UNIT – I

PROTECTIVE RELAYS

SYLLABUS (UNIT – I)

- trip circuit & circuit Breaker, Current transformer & protection, instantaneous over current relay, I.D.M.T. Relay, Differential relay, Directional relay, Generalized torque expression, impedance relay, reactance relay, mho relay.

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TRIP CIRCUIT & CIRCUIT BREAKER

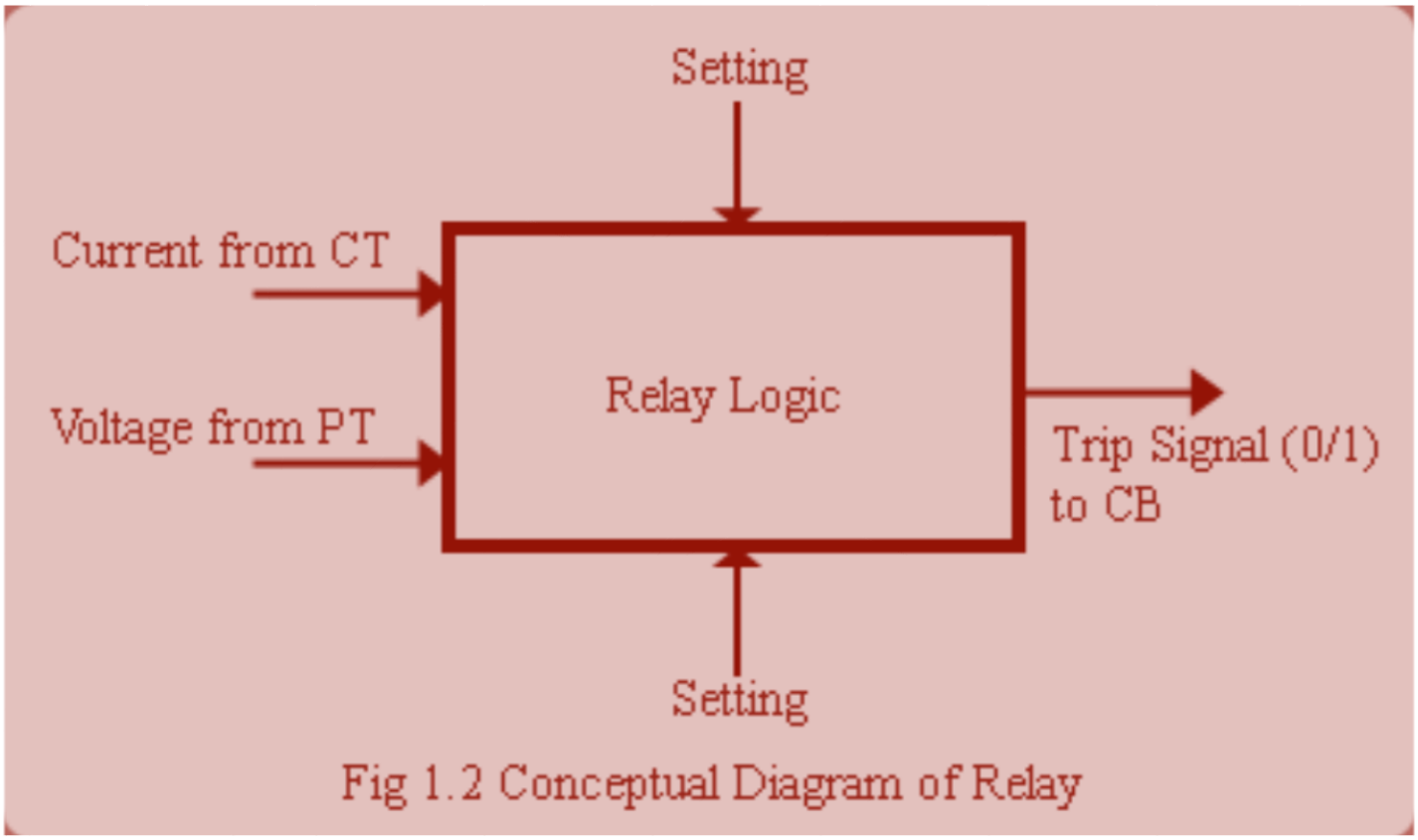


Fig 1.2 Conceptual Diagram of Relay

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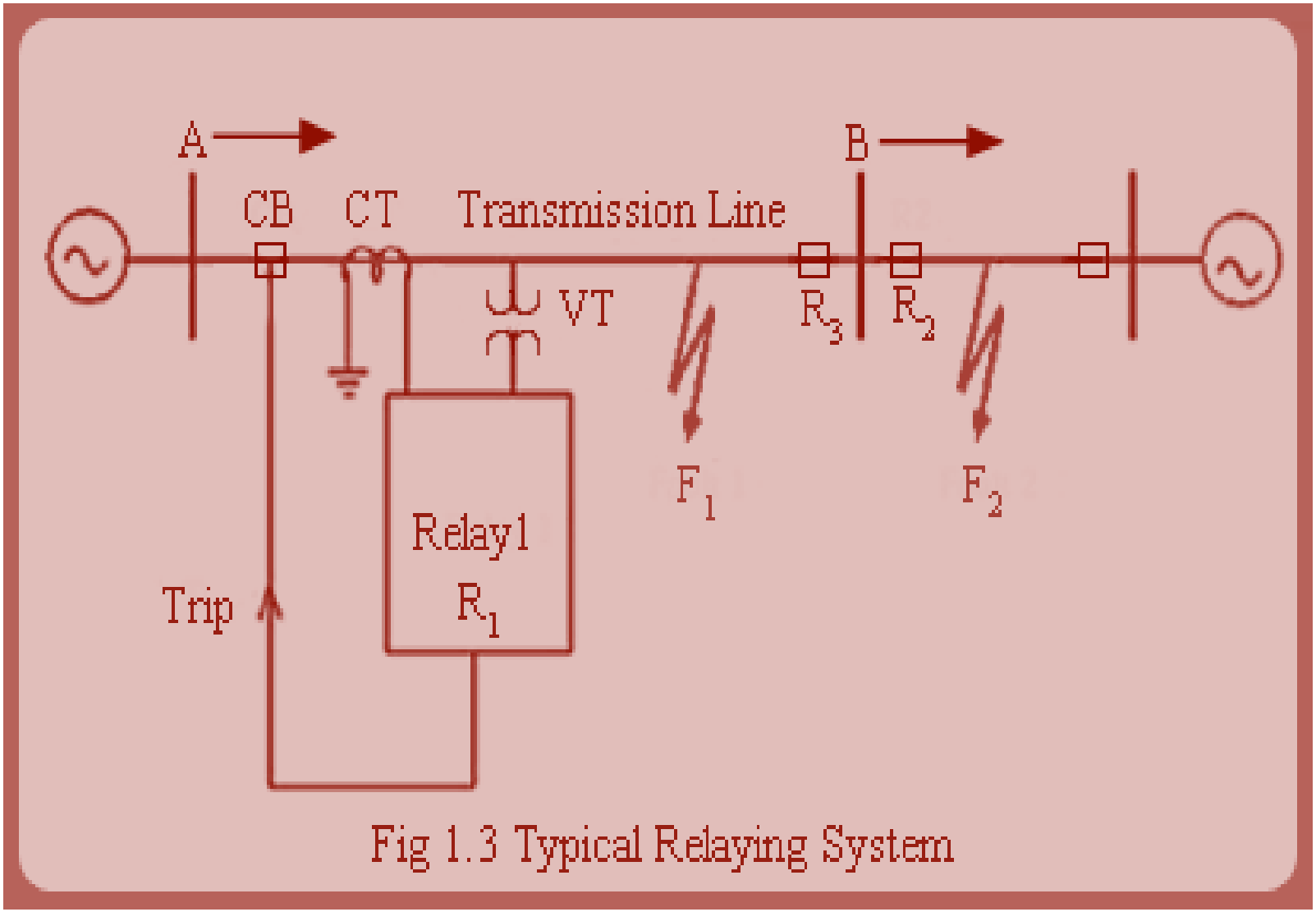


