Demonstration of Laboratory Experiments on Numerical Relays

Experiment 03(a): Verification of Directional Overcurrent Relay Characteristic

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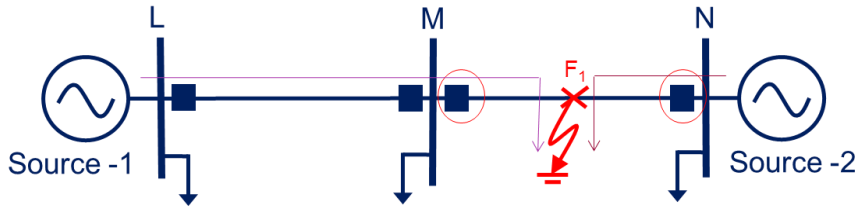
Verification of Directional Overcurrent Relay Characteristic

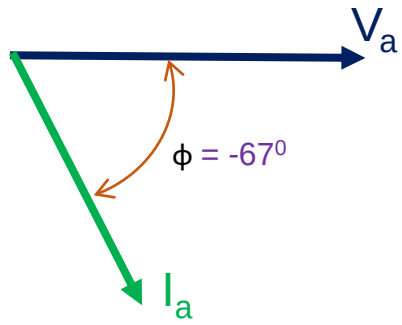
- Objective
- Theory
- Circuit diagram
- Relay Settings
- Observations and Verification

Objective:

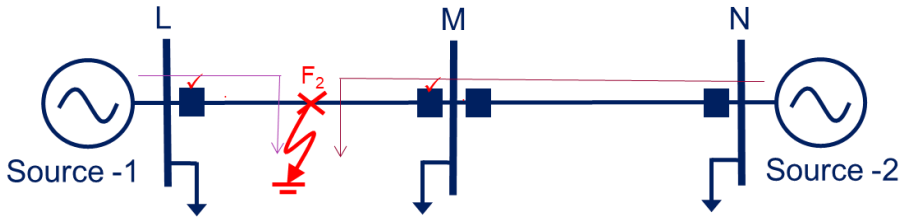
To Verify the Operating Characteristic of the Numerical Directional - Overcurrent Relay

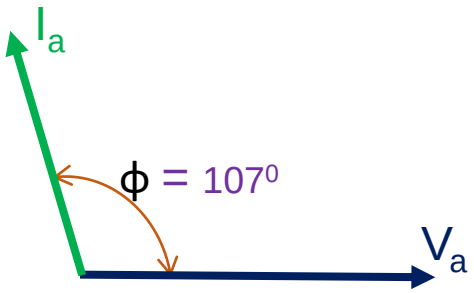
-Directional Overcurrent Relay- **MICOM P138** (Schneider Electric)





