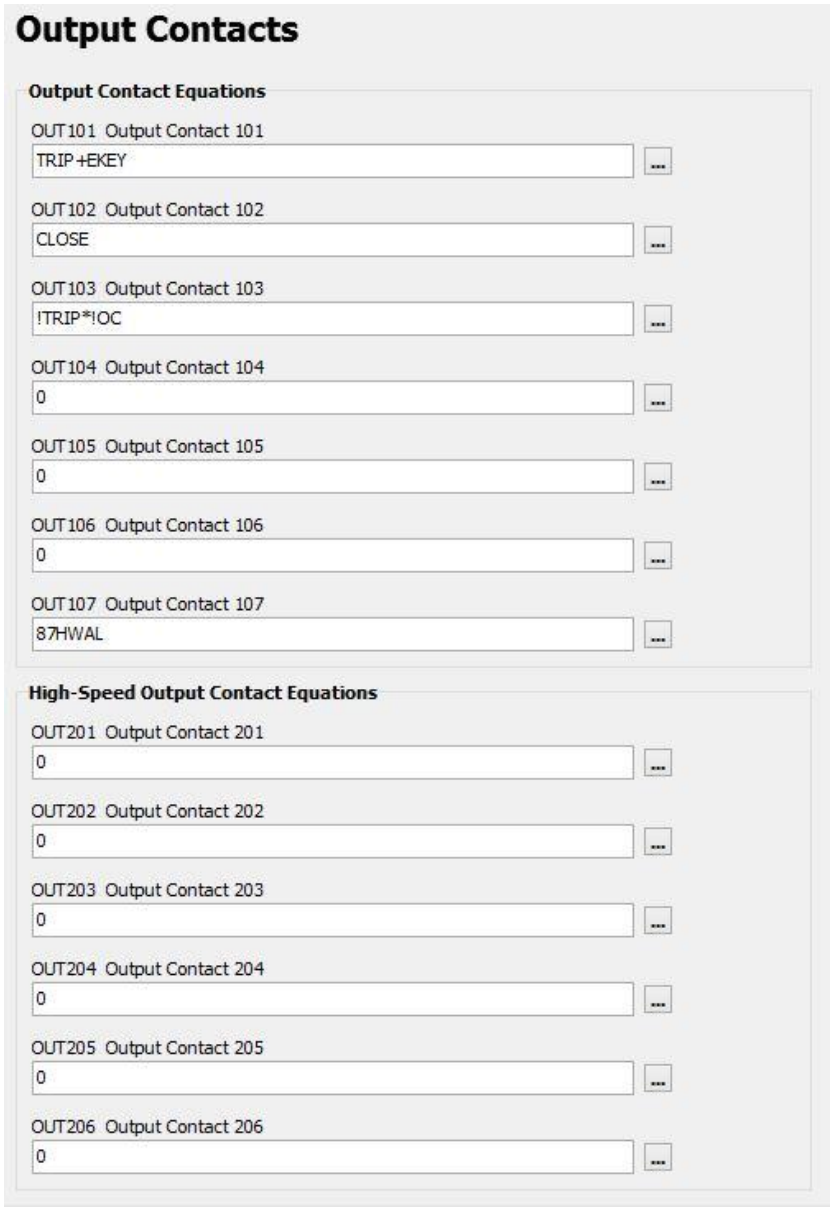


Figure 8. Output Contacts

8.5 REFERENCES

[1] J. L. Blackburn, and T. J. Domin, Protective Relaying Principles and Applications 4th Edition. Boca Raton, FL: Taylor & Francis Group, LLC, 2014.

[2] Schweitzer Engineering Laboratories, SEL-311L-1 -7 Relay Protection and Automation System Instruction Manual, Pullman, Washington: Schweitzer Engineering Laboratories, 2003-2014.

[3] IEEE Guide for Developing System Requirements Specifications," IEEE Std 1233-1996 , vol., no., pp.i,, 1996 doi: 10.1109/IEEESTD.1996.81000

[4] Schweitzer Engineering Laboratories, "SEL-311L Line Current Differential Protection and Automation System (Data Sheet)," Schweitzer Engineering Laboratories. [Online]. Available: https://www.selinc.com/SEL-311L/ [Accessed: Jan, 22, 2015]

[4] Bogdan Z. Kasztenny, Normann Fischer, "Transformer differential protection," U.S. Patent: 8 553 379, issued date October 8, 2013. Available: http://patft1.uspto.gov/netacgi/nph-Parser?patentnumber=8553379

[5] Schweitzer Engineering Laboratories, "SEL-2032 Communications Processor Instruction Manual," Schweitzer Engineering Laboratories. [Online]. Available: https://www.selinc.com/SEL-2032/ [Accessed: Jan, 22, 2015]

[6] IEEE Recommended Practice for Industrial and Commercial Power System Analysis," IEEE Std 399-1990 , vol., no., pp.1,384, Dec. 15 1990

[7] IEEE Guide for Protective Relay Applications to Transmission Lines," IEEE Std C37.113-1999 , vol., no., pp.i,, 2000

[8] Ghanizadeh Bolandi, T.; Seyedi, H.; Hashemi, S.M.; Soleiman Nezhad, P., "Impedance-Differential Protection: A New Approach to Transmission-Line Pilot Protection," Power Delivery, IEEE Transactions on , vol.PP, no.99, pp.1,1

[9] IEEE Guide for Protecting Power Transformers," IEEE Std C37.91-2008 (Revision of IEEE Std C37.91-2000) , vol., no., pp.1,139, May 30 2008

doi: 10.1109/IEEESTD.2008.4534870

[10] IEEE Guide for Determining Fault Location on AC Transmission and Distribution Lines," IEEE Std C37.114-2014 (Revision of IEEE Std C37.114-2004) , vol., no., pp.1,76, Jan. 30 2015