Demonstration of Laboratory Experiments on Numerical Relays

Experiment 01: Verification of Overcurrent Relay Characteristic

A K Pradhan

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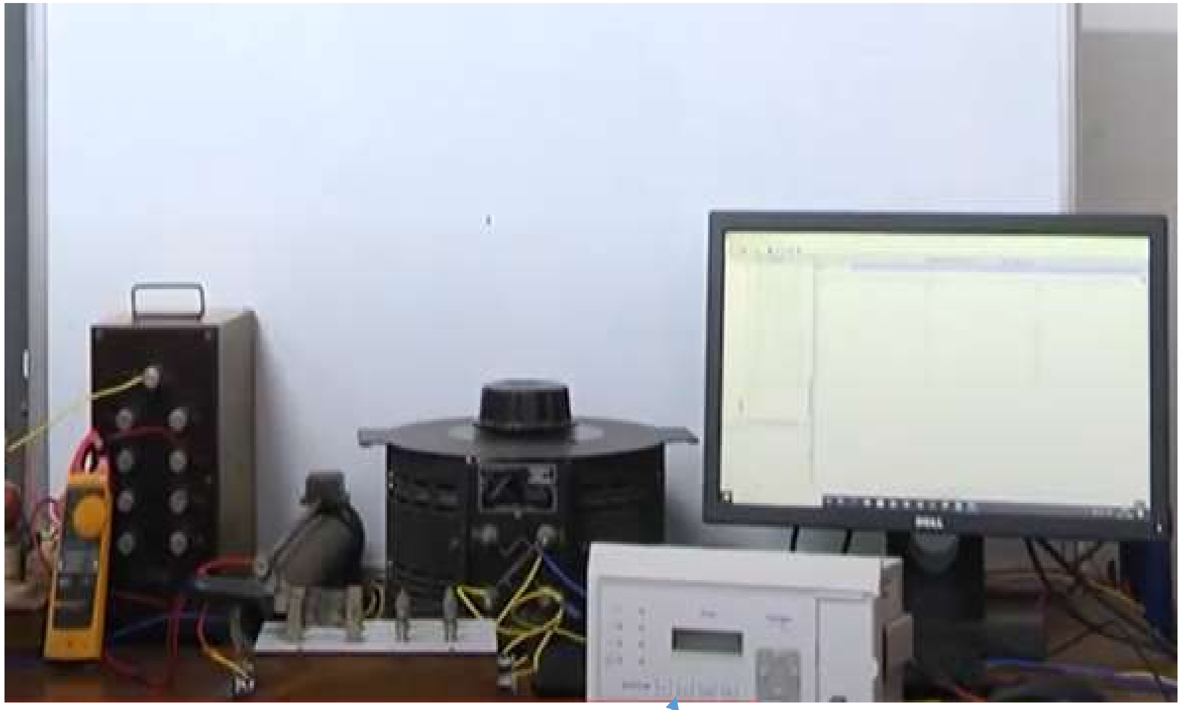
The setup in the laboratory

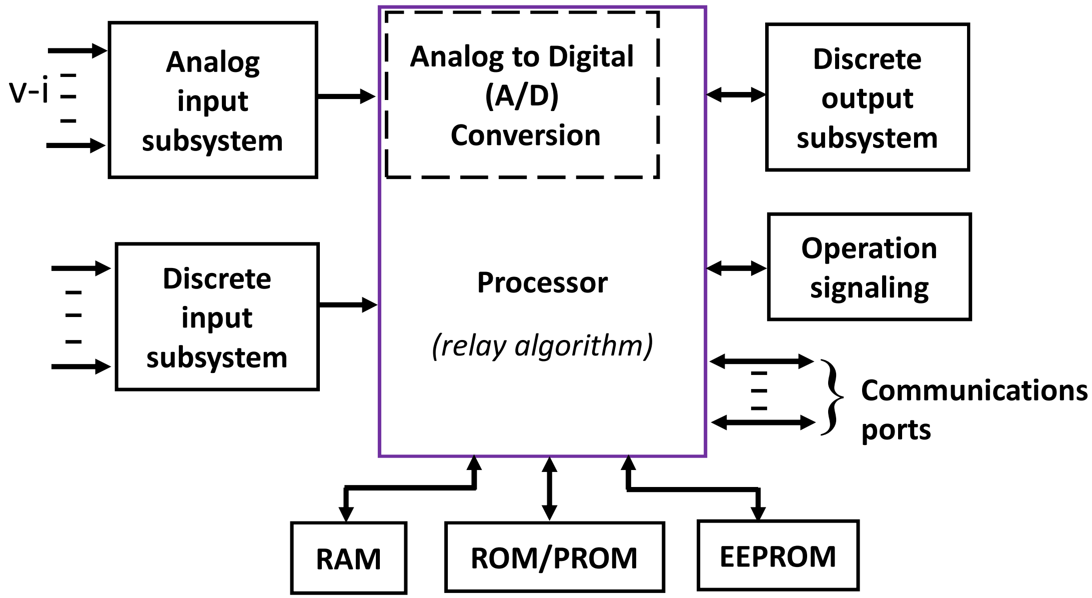


The Relay
MICOM P154 (Alstom make)

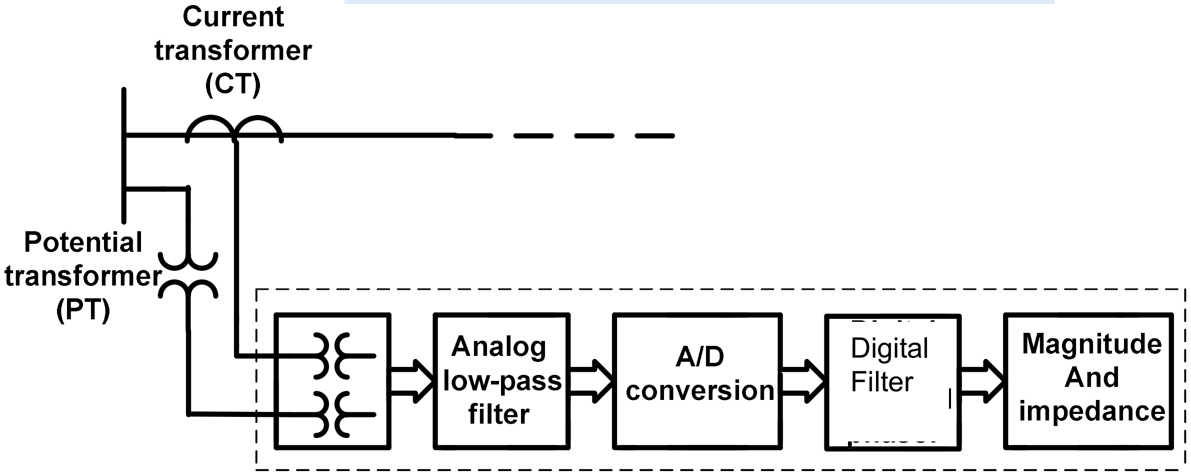
Verification of Overcurrent Relay Characteristic

- Theory/Background
- Objective
- Circuit diagram
- Relay Settings
- Observations and Verification

