ECE 526

PROTECTION OF POWER SYSTEMS II

SESSION no. 11

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ECE 526: Lab 1
Due: Session 15 (March 2)

Lab Objective

- Learn the principles of distance protection and distance relays
- Learn the basic setting of SEL 421 relays for distance protection
- Perform relay co-ordination by properly setting relay parameters (impedance, time-delay)
- Physically connect the laboratory test setup and create faults (3-phase, LL, SLG, etc)
- Set and communicate with SEL 421 relays through serial port commands
- Observe the impact of fault resistance on Mho distance relay.

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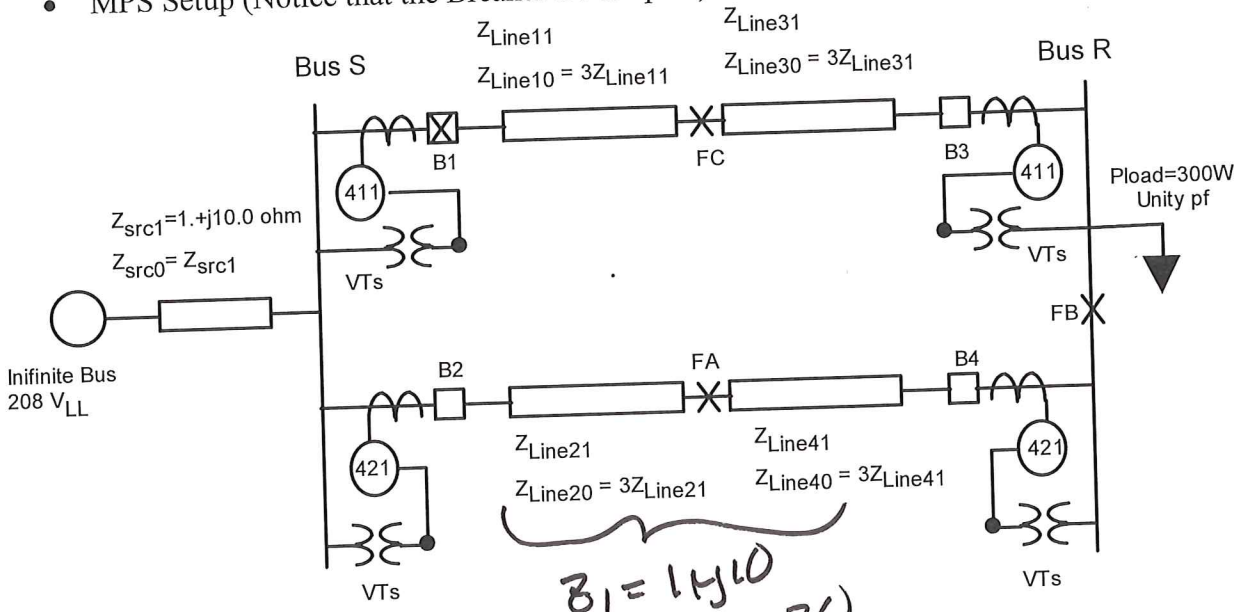
Lab Tasks

- Set distance relays and perform distance protection.
- MPS Setup (Notice that the Breaker B1 is open.)



