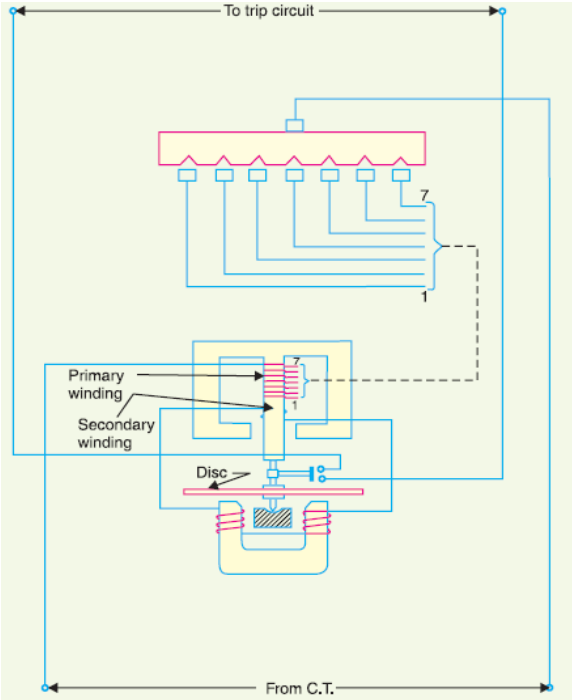
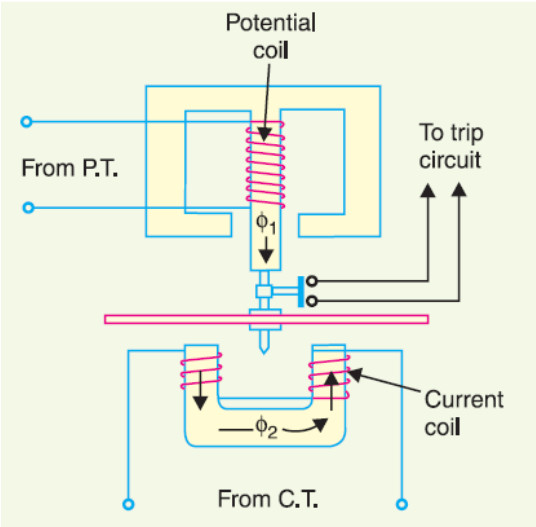

Faculty of Engineering
FE
EEE4227: POWER SYSTEM PROTECTION
TERM: FINAL-TERM

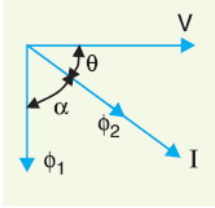

Lecture 08
Directional protection



Induction type non-directional over current relay

Induction type directional over power relay





- Produced driving torque-

$$T \propto \phi_1 \phi_2 \sin\alpha$$

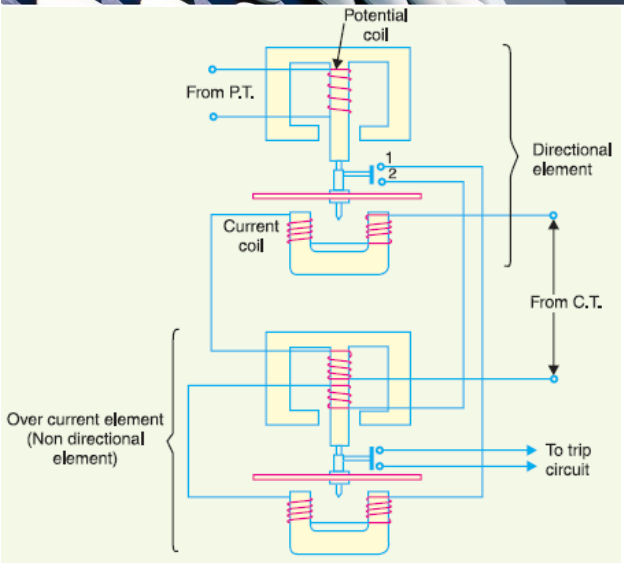
Since $\phi_1 \propto V$, $\phi_2 \propto I$ and $\alpha = 90 - \theta$

$$T \propto V I \sin(90 - \theta)$$

$$\propto V I \cos\theta$$

$$\propto \text{power in the circuit}$$

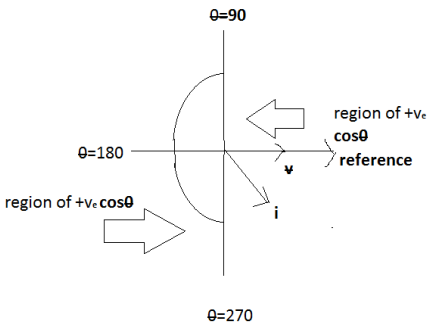
Induction type directional over-current relay



- Directional element
  - essentially a power relay which operates when power flows in a specific direction.
- Non-directional element
  - Over-current element similar in all respects to a non-directional over-current relay

Basics

- Active power flowing through a part of electronic circuit is- $p = vi\cos\theta$ where θ is the angle between V and I.