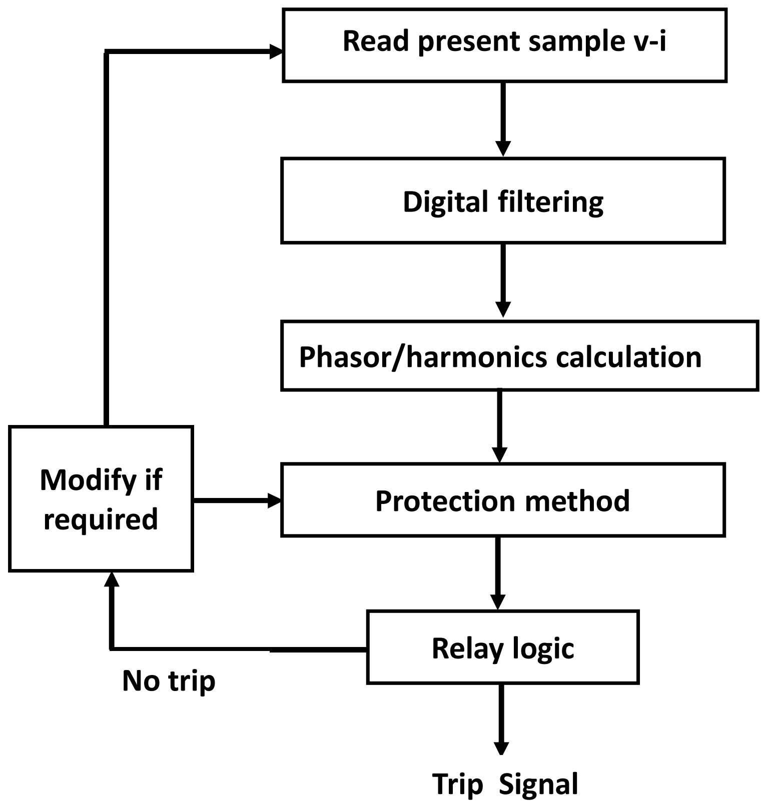
Digital relay architecture



Signal path in numerical relay

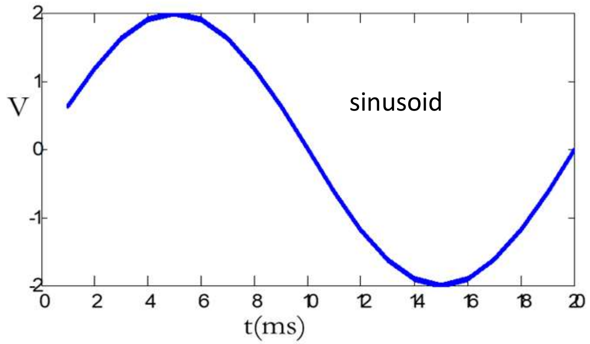


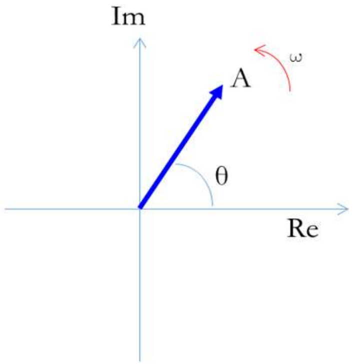
Numerical relay –Algorithm



Phasor Estimation –

Significance of phasors in relays- usage in most of the relays





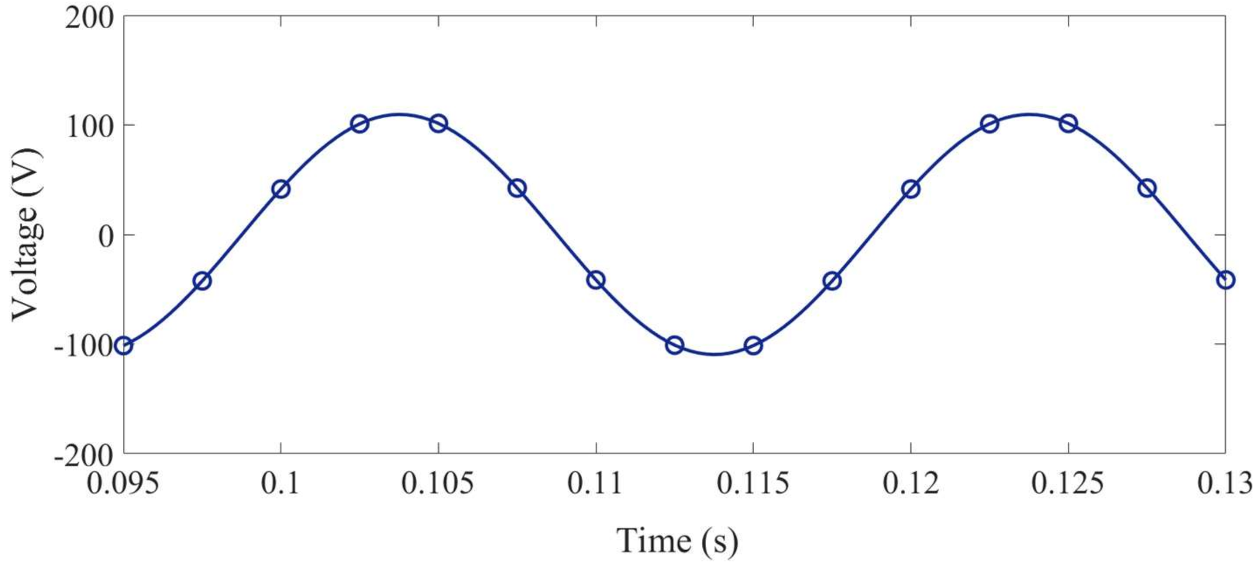
Discrete Fourier Transform(DFT)

- 1-cycle DFT

Discrete Fourier Transform(DFT)

Signal: $v(t) = V_p \sin(\omega t + \theta)$

Sampling: $v_n = V_p \sin(\omega t_n + \theta)$ where, $t_n = n\Delta t; n = 0,1,2, \dots \dots, \Delta t =$ time interval between sucessive samples



Data sampling: 8 samples/cycle

Phasor estimation: 1-cycle DFT

$$v_n = V_p \sin(\omega t_n + \theta)$$

Applying 1-cycle DFT ,

Voltage phasor, $\dot{V} = \frac{\sqrt{2}}{N} \sum_{n=0}^{N-1} (v_n e^{-j\frac{2\pi}{N}n})\,; 0 \le n \le N-1$ Where, N=number of samples in a cycle

$v_n = n^{th}\ sample\ of\ v(t)$

Defining

$$V_{real} = \frac{\sqrt{2}}{N}\sum_{n=0}^{N-1}[v_n \cos(2\pi\frac{n}{N})] \quad \text{and} \quad V_{imag} = \frac{\sqrt{2}}{N}\sum_{n=0}^{N-1}[v_n \sin(2\pi\frac{n}{N})]$$

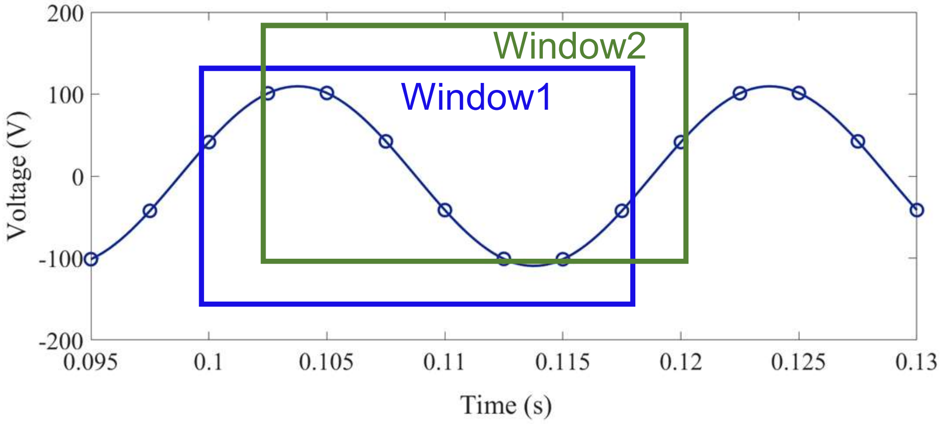
Computed Phasor:

$$\dot{V} = V_{real} - jV_{imag} = |V|\angle\theta$$

Where $|V| = \sqrt{V_{real}^2 + V_{imag}^2}$,$\theta = -\tan^{-1}(\frac{V_{imag}}{V_{real}})$

Data Sample window

$v_n = 109.53\sin(100\pi t_n + 22.25^{\circ})$(V) ,sampling rate of 0.4 kHz, N=8



Time(s)	$v_n(V)$
0.1	41.47
0.1025	101.01
0.105	101.37
0.1075	42.36
0.11	-41.47
0.1125	-101.01
0.1150	-101.37
0.1175	-42.36
0.12	41.47
0.1225	101.01

Window1

Window2

-Moving window
-with new sample

1-cycle DFT computation for window1 (0.1s to 0.1175 s, N=8 points)

$(0 \le n \le N-1)$

Time(s)	**Voltage Sample (v_n)**	$cos(2\pi \frac{n}{N})$	$sin(2\pi \frac{n}{N})$	$v_n\ cos(2\pi \frac{n}{N})$	$v_n\ sin(2\pi \frac{n}{N})$
0.1	41.47	1	0	41.47	0
0.1025	101.01	$1/\sqrt{2}$	$1/\sqrt{2}$	71.42	71.42
0.105	101.37	0	1	0	101.37
0.1075	42.36	$-1/\sqrt{2}$	$1/\sqrt{2}$	-29.95	29.95
0.11	-41.47	-1	0	41.47	0
0.1125	-101.01	$-1/\sqrt{2}$	$-1/\sqrt{2}$	71.42	71.42
0.115	-101.37	0	-1	0	101.37
0.1175	-42.36	$1/\sqrt{2}$	$-1/\sqrt{2}$	-29.95	29.95
				165.88	**405.48**

For window1,phasor $\dot{V} = \frac{\sqrt{2}}{8}[165.88 - j405.48]$

$= 77.45\angle - 67.75°$ (V)

1-cycle DFT computation for window2 (0.1025s to 0.12 s, N=8 points)

$$(0 \le n \le N-1)$$

Time(s)	**Voltage Sample (v_n)**	$cos(2\pi \frac{n}{N})$	$sin(2\pi \frac{n}{N})$	$v_n\ cos(2\pi \frac{n}{N})$	$v_n\ sin(2\pi \frac{n}{N})$
0.1025	101.01	1	0	101.01	0
0.105	101.37	$1/\sqrt{2}$	$1/\sqrt{2}$	71.68	71.68
0.1075	42.36	0	1	0	42.36
0.11	-41.47	$-1/\sqrt{2}$	$1/\sqrt{2}$	29.32	-29.32
0.1125	-101.01	-1	0	101.01	0
0.115	-101.37	$-1/\sqrt{2}$	$-1/\sqrt{2}$	71.68	71.68
0.1175	-42.36	0	-1	0	42.36
0.12	41.47	$1/\sqrt{2}$	$-1/\sqrt{2}$	29.32	-29.32
				404.02	**169.44**

For window2, $\dot{V} = \frac{\sqrt{2}}{8}[404.02 - j169.44]$

$= 77.45\angle -22.75°$ (V)

Working Principle of Overcurrent Relay

- An overcurrent device -operates when the measured current exceeds a predetermined threshold (*Pickup current*) -either instantaneously or with a delay

