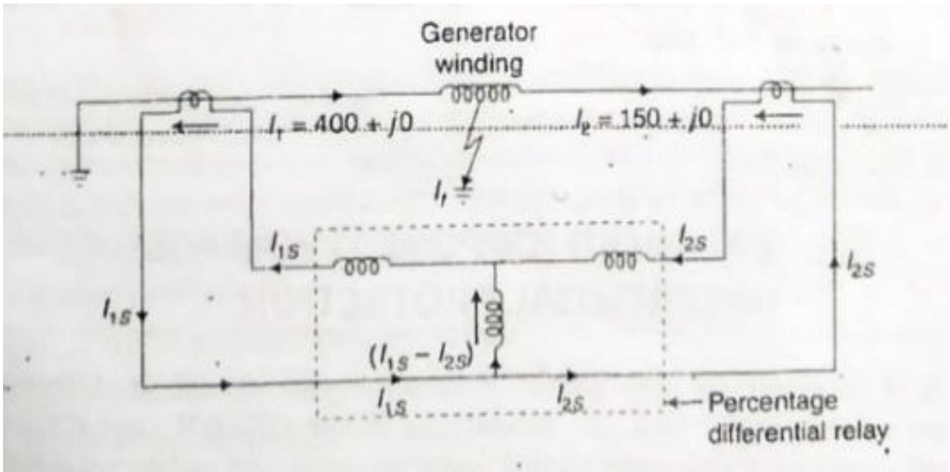
CMR INSTITUTE OF TECHNOLOGY	USN								
Internal Assesment Test - II									
Sub:	POWER SYSTEM PROTECTION							Code:	17EE72/18EE 72
Date:	17/12/2020	Duration:	90 mins	Max Marks:	50	Sem:	7th(A & B)	Branch:	EEE
Answer Any FIVE FULL Questions									

		Marks	OBE	
			CO	RBT
1	With a neat circuit diagram explain the construction and working of MHO Relay.	[10]	CO2	L2
2a	What are the important operating schemes which are used in wire pilot protection? With schematic diagram explain the circulating current scheme.	[5]	CO3	L2
2b	With a neat sketch explain frame leakage protection scheme.	[5]	CO4	L2
3a	Explain the working principle of Buchholz relay used for the protection of transformer.	[5]	CO4	L2
3b	With schematic diagram explain the protection of stator against overheating in an alternator.	[5]	CO4	L2
4a	A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding are shown if fig.1. Assuming CT ratios of 500/5 amperes, the relay operate to trip the circuit breakers? 	[5]	CO4	L4
4b	Explain the effect of power surge on the performance of distance relay	[5]	CO2	L2
5a	A generator is protected by restricted earth fault protection. The generator ratings are 13.2kV and 10MVA. The percentage of the winding protected against phase-ground fault is 85%. The relay setting is such that it trips for 20% out of balance. Calculate the resistance to be added in the neutral to ground connection.	[5]	CO4	L3

5b	Give notes on reach of Distance relays.	[5]	CO2	L1
6	Explain simple differential protection scheme with the help of relevant diagram and Plot its characteristics during internal and external fault conditions.	[10]	CO2	L2
7	With a neat circuit diagram explain the construction and working of Reactance Relay in details.	[10]	CO2	L2

Signature of CCI   Faculty In charge

1. With a neat circuit diagram explain the construction and working of MHO Relay. [CO2, L2] 10M

MHO (Admittance or Angle Admittance) Relay

A MHO relay measures a component of admittance $|Y| \angle \theta$. But its characteristic, when plotted on the impedance diagram (*R-X* diagram) is a circle, passing through the origin. It is inherently a directional relay as it detects the fault only in the forward direction. This is obvious from its circular characteristic passing through the origin, as shown in Fig. It is also called an admittance or angle admittance relay. It is called a mho relay because its characteristic is a straight line when plotted on an admittance diagram (G-B axes).

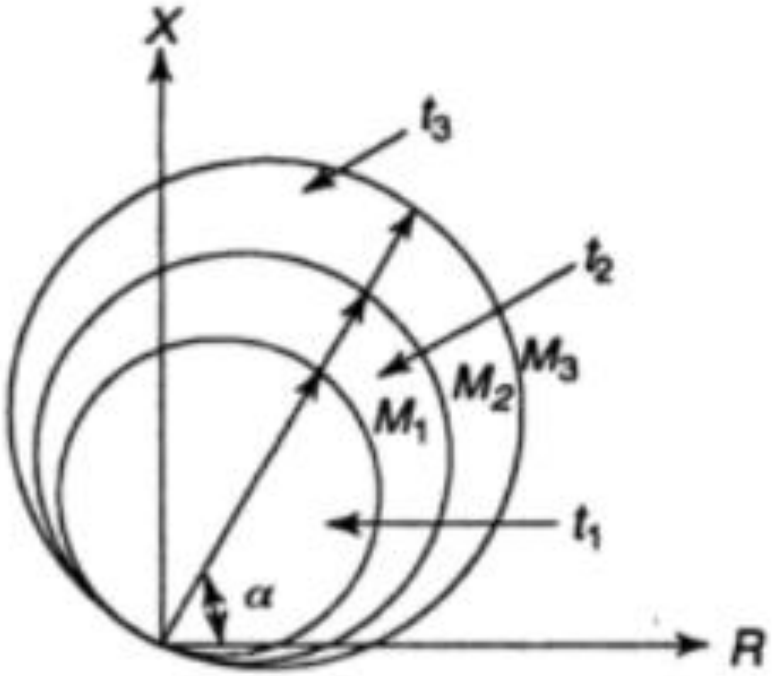


FIGURE Characteristics of MHO relay

Electromagnetic MHO Relay

An induction cup structure, as shown in Fig. is used to realise a MHO charac- teristic. The torque equation is given by

$$T = K_1 VI \cos(\phi - \alpha) - K_2 V^2 - K_3$$

The upper and lower poles are energised by a voltage V to produce a polarising flux. The series capacitor provides memory action which will be explained later on. The left pole is energised by a current which is the operating quantity. The flux produced by I interacts with the polarising flux to give an operating torque $K_1 VI \cos(\phi - \alpha)$. The angle α can be adjusted by varying resistance in the phase shifting circuit placed on the left pole (not shown in the figure). The right-hand side pole is energised by voltage. The flux produced by the right side pole interacts with the polarising flux to produce a restraining torque $K_2 V^2$.

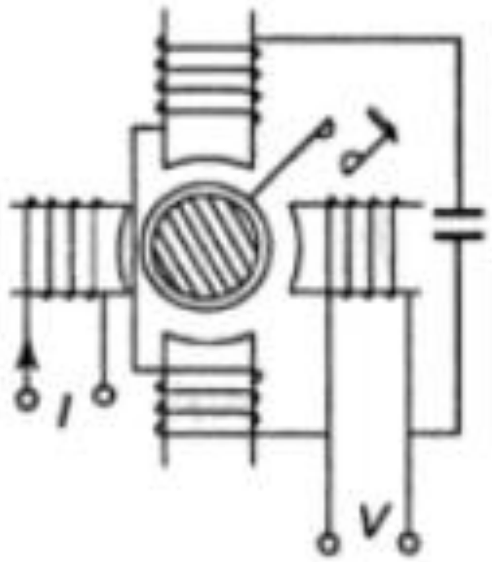


FIGURE Induction cup type MHO relay

The relay will operate when

$$K_1 VI \cos(\phi - \alpha) > K_2 V^2 \quad \text{or} \quad \frac{I}{V}\cos(\phi - \alpha) > \frac{K_2}{K_1}$$

$$\text{or} \quad Y \cos(\phi - \alpha) > \frac{K_2}{K_1} \quad \text{or} \quad \frac{1}{Y \cos(\phi - \alpha)} < K$$

$$\text{or} \quad \frac{Z}{\cos(\phi - \alpha)} < K \quad \text{or} \quad M < K$$

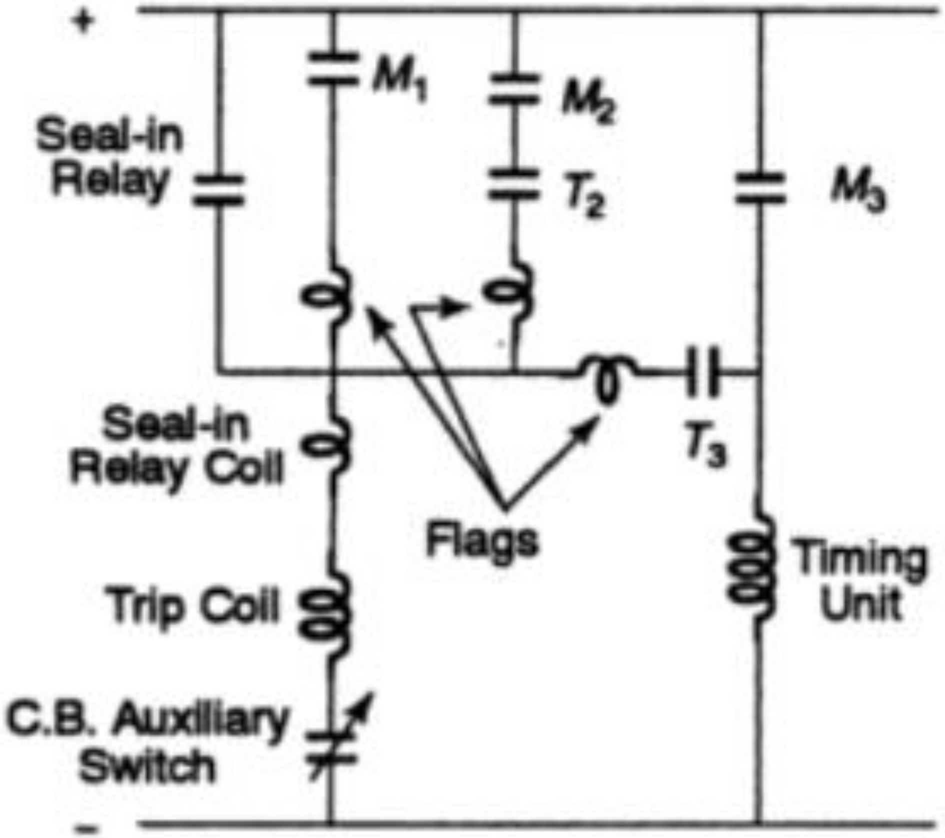


FIGURE Connections of MHO relays

Three units of MHO relays are used for the protection of a section of the line. The I unit is a high speed unit to protect 80%–90% of the line section. The II unit protects the rest of the line section, and its reach extends up to 50% of the adjacent line section. The III unit is meant for back-up protection of the adjacent line section. The II and III units operate after a preset delay, usually 0.2 s to 0.5 s and 0.4 s to 1 s respectively.

Figure shows the connection diagram for MHO units placed at one location.