Phase-a to ground-fault

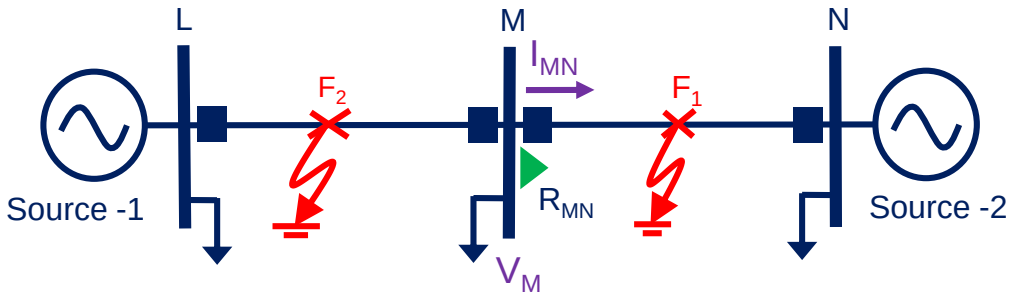


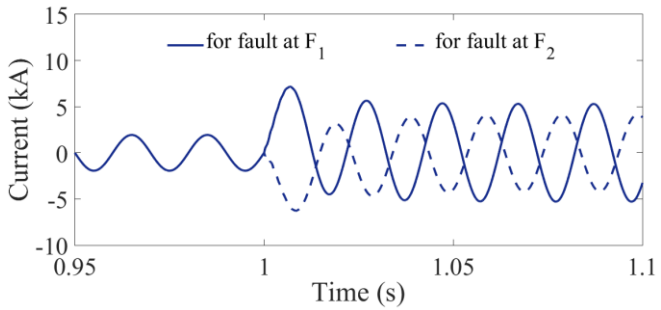


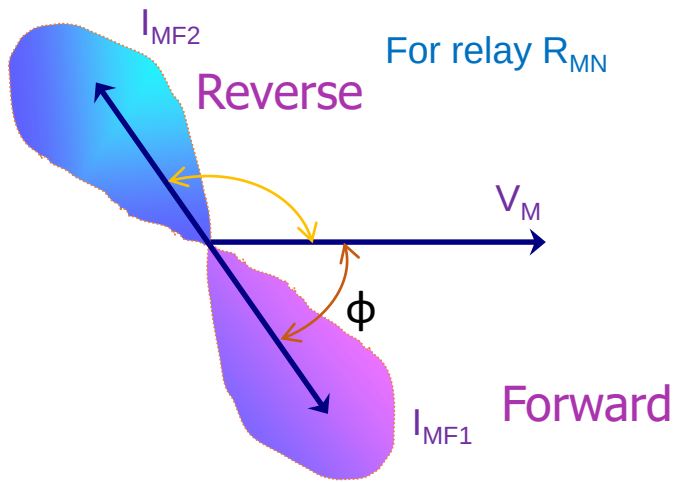
Theory: Principle of Directional Relaying

Based on angle between phase voltages and currents

- Transmission lines are predominantly inductive
  - For forward line faults (F_1), I lags *V* by the fault loop impedance angle, φ.
  - For reverse faults on the adjacent line (F_2), I leads V by approximately 180^0 minus the fault loop impedance angle, φ.