Purpose-to discriminate fault and load and isolate faulted section selectively

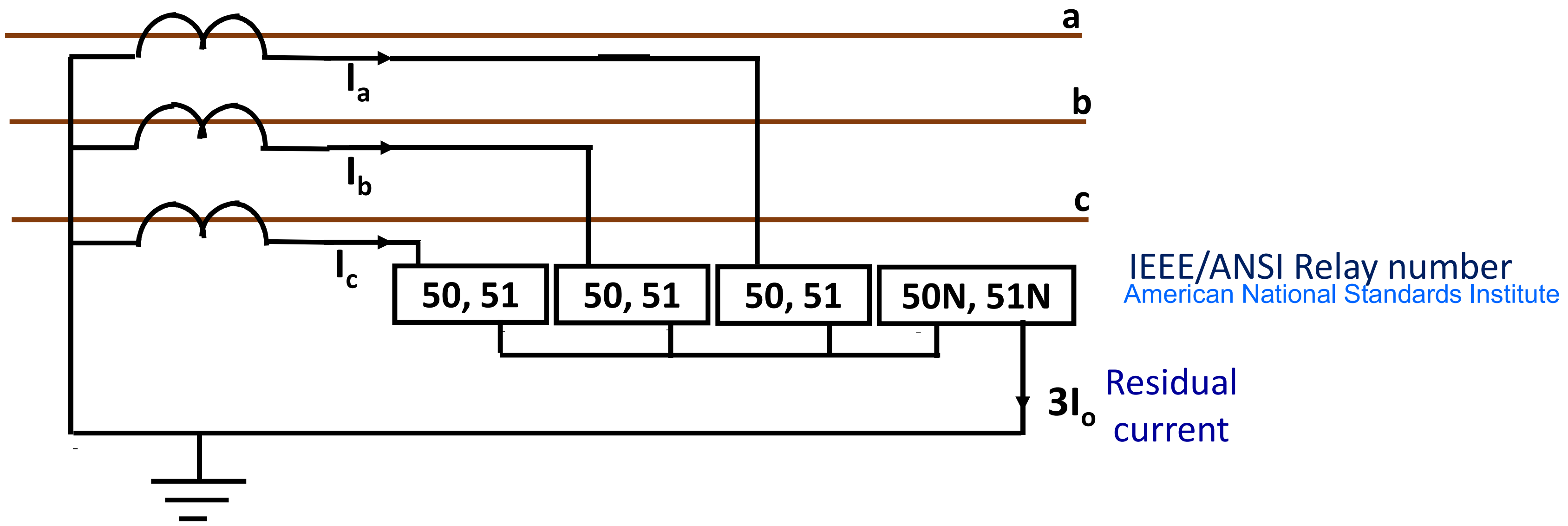
- The algorithm for overcurrent relay includes :
  1. The threshold (I_{pickup}) for discriminating –fault/load
  2. Compute the rms value of the fundamental component of the measured current (I)
  3. Confirms a fault- if the measured current is above the threshold.
  4. Command to trip the circuit breaker- immediately or with a delay

Note: Since currents are measured through current transformer, both I_{pickup} and I should be referred to either primary or secondary of the CT.

Types of Overcurrent Relays

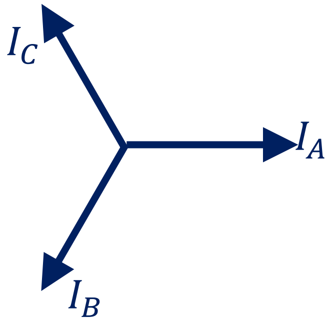
- Two types:
  1. Phase relay - to protect the system for phase faults
  2. Ground relay - to protect the system for faults involving ground

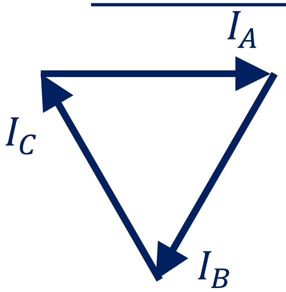
- Overcurrent Relay Connection Diagram



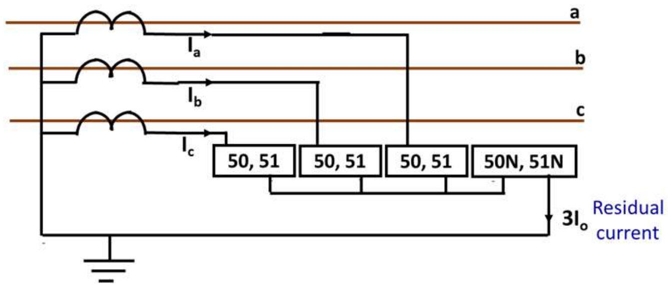
Digital Relays -Residual Current Calculation

Residual current for *balanced load* or *three-phase fault*

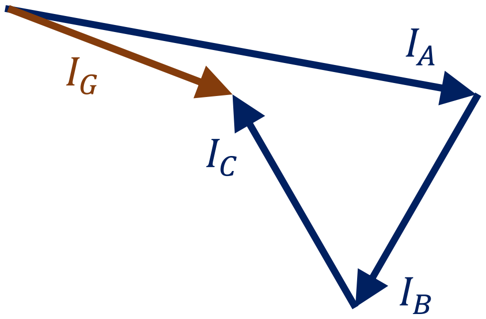




$$\vec{I}_A + \vec{I}_B + \vec{I}_C = 3\vec{I}_0 \quad = \vec{I}_G = 0$$



Residual current for *ground fault*



$$\vec{I}_A + \vec{I}_B + \vec{I}_C = 3\vec{I}_0 \quad = \vec{I}_G$$

Selection of Pickup Current for Phase Relays

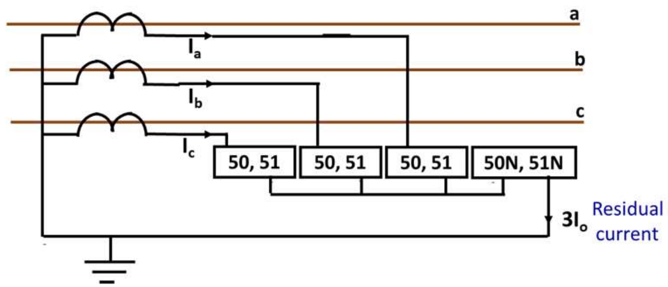
- Pickup setting of phase overcurrent relays :

 1. Pickup current should be above maximum load current, i.e.; $I_{pickup} \geq k\ I_{max.}$
    This ensures that relay does not trip on load. k-overload factor – for distribution lines it can be 2, for transformer, generator it is 1.25-1.5, for motor k=1.05.

 2. Pickup current should be below the minimum fault current i.e; $I_{pickup} < I_{Fmin.}$
    This ensure that protection system will operate for low fault current situations

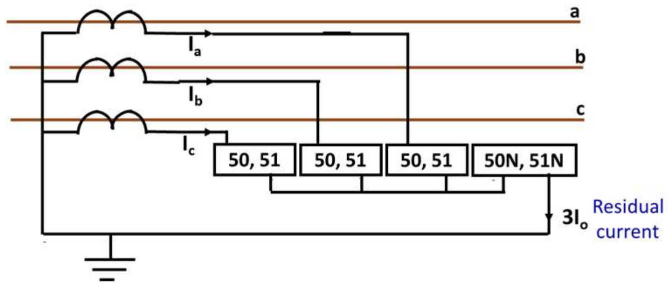
    For setting of pickup current is,

    $kI_{max} \leq I_{pickup} < I_{fmin}$



Selection of Pickup Current for Ground Relays

Ground faults are more frequent compared to phase faults



- Pickup setting of ground overcurrent relays
  - -Ground fault causes unbalancing in the system
  - -To note maximum unbalance during normal condition of the system
  - -Pickup current should be above the unbalanced prefault current

Setting: 20%-40% of the full-load current or minimum earth-fault current on the part of the system being protected
(Neutral impedance limits the residual current)

$I_{pickup} \geq 0.3\ I_{rated}$ for rural feeder

- For High voltage, the setting can be 10% of I_{rated}

- Ground relays are more sensitive than phase relays

Note- For pickup setting of (a) phase relays- three phase fault current
(b) ground relays- phase-to-ground fault current

Time-current Characteristics

- Overcurrent relay may generate a trip command either instantly or with a time delay
- The time-current characteristic for computation of trip time for overcurrent relay are:

  (a) Instantaneous relay

  (b) Time delayed definite time relay

  (c) Inverse definite minimum time (IDMT) relay

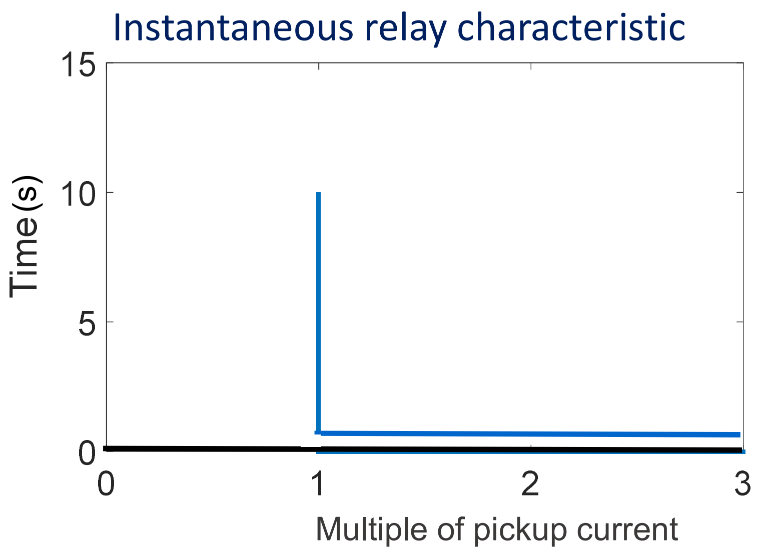
    i. Moderately inverse
    ii. Very inverse
    iii. Extremely inverse

Time-current Characteristics

1. Instantaneous overcurrent relay (IEEE/ANSI Relay number 50)

- The operating time of an instantaneous relay is of the order of a few milliseconds.
- It is used to protect a long feeder for close-in fault.