Static MHO Relay Using an Amplitude Comparator

Figure shows a rectifier bridge type amplitude comparator to realise a MHO characteristic. The actuating quantities to be compared are I and $(V/Z_r - I)$. The relay will operate, when

$$I > \left| \frac{V}{Z_r} - I \right|$$

Multiplying both sides by Z_r, we get

$$|IZ_r| > |V - IZ_r|$$

Dividing both sides by I, we get

$$|Z_r| > \left| \frac{V}{I} - Z_r \right| \quad \text{or} \quad |Z_r| > |Z - Z_r|$$

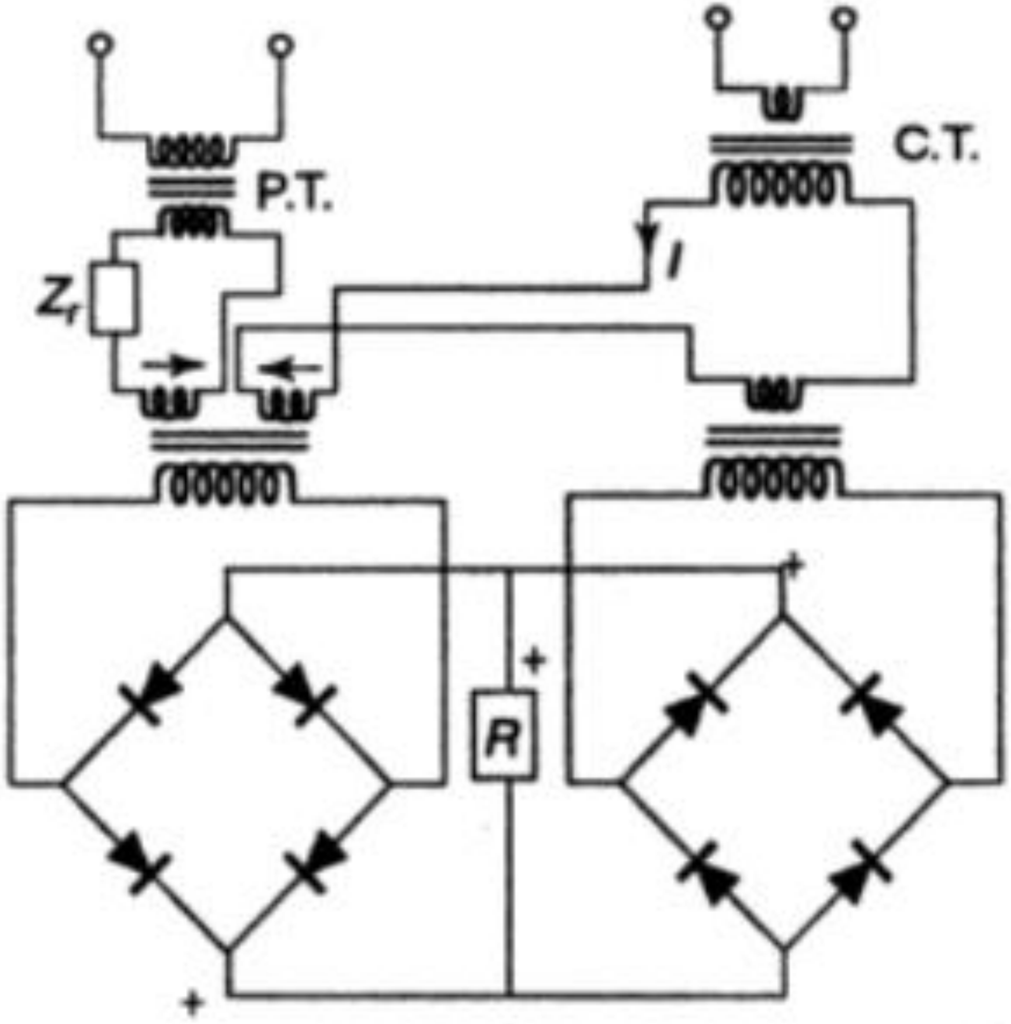


FIGURE Schematic diagram of a static MHO relay

When the above condition is satisfied, the characteristic obtained will be a MHO characteristic, as shown in Fig. 4.24. Z_r is the radius of the MHO circle, which is equal to the impedance of the voltage circuit. If a fault point Z lies within the circle, $|Z_r| > |Z - Z_r|$. If a fault point lies on the circumference of the circle, $|Z_r| = |Z - Z_r|$. If the fault point is outside the circle, $|Z_r| < |Z - Z_r|$. The above conditions are also true if the point P is anywhere on AB. When the fault point is very close to the relay location (close-up fault), the relay may fail to operate. To overcome this difficulty, a voltage called the polarising voltage, which is obtained from a pair of healthy phases is added to the actuating quantities. The operating input of the modified actuating quantities corresponds to $V_p/Z_p - I + V_r/Z_r$ and the restraining input corresponds to $V_p/Z_p + I - V_r/Z_r$, where Z_r is equal to the impedance of the relay restraining circuit and Z_p is equal to the impedance of the relay polarising circuit. V_p is the polarising voltage. A relay using polarising voltage is known as a *polarised MHO relay.*

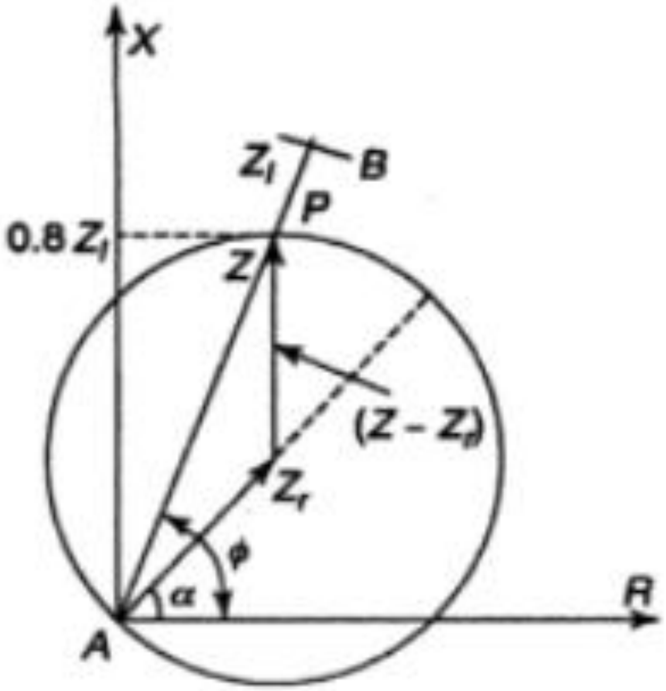


FIGURE MHO characteristic

Static MHO Relay Using a Phase Comparator

Figure (a) shows a vector diagram showing voltage, current and voltage drops. If we divide all vectors of this diagram by I, the resulting vector diagram will be as shown in Fig. (b). The phase angle between V and $(IZ_r - V)$ is θ. Now draw a circle with Z_r as diameter, as shown in Fig. (c). If the point P lies within the circle, θ is less than $\pm$ 90°. If P lies outside the circle, θ is greater than $\pm$ 90°. Therefore, to realise a MHO characteristic, the phase angle θ between $(IZ_r - V)$ and V is compared with $\pm$ 90°.

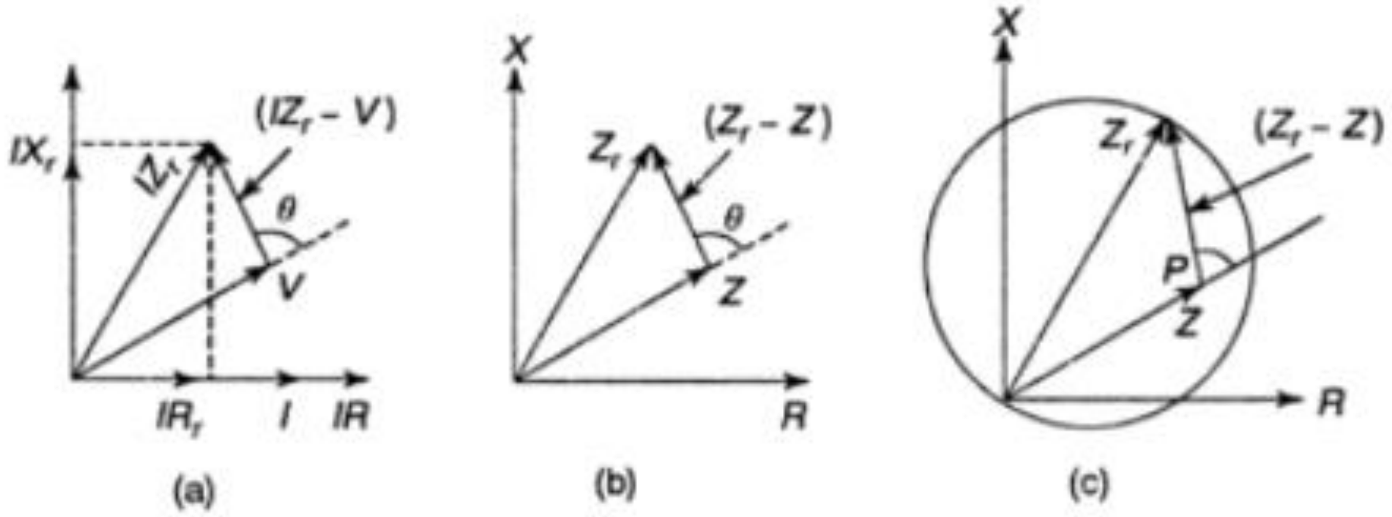


FIGURE (a) Phasor diagram showing V, I and voltage drop (b) Impedance diagram (c) MHO characteristic

A rectifier bridge phase comparator, as shown in Fig. can be employed to realise a MHO characteristic. The inputs to the phase comparator are $(IZ_r - V)$ and V. A phase comparator circuit using an operational amplifier has been shown in Fig. 4.27. Its operating principle has already been explained in the Section 2.3.5(c), Fig. 2.24.