Fig 1.3 Typical Relaying System

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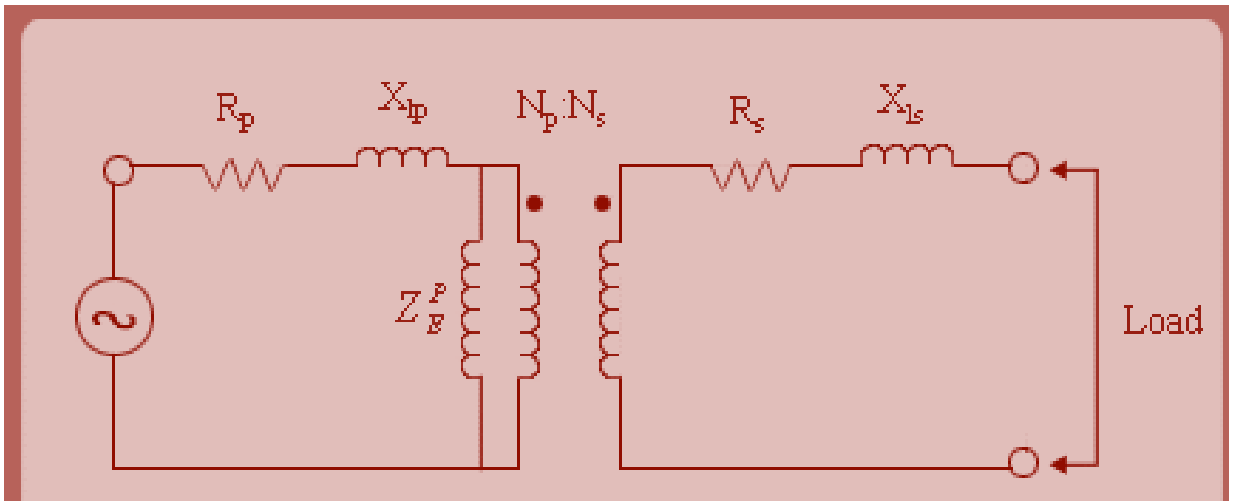
Current transformer (CT)

- Practically all electrical measurements and relaying decisions are derived from current and voltage signals. Since relaying hardware works with smaller range of current (in amperes and not kA) and voltage (volts and not kV), real life signals (feeder or transmission line currents) and bus voltages have to be scaled to lower levels and then fed to the relays. This job is done by current and voltage transformers (CTs and VTs). CTs and VTs also electrically isolate the relaying system from the actual power apparatus. The electrical isolation from the primary voltage also provides safety of both human personnel and the equipment. Thus

- CT and VTs are the sensors for the relay.

Equivalent Circuit of CT

- To begin with, equivalent circuit of a CT is not much different from that of a regular transformer However, a fundamental difference is that while regular power transformers are excited by a voltage source, a current transformer has current source excitation. Primary winding of the CT is connected in series with the transmission line. The load on the secondary side is the relaying burden and the lead wire resistance.



- The secondary voltage developed by the CT has to be monitored because as per the transformer emf equation, the flux level in the core depends upon it. The transformer emf equation is given by,

$$E_2 = 4.44 f N_2 \phi_m$$

- The CTs can be classified into following types:
  - Measurement CTs
  - Protection CTs

- Protection CTs are further classified into two group according to ANSI/IEEE
  - Class T CT
  - Class C CT

- Ratio Error :-

CT performance is usually gauged from the ratio error. The ratio error is the percentage deviation in the current magnitude in the secondary from the desired value. In other words, if the current measured in the secondary is I_s, true or actual value is I_p/N, where N is nominal ratio. ratio error is given by

$$\frac{\left|\frac{I_p}{N}\right| - |I_s|}{|I_s|} \times 100$$

Over Current Relay

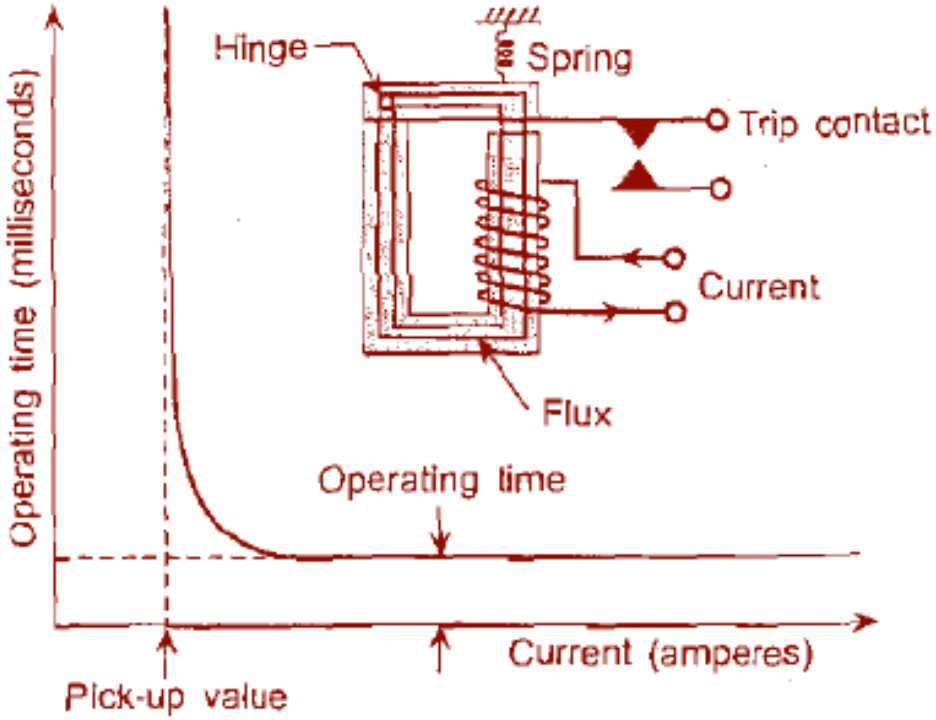
- An over-current (OC) relay has a single input in the form of ac current. The output of the relay is a normally-open contact, which changes over to closed state when the relay trips. The relay has two settings. These are the time setting and the plug setting. The time setting decides the operating time of the relay while the plug setting decides the current required for the relay to pick up.

Instantaneous OC Relay

- Instantaneous actually means no intentional time delay. Howsoever fast we want the relay to operate; it needs a certain minimum amount of time. The operating time of an instantaneous relay is of the order of a few milliseconds. Such a relay has only the pick-up setting and does not have any time setting.

- The construction and the characteristics of an instantaneous attracted armature type relay is shown in Figure wherein it can be seen that as the armature of the relay gets attracted towards the coil, the air-gap becomes smaller, and hence the reluctance becomes smaller. This results in increased flux which causes the force on the armature to build up (force being proportional to the square of the flux density)

- This is a positive feedback action which results in the armature moving quickly in an instantaneous snap action. The operating torque on the armature is proportional to the square of the current.