Plug setting multiplier or Multiple of pickup $=I_{relay}/I_{pickup}$

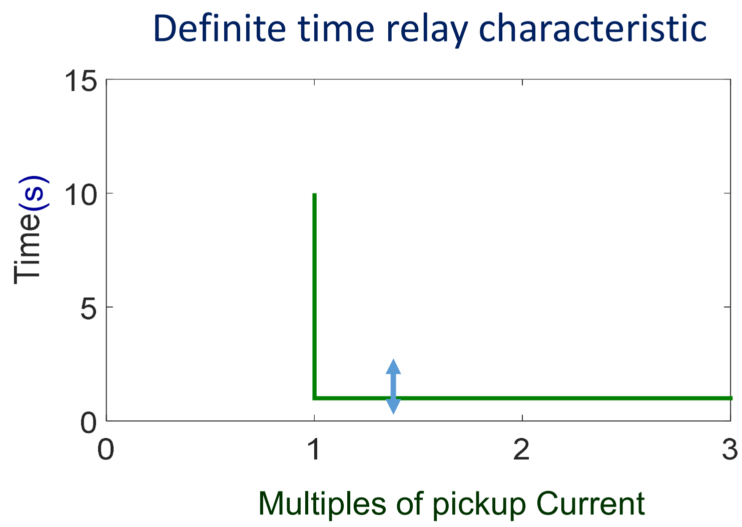


No intentional delay,
Execution will take small time

Time-current Characteristics

(b) Definite time overcurrent relay (50)

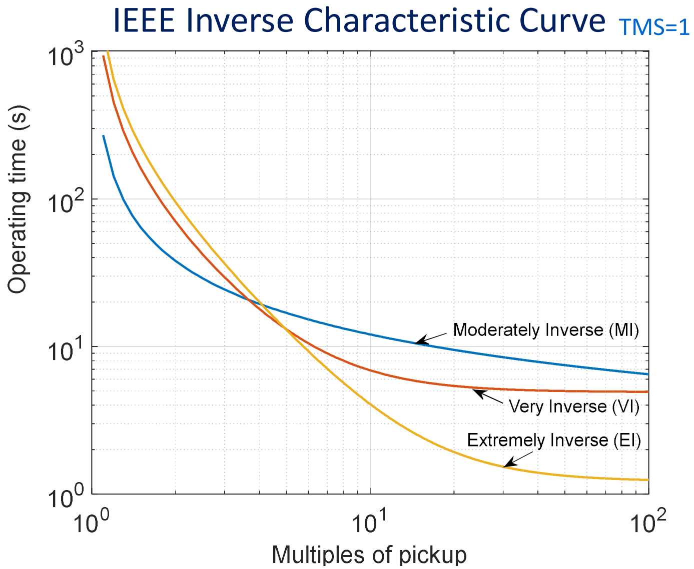
- The operating time of a definite time over-current relay is fixed.
- With adjustable time setting
- Used for short length feeders -where the fault current does not change much with the location of the fault across the feeder.
- In coordination of the relays- the relay takes more time for faults close to the source-*not desirable*
- The operating time of the relay near the source
  -may hit the upper limit of fault clearing time



Time-current Characteristics

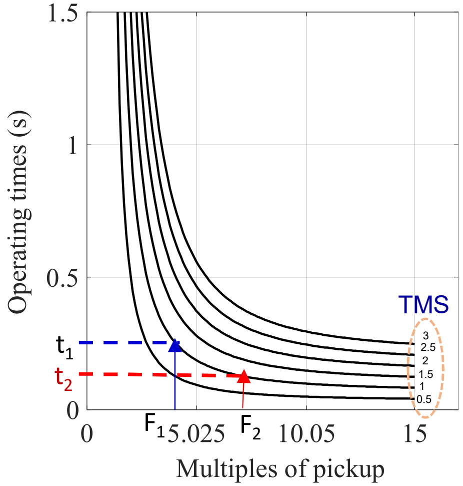
(c) Inverse definite minimum time (IDMT) overcurrent relay (51)

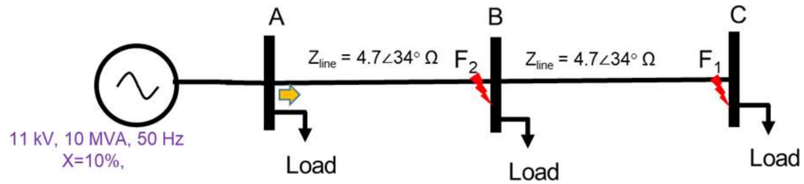
- It is inverse in the initial part and tends to approach a definite minimum operating time characteristic as the current becomes very high.
- These relays are preferred where less time of operation of relay is required.
- Suitable for coordination of relays



Decision time by relay for faults at different locations/sections

- Time multiplier setting (TMS) or Time dial setting (TDS)





Relay at A (TMS=1,say),
three phase faults at F_1 and F_2
Multiple of pickup (=I/I_{pickup}) calculated

- corresponding time shown t_1 and t_2
- F_1 is farther than F_2 fault
- $t_1 > t_2$

Use of Mathematical expressions for the relay characteristics

If the characteristics can be expressed in mathematical forms- useful in protection design and analysis.

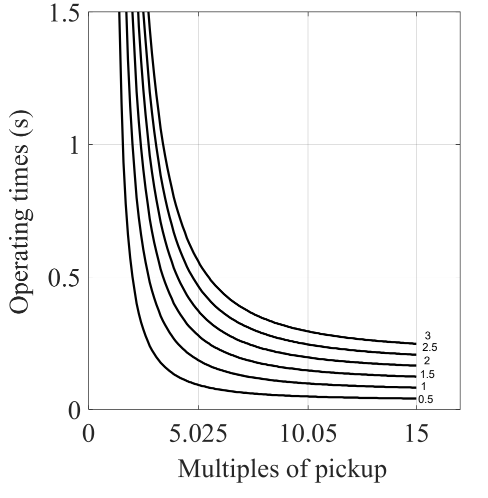
$$t = \left\{ \frac{K}{\left(I/I_{pickup}\right)^{\alpha} - 1} + L \right\} TMS$$

The constants α and β determine the slope of the relay characteristics. L = constant

Constants for IEEE standard inverse characteristics

Curve description	α	K	L
Moderately inverse	0.02	0.0515	0.114
Very inverse	2.0	19.61	0.491
Extremely inverse	2.0	28.2	0.1217

Given the relay characteristic, for a fault current, it is a straightforward to obtain the time response for a given TMS, pickup setting and the other values of the expression. Likewise, if a particular time response and pickup setting have been determined, the time dial setting is found by solving TMS from the same equation.

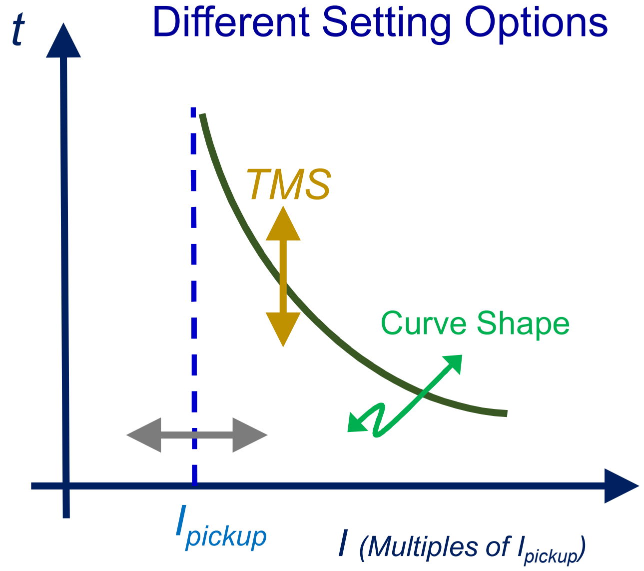


$$t = \left\{ \frac{K}{\left(I/I_{pickup}\right)^{\alpha} - 1} + L \right\} TMS$$

Type of curve	Standard	K factor	α factor	L factor
Short time inverse	AREVA	0.05	0.04	0
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time inverse	AREVA	120	1	0
Short time inverse	C02	0.02394	0.02	0.01694
Moderately Inverse	ANSI/IEEE	0.0515	0.02	0.114
Long time inverse	C08	5.95	2	0.18
Very inverse	ANSI/IEEE	19.61	2	0.491
Extremely inverse	ANSI/IEEE	28.2	2	0.1217
Rectifier protection	RECT	45900	5.6	0

Flexibility with Numerical 51 Relay

- Pickup current
- Time multiplier setting (TMS)
- Curve shape – inverse, very inverse etc.



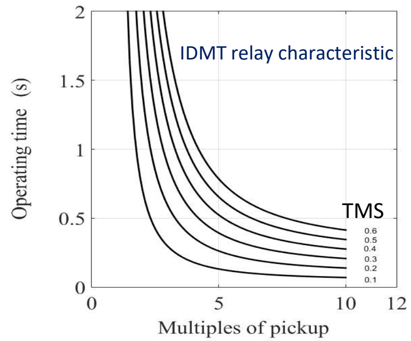
Coordination of Phase Overcurrent Relays

Phase and ground relays are coordinated differently

- For a fault, relay nearest to the fault point should operate first-why??
- Relays are coordinated to avoid the power outage of large area
- In case of failure of primary relay, backup relay should operate to remove the faulted segment.