- Forθ<±90°$cos\theta$,hence $cos\theta$ is positive ,hence the real power P is positive.
- Forθ=±90°$cos\theta$,$\theta = 270°$,the real power is zero.
- For $\theta >$±90°$cos\theta$, the power is negative.

Polarizing quantity

- The direction of power flow can be sensed by sensing the magnitude and sign of the $VIcos\theta$.
- The directional unit is a four pole induction cup unit .
- Two opposite poles are fed with current.
- The voltage is taken as the polarizing quantity.

The polarizing quantity is one of which produce one of two fluxes required for production of torque and this quantity is taken as the reference compared with the other quantity which is current here .

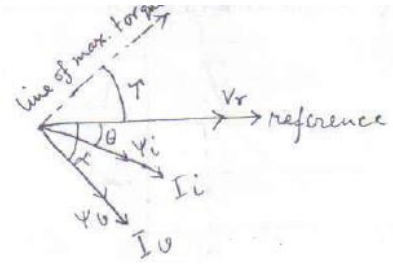
Equation of torque

- The torque developed by a directional unit is directly proportional to product of two fluxes and the sine of the angle between them-

$$F \propto \varphi_1 \varphi_2 \sin\phi$$

$$T = \psi_v \psi_i \sin(\alpha-\theta) - K$$

where, V_r is the voltage applied to the voltage coil
I_v is the current in the voltage coil
I_i is the current in the current coil
ψ_v is the flux due to I_v
ψ_i is the flux due to I_i
θ is the angle between V_r and I_i
K is the restraining force including spring and friction.



Equation of torque

- For a particular installation, sin(α-Θ) is constant k1. So, $T = K_1 V_r I_i - K$
- Under threshold condition, $T = 0 = K_1 VI - K$

$$VI = K/K_1 = \text{constant}$$

- The equation can be represented by a rectangular hyperbola

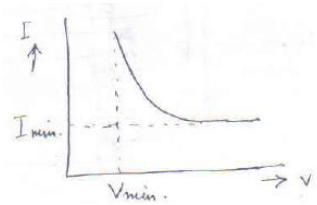


Fig 01- Constant product characteristics of a directional relay

Dead zone

- For satisfactory operation of the relay, the product of V and I should give a minimum torque which exceeds the friction and spring torque .From the characteristics it is clear that it is not enough to have the product greater than K, but there is minimum value of voltage and minimum value of current required for the torque to be developed . For a close up fault, the voltage at the relay point may collapse, so under that condition relay might not work.
- The maximum distance up to which the voltage is less than the minimum voltage is known as the *dead zone* of the directional relay.

Methods of connection

- For satisfactory result the directional elements in each relay must respond quickly and decisively in a forward direction when it operation of the over current element is required and in reverse direction, to restrain .when it is not.
- To achieve this for all types of fault the relay cannot be connected to operate on true wattmeter type since the torque would not be sufficient when the voltage is small as occur, for example with close up faults.
- To overcome this, and thus to ensure that sufficiently torque is always available; each relay is supplied with current from its respective phase and voltage from two phase.
- One of the two methods of connection is normally used-
  - 30 °connection
  - 90 ° connection

Summary of connection

30° connection			90° connection		
relay	I_r	V_r	relay	I_r	V_r
I	I_A	V_{AC}	I	I_A	V_{BC}
II	I_B	V_{BA}	II	I_B	V_{CA}
III	I_C	V_{CB}	III	I_C	V_{AB}