INVERSE DEFINITE MINIMUM TIME (IDMT) OVER-CURRENT RELAY

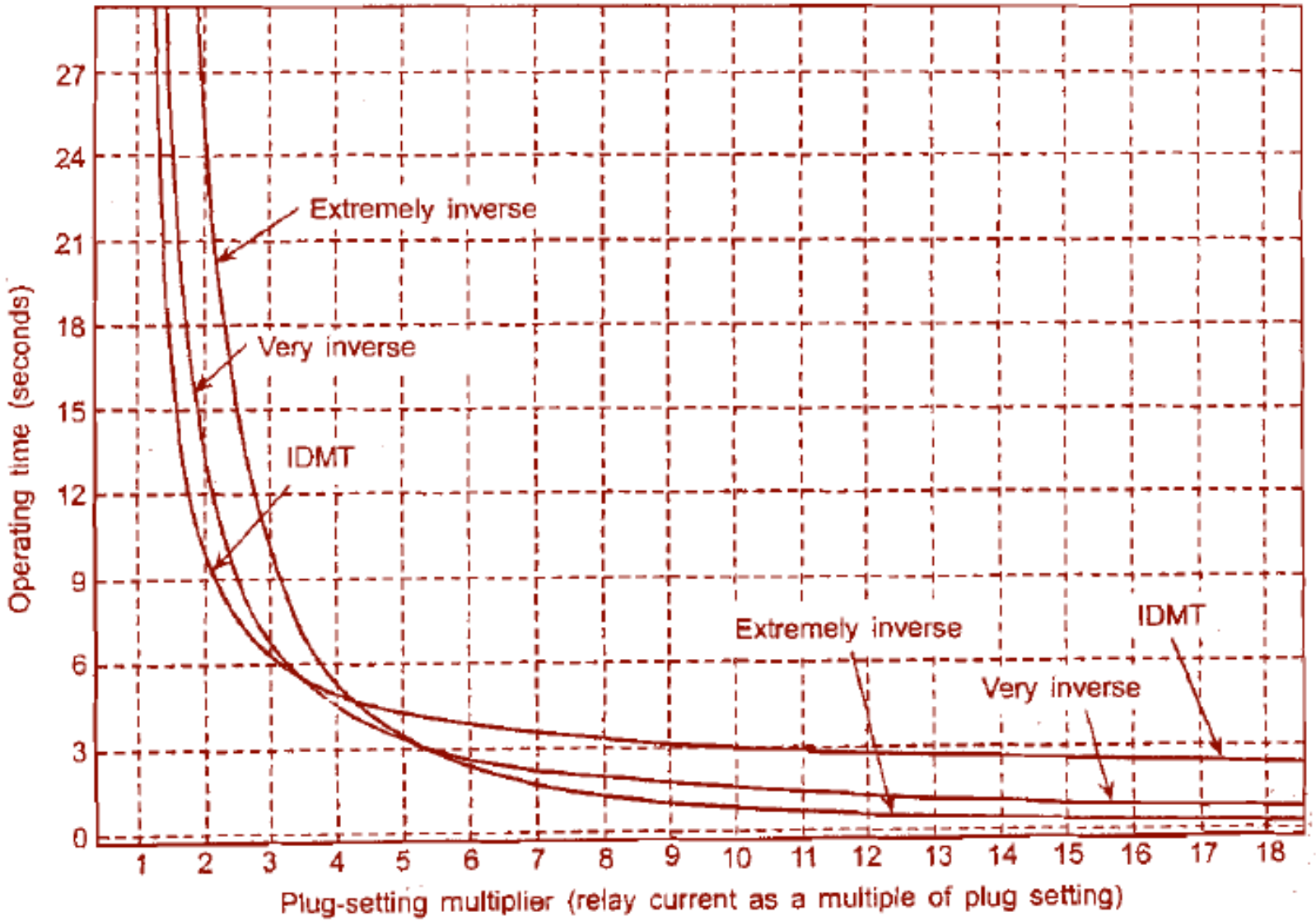
- This is possibly the most widely used characteristic. The characteristic is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high. The reason for the operating time becoming definite minimum, at high values of current, is that in the electromechanical relays the flux saturates at high values of current and the relay operating torque, which is proportional to the square of the flux, does not increase substantially after the saturation sets in.

- The mathematical relation between the current and the operating time of IDMT characteristic - can be written as

$$t_{op} = \frac{0.14\,(\mathrm{TMS})}{(\mathrm{PSM})^{0.02} - 1}$$

- where PSM is the plug-setting multiplier and TMS is the time-multiplier setting of the relay. Thus, the operating time is directly proportional to the TMS and inversely proportional to the PSM. The characteristics of the IDMT relay are shown in Figure

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Operating time (seconds)
27
24
21
18
15
12
9
6
3
0
Extremely inverse
Very inverse
IDMT
Extremely inverse
IDMT
Very inverse
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Plug-setting multiplier (relay current as a multiple of plug setting)

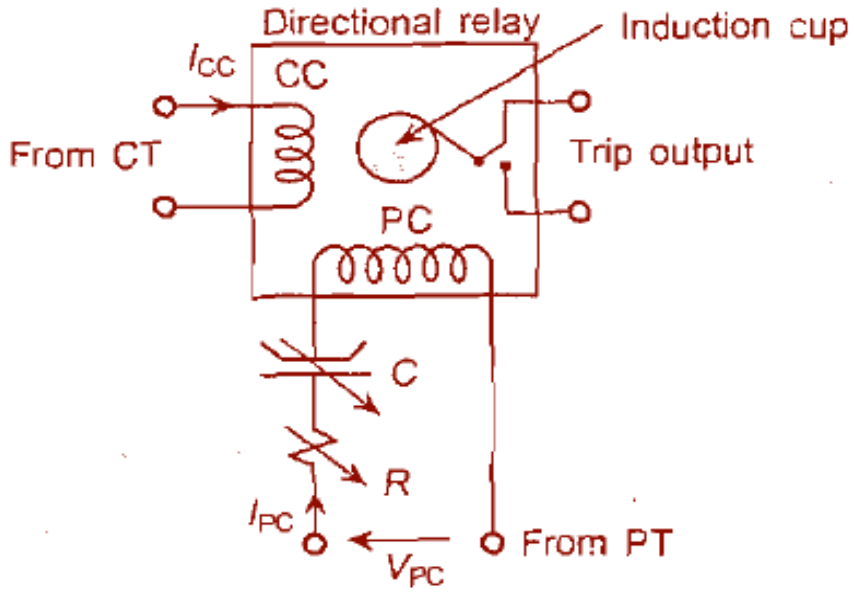
DIRECTIONAL OVER-CURRENT RELAY

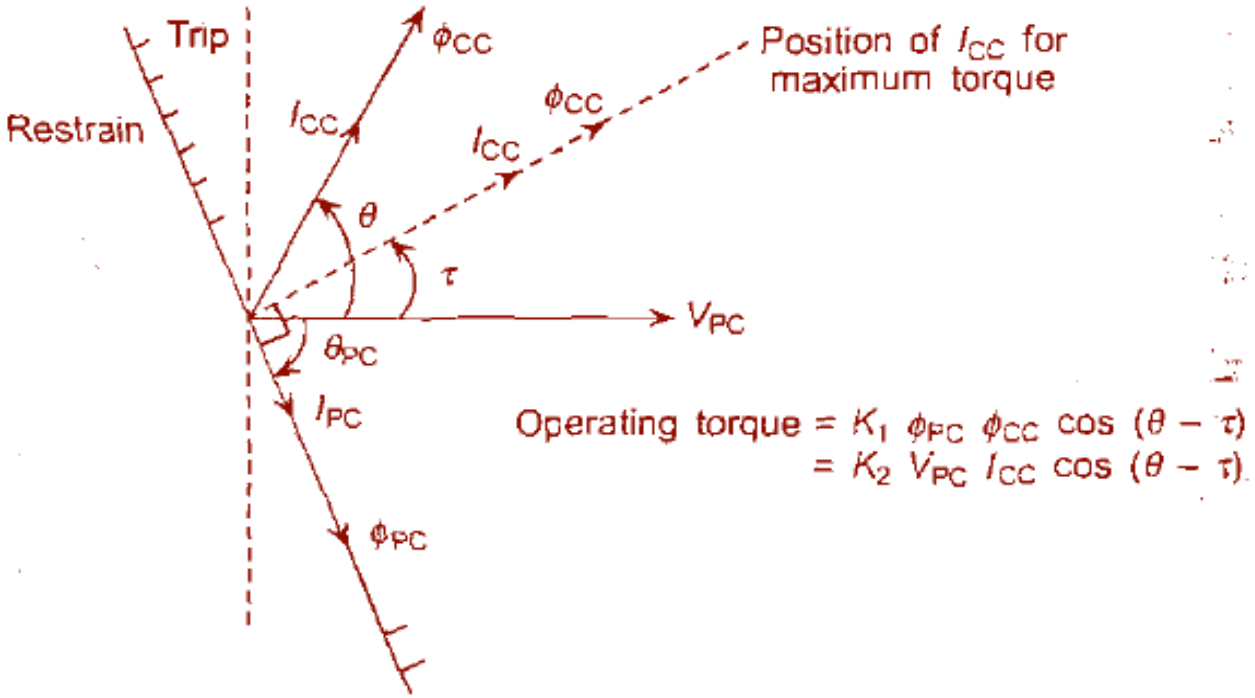
- A directional over current relay operates when the current exceeds a specified value in a specified direction.