Phase Overcurrent Relay Coordination by both **Time and Current**

- IDMT relay characteristic is used here



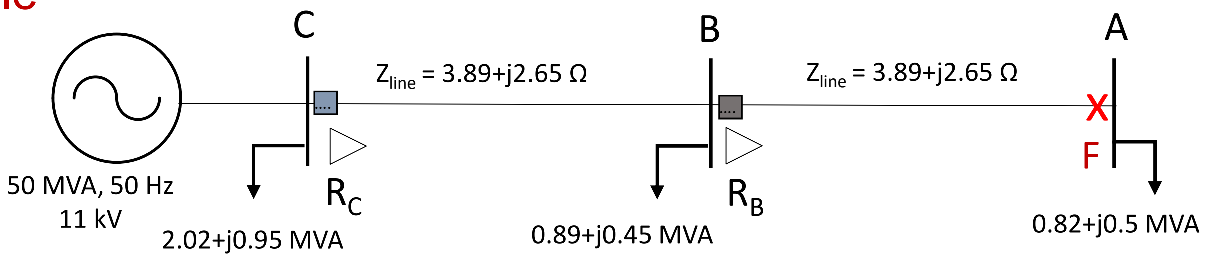
- Coordination of relays by both Time and Current:

  1. CT ratios for all relays are selected such that the steady state secondary current does not exceed 5 A (for 5 A CT) , 1 A (for or 1 A CT).
  2. Set the pickup current for which the relay must operate- using load current and minimum fault current
  3. The relay settings are first determined to give the shortest operating times at maximum fault levels and then checked to see if operation will also be satisfactory at the minimum fault current expected.
  4. TMS for the primary relay on a feeder is selected at the fastest possible setting which usually corresponds to the minimum TMS.
  5. Relays are coordinated for maximum fault current seen by the relay.
  5. TMS for backup relay is selected so that the coordination time interval (CTI) must maintain at 0.2-0.4 s.

- Note:
  1. Use relays with the same operating characteristic.
  2. The relay farthest from the source should have current settings equal to or less than the relays behind it.

Phase Overcurrent Relay Coordination with IDMT characteristic for a Radial System

Example



For a fault at F

Primary relay: R_B

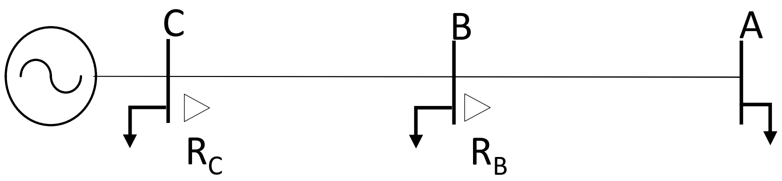
Backup relay: R_C

Data Sheet :Maximum load current, minimum and maximum fault currents

Bus, Relay	Max load current (A)	Minimum fault current (A)	Maximum fault current (A)
B, R_B	58	578	965
C, R_C	115	1036	2580

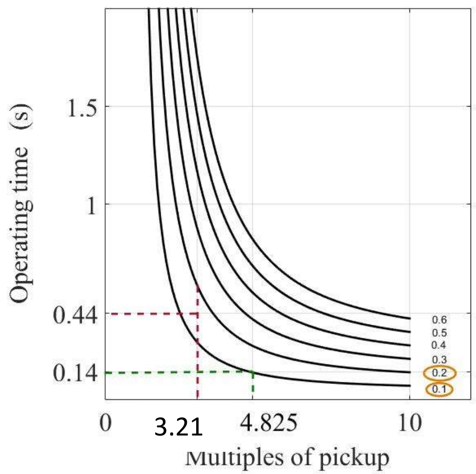
- Minimum fault current is for LG/L-L fault at the end of the feeder (F-point)
- Maximum fault current is for 3-phase fault at the relay.
- Very inverse IDMT characteristic is selected for relay coordination

Phase Overcurrent Relay Coordination ...



- The relays settings are summarized as

Relays	CT ratio	Pickup current (A)	TMS
R_B	100:5	10	0.1
R_C	150:5	10	0.2



For coordination between R_B and Rc, Max fault current=965A at B

For R_B relay sees $965/CT_B$=965/(100/5)=48.25A

Multiple of pickup= 48.25/10=4.825

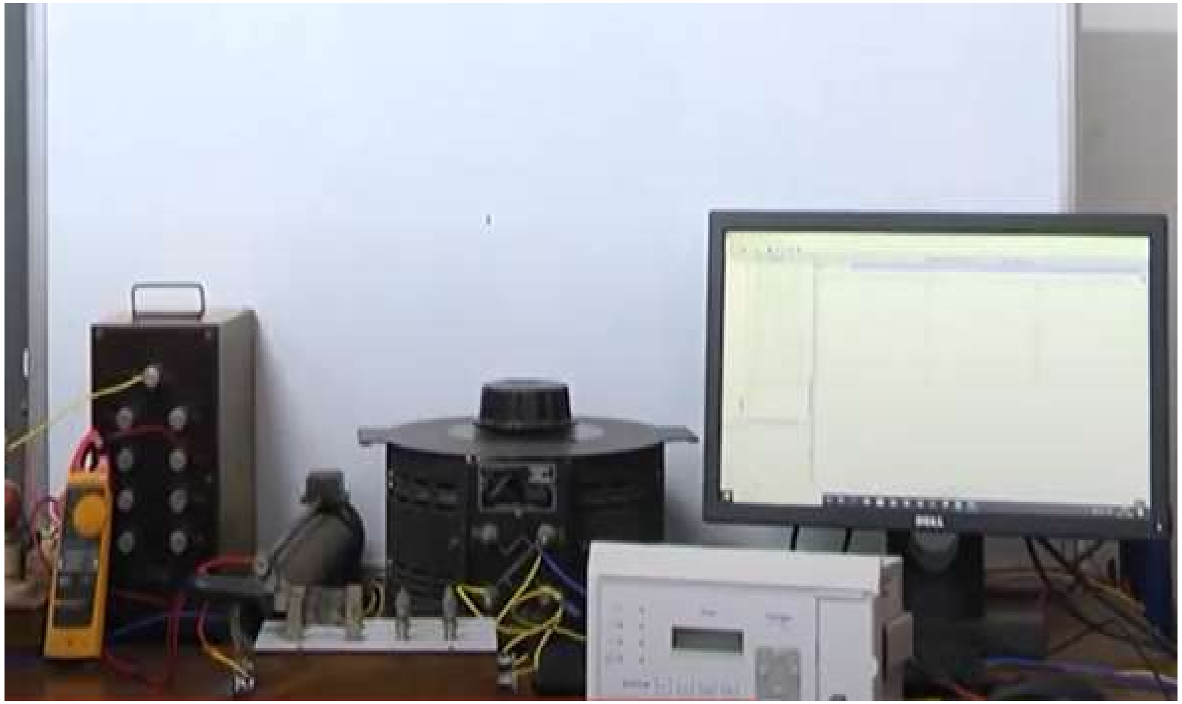
For Rc, 965/(150/5)=32.1A

Multiple of pickup=32.1/10=3.21

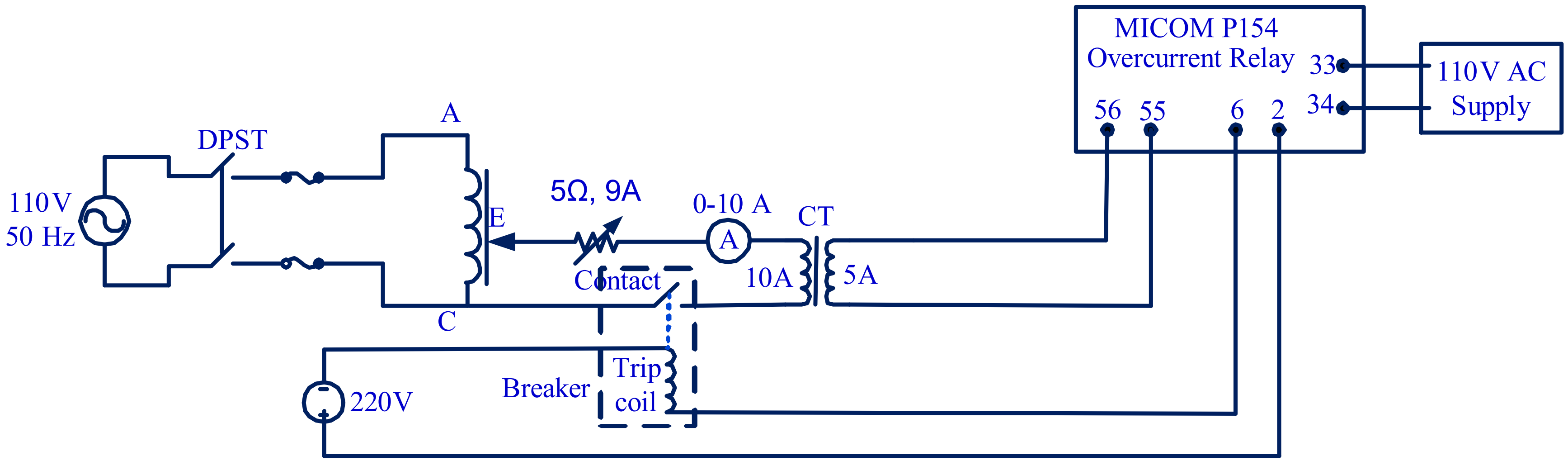
Objective:

To Verify the Operating Characteristic of the Numerical Overcurrent Relay

-Numerical Overcurrent Relay- MICOM P154 (Alstom make)



Circuit Diagram:



MICOM P154 (Alstom make)

Relay operates when, relay current $I \geq K_1 I_{ref}$, where K_1 = pickup setting

Operating time of IDMT relay, $t = TMS\left(\frac{K}{\left(I/I_S\right)^{\alpha} - 1} + L\right)$

Where, K= coefficient as in Table,

I = value of measured current,

Is = pickup current,

α = coefficient as in Table,

L = ANSI/IEEE coefficient as in Table,

TMS = Time multiplier between 0.025 and 1.5.