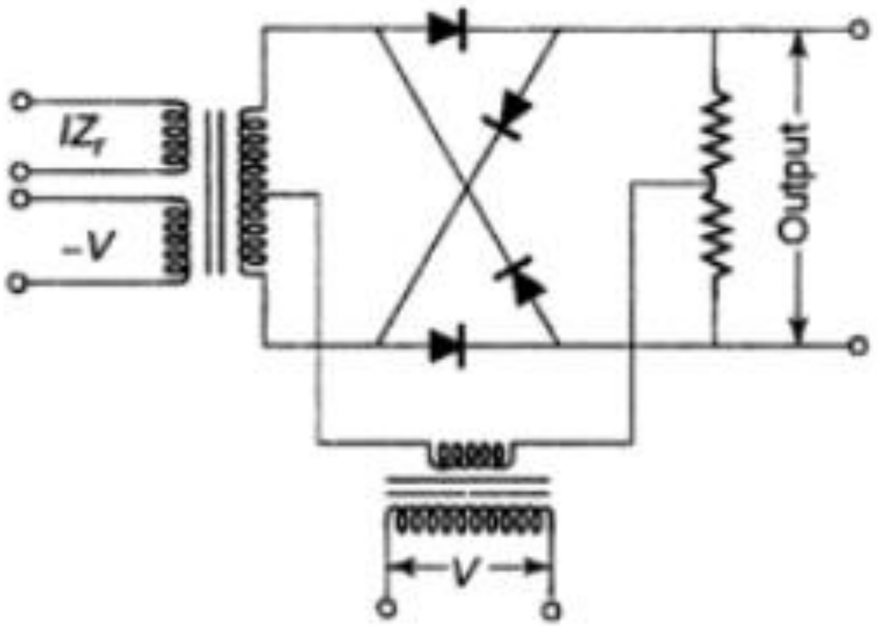


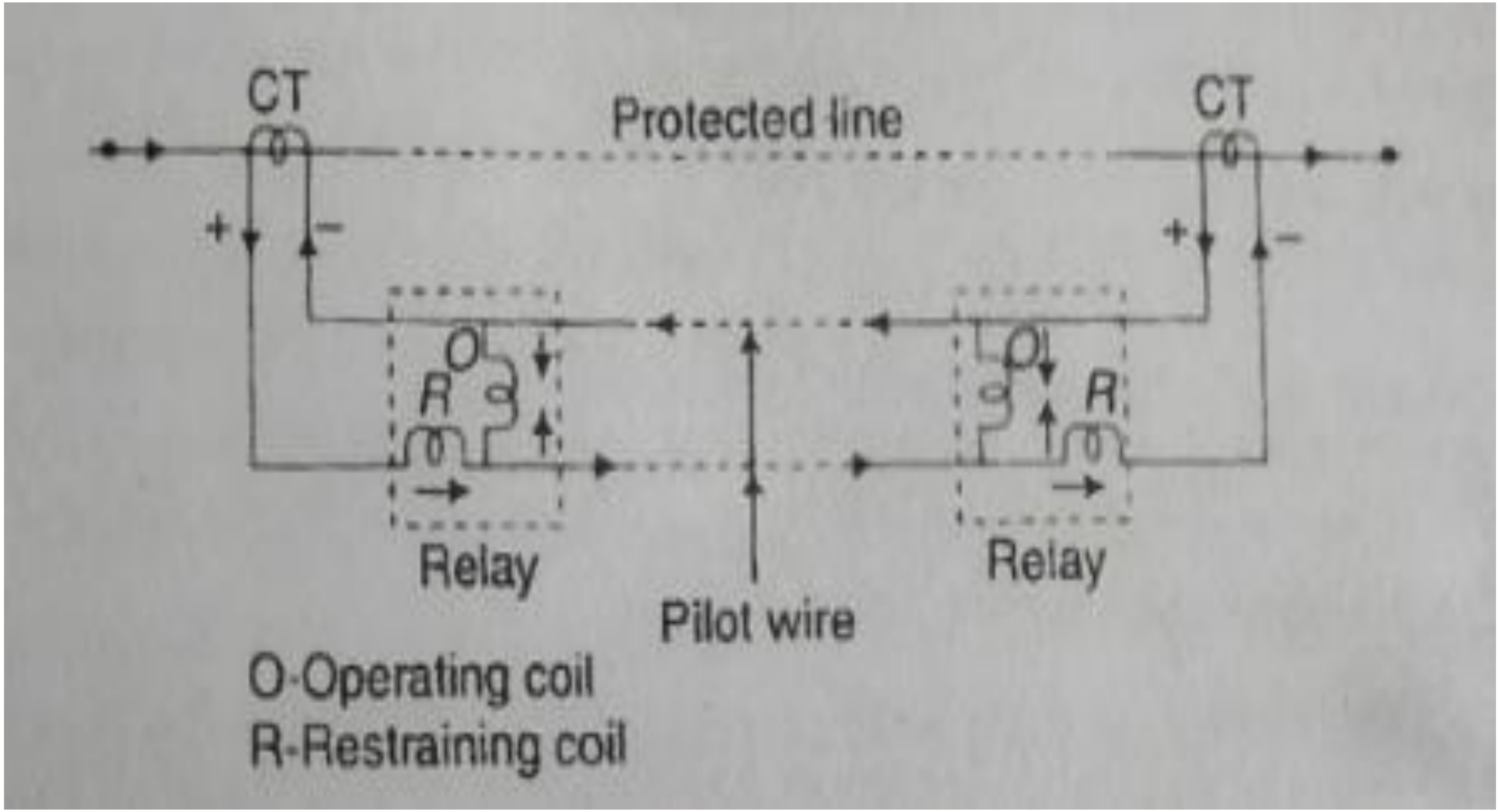
FIGURE Rectifier bridge phase comparator

2(a). What are the important operating schemes which are used in wire pilot protection? With schematic diagram explain the circulating current scheme. [CO3, L2] (5M)

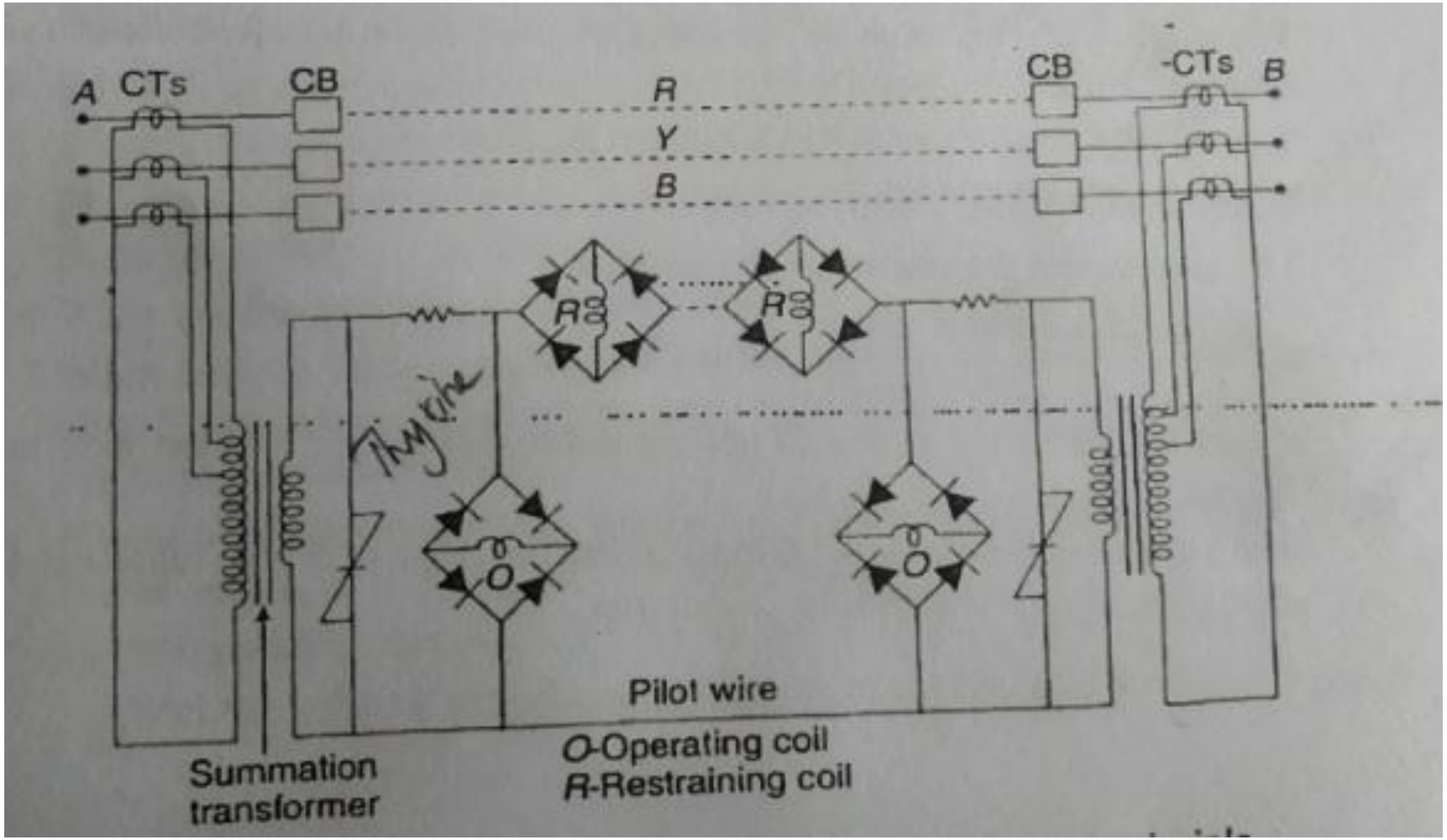
Operating schemes which are used in wire pilot protection

- 1. Circulating Current Scheme
- 2.Balanced Voltage (or Opposed Voltage) Scheme
- 3. Transley Scheme
- 4.Half-Wave Comparison Scheme

1. Circulating Current Scheme



Practical scheme on circulating current principle



Circulating Current Scheme

- This is suitable for pilot loop resistance up to 1000 Ω and inner core capacitance up to 2.5μF.
- Under normal condition and external faults current does not flow through the operating coil.
- During internal fault, polarity of the remote end CT is reversed hence current flows through the operating coil.

2(b). With a neat sketch explain frame leakage protection scheme. [CO4, L2] (5M)

Frame Leakage Protection

Figure shows a scheme of frame leakage protection. This is more favoured for indoor than outdoor installations. This is applicable to metal clad type switchgear installations. The frame work is insulated from the ground. The insulation is light, anything over 10 ohms is acceptable. This scheme is most effective in case of isolated-phase construction type switchgear installations in which all faults involve ground. To avoid the undesired operation of the relay due to spurious currents, a check relay energised from a C.T. connected in the neutral of the system is employed. An instantaneous overcurrent relay is used in the frame leakage protection scheme if a neutral check relay is incorporated. If neutral check relay is not employed, an inverse time delay relay should be used.

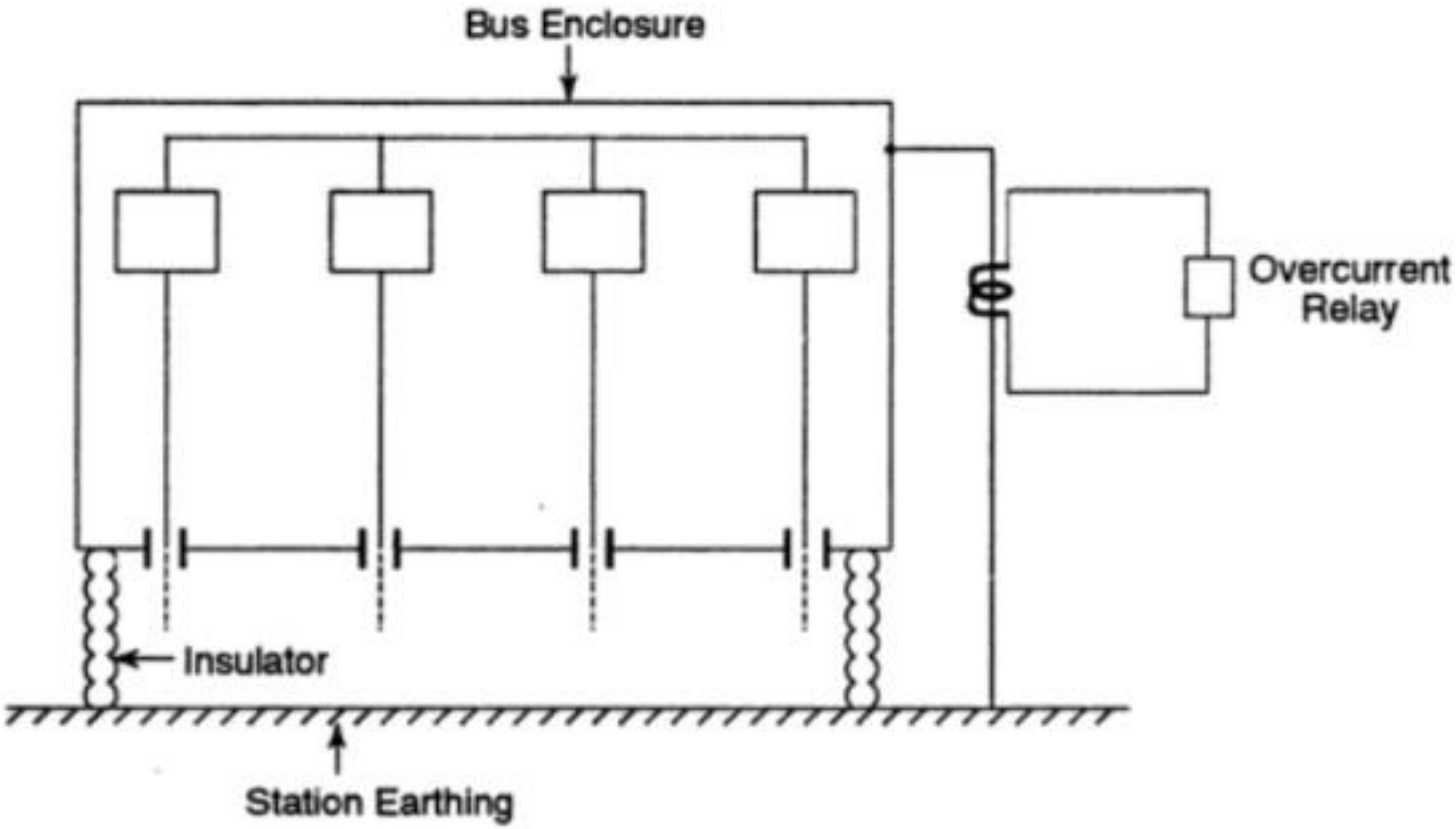


FIGURE Frame leakage protection

3(a). Explain the working principle of Buchholz relay used for the protection of transformer. [CO4, L2] (5M)

Buchholz Relay

It causes an alarm to sound and alert the operator. For reliable operation, a mercury switch is attached with the float. Some manufacturers use open-topped bucket in place of a bob. When the oil level falls because of gas accumulation, the bucket is filled up with oil. Thus, the force available to operate the contacts is greater than with hollow floats. The accumulated gas can be drawn off through the petcock via a pipe for analysis to know the type of fault. If there is a severe fault, large volumes of gases are produced which cause the lower float to operate. It finally trips the circuit breakers of the transformer.