CHARACTERISTICS OF DIRECTIONAL RELAY

- A directional relay can be compared to a contact making wattmeter. A wattmeter develops maximum positive torque when the current and voltage supplied to the current coil and the pressure coil are in phase. If we define the maximum torque angle (MTA) as the angle between the voltage and current at which the relay develops maximum torque, then a wattmeter can be called a directional relay with MTA of zero degree. The phasor ***diagram for a directional relay is depicted in Figure***

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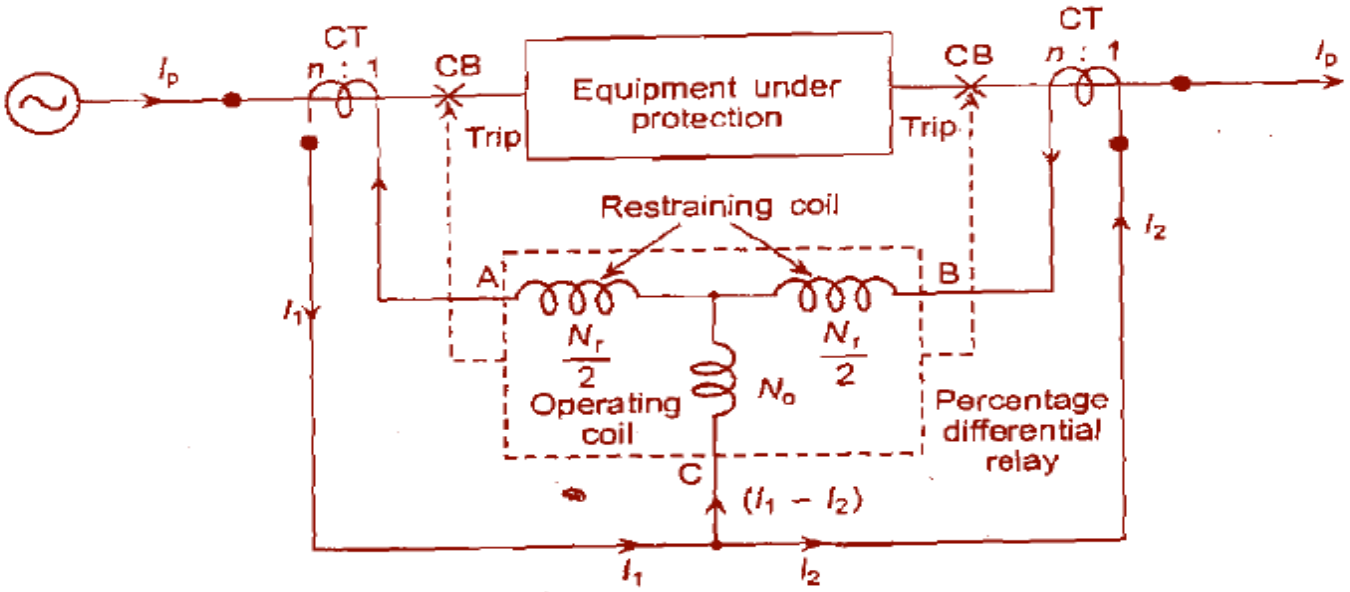


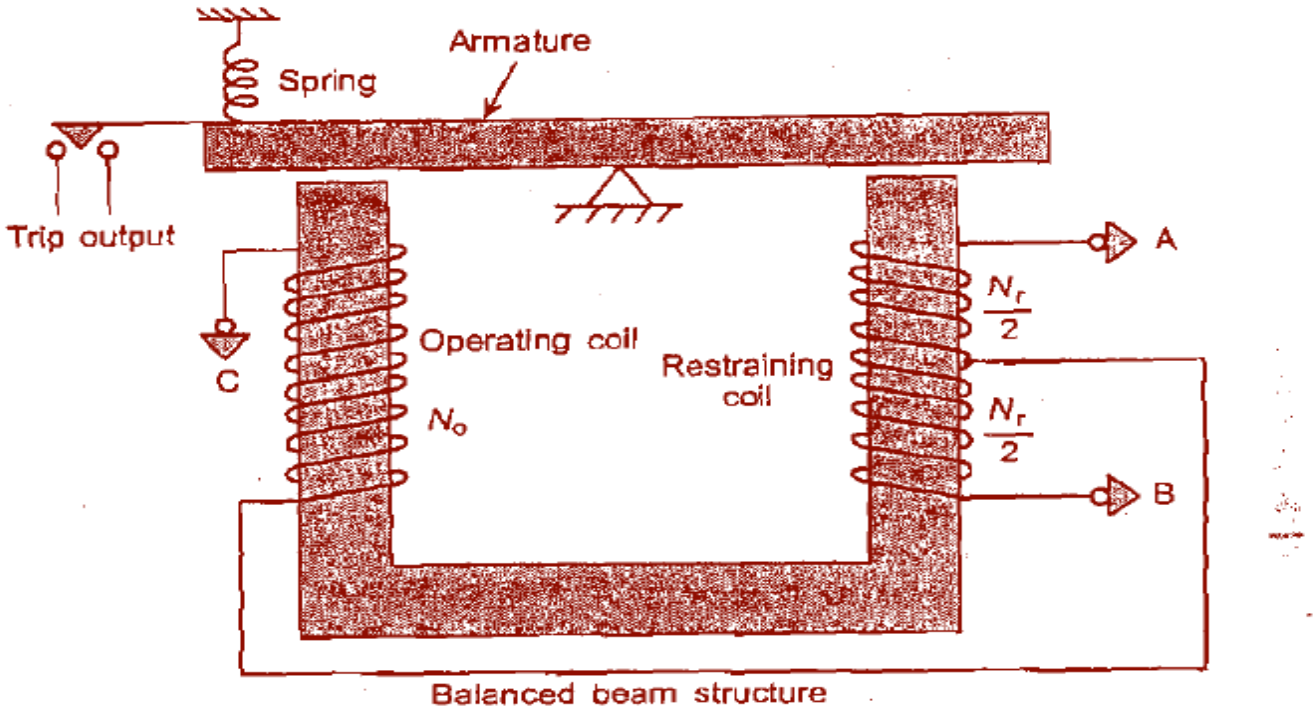
Operating torque = $K_1 \phi_{PC} \phi_{CC} \cos(\theta - \tau)$
= $K_2 V_{PC} I_{CC} \cos(\theta - \tau)$

Differential Relay

- The simple differential relay can be made more stable, if somehow, a restraining torque proportional to the 'through fault' current could be developed-the operating torque still being proportional to the spill current.