Type of curve	Standard	K factor	α factor	L factor
Short time inverse	AREVA	0.05	0.04	0
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time inverse	AREVA	120	1	0
Short time inverse	C02	0.02394	0.02	0.01694
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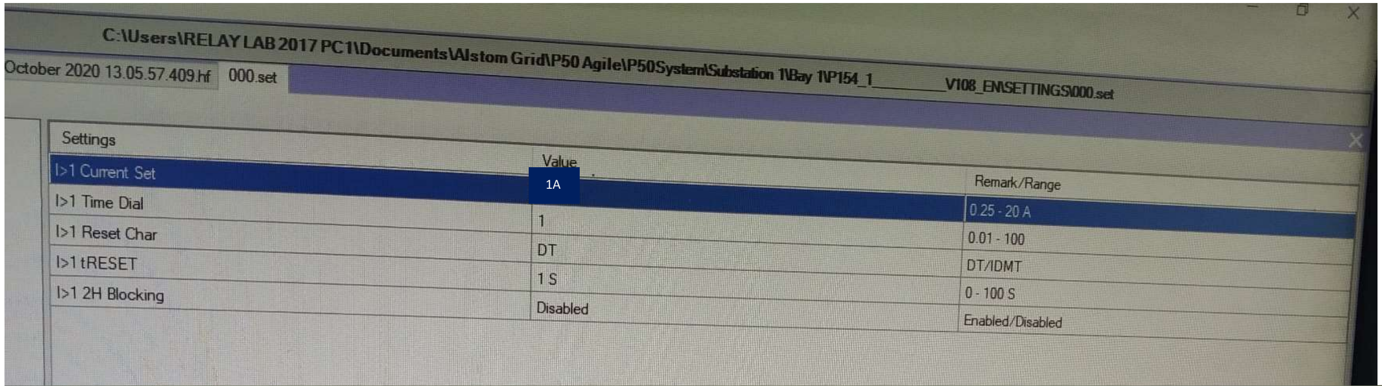
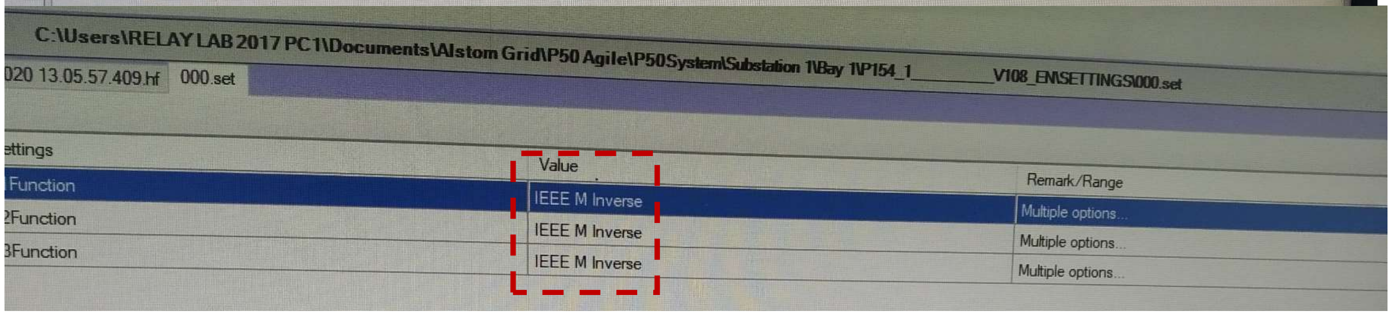
Long time inverse	C08	5.95	2	0.18
Very inverse	ANSI/IEEE	19.61	2	0.491
Extremely inverse	ANSI/IEEE	28.2	2	0.1217
Rectifier protection	RECT	45900	5.6	0

Settings:

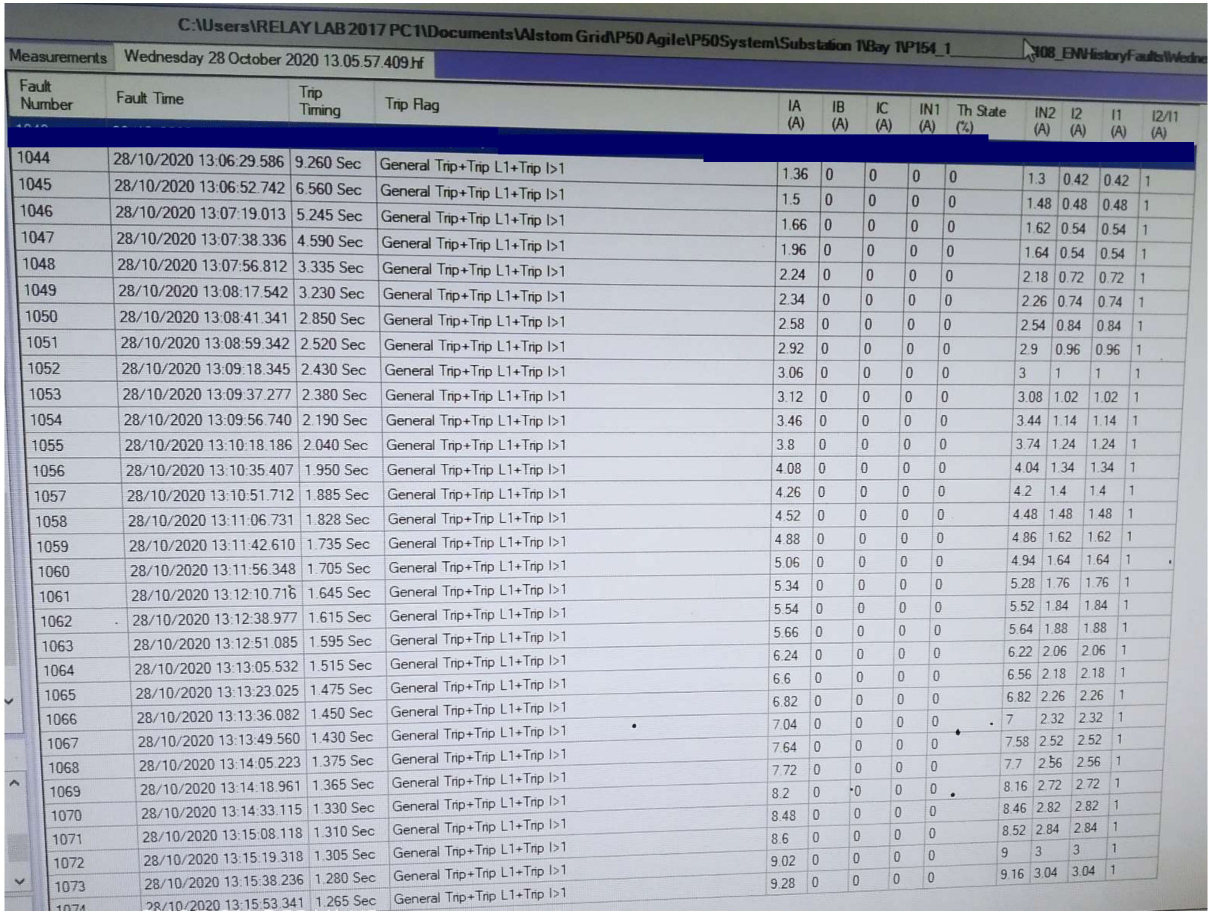
Relay pickup current setting (I_s) (primary side) = 1 A.
Time multiplier (TMS) = 1
IEEE moderately inverse curve
CT ratio= 10:5A

$$t = TMS\left(\frac{K}{\left({}^{I}/_{I_S}\right)^{\alpha} - 1} + L\right)$$





Observation:



C:\Users\RELAY LAB 2017 PC1\Documents\Alstom Grid\P50 Agile\P50System\Substation 1\Bay 1\P154_1