30 °connection

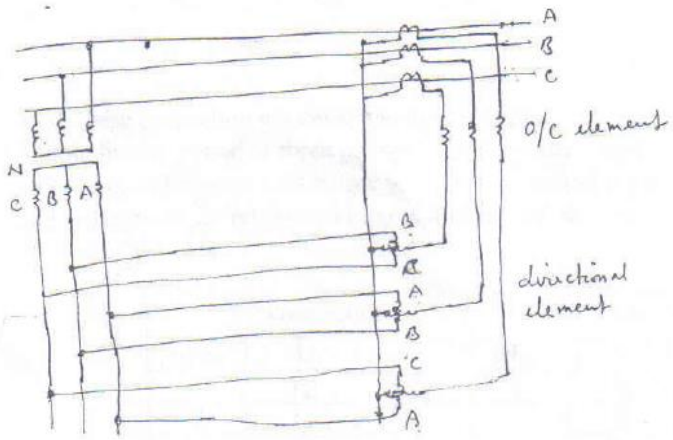


Fig 02: configuration of 30 ° connection with no internal compensation

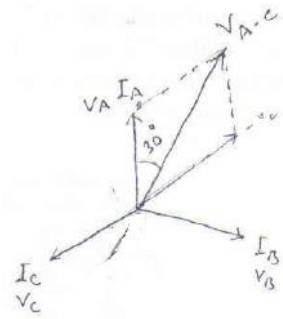


Fig 03: vector diagram of 30 ° connection

90 ° connection

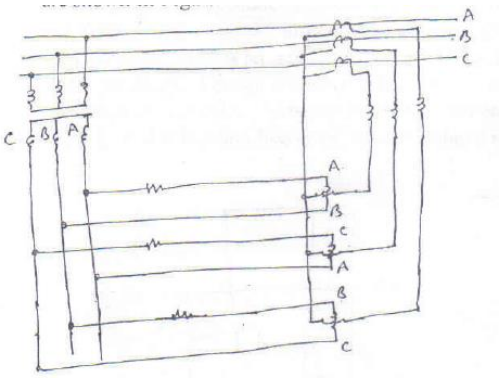


Fig 04: 90° connection with internal compensation ,R is applied for applied for compensation to provide 45° lead of the flux from voltage coil

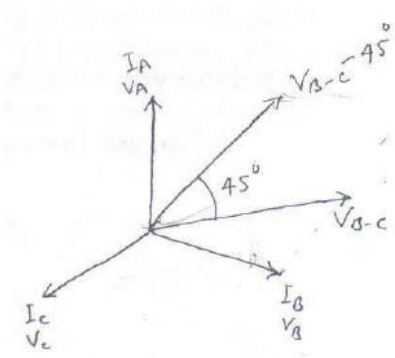
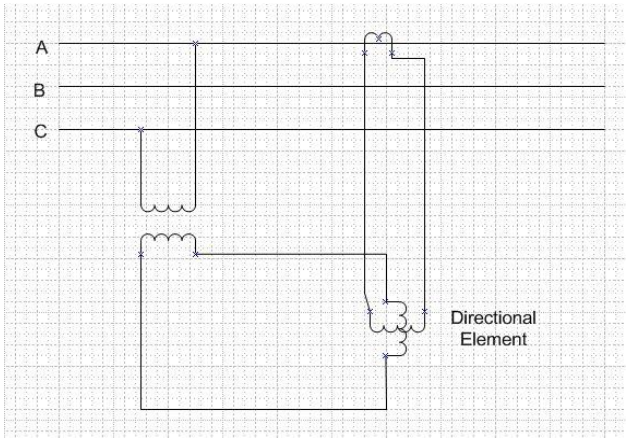


Fig 05: vector diagram of 90 ° connection

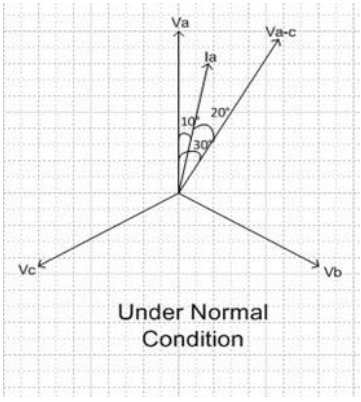
Mathematical problem

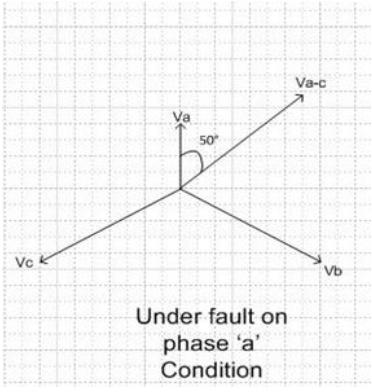
Problem 01- A circuit with an impedance angle of 10° is to be protected by directional O/C relays. Use 30° connection for the directional element as shown in the following figure. The relay potential coil has an impedance of 1000∠60° Ω. What modification should be made and also find the quantitative value if it is desired that the relay will develop maximum torque under a close up fault condition on phase 'a'. The angle between V_a and V_{ac} at relay location becomes 50° under above mentioned fault condition.