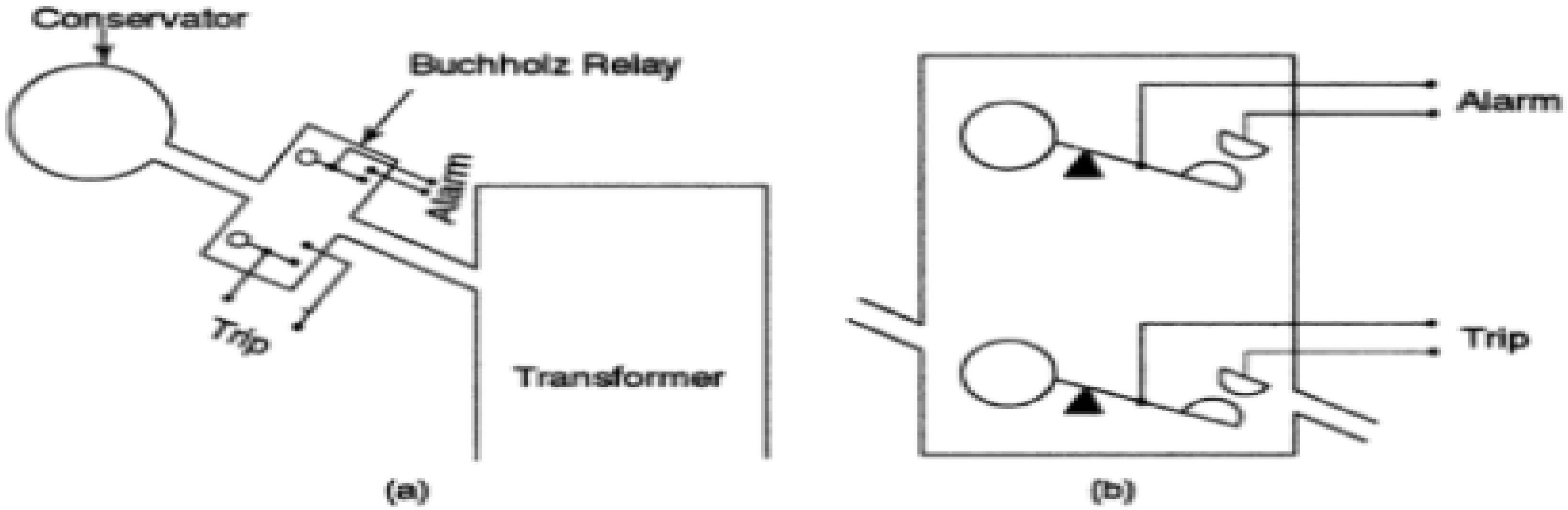


FIGURE 6.12 (a) Transformer tank, Buchholz relay and conservator
(b) Buchholz relay

The buchholz relay is a slow acting device, the minimum operating time is 0.1 s, the average time 0.2 s. Too sensitive settings of the mercury contacts are not desirable because they are subjected to false operation on shock and vibration caused by conditions like earthquakes, mechanical shock to the pipe, tap changer operation and heavy external faults. This can be reduced by improved design of the mercury contact tubes.

When a fault develops slowly, it produces heat, thereby decomposing solid or liquid insulating material in the transform. The decomposition of the insulating material produces inflammable gases. The operation of the Buchholz relay gives an alarm when a specified amount of gas is formed. The analysis of gas collected in the relay chamber indicates the type of the incipient fault. The presence of; (a) C_2H_2 and H_2 shows arcing in oil between constructional parts; (b) C_2H_2, CH_4 and H_2 shows arcing with some deterioration of phenolic insulation, e.g. fault in tap changer; (c) CH_4, C_2H_4 and H_2 indicates hot spot in core joints; (d) C_2H_4, C_3H_6, H_2 and CO_2 shows a hot spot in the winding.

3(b). With schematic diagram explain the protection of stator against overheating in an alternator. [CO4, L2] (5M)

Stator Over Heating Protection

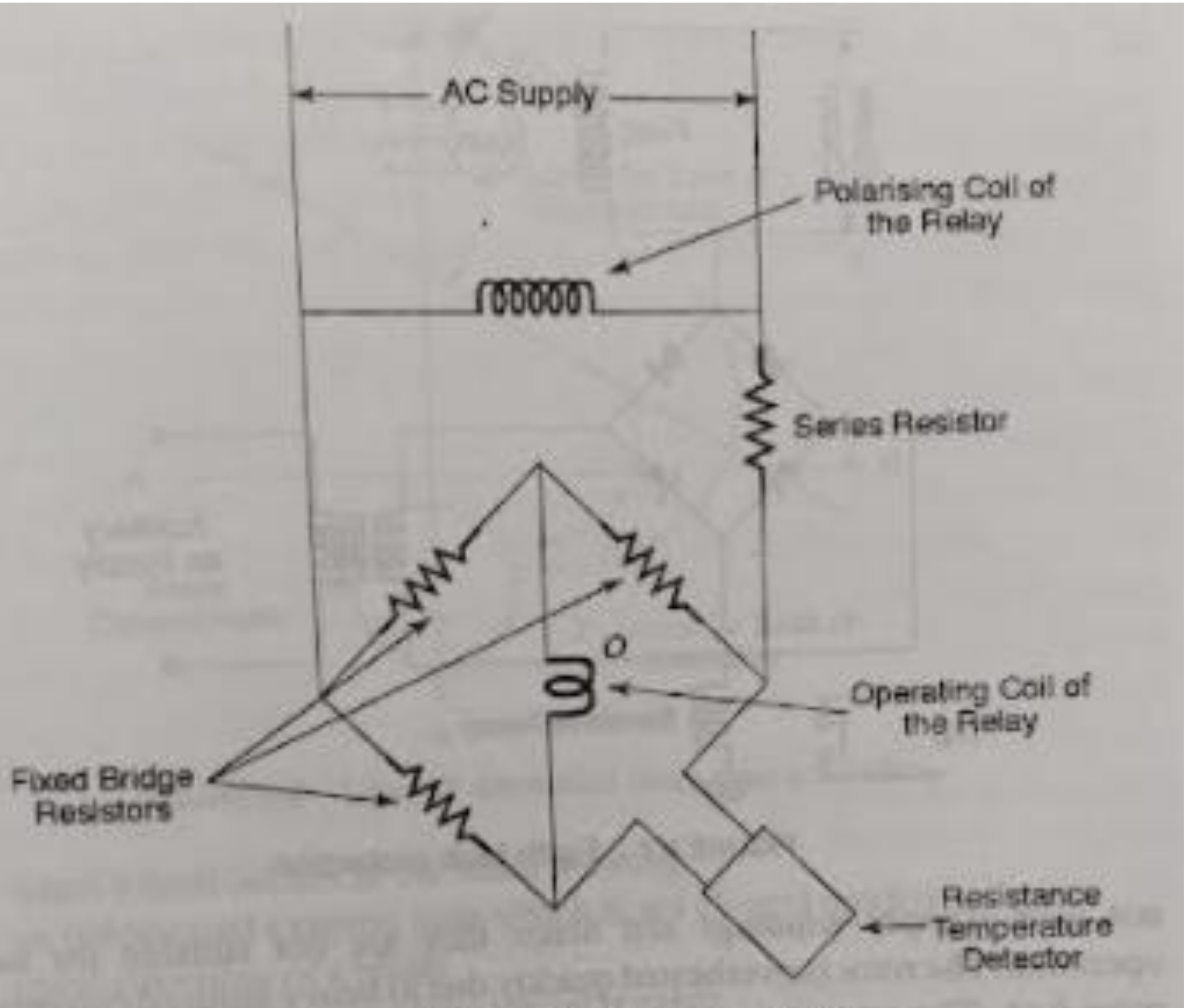


FIGURE 6.6 Stator overheating protection

Stator-overheating protection Overheating of the stator may be caused by the failure of the cooling system, overloading or core faults like short-circuited laminations and failure of core bolt insulation. Modern generators employ two methods to detect overheating both being used in large generators (above 2 MW). In one method, the inlet and outlet temperatures of the cooling medium which may be hydrogen/water are compared for detecting overheating. In the other method, the temperature sensing elements are embedded in the stator slots to sense the temperature. Figure shows a stator overheating relaying scheme. When the temperature exceeds a certain preset maximum temperature limit, the relay sounds an alarm. The scheme employs a temperature detector unit, relay and Wheatstone-bridge for the purpose. The temperature sensing elements may either be thermistors, thermocouples or resistance temperature indicators. They are embedded in the stator slots at different locations. These elements are connected to a multi-way selector switch which checks each one in turn for a period long enough to operate an alarm relay.

For small generators, a bimetallic strip heated by the secondary current of the C.T. is placed in the stator circuit. This relay will not operate for the failure of the cooling system.

Thermocouples are not embedded in the rotor winding as this makes slip ring connections very complicated. Rotor temperature can be determined by measuring the winding resistance. An ohm-meter type instrument, energised by the rotor voltage and current and calibrated in temperature is employed for the purpose.

4(a). A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding are shown if fig.1. Assuming CT ratios of 500/5 amperes, the relay operate to trip the circuit breakers? [CO4, L4] (5M)

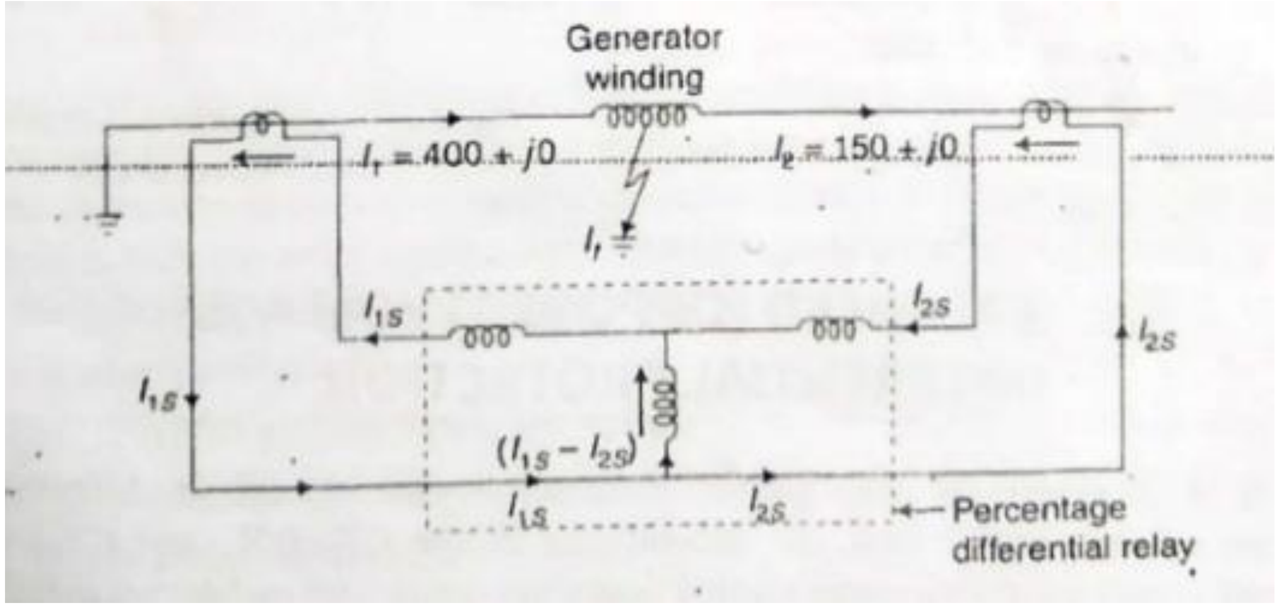


Fig. 1.