$B_1 = 1+j10$
$Z_0 = 3+j30$

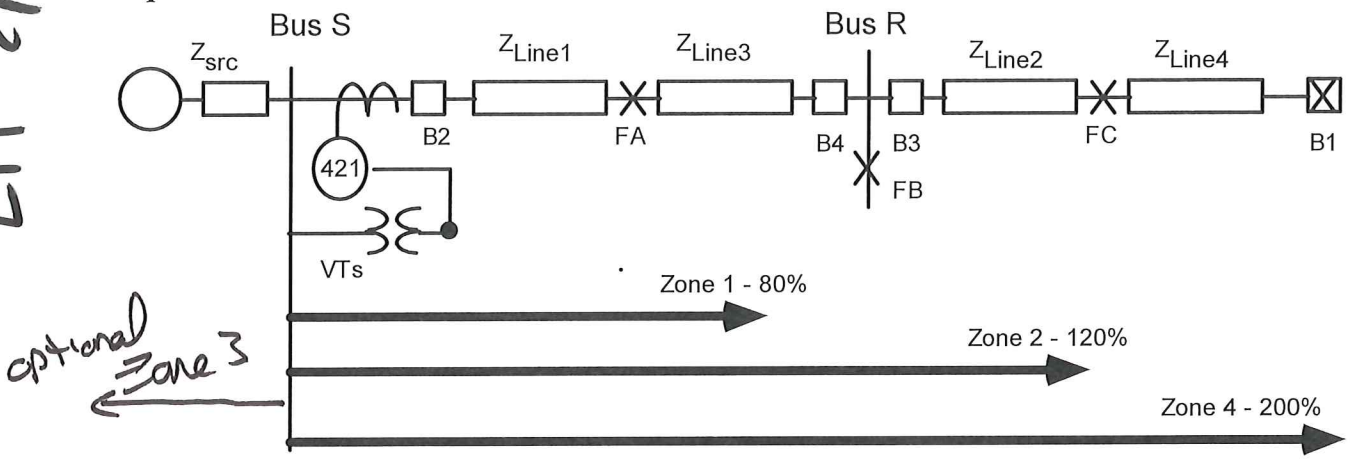
Set line impedances as follows

	Z_{line2}	Z_{line4}	Z_{line3}	Z_{line1}
Case 1	(0.8+j8.0) ohm	(0.2+j2.0) ohm	(0.5+j5.0) ohm	(0.5+j5.0) ohm
Case 2	(0.8+j8.0) ohm	(0.2+j2.0) ohm	(0.5+j5.0) ohm	(0.5+j5.0) ohm
Case 3	(0.8+j8.0) ohm	(0.2+j2.0) ohm	(0.9+j9.0) ohm	(0.1+j1.0) ohm
Case 4	(0.7+j7.0) ohm	(0.3+j3.0) ohm	(0.5+j5.0) ohm	(0.5+j5.0) ohm

Note: positive sequence impedances are: Between B2-B3: $Z_{line1} + Z_{line3}$ = (1.0+j10.0) ohm, Between B3-B1, $Z_{line2} + Z_{line4}$ = (1.0+j10.0) ohm, and source impedance: Z_{src} = (1.0+j10.0) ohm

The relay SEL 421 at Bus S provides instantaneous distance protection for zone 1 which is set at 80% of line L1-L3. The relay should have two time delayed overreaching backup zones, zone2 which is set at 150% of the impedance of line L1-L3 (note in this case this is 100% of line L1-L3 plus 50% of line L2-L4), and zone 4 which is set at 200% of line L1-L3 (so 100% of line L1-L3 and 100% of line L2-L4. The zone 3 setting is optional in this lab.

Equivalent Circuit with Zone Reaches:



Case 1: Set the phase and ground distance elements in the SEL 421 at Bus S to provide instantaneous under-reaching tripping against faults (3-phase, LL, SLG) at FA.

Case 2: Set SEL 421 at Bus S to provide time-delayed overreaching backup tripping against faults (3-phase, LL, SLG) at FB and FC. Let's set 10-cycle time delay in this case.

Case 3: Test the setting of SEL 421 at Bus S such that relay will NOT response to faults at FC beyond the zone 2 reach setting (overreaching) in Zone 2. Zone 4 should still pick up.

Case 4: Test the response of SEL421 at Bus S with varying the fault resistance for SLG fault at FA. Use the single phase resistor bank. Record the resistance value where zone 1 fails to pick up.

Pre-lab Preparation

(1) Calculate the relay impedance settings for each task and each case.
(2) Please also calculate the fault current values for LL, SLG and 3-phase faults.
(3) Possibly do computer simulations to verify your calculations and settings.

Relay Settings

The SEL 421 relay provides a large set of protection functions, we will use a small part of these. For your reference, a list of relevant settings is given below. For a complete reference, please visit www.selinc.com to download the SEL 421 relay manual in the lab.

(1) Set CT and PT ratio

CTR , PTR : CT ratio and PT ratio which are set as CTR = 200.0 and PTR = 200.0

(2) Calculate Line Impedance

- **Z1MAG , Z1ANG** : magnitude and angle of line positive-sequence impedance (secondary)
- **Z0MAG , Z0ANG** : magnitude and angle of line zero-sequence impedance (secondary)
- Let **k** = PTR/CTR
- Z1MAG(secondary) = Z1MAG(primary) / k ; Z0MAG(secondary) = Z0MAG(primary) / k .