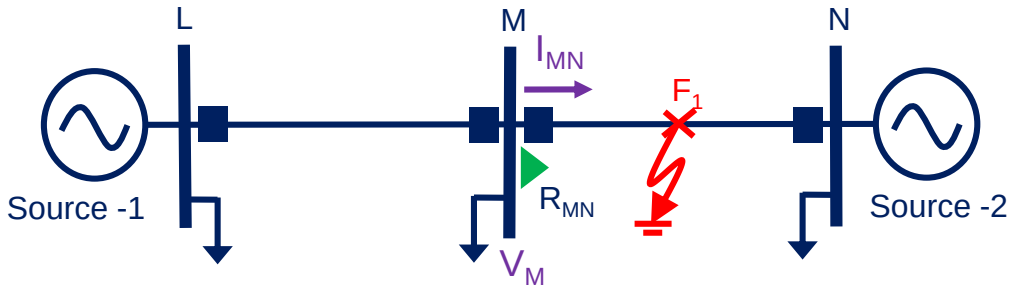






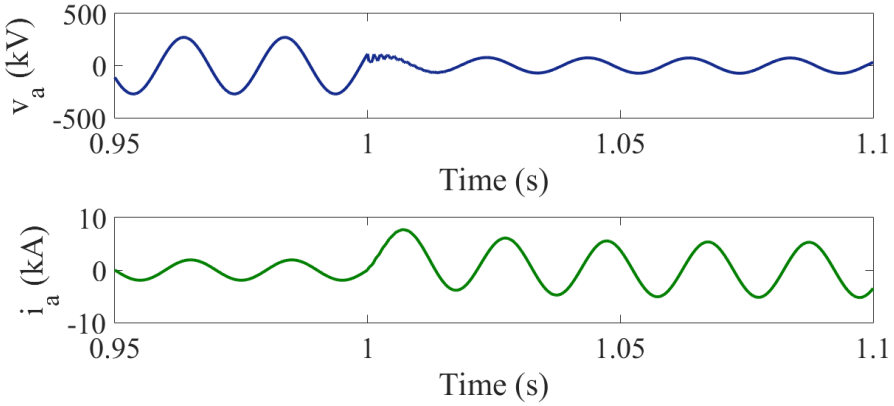
V_M polarizing voltage at bus M

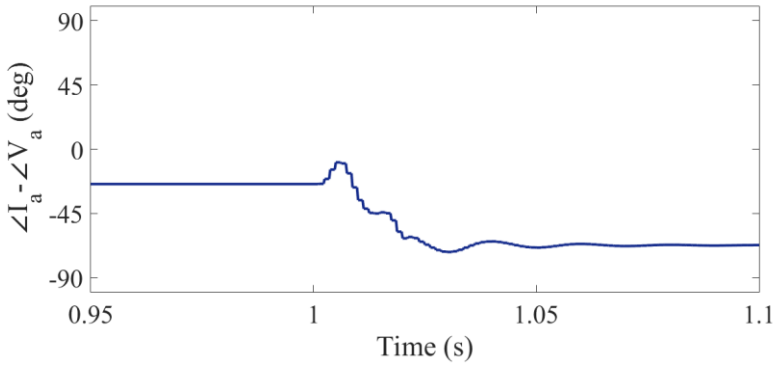
Principle of Directional Relaying..

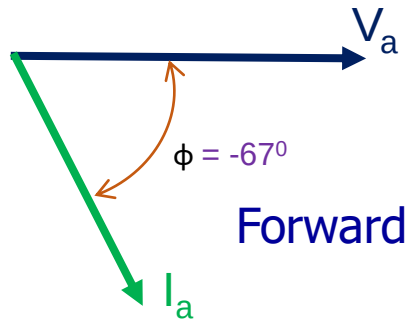


400 kV 3-phase transmission network

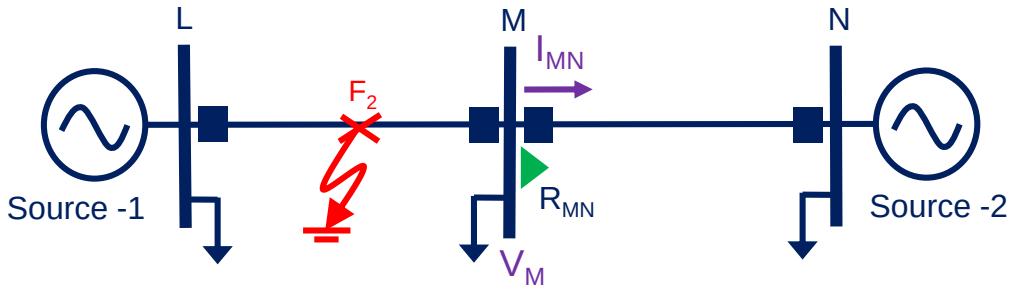
For a 3-phase fault at F_1





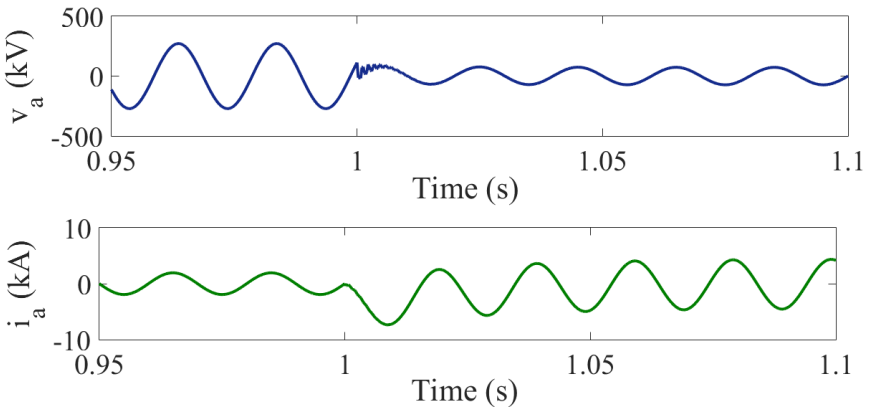


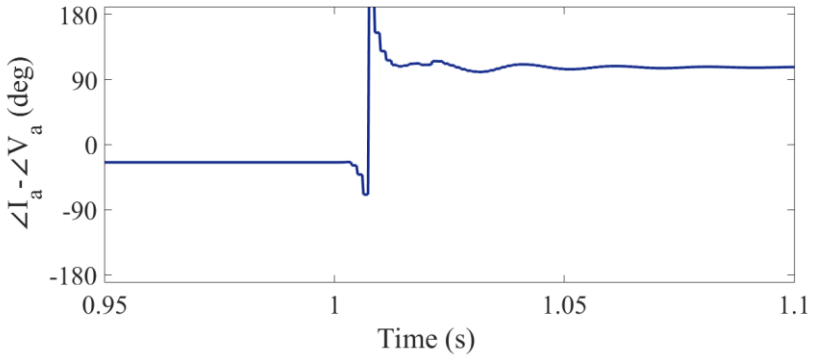
Fundamental Principle of Directional Relaying