Solution :

$I_1 = 400 + j0$ A ; $I_2 = 150 + j0$; C.T. ratio = $\frac{500}{5}$ A = 100 A.

$$I_{1s} = \frac{400}{100} = 4 \text{ A}.$$

$$I_{2s} = \frac{150}{100} = 1.5 \text{ A}.$$

$$I_d = I_{1s} - I_{2s} = 4 - 1.5 = 2.5 \text{ A}.$$

$$I_r = \frac{I_{1s} + I_{2s}}{2} = \frac{4 + 1.5}{2} = 2.75A.$$

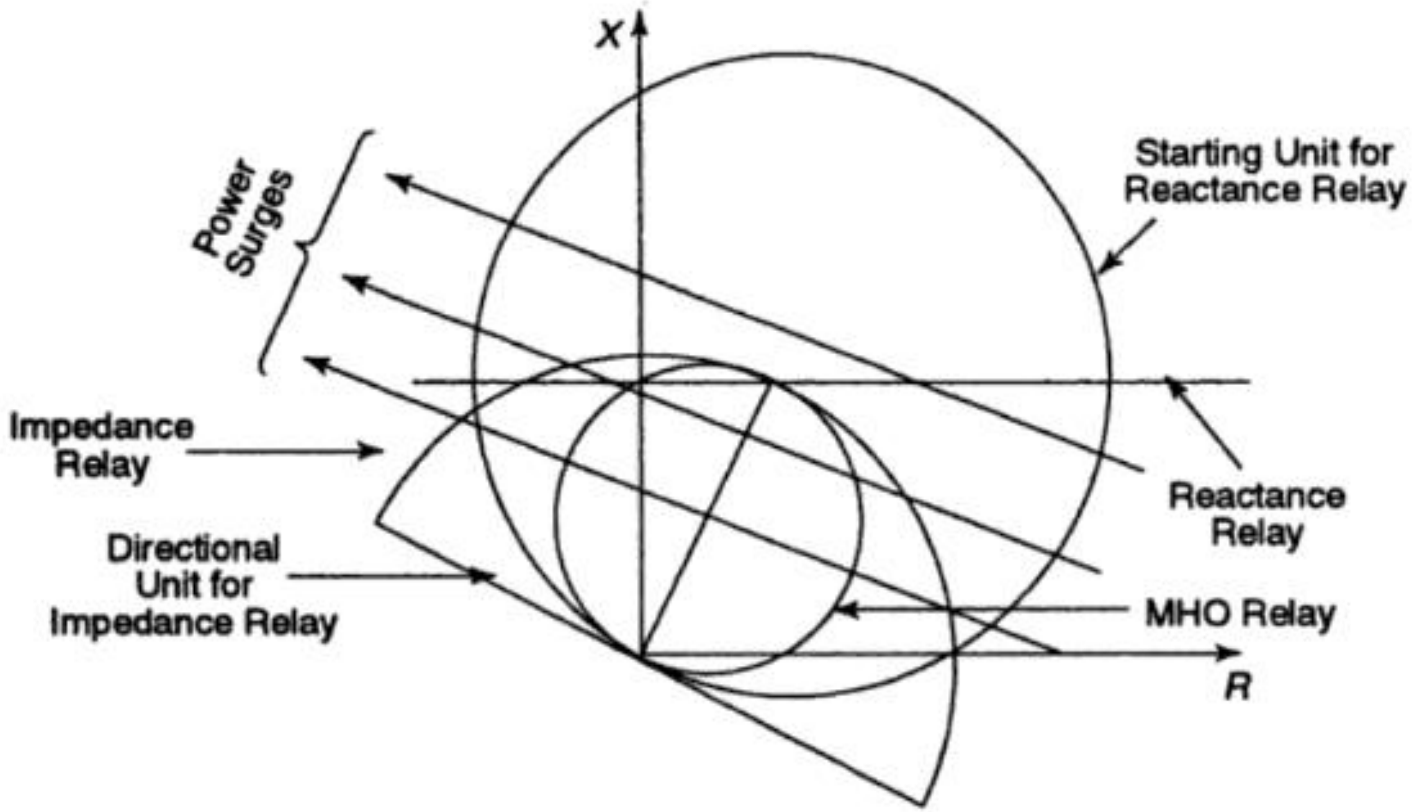
$K = 0.1 \Rightarrow KI_r = 0.1 \times 2.75 = 0.275A$

For relay operation ; $I_d > KI_r$.

So relay operates and trip the C.B.

4(b). Explain the effect of power surge on the performance of distance relay [CO2, L2] (5M)

Effect of Power Surges on the Performance of Distance Relays



Power Swing Analysis

Figure 4.39 shows a section of a transmission line with generating stations beyond either end of the line section. The generated voltages are E_A and E_B, respectively. The voltage at the relay location is V. Impedances are as shown in the figure. The current flowing through the line is given by

$$I = \frac{E_A - E_B}{Z_A + Z_L + Z_B} = \frac{E_A - E_B}{Z_T} \quad (\text{where } Z_T = Z_A + Z_L + Z_B)$$

$$V = E_A - IZ_A$$

The impedance 'seen' by the relay is given by

$$Z = \frac{V}{I} = \frac{E_A - IZ_A}{I} = \frac{E_A}{I} - Z_A$$

$$= \frac{E_A Z_T}{E_A - E_B} - Z_A$$

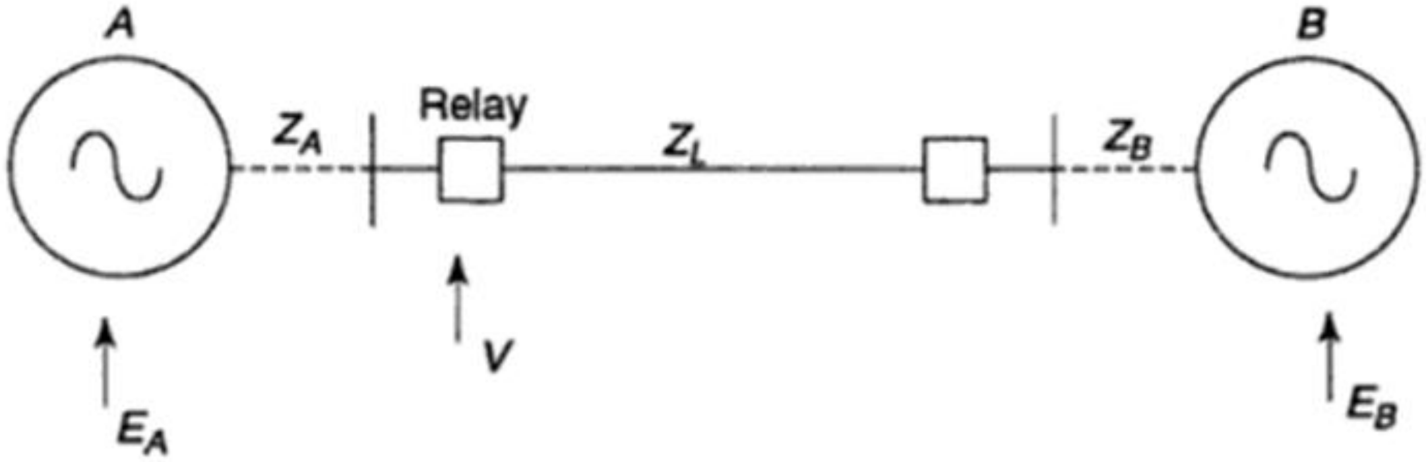


FIGURE One line diagram of a system to illustrate loss of synchronism

If E_A leads E_B by an angle δ and $E_A/E_B = n$, the above expression is written as