(3) Set **E21MP**: Enable Phase MHO protection. Set **E21MP** = 2 (or 3) for two (three)

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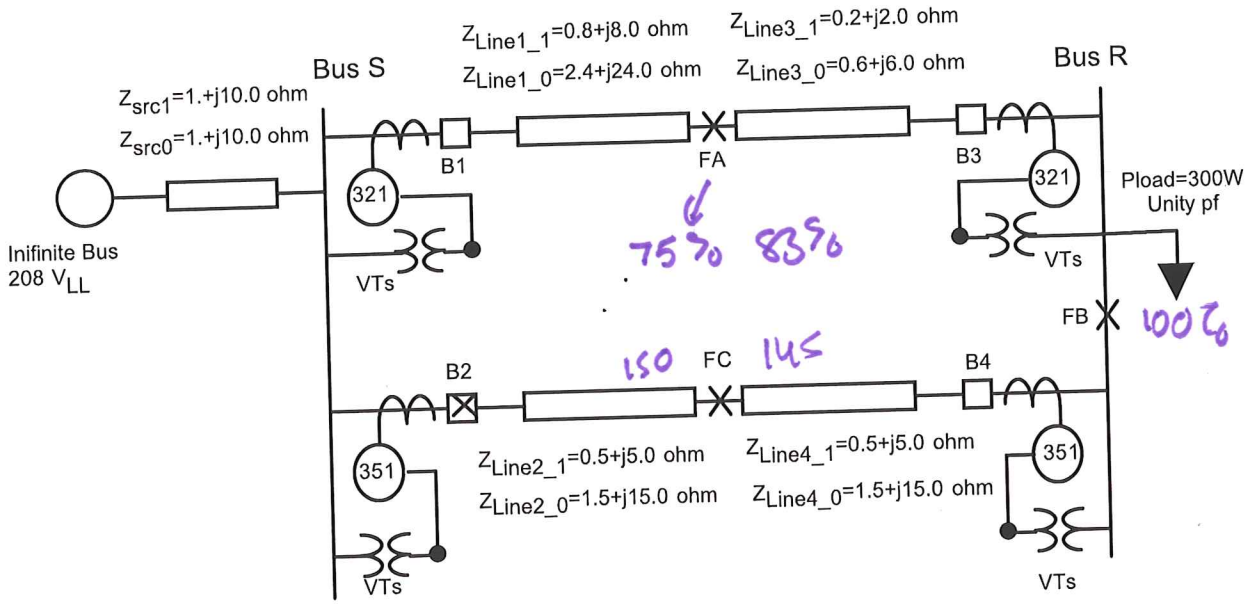
The simulated power system is configured as shown below, with a single source supplying two parallel lines. Each line segment has a series impedance of 1+j10 Ω, divided more or less equally between 10 taps. The source impedance can also be varied with taps and is set at its maximum.

- The simulated CT's have a CTR of 1:1
- The voltage transformers on the upper line have a VTR of 1:1



Please Note: breaker B2 is open, distance relay SEL 321 is used to provide 2-zone distance protection.

Lab 1 Procedure:

1. Determine relay settings for distance elements (phase and ground)
   - Instantaneous trip faults up to 80% of the upper line (Line 1 + Line 3) as shown above.
   - Time delayed trip (5 cycles) for faults between 80% and 150% (half way down the series set Line 2 + Line 4

   The phase and distance relay settings are as follows:
   a. Positive sequence line impedance
   b. Zero sequence line impedance
   c. The relay model will calculate k0 based on Z1 and Z0 so you don't need to enter it.
   d. Percentage reach for zone 1 (default set at 75% of the line length, you should update this) for both ground and phase elements.
   e. Percentage reach for zone 2 (default set at 125% of the line length) for both ground and phase elements.