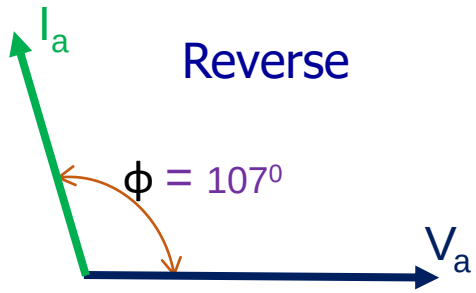


400 kV 3-phase transmission network

For a 3-phase fault at F_2







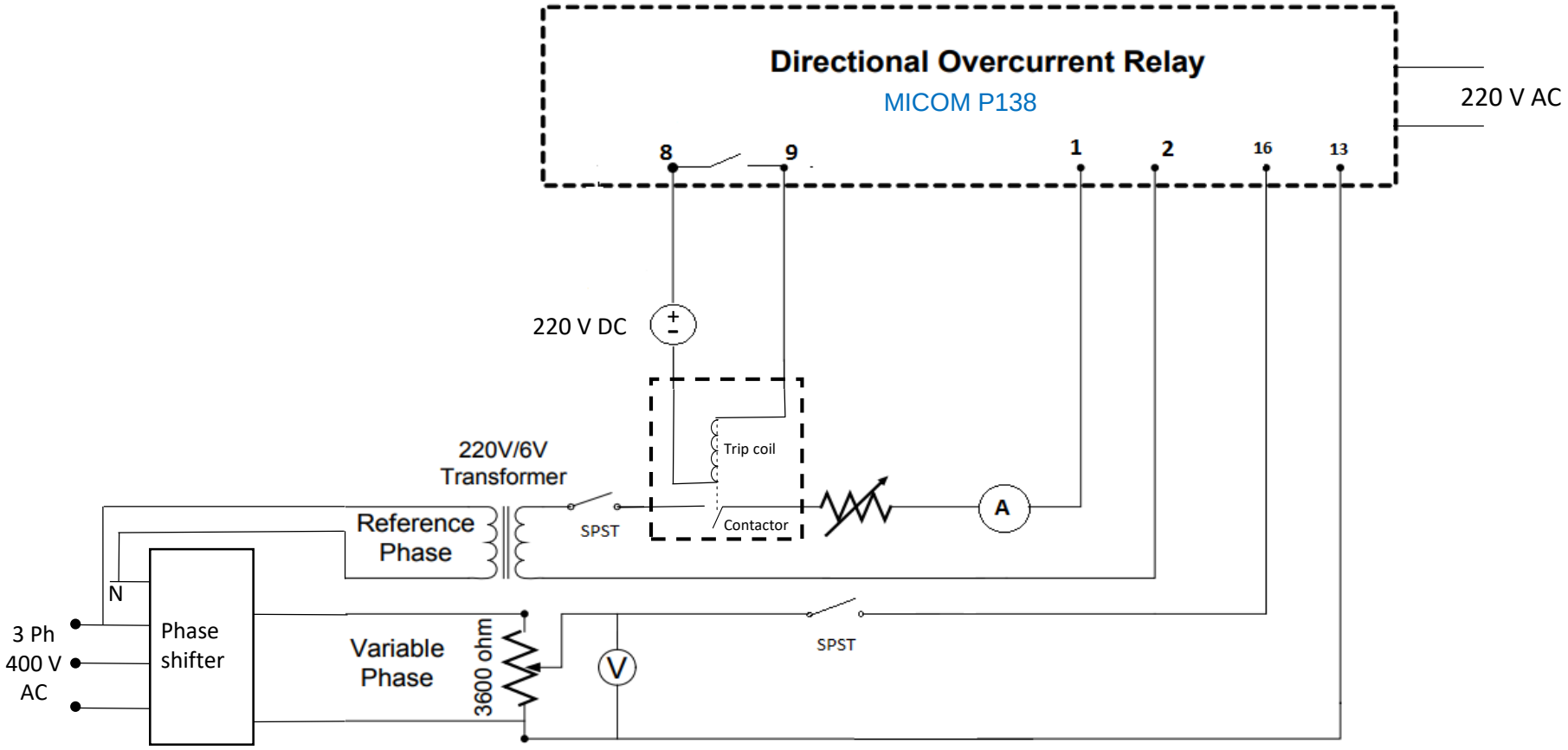
Directional-overcurrent relay (67)