- This relay has a restraining coil which is tapped at the centre, thus forming two sections with equal number of turns, ***N/2. The restraining coil is connected in the*** circulating current path, thus receiving the 'through fault' current. The operating coil, having ***No number of turns, is connected in the spill path.***
  - Ampere-turns acting on the left-hand section of the restraining coil = (N/2)****I1***
  - Ampere-turns acting on the right-hand section of the restraining coil = (N/2)****I***
  - Total ampere-turns acting on the restraining coil = (N/2)* ***(I1 + I 2)***
- Noting that torque in an electromagnetic relay is proportional to the square of the flux,
  - Torque produced by the restraining coil = M(N *(I1 + I2)/2)^2
- where M is a constant of proportionality.
- Restraining torque produced by control spring = **Tspring**


CT
n : 1
CB
Equipment under protection
Trip
CB
CT
n : 1
I_p
I_p
Restraining coil
A
B
I_1
I_2
$\frac{N_r}{2}$
Operating coil
N_o
$\frac{N_r}{2}$
Percentage differential relay
C
$(I_1 - I_2)$
I_1
I_2

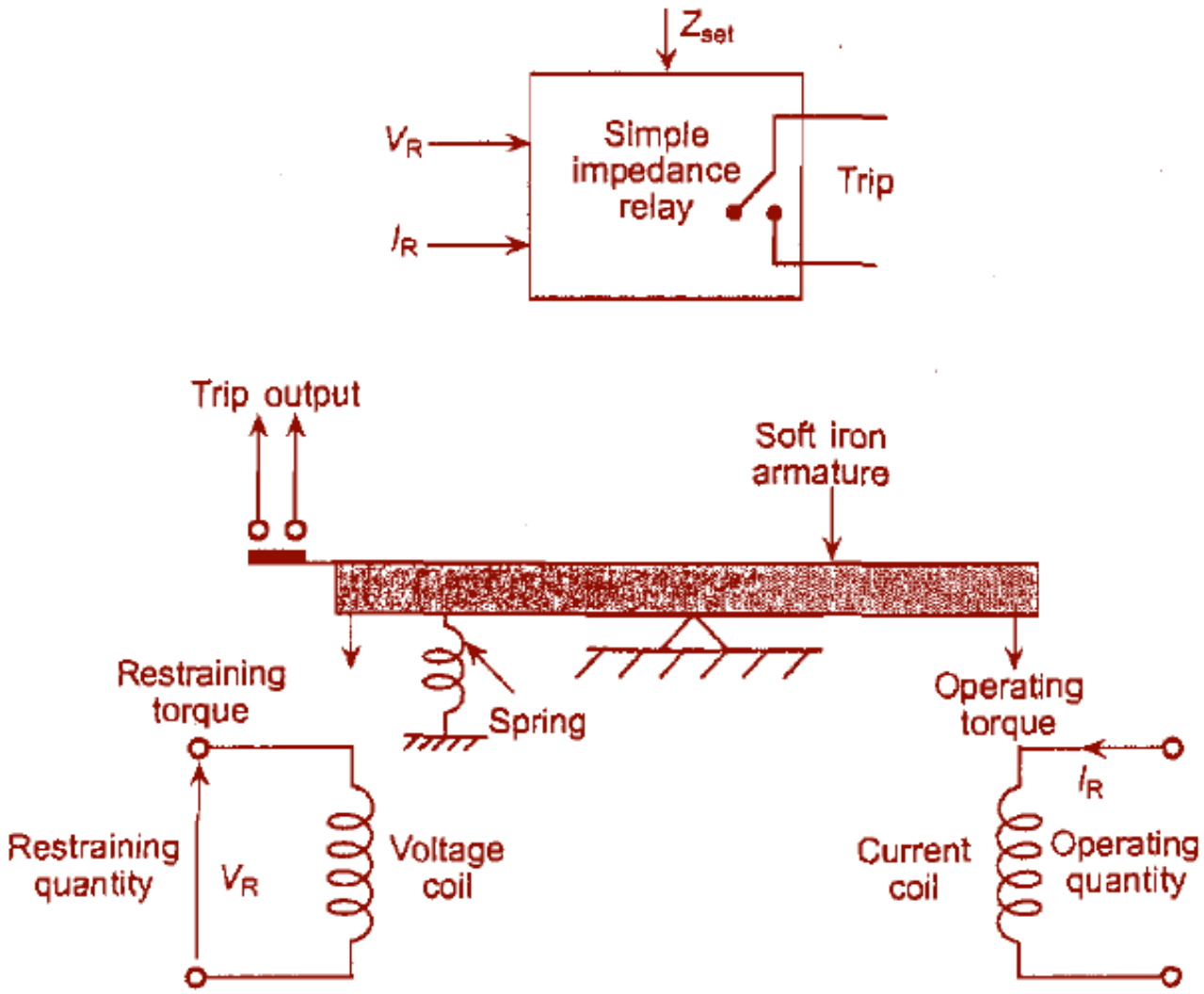

Armature
Spring
Trip output
A
C
Operating coil
N_o
Restraining coil
$\frac{N_r}{2}$
$\frac{N_r}{2}$
B
Balanced beam structure

IMPEDANCE RELAY

- It is possible to synthesize many types of relays using the electromechanical structures. We can write a generic torque equation for such a structure where there are torques produced within the relay structure by
  - current at relay location
  - voltage at relay location
  - interaction between the above volCage and current (directional unit).

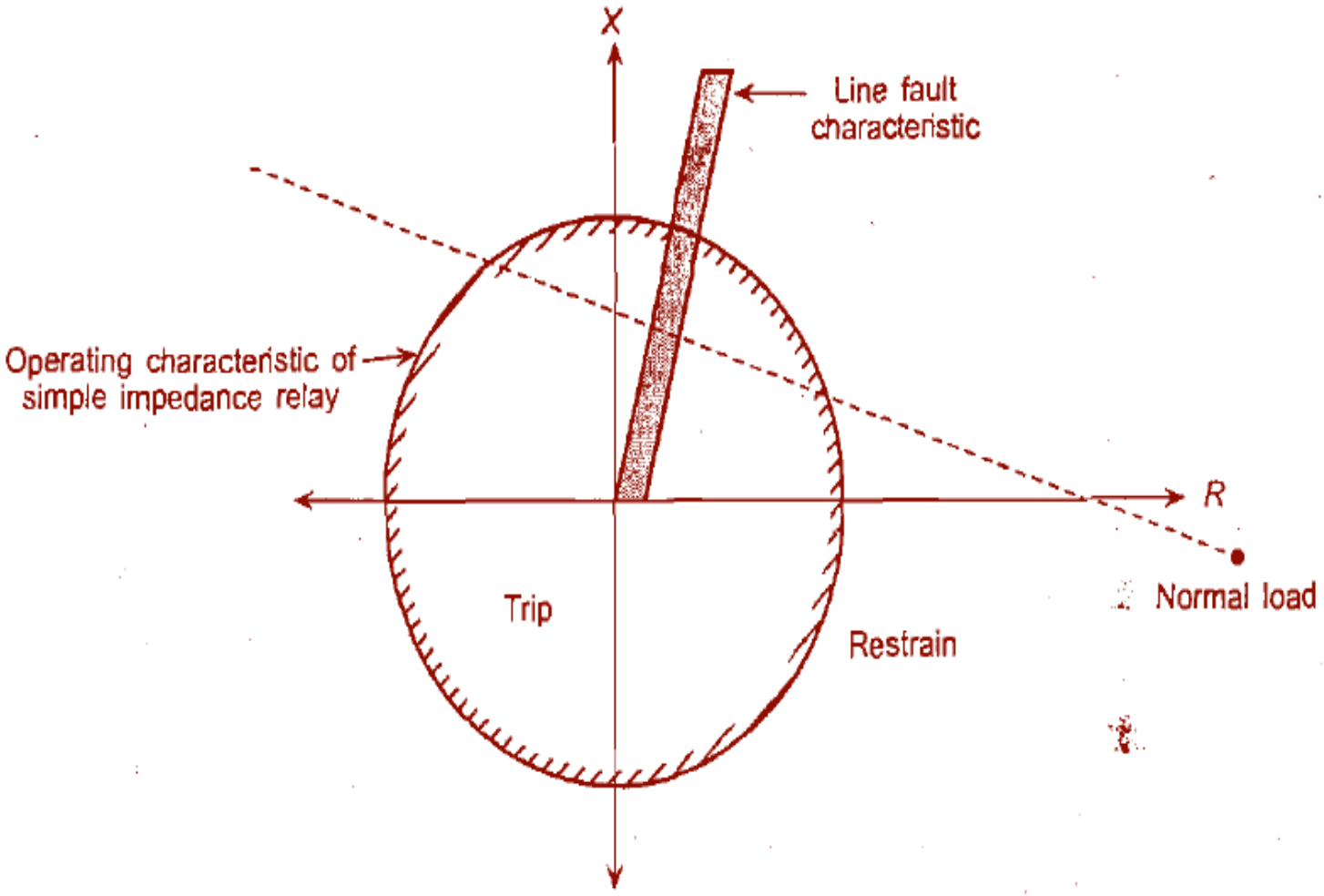
- Individual torques may be made to act in such a way **as to close the trip contact or** to oppose the closing of the trip contact. The torque which tends to close the trip contact, is called the ***operating torque, and the torque which tends to oppose the closing of the trip*** contact, is called the ***restraining torque.***