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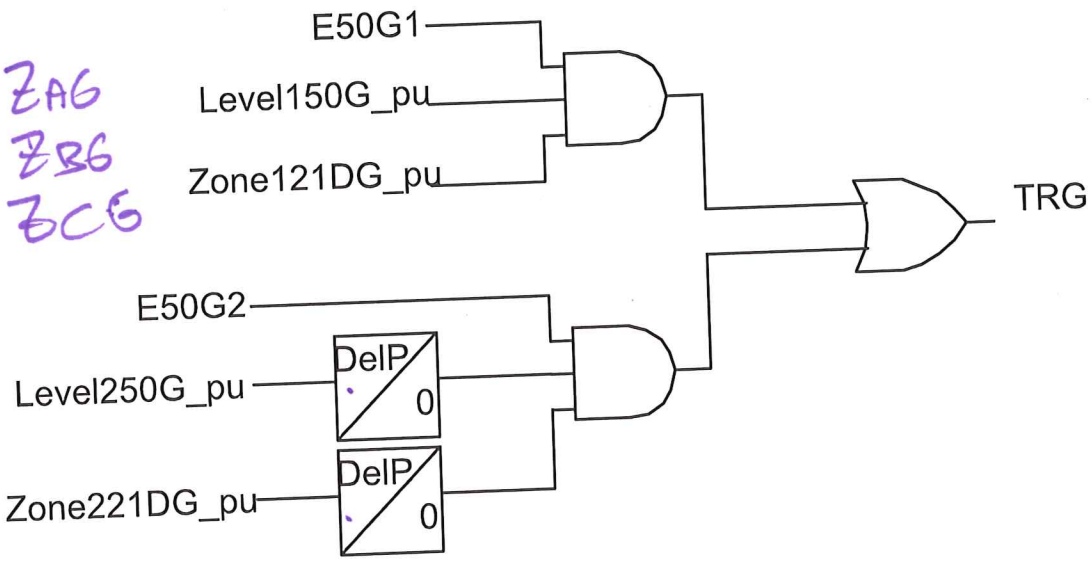
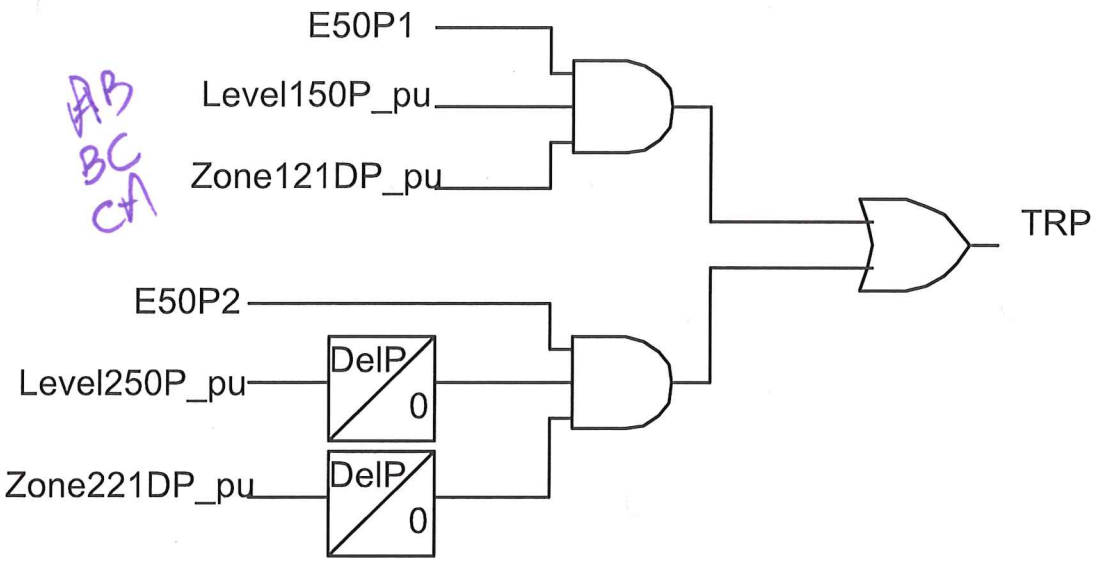
2. Determine relay settings for instantaneous overcurrent supervisory elements (phase and ground). In this case, the instantaneous elements are set to ensure that the distance elements are only active in the case of a fault. Therefore they should be set to a current above the maximum load current and below the minimum fault current you want to be able to cover for zone 1 or zone 2 (you have settings for each). The logic diagram is as shown in the figures below.

   Relay settings:
   a. Enable 50P or 50G element overcurrent supervisors
   b. Set minimum overcurrent pickup for zone 1 ground and phase elements
   c. Set minimum overcurrent pickup for zone 2 ground and phase elements

Ground distance element logic diagram:



Phase distance element logic diagram:

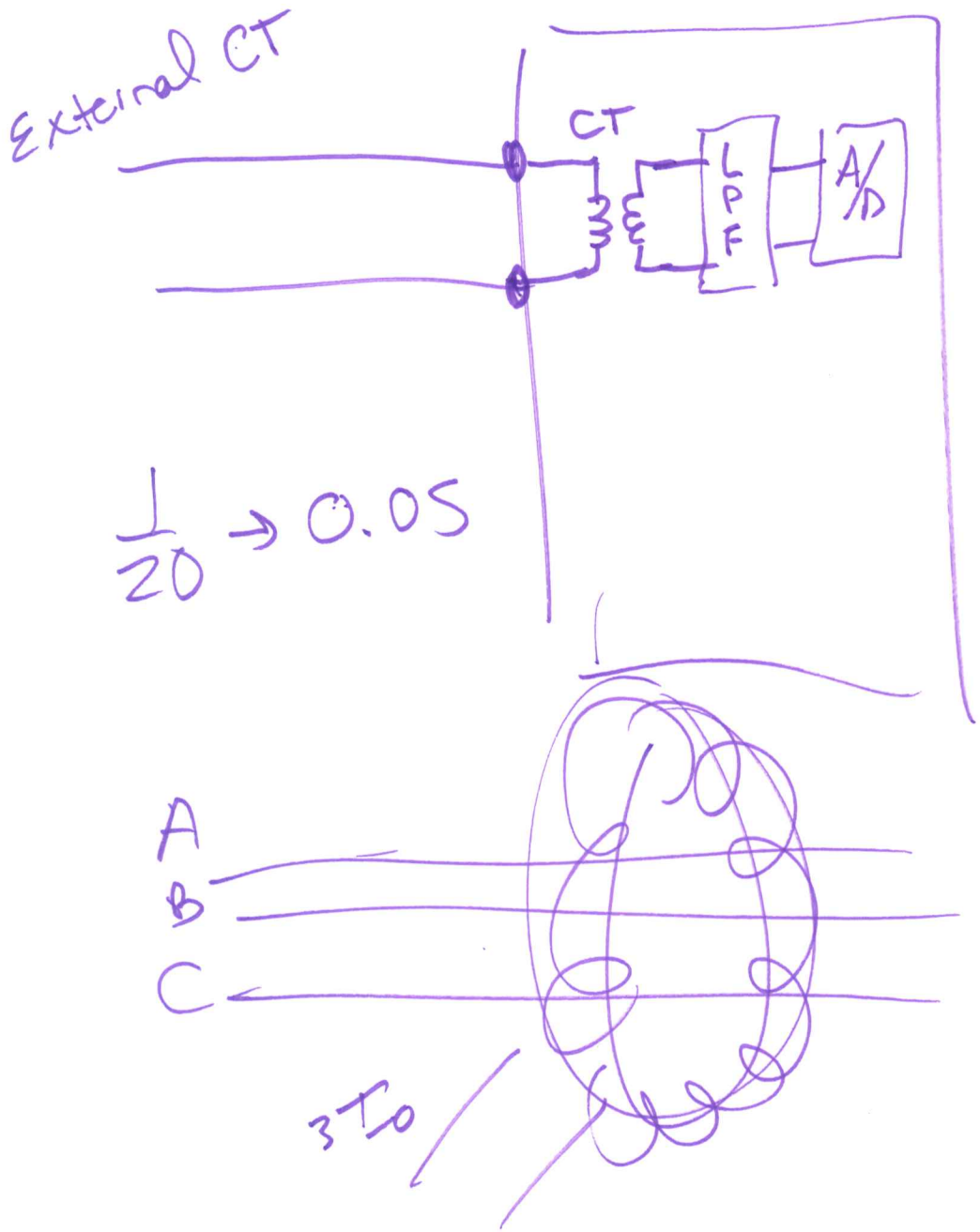


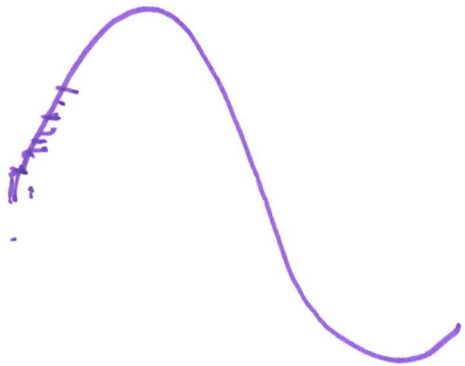
TRIP = TRG and TRP

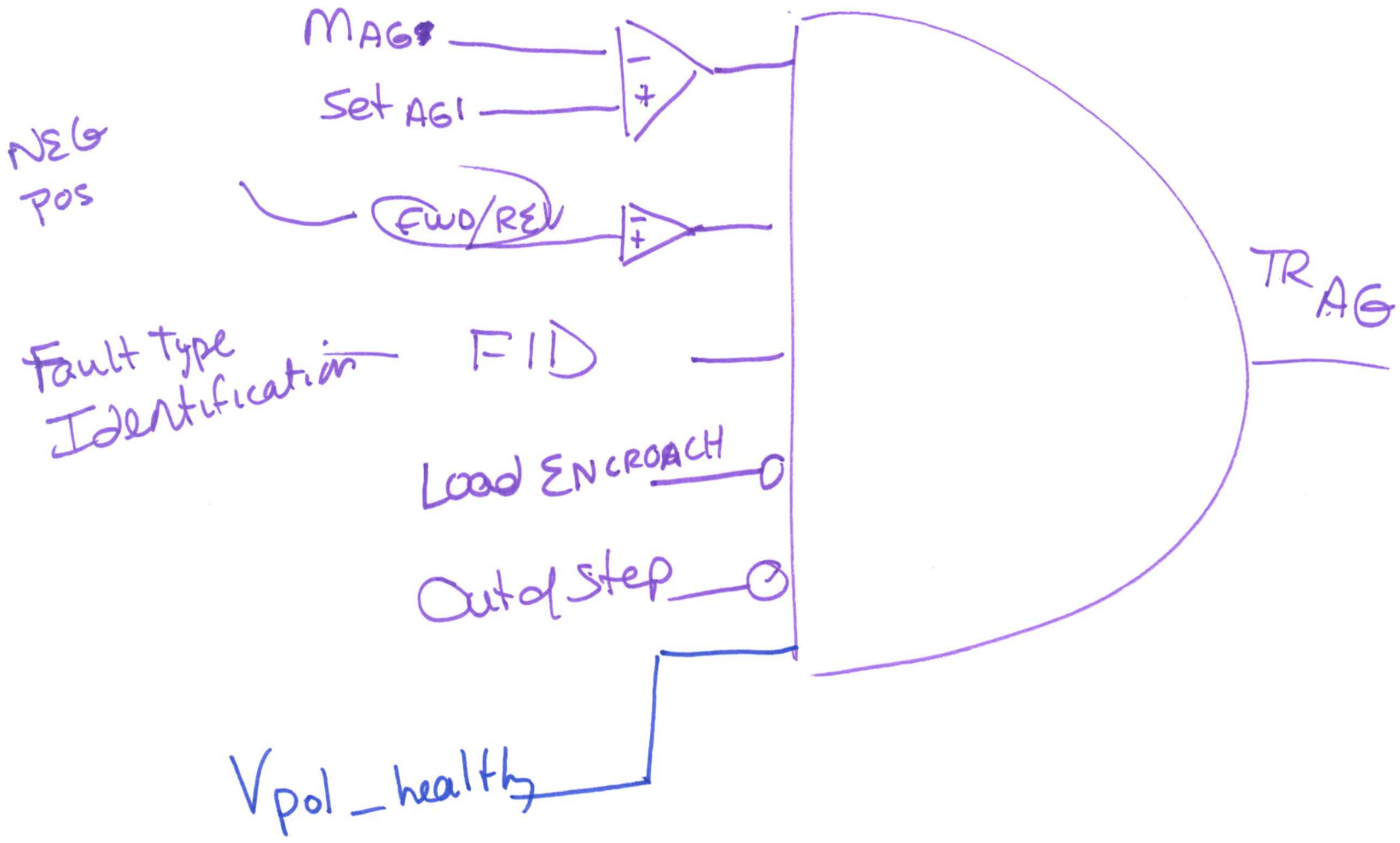
3. Modify trip equation at the end of this file (if needed).
4. Download COMTRADE files for faults at points FA, FB, and FC. The files for have 3 phase, SLG, LL, and DLG records at 75%, 83%, 100%, 145% and 155% of the line length. These will be placed on the web page as zip files (each with a *.hdr, *.cfg, *.dat) file.
5. Also download the COMTRADE files for Zone1RF, which have faults with non-zero fault resistance at different locations within the zone 1 reach.
6. Load each of the COMTRADE files into the MathCAD relay model and test your settings. It is better to underreach than overreach.
7. Comment on which levels of fault resistance cause the distance element to fail to pick up in zone 1 (note whether the overcurrent setting or the distance element reach is the problem).

Report:

1. Your report should list your relay settings
2. Show summaries from the MathCAD results demonstrating that the relay settings operate correctly. Possible show a few plots demonstrating the results (but not all cases!).


