Demonstration of Laboratory Experiments on Numerical Relays

Experiment 03(b): Verifying Zone-1 operation of **Distance Relay** (REL 511)

To Verify Zone-1 operation of Distance Relay (REL 511)

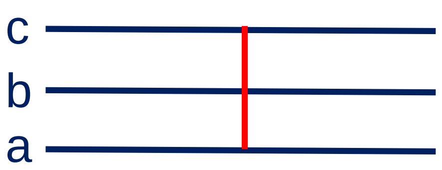
- Objective
- Theory
- Circuit diagram
- Line parameters and setting
- Results and verification

Objective:

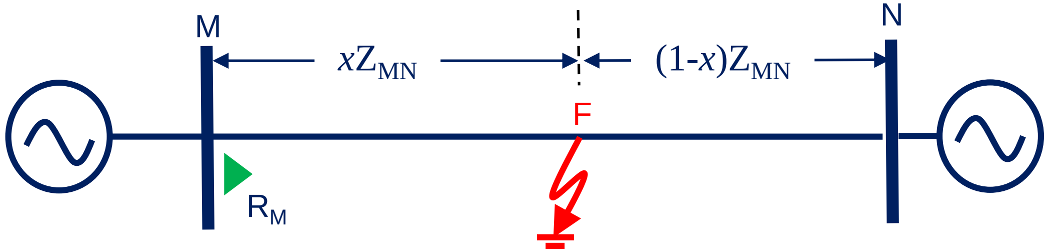
Verification of Zone-1 operation of Distance Relay

- Distance Relay- REL 511 (ABB make)

Three phase fault



abc



x = *normalized fault distance from relay*

$$V_{aF} = V_{bF} = V_{cF} = 0$$

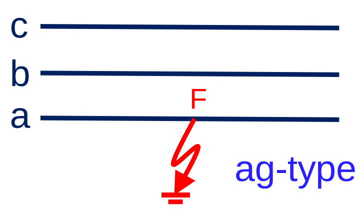
$$V_{aM} = I_{aM}(xZ_{1MN}) \quad V_{bM} = I_{bM}(xZ_{1MN}) \quad V_{cM} = I_{cM}(xZ_{1MN})$$

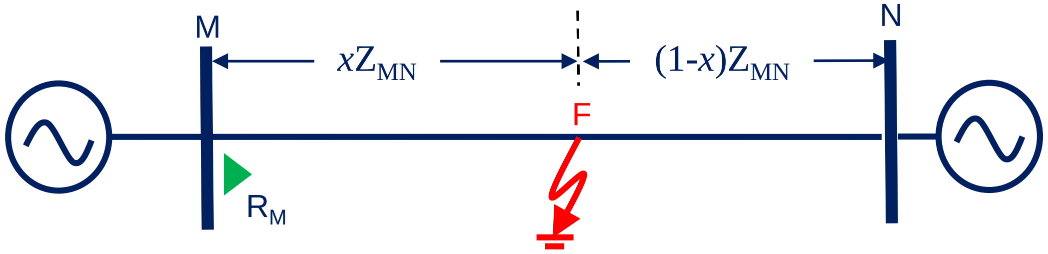
$$\boxed{xZ_{1MN} = \frac{V_{aM}}{I_{aM}} = \frac{V_{bM}}{I_{bM}} = \frac{V_{cM}}{I_{cM}}}$$

where xZ_{1MN} the positive sequence impedance up to fault point

Thus, $$\boxed{Z_{app} = \frac{V_{aM}}{I_{aM}}}$$

Phase-to-ground fault





$V_{aF} = 0$

$V_{a1F} + V_{a2F} + V_{a0F} = 0$

$V_{a1M} = V_{a1F} + I_{a1M}(xZ_{1MN})$ $\quad V_{a2M} = V_{a2F} + I_{a2M}(xZ_{2MN})$ $\quad V_{a0M} = V_{a0F} + I_{a0M}(xZ_{0MN})$

$$V_{aM} = V_{a1M} + V_{a2M} + V_{a0M}$$

$$= V_{a1F} + I_{a1M}(xZ_{1MN}) + V_{a2F} + I_{a2M}(xZ_{2MN}) + V_{a0F} + I_{a0M}(xZ_{0MN})$$