Balanced beam construction of simple impedance relay.



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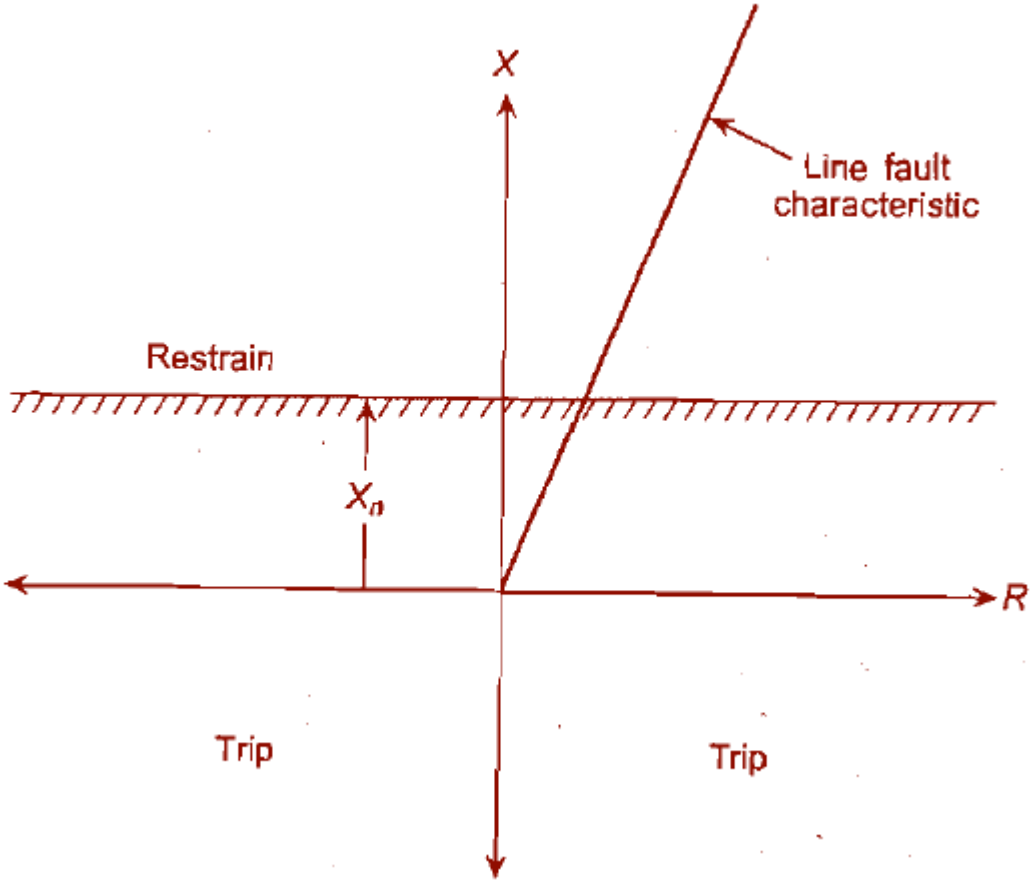
Performance of Simple Impedance Relay During Normal Load Flow



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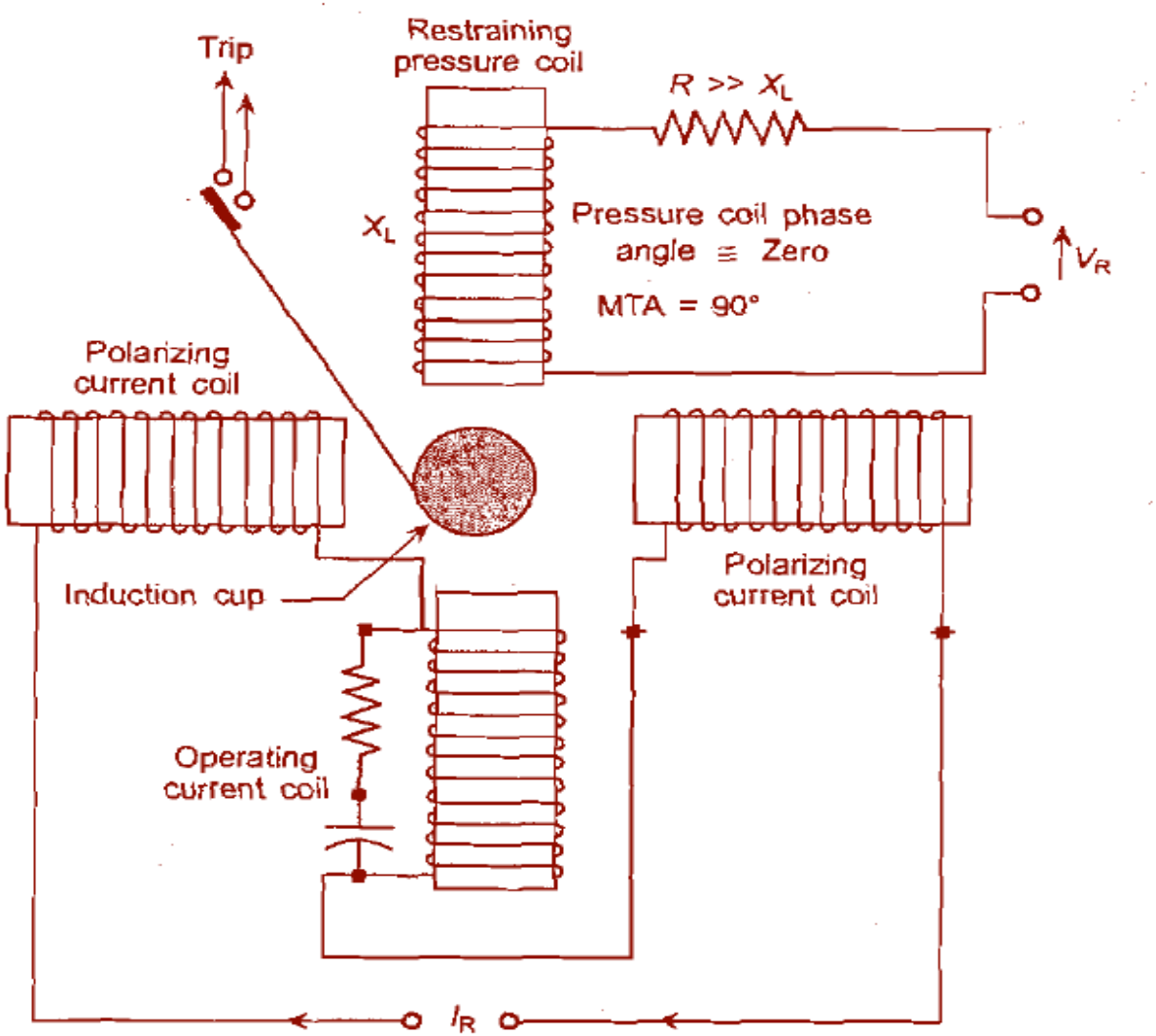
REACTANCE RELAY