X: Overcurrent relay output

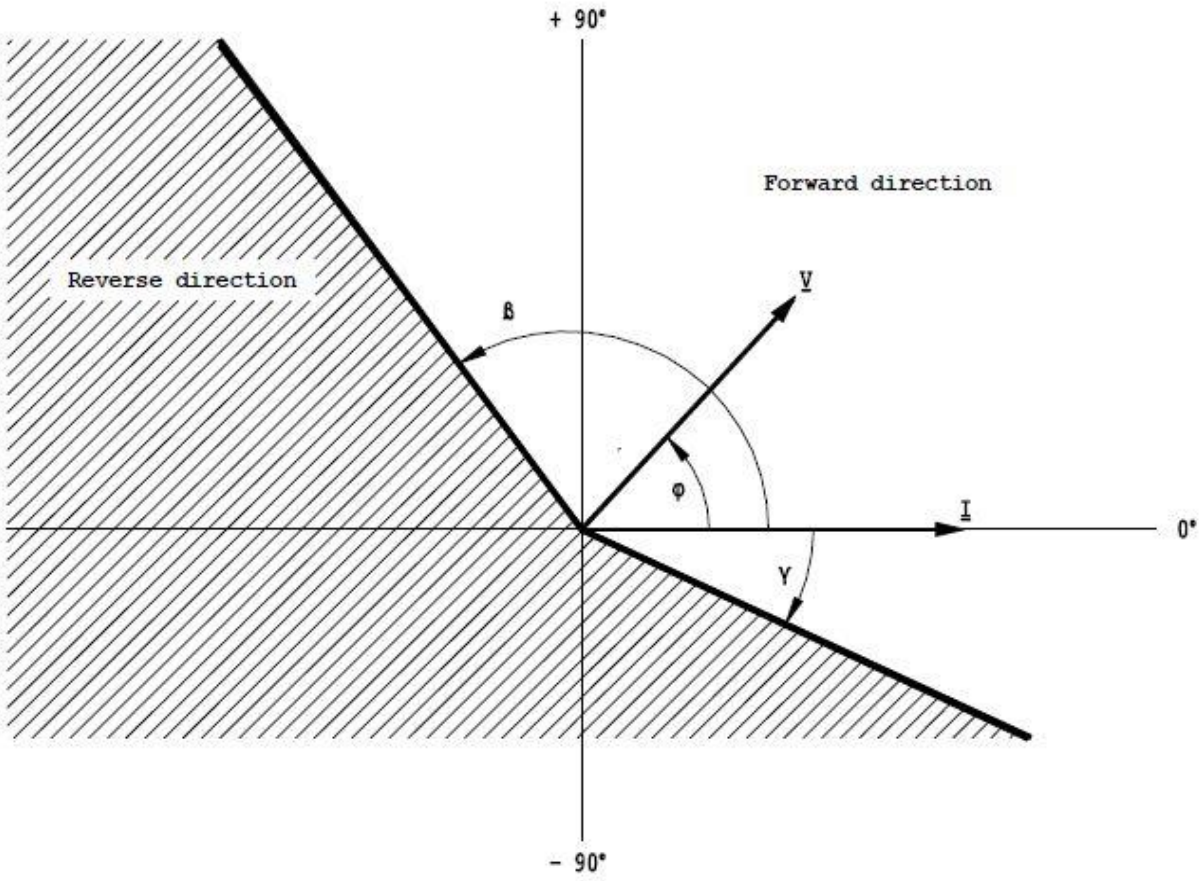
Y: Directional relay output

Trip = X AND Y

Circuit Diagram:



Settings



100

Settings

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

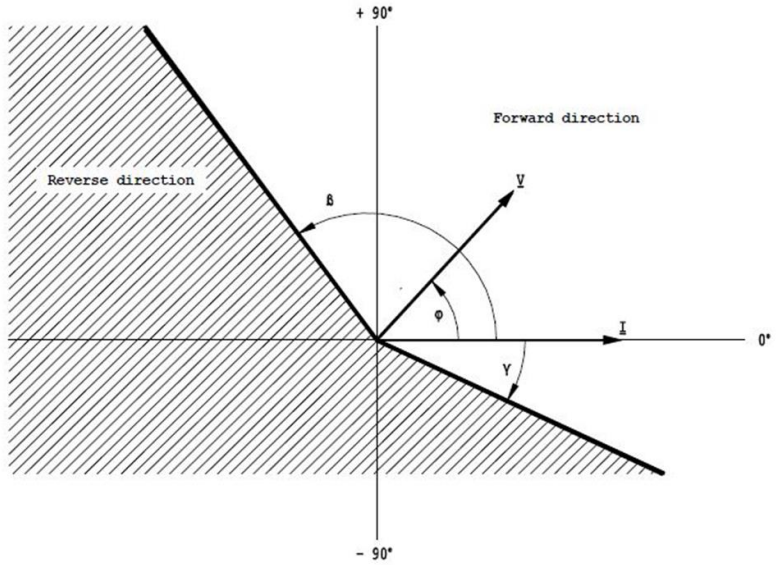
Operating time of IDMT relay, $t = T \times \left(\frac{K}{\left({}^{I}/_{I_S} \right)^{\alpha} - 1} + L \right)$

For IEEE moderately inverse curve,

K= 0.0515

α = 0.02

L = 0.114



Settings:

Nominal Current (I_{nom})= 5A, Pickup setting= $0.3 I_{nom}$ = 1.5

Characteristic curve= IEEE M Inverse.

Direction: $\beta = 135^0$, $\Upsilon = -45^0$

Case-1Setting:

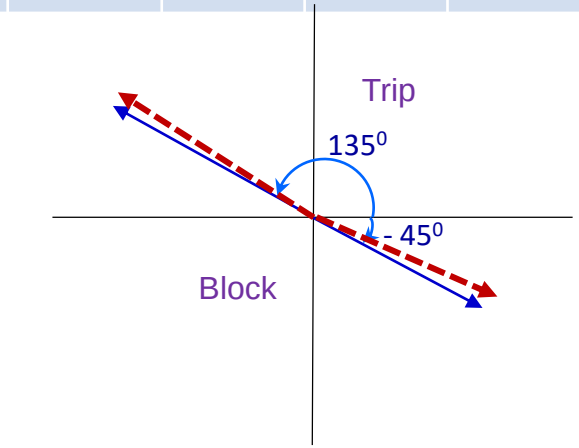
Nominal Current (I_{nom})= 5A, Pickup setting= $0.3I_{nom}$ = 1.5 A. Characteristic curve= IEEE M Inverse.

$\beta = 135^0$, $\Upsilon = -45^0$

Observation: Fixed Fault current injected =2.67A

Angle (V-I) (deg) →	1	15	27	42	64	86	99	117	134	138	148	156	164	178
Trip/ No trip (relay decision) →	**Trip**	**Trip**	**Trip**	**Trip**	**Trip**	**Trip**	**Trip**	**Trip**	**Trip**	No trip	No trip	No trip	No trip	No trip
Angle (V-I) (deg) →	**-6**	**-18**	**-28**	**-39**	**-43**	**-46**	**-58**	**- 71**	**- 82**	**- 105**	**- 125**	**- 154**	**- 170**	**- 176**
Trip/ No trip (relay decision) →	Trip	Trip	Trip	Trip	Trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip

Conclusion:



Trip region is observed to be within -43^0 and 134^0

Case-2 Setting:

Nominal Current (I_{nom})= 5A, Pickup setting= $0.3I_{nom}$ = 1.5 A. Characteristic curve= IEEE M Inverse.