$$Z = \frac{ne^{i\delta}}{ne^{i\delta} - 1} Z_T - Z_A$$

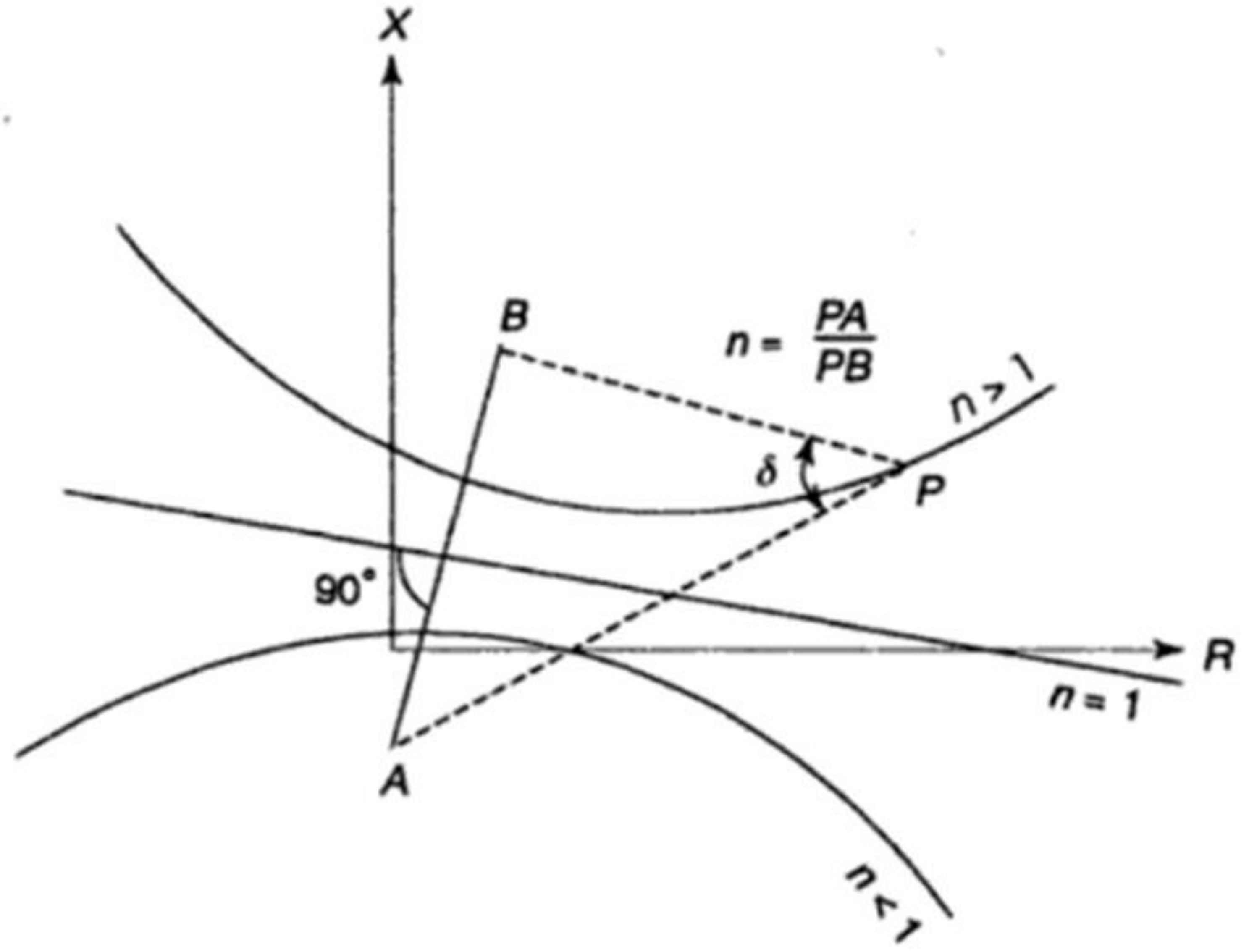


FIGURE General loss of synchronism characteristics

For $n > 1$, the distance from B to the centre of circle = $Z_T/(n^2 - 1)$

$$\text{Radius of circle} = \frac{nZ_T}{n^2 - 1}$$

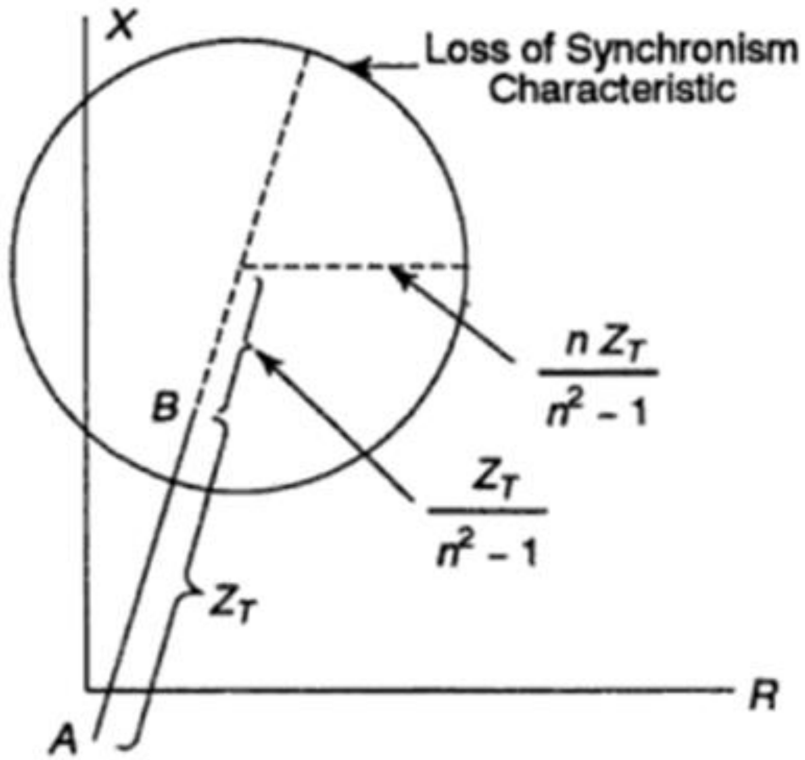


FIGURE Graphical construction of loss of synchronism characteristic

These are shown in Fig.

For $n < 1$, the circles are symmetrical to those for $n > 1$, but with their centres beyond A, as shown in Fig. The same formulae can be used for the radius and the distance of the centre of the circle by putting $1/n$ in place of n. So long as the power swing locus remains in the characteristic zone of a distance relay on the R-X diagram, the relay will see a fault and it will have a tendency to trip. Whether the relay will trip or not depends on the period for which the swing locus influences the relay characteristic.

5(a). A generator is protected by restricted earth fault protection. The generator ratings are 13.2kV and 10MVA. The percentage of the winding protected against phase-ground fault is 85%. The relay setting is such that it trips for 20% out of balance. Calculate the resistance to be added in the neutral to ground connection. [CO4, L3] (5M)

Solution:

Current at which relay operates =

$$\frac{10 \times 10^3}{\sqrt{3} \times 13.2 \times 10^3} \times \frac{20}{100} = 87.477 \text{ A}.$$

$$P = 100 - 85 = 15\%.$$

The fault current $= \frac{P}{100} \times \frac{13.2 \times 10^3}{\sqrt{3}\, R}$.

$$\frac{15}{100} \times \frac{13.2 \times 10^3}{\sqrt{3}\, R} = 87.477$$

$$\frac{1143.15}{R} = 87.477.$$

$$R = 13.068 \, \Omega$$

5(b). Give notes on Reach of Distance Relay [CO2, L1] (5M)

Reach of Distance Relay

- A distance relay is set to operate up to a particular value of impedance; for an impedance greater than this set value the relay should not operate. This impedance, or the corresponding distance is known as the **Reach of Distance Relay**.
- The tendency of a Reach of Distance Relay to operate at impedance larger than its setting value is known as **overreach.**
- The tendency to restrain at the set value of impedance or impedances lower than the set value is known as **underreach**.

Overreach

An important reason for overreach is the presence of d.c. offset in the fault current wave, as the offset current has a higher peak value than that of a symmetrical wave for which the relay is set.

The transient overreach is defined as:

$$\text{Percent transient overreach} = \frac{Z_{os} - Z_{sy}}{Z_{sy}} \times 100$$

Where

Z_{os} = the maximum impedance for which the relay will operate with an offset current wave, for a given adjustment

Z_{sy} = the maximum impedance for which the relay will operate for symmetrical currents for the same adjustment as for Z_{os}.

overreach

The transient overreach increases as the system angle $\tan^{-1} X/R$ increases. Figure shows the variation of overreach with system angle.

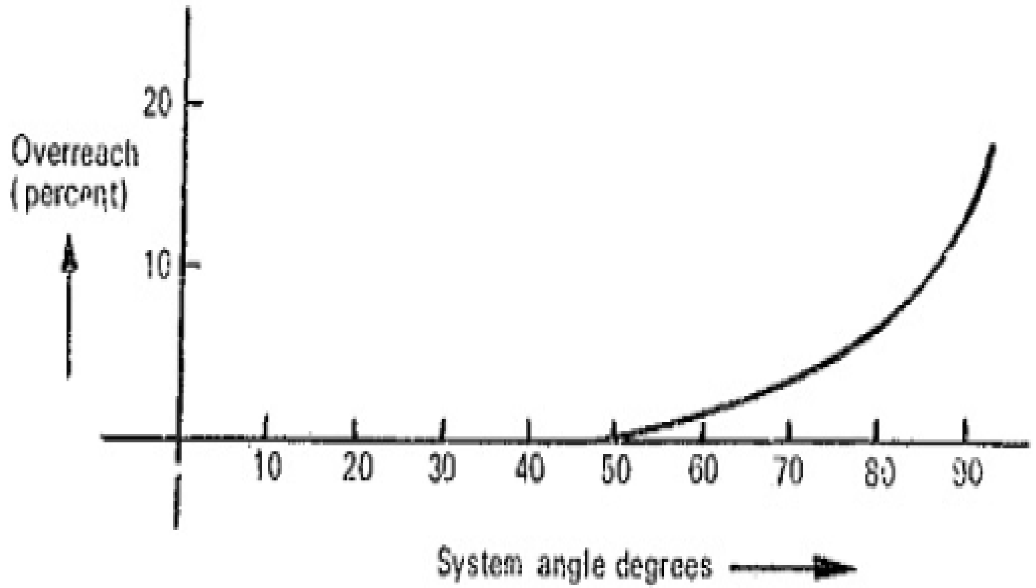


FIGURE Overreach characteristics.

Underreach

A distance relay may underreach because of the introduction of fault resistance as illustrated in Fig. . Relay at O is set for protection up to P. Now if a fault at P occurs such that fault resistance (PP′) is high and by adding this resistance the impedance seen by the relay is OP′ such that P′ lies outside the operating region of the relay, then the relay does not operate.

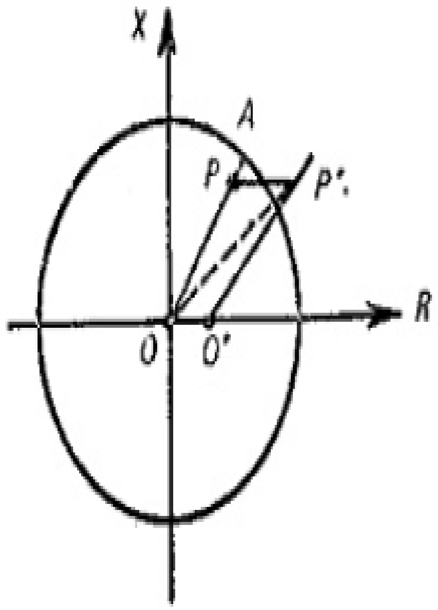


FIGURE Underreach of distance relay.

6. Explain simple differential protection scheme with the help of relevant diagram and Plot its characteristics during internal and external fault conditions. [CO2, L2] (10M)

SIMPLE (BASIC) DIFFERENTIAL PROTECTION

The main constituent of a simple differential protection scheme is a simple differential relay. A simple differential relay is also called basic differential relay. A simple differential relay is an overcurrent relay having operating coil only which carries the phasor difference of currents at the two ends of a protected element. It operates when the phasor difference of secondary currents of the CTs at the two ends of the protected element exceeds a predetermined value. The secondary of the CTs at the two ends of the protected element are connected together by a pilot-wire circuit. The operating coil of the overcurrent relay is connected at the middle of pilot wires. The differential protection scheme employing simple differential relay is called Simple differential protection or Basic differential protection. The simple differential protection scheme is also called circulating current differential protection scheme of Merz-Price protection scheme.

Behaviour of Simple Differential Protection during Normal Condition

Figure 8.1 illustrates the principle of simple differential protection employing a simple differential relay. The CTs are of such a ratio that their secondary currents are equal under normal conditions or for external (through) faults. If the protected element (equipment) is either a 1:1 ratio transformer or a generator winding or a busbar, the two currents on the primary side will be equal under normal conditions and external (through) faults. Hence, the ratios of the protective CTs will also be identical.

If n be the CT ratio, the secondary current of CT_1 $(I_{s1}) = I_L/n$, secondary current of CT_2 $(I_{s2}) = I_L/n$, and the secondary load current $(I'_L) = I_L/n$.

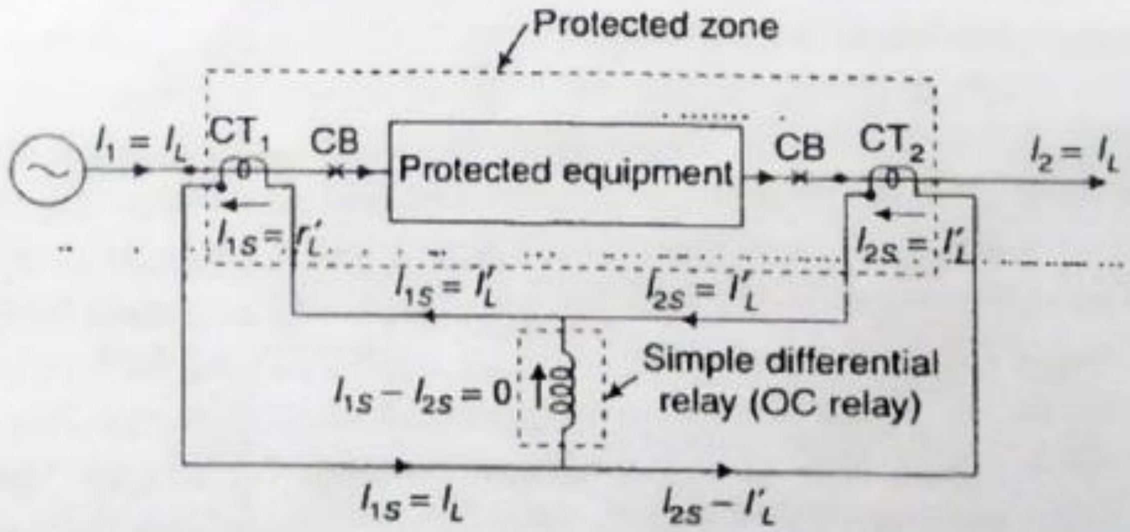


Fig. 8.1 *Simple differential protection scheme behaviour under normal condition.* *($I_1 = I_2 = I_L$ and $I_{1S} = I_{2S} = I_L$, hence $I_{1S} - I_{2S} = 0$)*

Behaviour of Simple Differential Protection during External Fault

Figure 8.2 illustrates the behaviour of the simple differential protection scheme under external (through) fault. An external (through) fault occurs outside the protected zone, i.e., outside the CT locations and not in the protected equipment. As in the case of normal conditions, the current through the OC relay is zero. The secondary currents I_{1s} and I_{2s} of the CTs are equal to the secondary fault current I'_F, and the differential (spill) current $(I_{1s} - I_{2s})$ flowing through the operating coil of the OC relay is zero. Hence the OC relay does not operate under external (through) faults.