Characteristics

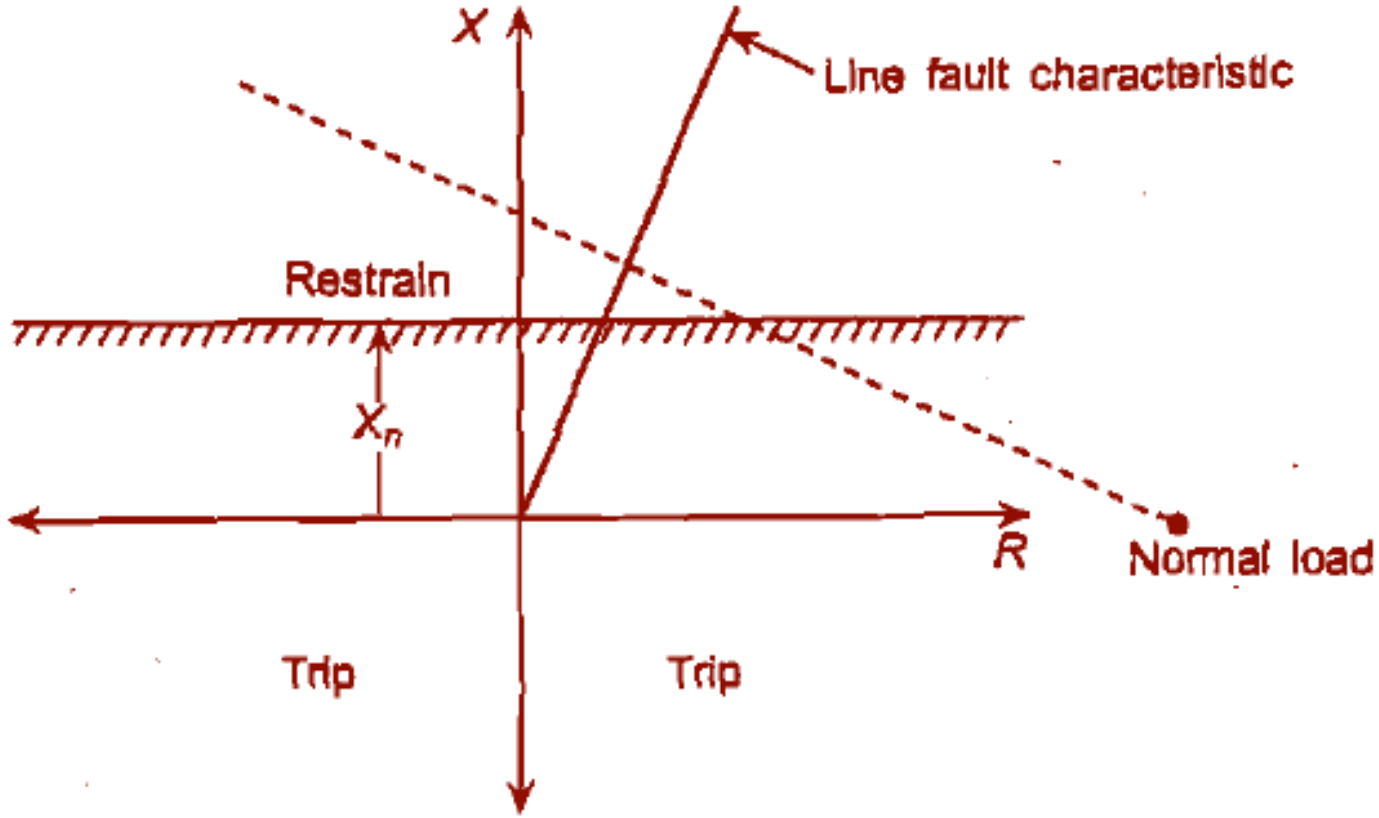


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Implementation of Reactance Relay Using the induction Cup Structure



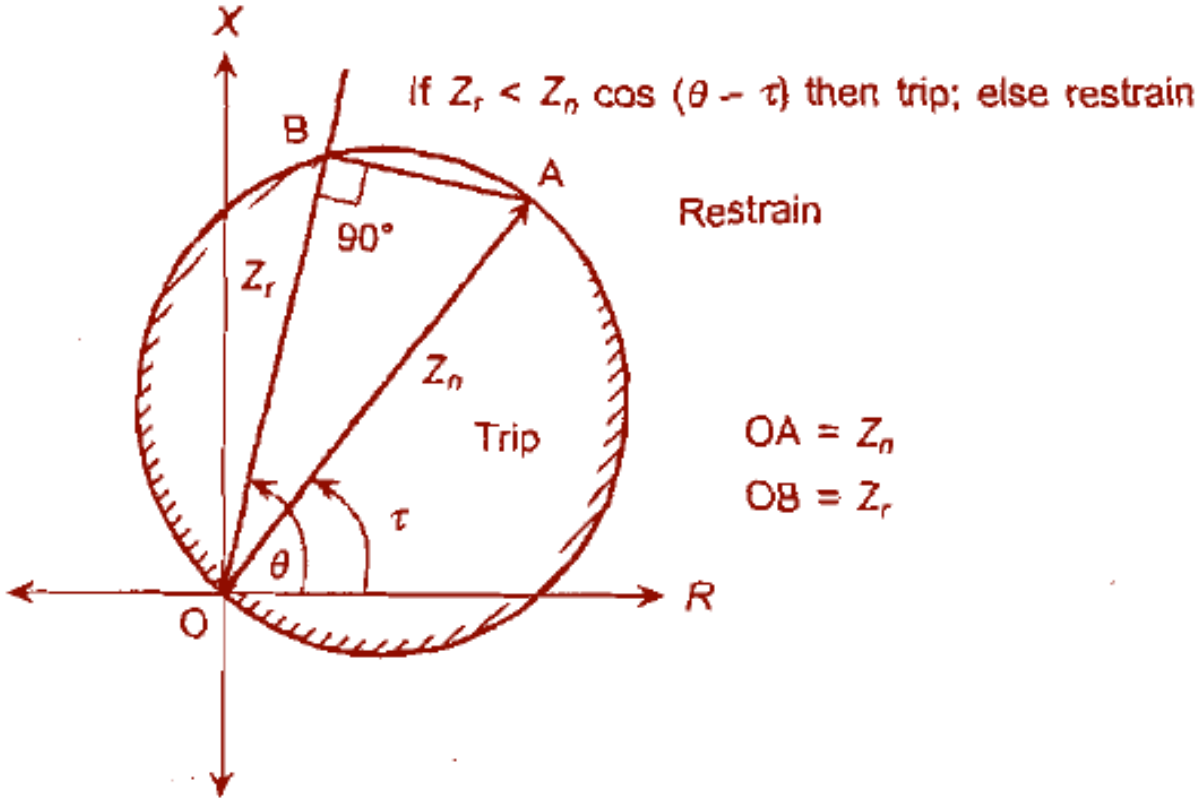
Performance of Reactance Relay During Normal Load Flow