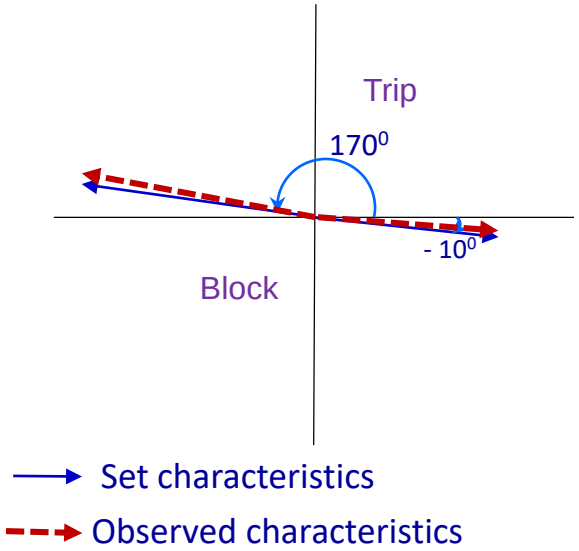
$\beta = 170^0$, $\Upsilon = -10^0$

Observation: Fixed injected Fault current =2.67A

Angle (V-I) (deg)	4	16	33	42	53	62	78	98	125	144	165	174	176	179
Trip/ No trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	Trip	No trip	No trip	No trip

Angle (V-I) (deg)	- 6	- 13	- 21	- 46	- 60	- 78	- 89	- 100	- 113	- 121	- 138	- 154	- 164	- 177
Trip/ No trip	Trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip	No trip

Conclusion:



Trip region is observed to be within -10^0 and 170^0

Demonstration is available on:

https://www.youtube.com/watch?v=gsZazbNwI6A&feature=emb_logo

Directional relay lectures:

https://www.youtube.com/watch?v=wDDLYkVm3ig&feature=emb_title

https://www.youtube.com/watch?v=9W071FEwtk4&feature=emb_title

Directional relay experiment demonstration:

https://www.youtube.com/watch?v=gsZazbNwI6A&feature=emb_logo

Schneider electric book link (Directional overcurrent--page no. 164):

https://www.se.com/ww/en/tools/npag-online/pdf/C1-Overcurrent_Protection_for_Phase_and_Earthfaults.pdf

Report Submission Guidelines:

1. Obtain the trip and block region for the directional relay based on the given two data sets. (Write your roll number and name at the top of the sheets)
2. Plot the actual operating characteristic for the relay based on the settings provided for each case (on the same plots as in (1)).
3. Write on your assessment for each experimental data set compared to actual operating characteristic.
4. Write your suggestions how the performance of the relay and the **testing** can be improved further.
5. Check whether the directional relay will operate or not for the following fault cases.

Setting of the directional overcurrent relay: $\beta = 160^0$, $\gamma = -20^0$, pickup current = 0.3 kA

Case-1

Voltage and current data during fault

V_a: 104.77∠ 78.43^0 kV I_a: 0.08∠ -87.91^0 kA

V_b: 53.84∠-85.74^0 kV I_b: 0.72∠ -96.16^0 kA

V_c: 54.96∠-117.07^0 kV I_c: 0.79∠84.70^0 kA

Case-2

Voltage and current data during fault

V_a: 22.52∠98.26^0 kV I_a: 0.63∠-164.74^0 kA

V_b: 22.94∠-19.90^0 kV I_b: 0.64∠53.15^0 kA

V_c: 22.10∠-139.94^0 Kv I_c: 0.61∠-45.39^0 kA

Sequence Components from phase quantities

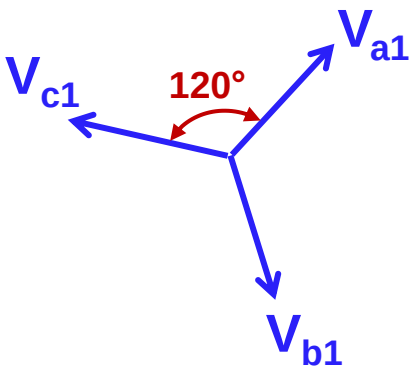
$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \qquad \alpha = 1\angle 120°$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\left[V^{abc}\right] = [T]\left[V_a^{012}\right]$$