In Fig. 8.2,

I_1 = Current entering the protected zone, $= I_F$

I_2 = Current leaving the protected zone $= I_F$

Hence, $I_1 = I_2 = I_F$, and through fault current $= \dfrac{I_1 + I_2}{2} = I_F$

$$I_{1S} = I_{2S} = I'_F = I_F/n, \text{ where } n \text{ is the CT ratio}$$

Secondary value of through fault current $= \dfrac{I_{1s} + I_{2s}}{2} = I'_F$

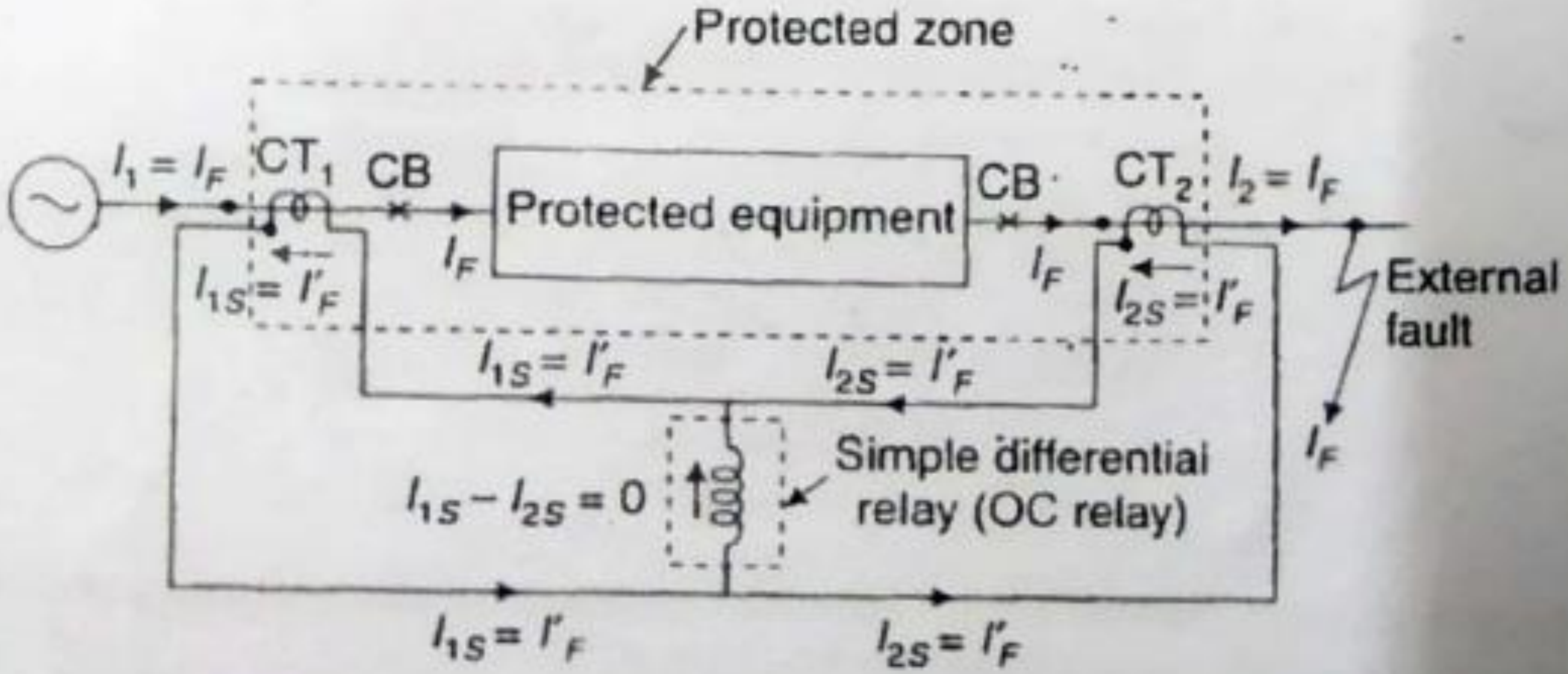
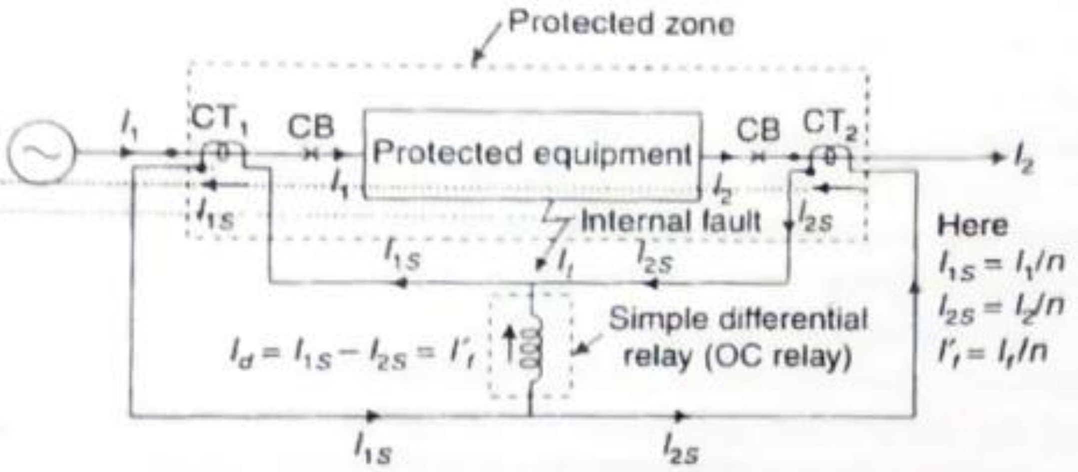


Fig. 8.2 *Behaviour of simple differential protection scheme on external (through) fault.* $(I_{1S} - I_{2S}) = 0$ *(No current in OC relay)*

Behaviour of Simple Differential Protection during Internal Fault

Figure 8.3 illustrates the behaviour of simple differential protection scheme during internal faults in a single-end-fed system. An internal fault occurs inside the protected zone, i.e., within the CT locations. In case of internal fault the current entering the protected zone is I_1 whereas that leaving it is I_2, such that $I_1 = I_2 + I_f$ i.e. $I_1 \neq I_2$. Hence, the two secondary currents (I_{1s} and I_{2s}) through CTs are not equal and the differential or spill current ($I_{1s} - I_{2s}$) flows through OC relay. If the differential current ($I_{1s} - I_{2s}$) is higher than the pick-up value of the overcurrent relay, the relay will operate and both the circuit breakers will be tripped out isolating the protected equipment from the system.



$I_1 = I_2 + I_f$, Differential current $(I_d) = I_{1s} - I_{2s} = I'_f$

If both CTs (CT_1 and CT_2) have same CT ratio (n), $I_{s1} = I_1/n$, $I_{s2} = I_{s2}/n$ and $I'_f = I_f/n$

If both CTs have different CT ratios (n_1 and n_2) as in the case of transformer,

$I_{s1} = I_1/n_1$ and $I_{s2} = I_2/n_2$

Fig. 8.3. *Behaviour of simple differential protection during internal fault*

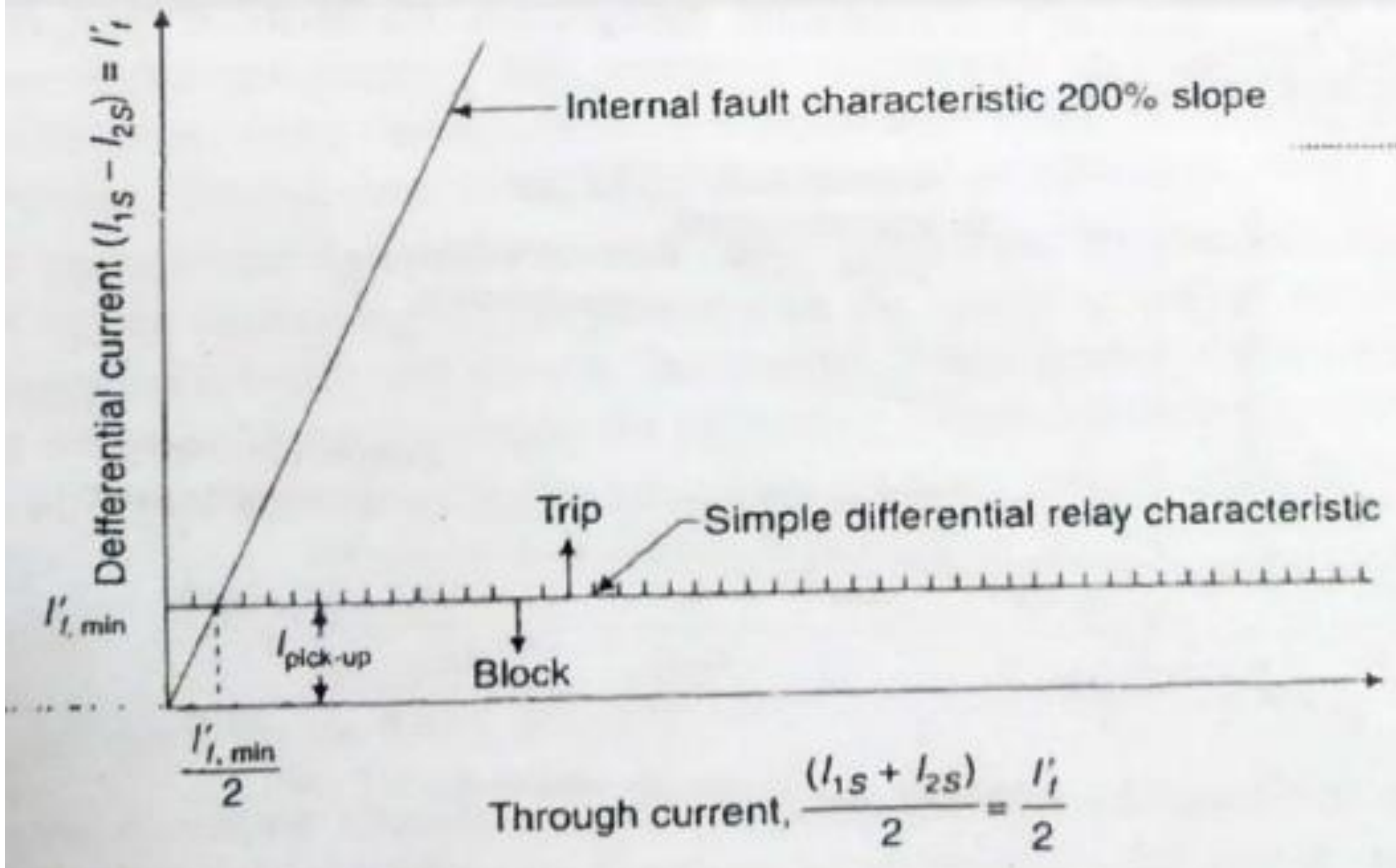
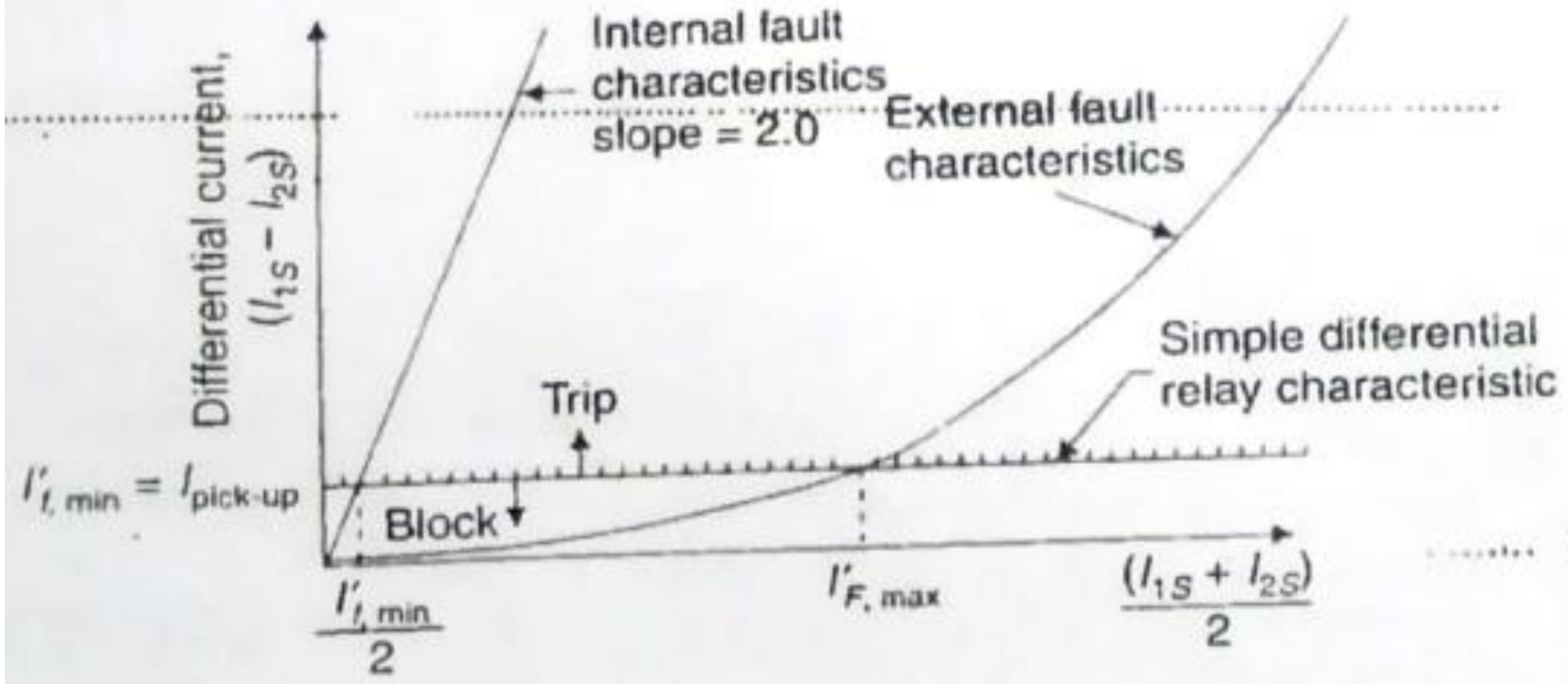