$$= I_{a1M}(xZ_{1MN}) + I_{a2M}(xZ_{2MN}) + I_{a0M}(xZ_{1MN}) - I_{a0M}(xZ_{1MN}) + I_{a0M}(xZ_{0MN})$$

for line $Z_{2MN}=Z_{1MN}$

$$= xZ_{1MN}[I_{a1M} + I_{a2M} + I_{a0M}] - I_{a0M}(xZ_{1MN}) + I_{a0M}(xZ_{0MN})$$

$$= xZ_{1MN}I_{aM} + I_{a0M}(xZ_{1MN})\left(\frac{Z_{0MN} - Z_{1MN}}{Z_{1MN}}\right)$$

$$= xZ_{1MN}I_{aM} + K_0 I_{a0M}(xZ_{1MN})$$

$$xZ_{1MN} = \frac{V_{aM}}{I_{aM} + K_0 I_{a0M}}$$

where

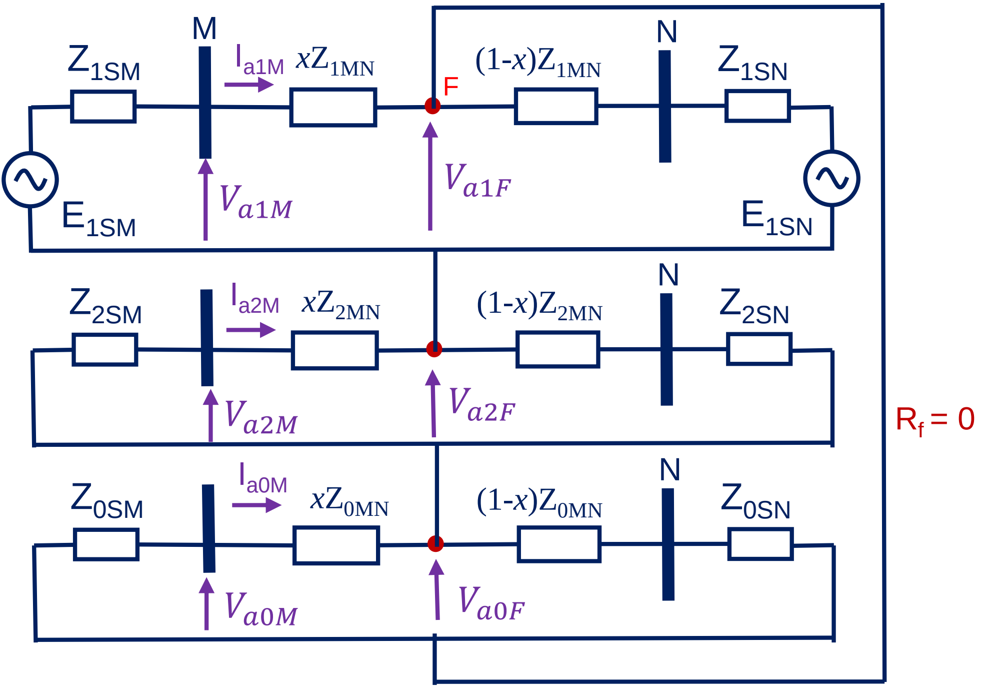
$$K_0 = \left(\frac{Z_{0MN} - Z_{1MN}}{Z_{1MN}}\right)$$