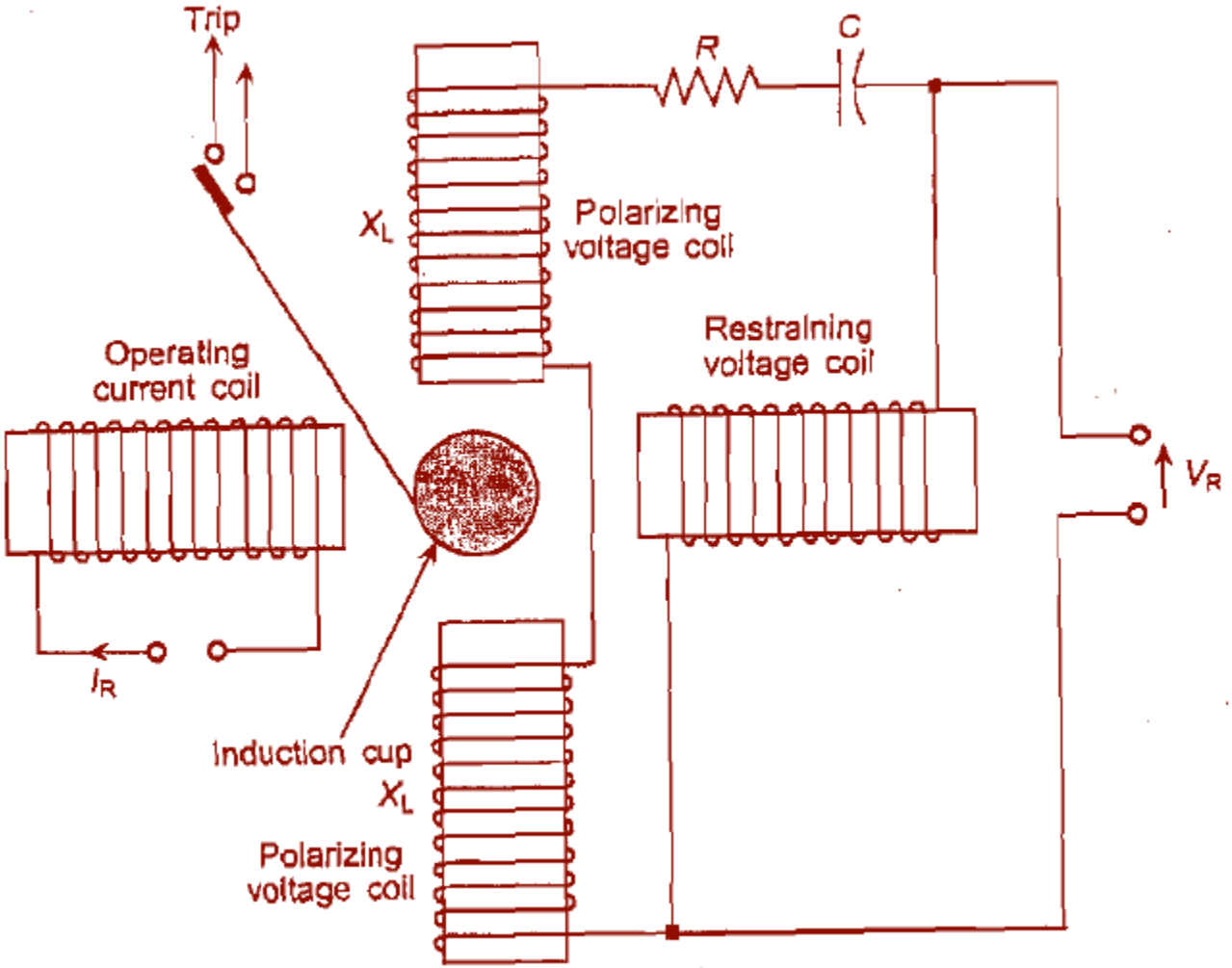
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MHO RELAY

Characteristic

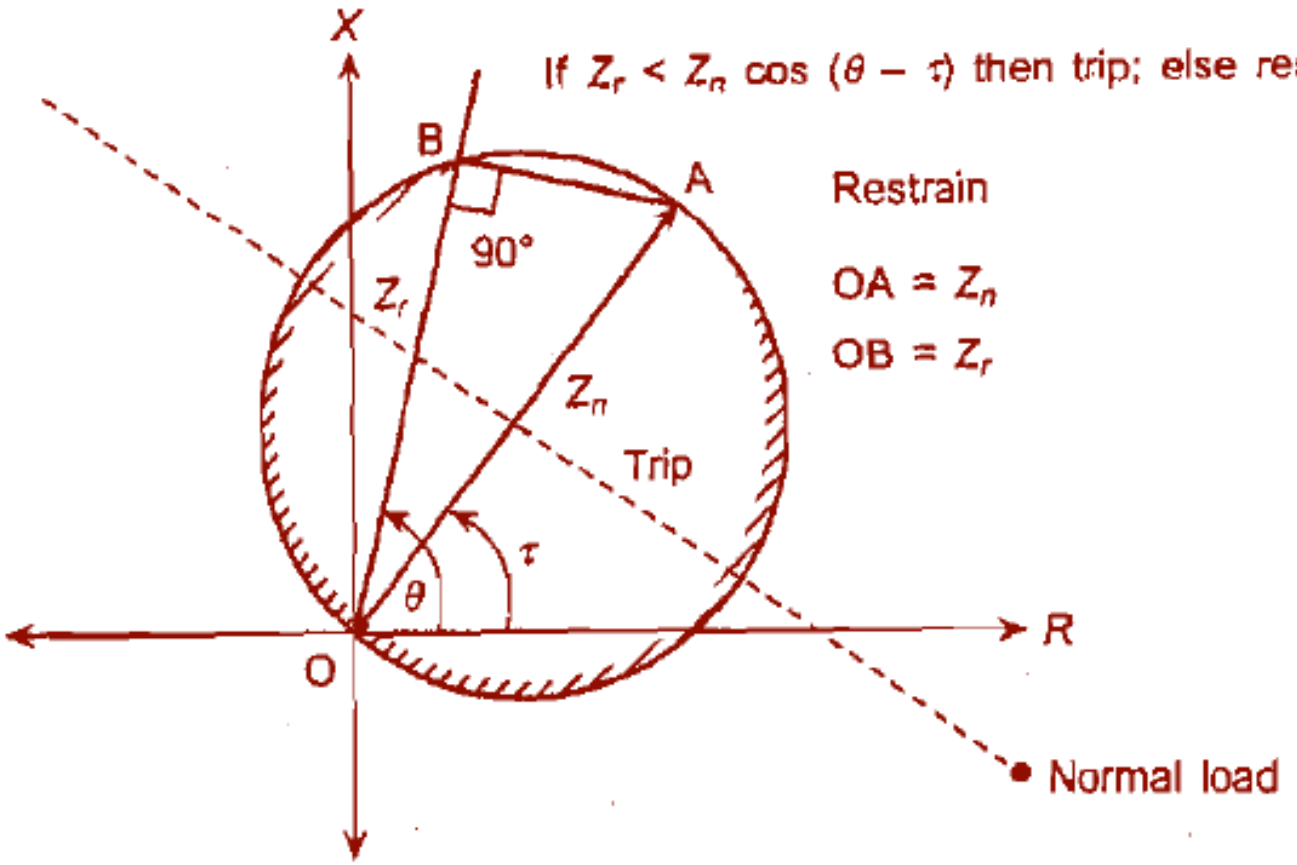


IMPLEMENTATION OF MHO RELAY USING INDUCTION CUP STRUCTURE



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Performance of Mho Relay During Normal Load Flow



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