Measurements | Wednesday 28 October 2020 13.05.57.409.hf

Fault Number	Fault Time	Trip Timing	Trip Flag	IA (A)	IB (A)	IC (A)	IN1 (A)	Th State (%)	IN2 (A)	I2 (A)	I1 (A)	I2/I1 (A)
1044	28/10/2020 13:06:29.586	9.260 Sec	General Trip+Trip L1+Trip I>1	1.36	0	0	0	0	1.3	0.42	0.42	1
1045	28/10/2020 13:06:52.742	6.560 Sec	General Trip+Trip L1+Trip I>1	1.5	0	0	0	0	1.48	0.48	0.48	1
1046	28/10/2020 13:07:19.013	5.245 Sec	General Trip+Trip L1+Trip I>1	1.66	0	0	0	0	1.62	0.54	0.54	1
1047	28/10/2020 13:07:38.336	4.590 Sec	General Trip+Trip L1+Trip I>1	1.96	0	0	0	0	1.64	0.54	0.54	1
1048	28/10/2020 13:07:56.812	3.335 Sec	General Trip+Trip L1+Trip I>1	2.24	0	0	0	0	2.18	0.72	0.72	1
1049	28/10/2020 13:08:17.542	3.230 Sec	General Trip+Trip L1+Trip I>1	2.34	0	0	0	0	2.26	0.74	0.74	1
1050	28/10/2020 13:08:41.341	2.850 Sec	General Trip+Trip L1+Trip I>1	2.58	0	0	0	0	2.54	0.84	0.84	1
1051	28/10/2020 13:08:59.342	2.520 Sec	General Trip+Trip L1+Trip I>1	2.92	0	0	0	0	2.9	0.96	0.96	1
1052	28/10/2020 13:09:18.345	2.430 Sec	General Trip+Trip L1+Trip I>1	3.06	0	0	0	0	3	1	1	1
1053	28/10/2020 13:09:37.277	2.380 Sec	General Trip+Trip L1+Trip I>1	3.12	0	0	0	0	3.08	1.02	1.02	1
1054	28/10/2020 13:09:56.740	2.190 Sec	General Trip+Trip L1+Trip I>1	3.46	0	0	0	0	3.44	1.14	1.14	1
1055	28/10/2020 13:10:18.186	2.040 Sec	General Trip+Trip L1+Trip I>1	3.8	0	0	0	0	3.74	1.24	1.24	1
1056	28/10/2020 13:10:35.407	1.950 Sec	General Trip+Trip L1+Trip I>1	4.08	0	0	0	0	4.04	1.34	1.34	1
1057	28/10/2020 13:10:51.712	1.885 Sec	General Trip+Trip L1+Trip I>1	4.26	0	0	0	0	4.2	1.4	1.4	1
1058	28/10/2020 13:11:06.731	1.828 Sec	General Trip+Trip L1+Trip I>1	4.52	0	0	0	0	4.48	1.48	1.48	1
1059	28/10/2020 13:11:42.610	1.735 Sec	General Trip+Trip L1+Trip I>1	4.88	0	0	0	0	4.86	1.62	1.62	1
1060	28/10/2020 13:11:56.348	1.705 Sec	General Trip+Trip L1+Trip I>1	5.06	0	0	0	0	4.94	1.64	1.64	1
1061	28/10/2020 13:12:10.716	1.645 Sec	General Trip+Trip L1+Trip I>1	5.34	0	0	0	0	5.28	1.76	1.76	1
1062	28/10/2020 13:12:38.977	1.615 Sec	General Trip+Trip L1+Trip I>1	5.54	0	0	0	0	5.52	1.84	1.84	1
1063	28/10/2020 13:12:51.085	1.595 Sec	General Trip+Trip L1+Trip I>1	5.66	0	0	0	0	5.64	1.88	1.88	1
1064	28/10/2020 13:13:05.532	1.515 Sec	General Trip+Trip L1+Trip I>1	6.24	0	0	0	0	6.22	2.06	2.06	1
1065	28/10/2020 13:13:23.025	1.475 Sec	General Trip+Trip L1+Trip I>1	6.6	0	0	0	0	6.56	2.18	2.18	1
1066	28/10/2020 13:13:36.082	1.450 Sec	General Trip+Trip L1+Trip I>1	6.82	0	0	0	0	6.82	2.26	2.26	1
1067	28/10/2020 13:13:49.560	1.430 Sec	General Trip+Trip L1+Trip I>1	7.04	0	0	0	0	7	2.32	2.32	1
1068	28/10/2020 13:14:05.223	1.375 Sec	General Trip+Trip L1+Trip I>1	7.64	0	0	0	0	7.58	2.52	2.52	1
1069	28/10/2020 13:14:18.961	1.365 Sec	General Trip+Trip L1+Trip I>1	7.72	0	0	0	0	7.7	2.56	2.56	1
1070	28/10/2020 13:14:33.115	1.330 Sec	General Trip+Trip L1+Trip I>1	8.2	0	0	0	0	8.16	2.72	2.72	1
1071	28/10/2020 13:15:08.118	1.310 Sec	General Trip+Trip L1+Trip I>1	8.48	0	0	0	0	8.46	2.82	2.82	1
1072	28/10/2020 13:15:19.318	1.305 Sec	General Trip+Trip L1+Trip I>1	8.6	0	0	0	0	8.52	2.84	2.84	1
1073	28/10/2020 13:15:38.236	1.280 Sec	General Trip+Trip L1+Trip I>1	9.02	0	0	0	0	9	3	3	1
1074	28/10/2020 13:15:53.341	1.265 Sec	General Trip+Trip L1+Trip I>1	9.28	0	0	0	0	9.16	3.04	3.04	1

Verification:

$$t = TMS\left(\frac{K}{\left({}^{I}/_{I_S}\right)^{\alpha} - 1} + L\right)$$

For IEEE moderately inverse curve,

$K = 0.0515$

$\alpha = 0.02$

$L = 0.114$

As per setting,

TMS = 1,

I_s = 1 A,

CT ratio = 10:5A

Fault Time	Trip time(S)	Ia(A)	Ib(A)	Ic(A)	I2(A)	I1(A)
13:06:29.586	9.26	1.36	0	0	0.42	0.42
13:06:52.586	6.56	1.5	0	0	0.48	0.48
13:07:19.013	5.245	1.66	0	0	0.54	0.54
13:07:38.336	4.59	1.96	0	0	0.54	0.54
13:07:56.812	3.335	2.24	0	0	0.72	0.72
13:08:17.542	3.23	2.34	0	0	0.74	0.74
13:08:41.341	2.85	2.58	0	0	0.84	0.84
13:08:59.342	2.52	2.92	0	0	0.96	0.96
13:09:18.345	2.43	3.06	0	0	1	1
13:09:37.277	2.38	3.12	0	0	1.02	1.02
13:09:56.740	2.19	3.46	0	0	1.14	1.14
13:10:18.186	2.04	3.8	0	0	1.24	1.24
13:10:35.407	1.95	4.08	0	0	1.34	1.34
13:10:51.712	1.885	4.26	0	0	1.4	1.4
13:11:06.731	1.828	4.52	0	0	1.48	1.48
13:11:42.610	1.735	4.88	0	0	1.62	1.62
13:11:56.348	1.705	5.06	0	0	1.64	1.64
13:12:10.716	**1.645**	**5.34**	0	0	1.76	1.76
13:12:38.977	1.615	5.54	0	0	1.84	1.84
13:12:51.085	1.595	5.66	0	0	1.88	1.88
13:13:05.532	1.515	6.24	0	0	2.06	2.06
13:13:23.025	1.475	6.6	0	0	2.18	2.18
13:13:36.082	1.45	6.82	0	0	2.26	2.26
13:13:49.560	1.43	7.04	0	0	2.32	2.32
13:14:05.223	1.375	7.64	0	0	2.52	2.52
13:14:18.961	1.365	7.72	0	0	2.56	2.56
13:14:33.115	1.33	8.2	0	0	2.72	2.72
13:15:08.118	1.31	8.48	0	0	2.82	2.82
13:15:19.318	1.305	8.6	0	0	2.84	2.84
13:15:38.236	1.28	9.02	0	0	3	3
13:15:53.341	1.265	9.28	0	0	3.04	3.04