zero sequence compensation factor

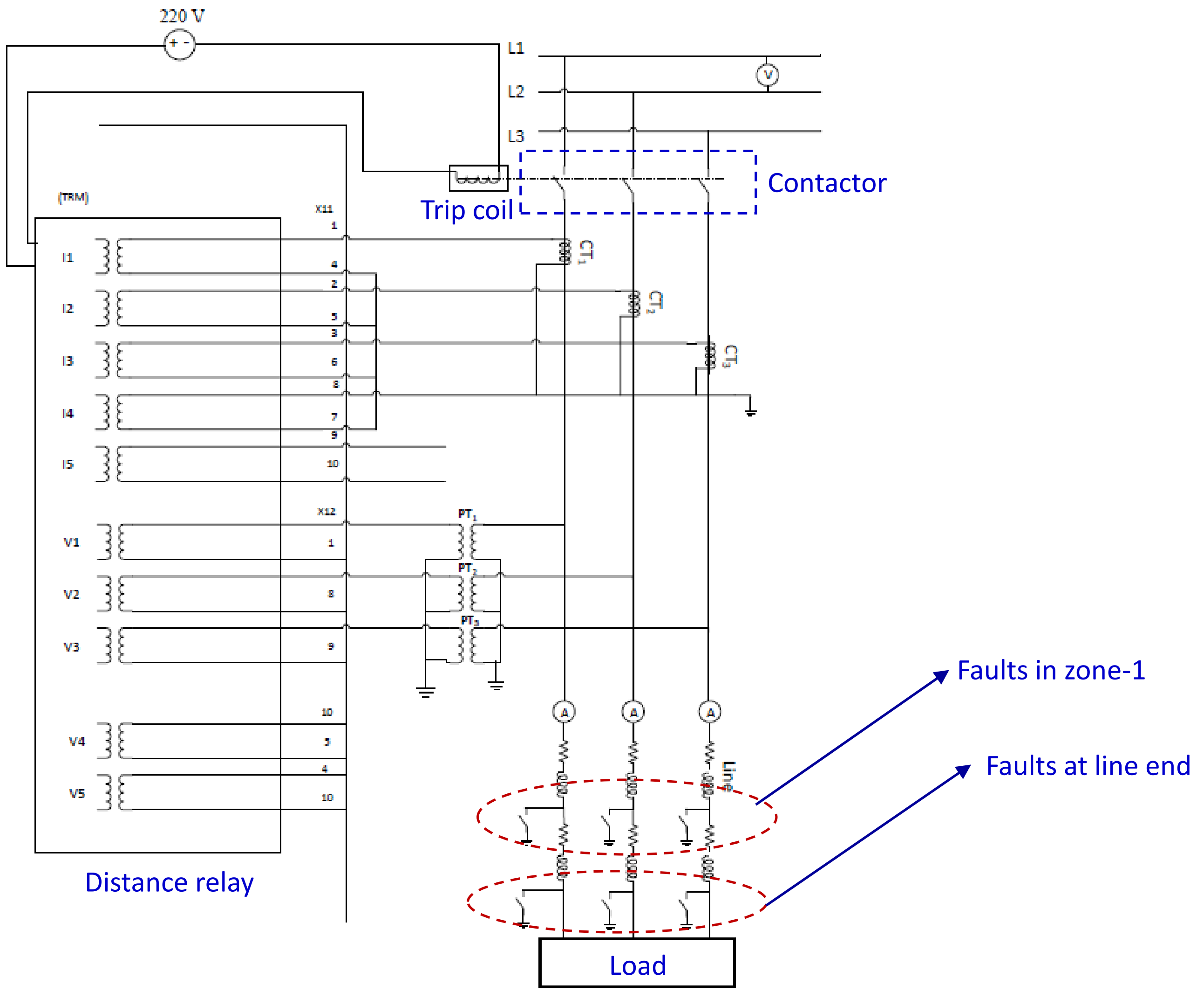
Complex number

Thus

$$\boxed{Z_{app} = \frac{V_{aM}}{I_{aM} + K_0 I_{a0M}}}$$



Circuit Diagram:



Line parameters and Distance relay setting:

Line resistance (R): 2 Ω

Line inductance (L): 91 mH

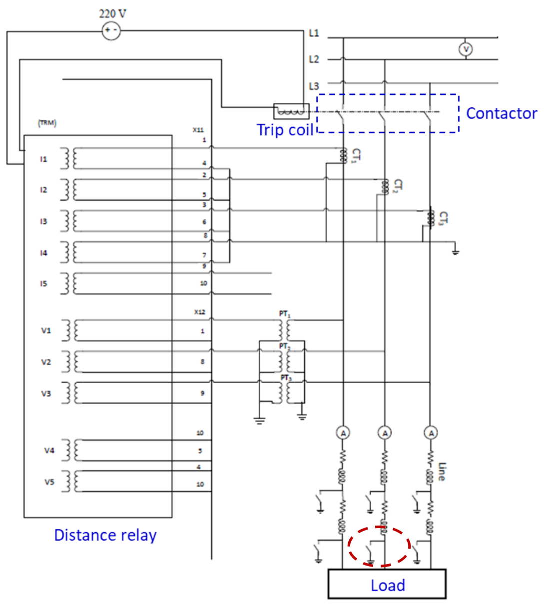
Line impedance (Z_L): 1.7 + j (2π x50x0.091) Ω = (1.7 +j 28.59) Ω