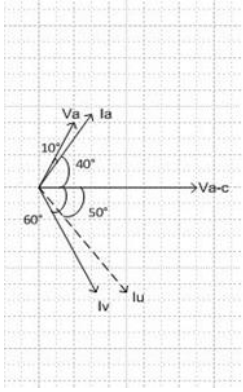


Mathematical problem

Solution:







Mathematical problem

Impedance of PT coil- 1000∠60° = (500 + j 866)

for angle to be 50°,

$\tan^{-1}(X/R) = 50$

or, tan 50 = X/R,

or, X = 596, but we have inductive reactance of 866 Ω

therefore, capacitive reactance required = 866 - 596 = 270 Ω

$X_c = 1/(2\pi fC)$,

or, C = 1/(314*270) = 11.8 μf

Ring main protection by directional relay

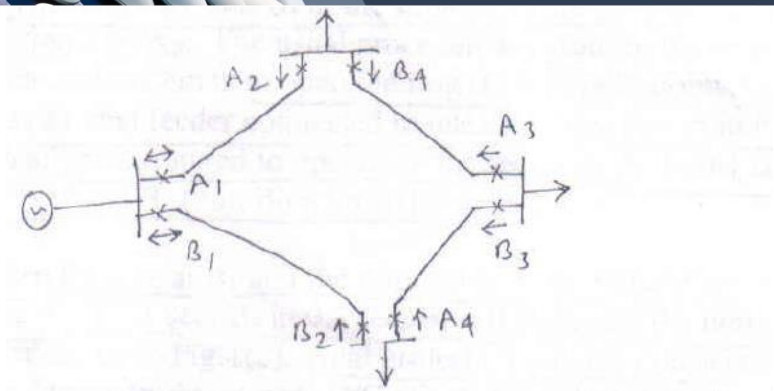


Fig. 1 (a) : Ring main to be protected

Ring main protection by directional relay

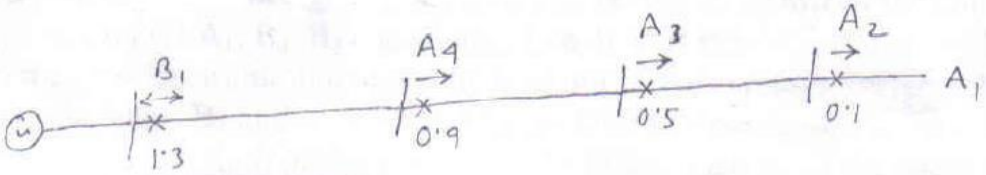


Fig. 1 (b)

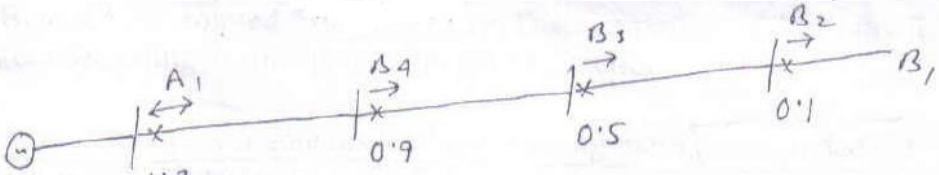
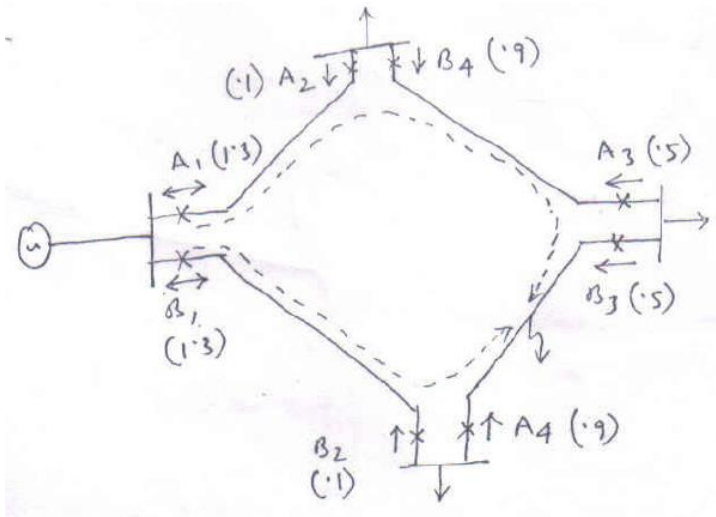


Fig. 1 (c)

Ring main protection by directional relay



- Reference-
- Topics 21.1-21.3/Chapter 21/ Principles of power systems/ V.K.Mehta & Rohit Mehta.

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