External CT
CT
LPF
A/D
1/20 → 0.05
A
B
C
3 To




MAG
Set AG1
NEG
POS
FWD/REV
TRAG
Fault type Identification
FID
Load ENCROACH
Out of step
Vpol_healthy

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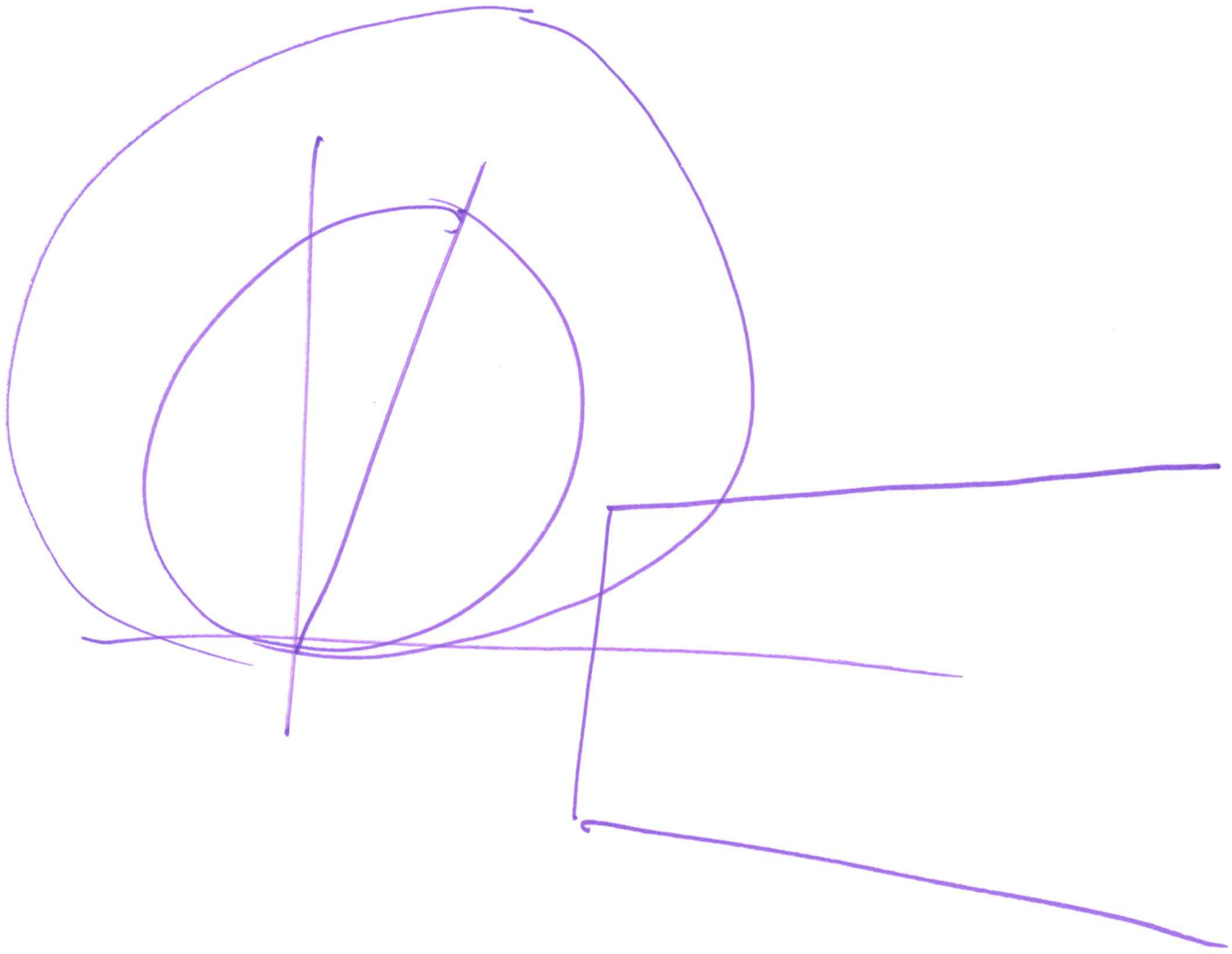