Zone-1 setting: 80% of Z_L = (1.36 +j 22.87) Ω = $22.91\angle 87^0$ Ω

Results and verification

Monitoring and Line impedance verification

During Normal Condition	
Line-to-line voltage (V_{LL}): 421 V	Positive sequence current (I_1): 0.340 A



For phase-b-to-ground (bg) fault at the end of the line

Line-to-line voltage (V_{LL}): 421 V

Positive sequence current (I_1): 2.859 A

Phase-b current = $3 \times I_1 = 8.577$ A

For line-to-ground fault, $I_1 = I_2 = I_0$

$$K_0 = \frac{Z_0 - Z_1}{Z_1} = 0, Z_0 = Z_1$$

$$\text{Apparent impedance} = \frac{V_b}{I_b + K_0 I_0}$$

Apparent impedance = $((421/\sqrt{3})/8.577)\ \Omega = 28.34\ \Omega$

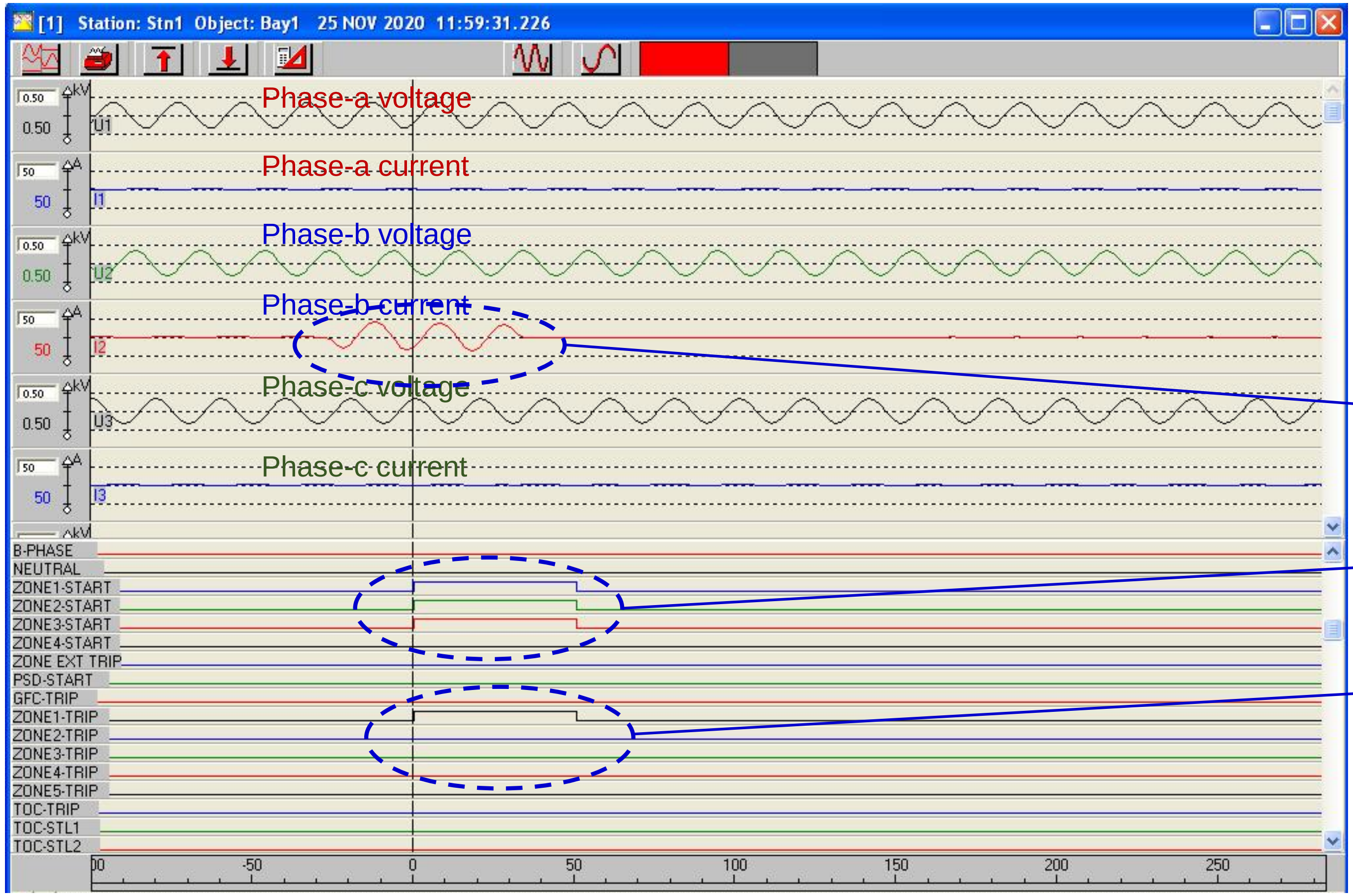
Actual Line impedance (Z_L): = 28.64 Ω

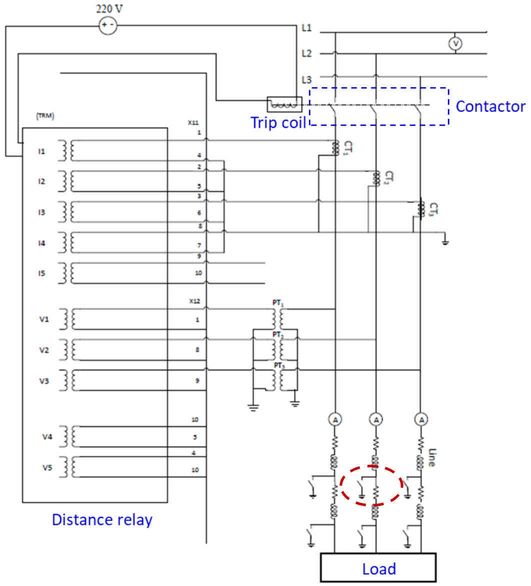
Remarks:

1. Calculated impedance for line-end fault is close to actual line impedance. → This is not a zone-1 fault
2. Zone-1 of distance relay is not tripping for this out-of-zone fault.

Results and verification

phase-b-ground fault at 60% of the line → Fault in Zone-1:





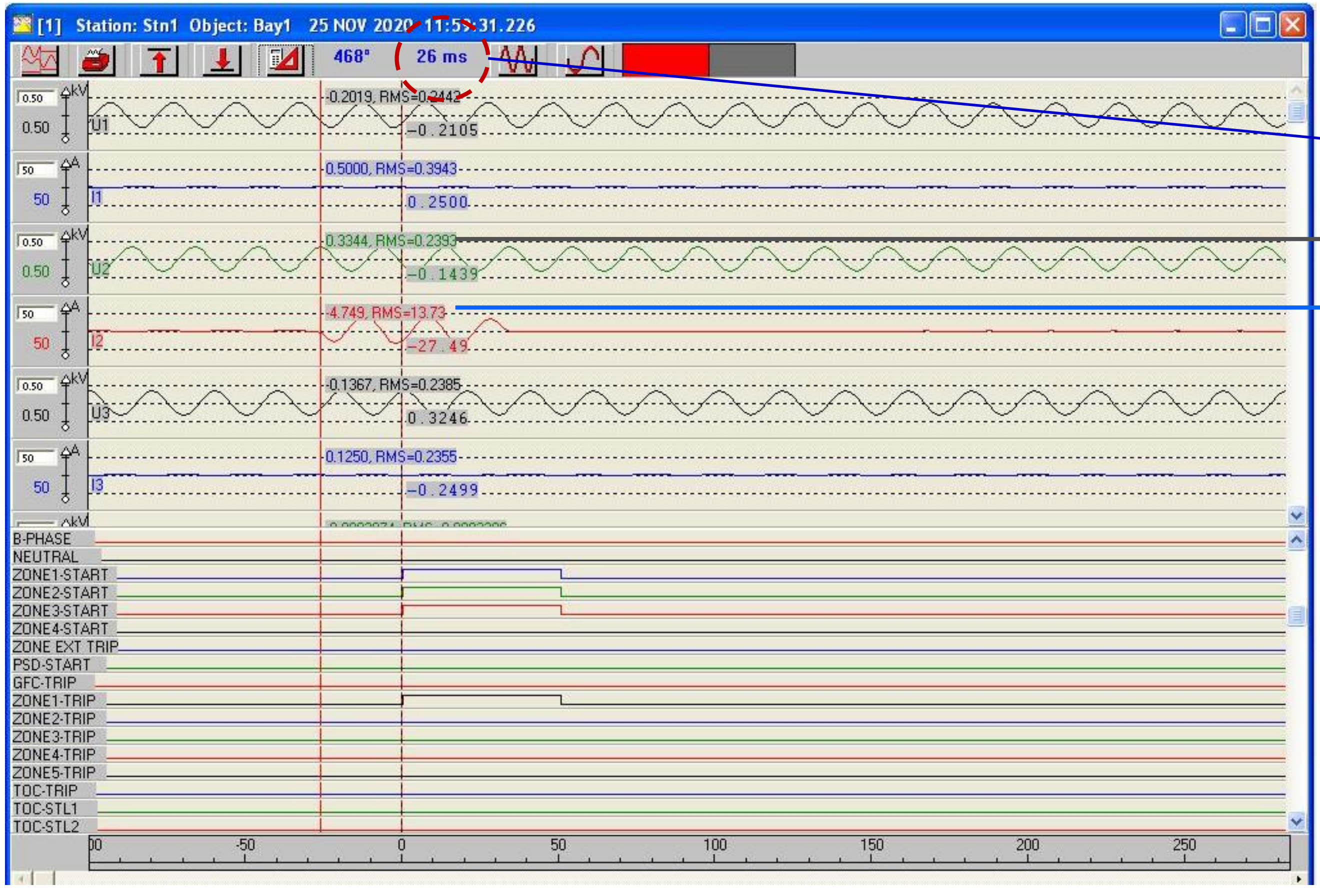
High current observed in phase-b

All 3-zones started following fault detection

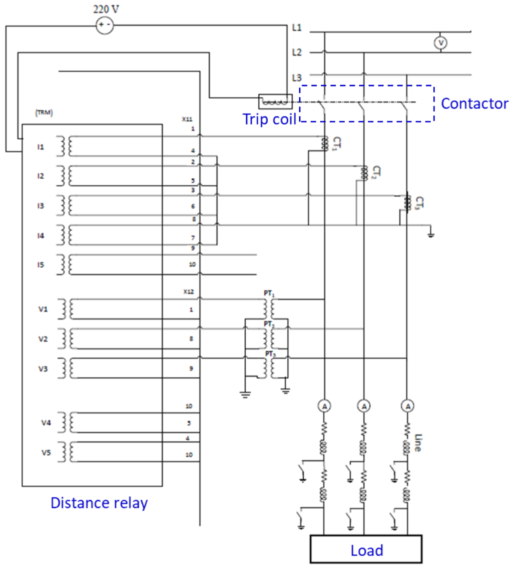
Zone-1 tripped

Results and verification

Fault in Zone-1: phase-b-ground fault



Relay decision time



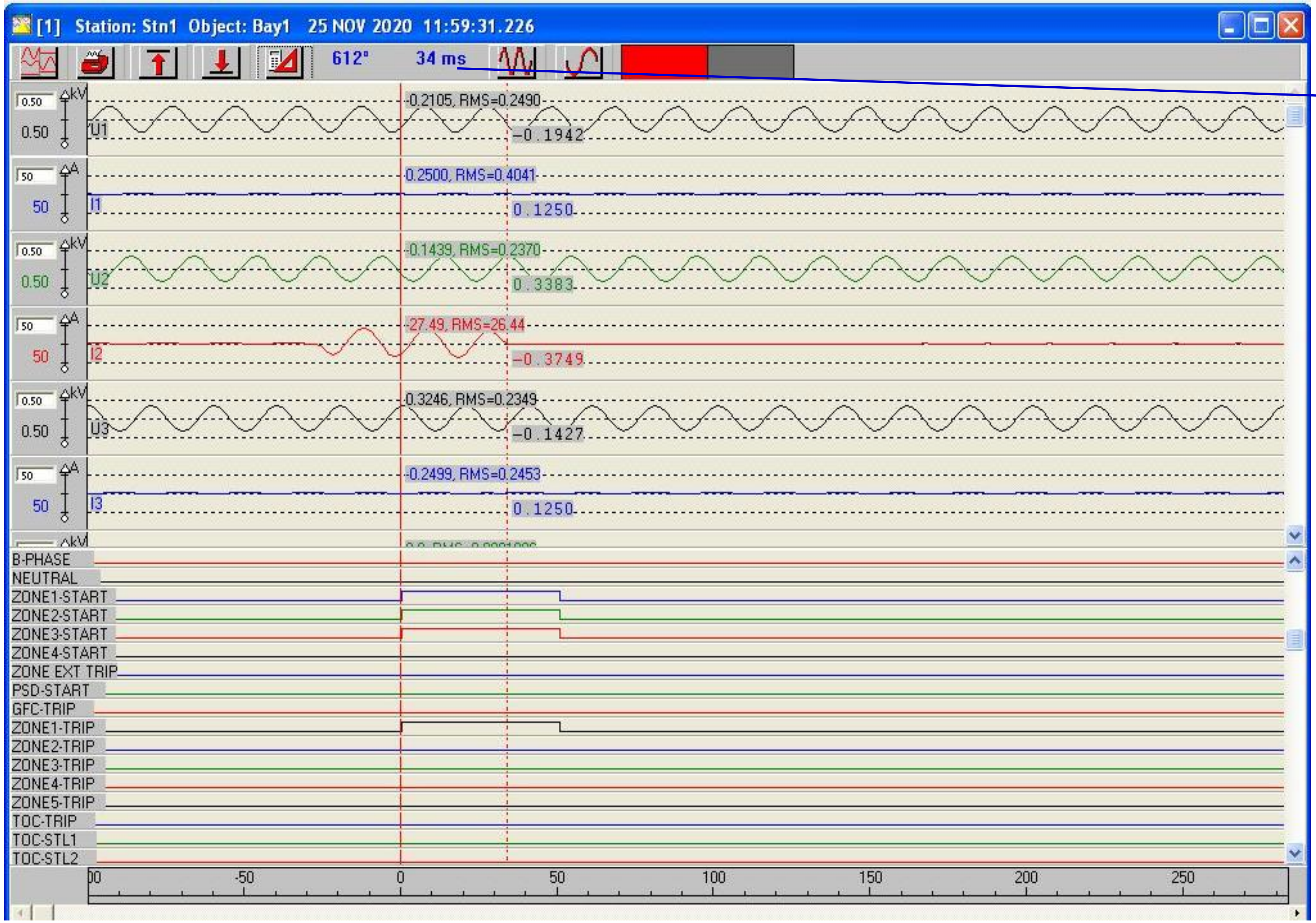
Apparent impedance
= (239.3/13.73) Ω = 17.42 Ω

Actual impedance up to fault point
= 0.6 x 28.64 = 17.18 Ω

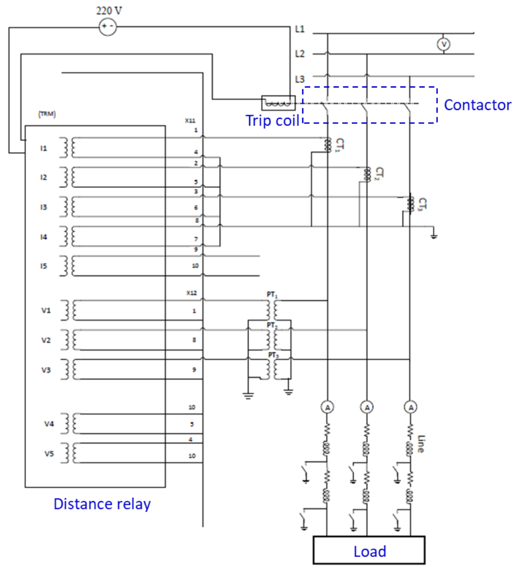
Apparent impedance < Zone-1 setting (22.904 Ω)

Results and verification

Fault in Zone-1: phase-b-ground fault



Circuit breaker opening time



Remarks:

1. Zone-1 of the distance relay tripped for a fault at 60% of the line, whereas did not tripped for out-of-zone fault (fault at line end).
2. Apparent impedance measured by the relay is close to actual line impedance.

Similarly tripping of other zones can also be verified.

Demonstration is available on:

https://www.youtube.com/watch?v=06sfThlrEko&feature=emb_logo

Distance relay lectures:

https://www.youtube.com/watch?v=GjJFRtgWhCM&feature=emb_title

https://www.youtube.com/watch?v=qDD7SkEhbOs&feature=emb_title

https://www.youtube.com/watch?v=D8grremWWSE&feature=emb_title

Distance relay experiment demonstration:

https://www.youtube.com/watch?v=06sfThlrEko&feature=emb_logo

Schneider electric book link (Distance):
https://www.se.com/ww/en/tools/npag-online/pdf/C3-Distance_Protection.pdf

Report Submission Guidelines:

For each given oscillogram output from the distance relay (refer two pdf files for the cases)

1. Identify the fault type.
2. Mention the voltage and current of the faulted phase during fault.
3. Calculate the apparent impedance.
4. Identify whether the fault is in zone-1 or not.
5. If relay has tripped for the fault, mention the approximate relay decision time and circuit breaker operation time.