$$t = TMS\left(\frac{K}{\left({}^{I}/_{I_S}\right)^{\alpha} - 1} + L\right)$$

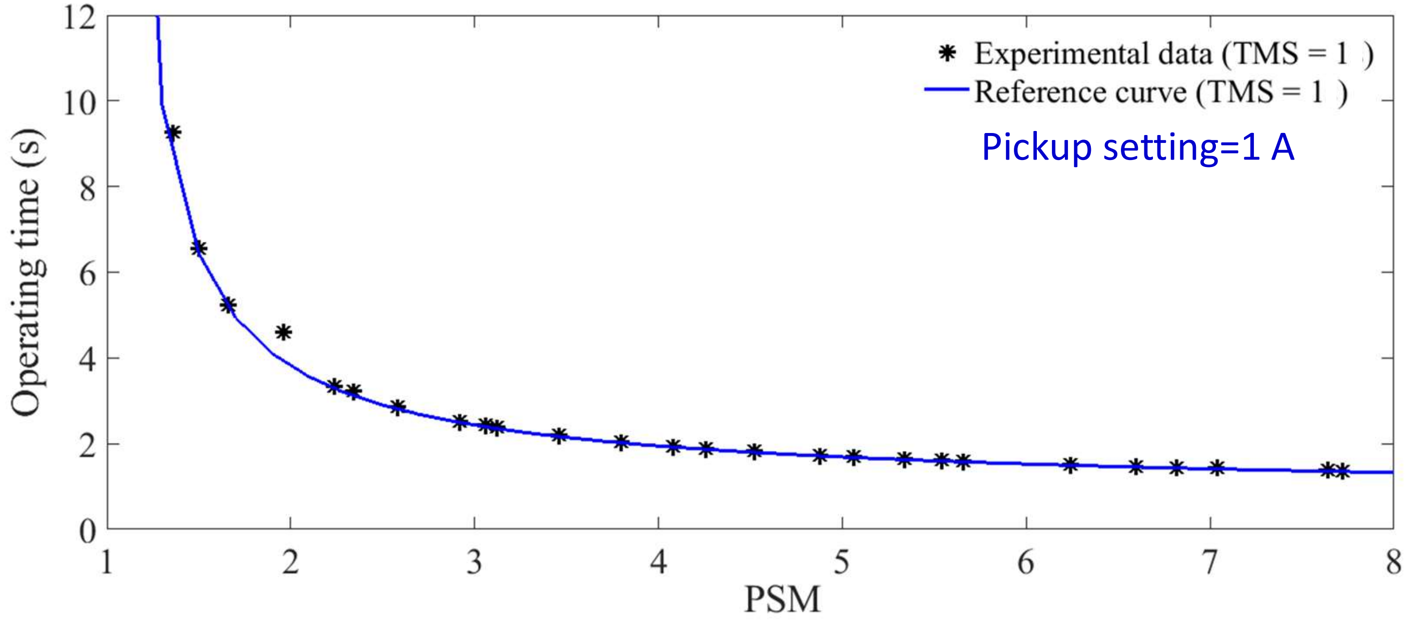
For I = 5.34 A

Substituting in the above equation **t = 1.625 s**

With experimental observation,

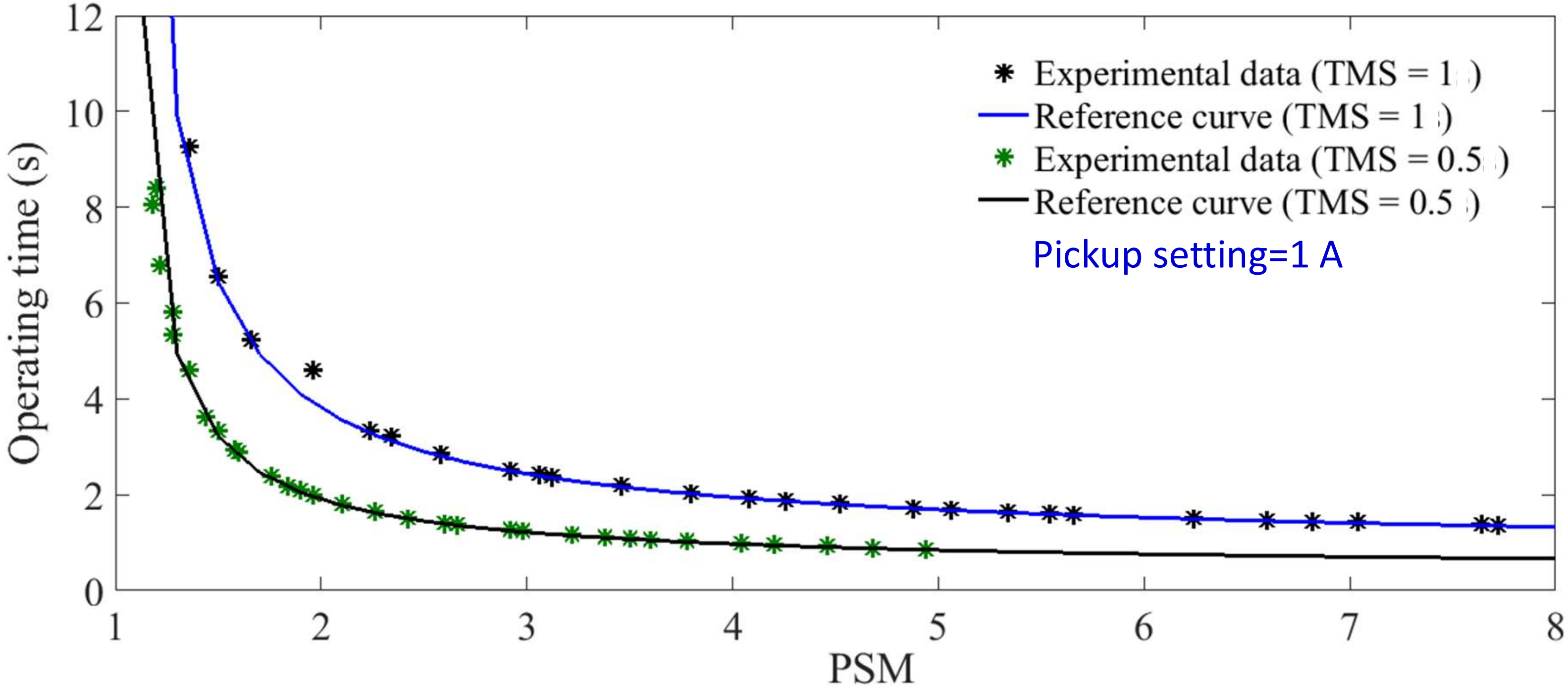
t = 1.645 s

Verification of overcurrent relay characteristics:



Conclusion: The overcurrent relay characteristic drawn using experimental data matches closely to the IEEE moderately inverse curve as set.

Comparison with different TMS values



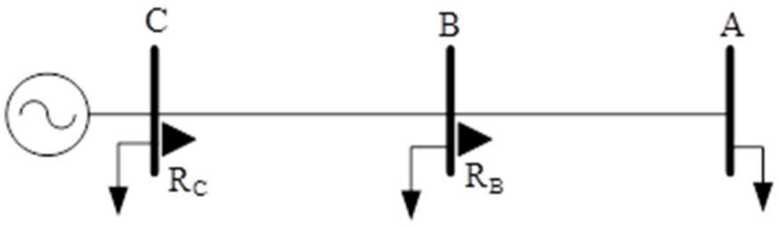
Demonstration is available on:

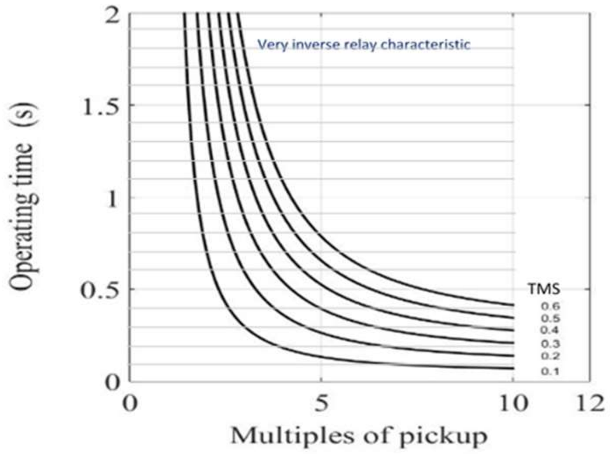
https://www.youtube.com/watch?v=UqkyJzilSJE&feature=emb_logo

Report Submission : *Handwritten*

1. Plot the overcurrent relay characteristics for the four data sets provided in four graph sheets. (Write your roll number and name at the top of the sheets)
2. Also plot the reference characteristic (calculated by overcurrent relay standard equation as for the particular curve used) with each plotted graph.
3. Write your assessment for each experimental data set compared to reference curve.
4. Write your suggestions, how the performance of the relay can be improved further?

5. Relays R_B and R_C have CTs of 100:5. Maximum fault current at bus B is 800 A. Pickup current of both relays is 8 A. Relays R_B and R_C are set with TMS = 0.1 and 0.3 respectively. If the coordination time interval required is 0.3 s, comment on the TMS settings of the relays for the system.





Report Submission:

6. A 12.47 kV distribution system is shown below. Relays R_B and R_C are set with IEEE Very Inverse (VI) curve and coordinated with a time interval of 0.3 s. CTs for R_B and R_C are of 100:5 and 200:5 respectively. Pickup setting and TMSs of both the relays are provided below in the Table-I. The Simulink model of the system is provided. Create phase-A-to-ground faults at F_1, F_2 and F_3, as shown in the figure with a fault resistance of (Last digit of your Roll Number) ohm. Fill Table-II with fault current values measured by the relays and corresponding operating times (see instruction in the table for R_f).

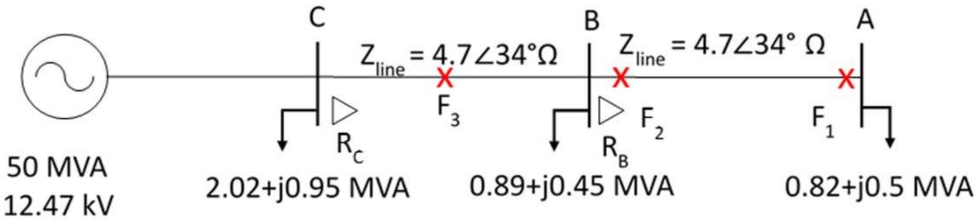


Table-I

Relays	I_{Pickup} (A)	TMS
R_B	79	0.1
R_C	162	0.4

Very Inverse (VI) - IDMT characteristics,

$$t = \left(\frac{19.61}{\left(I/I_{pickup}\right)^2 - 1} + 0.491 \right) TMS$$

Table-II

Roll Number:						
R_f = (Last digit of Roll Number) ohm, in case of zero, take 0.01 ohm						
Fault Locations	F_1		F_2		F_3	
Relays	R_B	R_C	R_B	R_C	R_B	R_C
I (A)						
t (s) simulation						
t_ref(s) standard curve						

Pages to be submitted

- Page-1 :Roll No, Name at the top, discussion on observations of the 4 cases as mentioned in the earlier slide
- Page-2 –page-5- graph papers with plots (roll No, Name at the top)
- Page 6- the assignment given in point-5 in earlier slide (roll No, Name at the top)
- Page 7- fill up the table with your results
- Create a pdf of all the pages in order and submit

Thanks

Queries/Questions