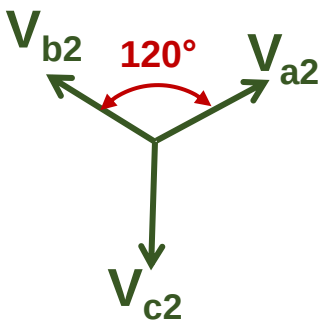
$$\left[V_a^{012}\right] = [T]^{-1}\left[V^{abc}\right]$$

$$\left[I_a^{012}\right] = [T]^{-1}\left[I^{abc}\right]$$



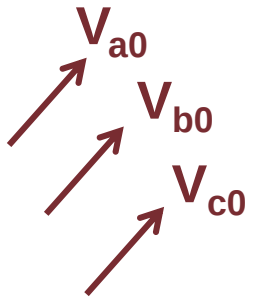
$$V_{b1} = \alpha^2 V_{a1}$$

$$V_{c1} = \alpha V_{a1}$$



$$V_{b2} = \alpha V_{a2}$$

$$V_{c2} = \alpha^2 V_{a2}$$

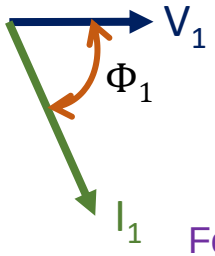


$$V_{a0} = V_{b0} = V_{c0}$$

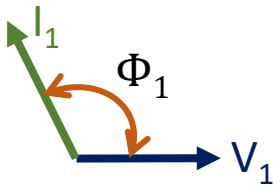
Phasor diagrams and rules for sequence components based directional relaying

$$\Phi_1 = \angle I_{1MN} - \angle V_{1M}$$

- negative for forward fault
- Positive for reverse fault



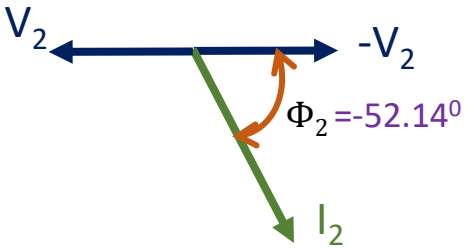
Forward fault



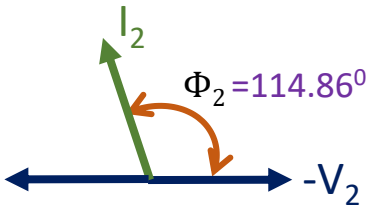
Reverse Fault

$$\Phi_2 = \angle I_{2MN} - \angle -V_{2M}$$

- negative for forward fault
- Positive for reverse fault



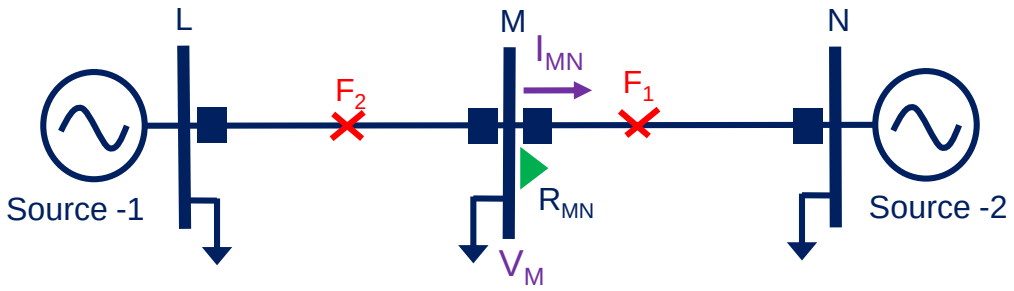
Forward fault



Reverse Fault

Report Submission Guidelines:

6. A Simulink model of 3-bus equivalent system is provided. A directional relay is provided at bus M with a setting of β = 160^0, γ= -20^0, pickup current = 0.3 kA. Create phase –A-to-ground faults at F1 and F2 and write your observation in the following table.



Roll No:				
Fault position	Fault resistance	Voltage	Current	Decision (Trip/ No trip)
F_1	Last digit of roll number			
F_2	Last digit of roll number			

Pages to be submitted

(one pdf file for this experiment)

- Page-1 :roll No, Name at the top, discussion on observations of the 2 cases as mentioned in the earlier slide including point(4)
- Page-2 –page-3- papers with plots (roll No, Name at the top)
- Page 4- for the problem in point 5
- Page 5- for the result sheet on point 6 (Simulink)