(Write your roll number and name at the top of each sheet)

Given for the two cases relay setting:

Line impedance (Z_L): (1.7 +j 28.59) Ω

Zone-1 setting: 80% of Z_L = (1.36 +j 22.87) Ω = $22.91\angle 87^0$ Ω

6. Your remarks and discussion for each case

7. For each case, use a separate page *Till this Pages-1 and 2*

8. The specifications of the sensors to scale down the signals in a protection scheme are: potential transformer PT_{ratio} =33 kV/110 V, current transformer CT_{ratio} =200:5 A. If the apparent impedance (Z_{app}) computed by the distance relay using secondary signals of the sensors is 2.75 ohm during a fault in the system, calculate the corresponding impedance referred to primary side. If the line is of 120 km having a positive sequence impedance of (0.03 + j 0.3) Ω/ km and zone-1 covers 80% of the line, decide whether the fault is in zone-1 or not? *Page-3*

9. A simulink model of a 3-bus equivalent system is attached. A distance relay is provided at bus B1. Create phase-A-to-ground faults at F_1 and F_2 and write your observation in the following table. *Page-4*

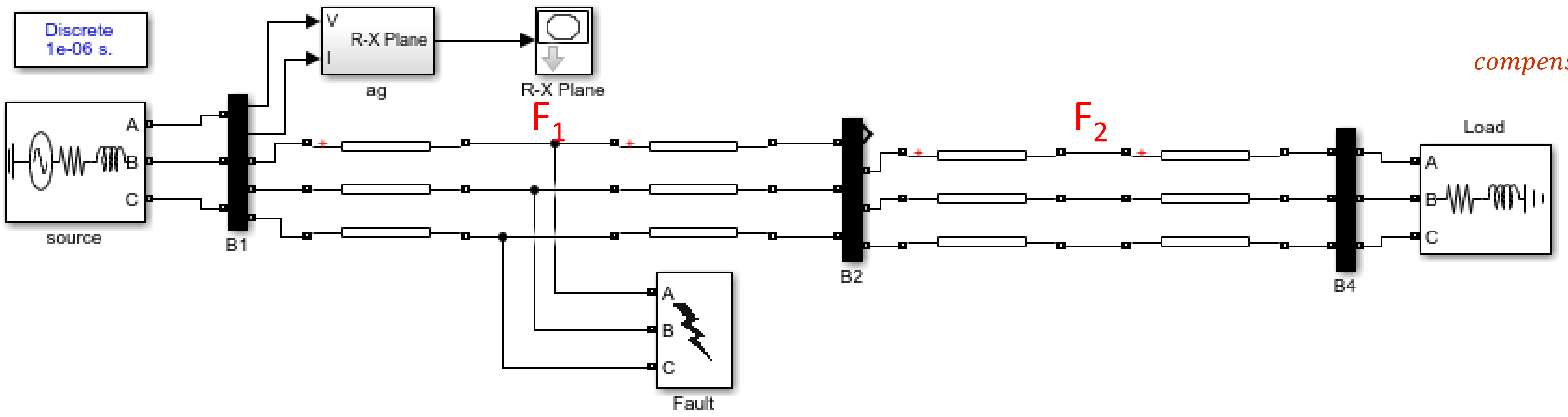
$$Z_{app} = \frac{V_A}{I_A + K_0 I_{A0}}$$

where

$$K_0 = \left(\frac{Z_{0MN} - Z_{1MN}}{Z_{1MN}}\right)$$

zero sequence compensation factor for the line

Complex number



Roll No:							
Fault position	Fault resistance	Measured Voltage phasor (phase-A) V_A	Measured Current phasor (phase-A) I_A	Zero sequence current I_{A0}	Apparent impedance calculated by the relay(Zapp)	Zone-1 trip decision	Comment on the decison
F_1	Last digit of roll number						
F_2	Last digit of roll number						

Pages to be submitted-Distance Relay Exp –one pdf

- Pages-1-2 :roll No, Name at the top, for the two cases
- Page 3- for problem in (8)
- Page 4, for result sheet of problem-9
- Create one pdf file containing all the pages

Thanks

Queries/Questions