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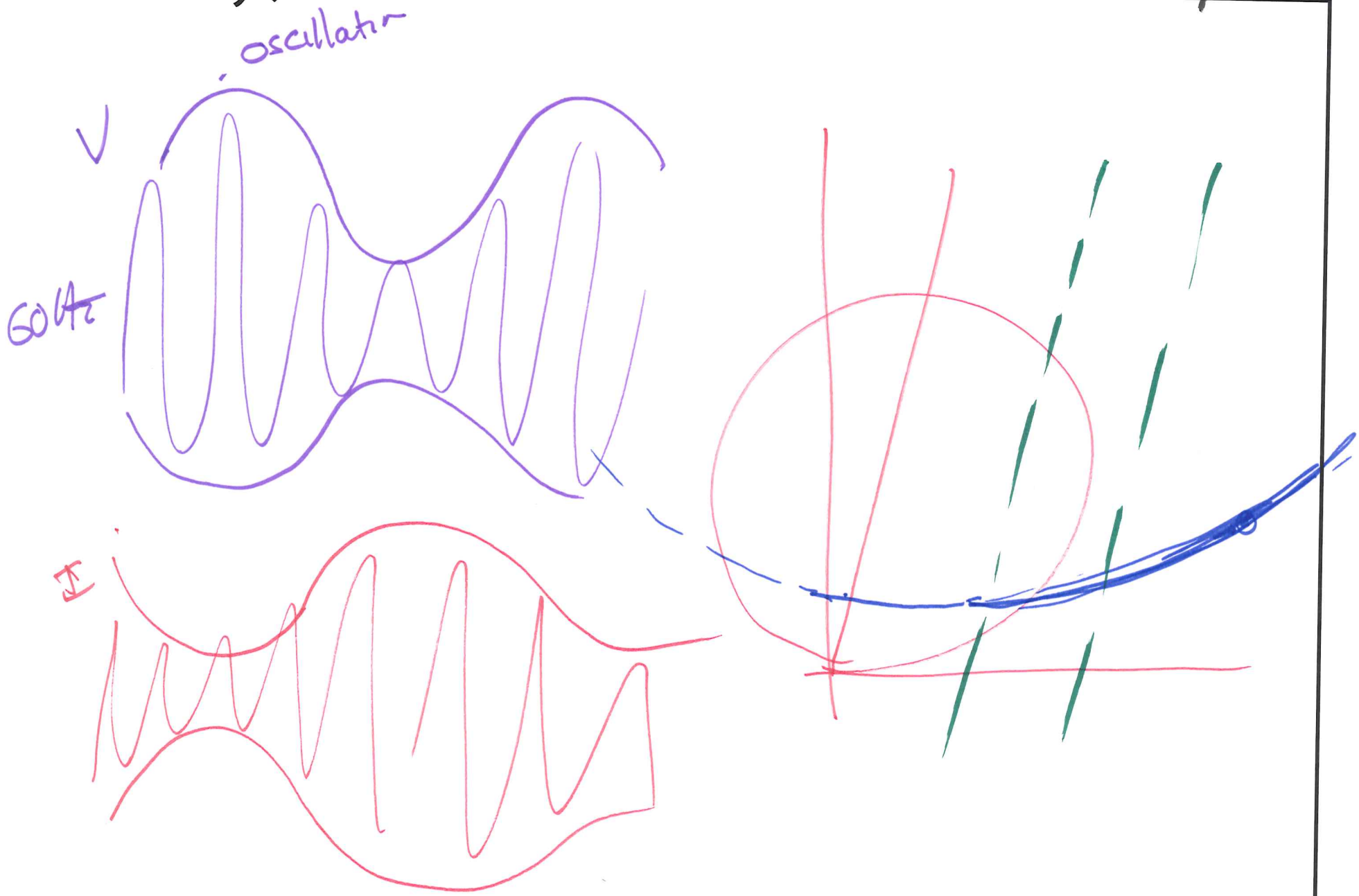
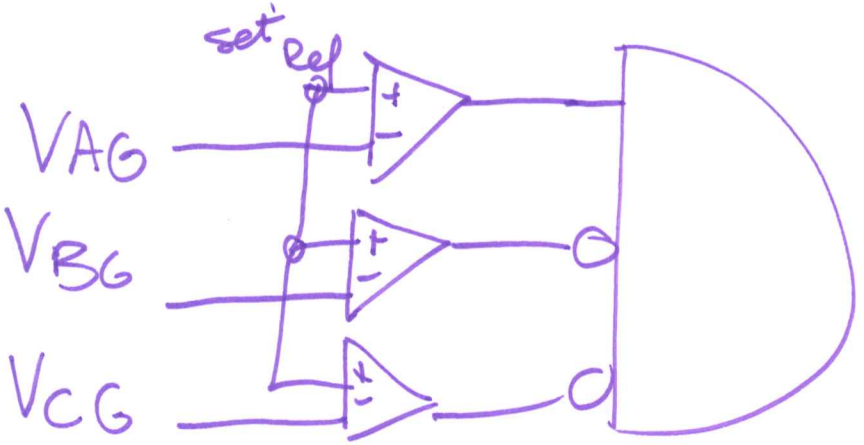


Fault Type ID with voltages



- active if currents below threshold