Fig. Internal fault characteristics



$I'_{f,\,min} = I_{pick\text{-}up}$, and $I'_{F,\,max} = I_{F,\,max}/n$, where n = CT ratio

Fig. *Simple differential relay, internal fault and external fault characteristics*

7. With a neat circuit diagram explain the construction and working of Reactance delay in detail. [CO2, L2] (10M)

Reactance Relay

- The reactance relay is a high-speed relay. This relay consists of two elements an overcurrent element and a current-voltage directional element.
- The current element developed positive torque and a current voltage developed directional element which opposes the current element depending on the phase angle between current and voltage.
- Reactance relay is an overcurrent relay with directional limitation.
- The directional element is arranged to develop maximum negative torque when its current lag behinds its voltage by 90°.
- The induction cup or double induction loop structures are best suited for actuating reactance type distance relays.

Electromagnetic Reactance Relay

An induction cup structure, as shown in Fig. , is used to realise a reactance relay characteristic. The torque equation of the relay is given by

$$T = K_1I^2 - K_2VI\cos(90-\phi) - K_3$$
$$= K_1I^2 - K_2VI\sin\phi - K_3$$

The current produces polarising flux in the upper and lower poles. Also, current is the operating quantity which produces flux in the right-hand side pole. The flux in the right-hand side pole is out of phase with that in the upper and lower poles because of the secondary winding which is closed through a phase shifting circuit and is placed on the right-hand side pole. The interaction of the polarising flux and the flux in the right-hand side pole produces an operating torque K_1I^2. The winding placed on the left-hand side pole produces a flux which interacts with the polarising flux to produce a restraining torque. There is a phase-angle adjustment circuit connected in series with the voltage coil. The restraining torque is proportional to $VI\cos(90-\phi)$. The angle between the actuating quantities which are proportional to V and I can be changed to realise the desired characteristic. In this case, the angle between the actuating quantities is kept $(90-\phi)$. The relay operates when $K_1I^2 > K_2VI\sin\phi$, neglecting K_3 which is a constant for the spring's torque. Thus, we have

$$\frac{V}{I}\sin\phi < \frac{K_1}{K_2}$$

or $$Z\sin\phi < K \quad \text{or} \quad X < K$$

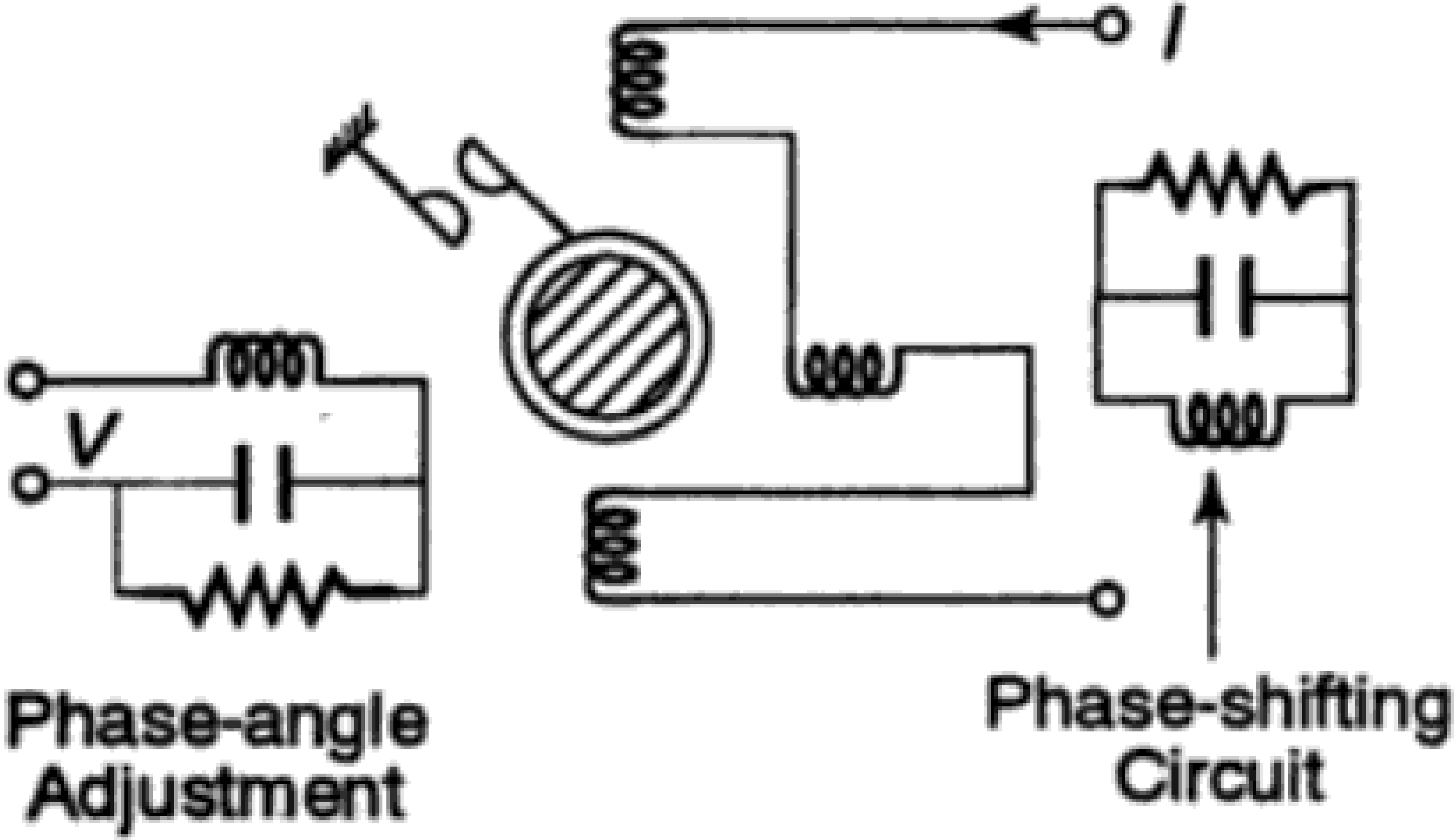


FIGURE Induction cup type reactance relay

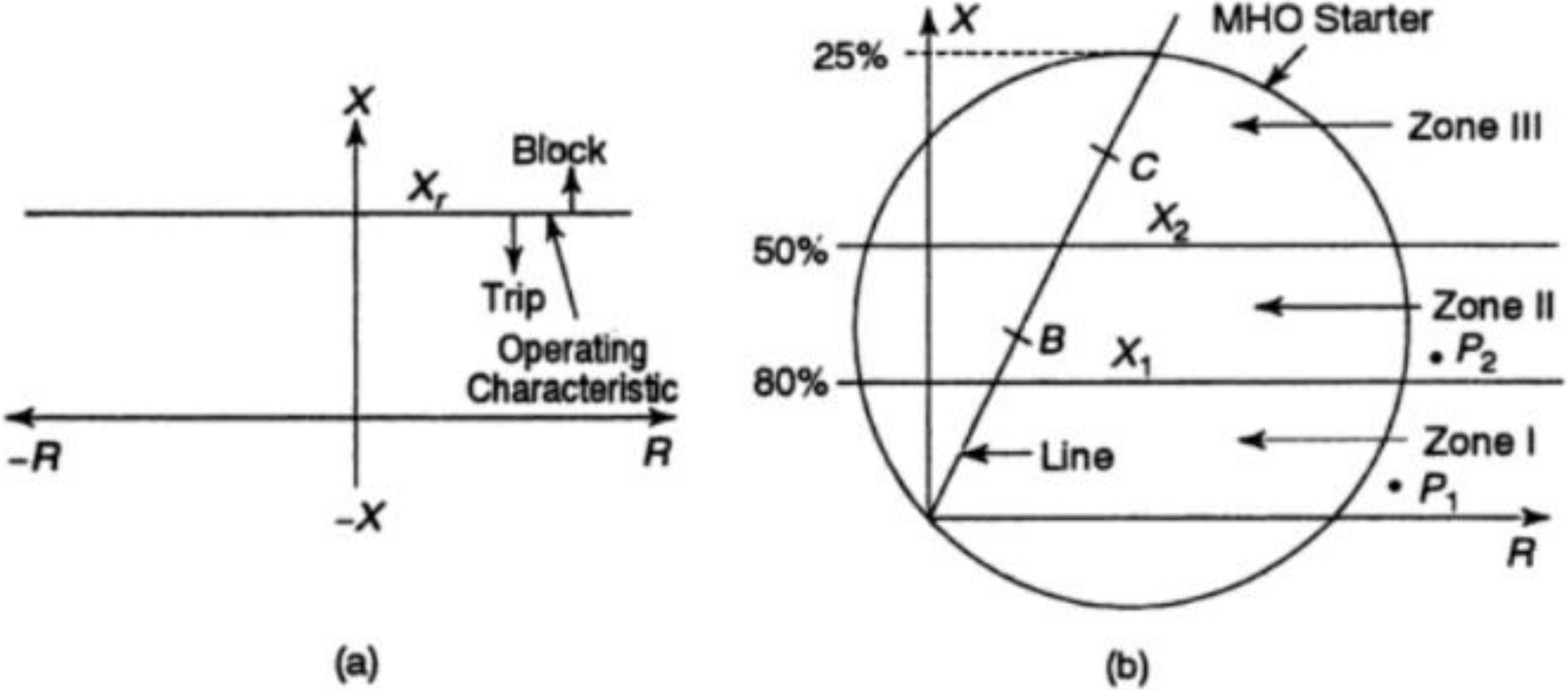


FIGURE (a) Operating characteristic of a reactance relay
(b) Reactance relay with starting unit

The characteristic of the reactance relay on the *R-X* diagram is shown in Fig. (a). It will operate when the measured value of the reactance is less than the predetermined value *K*. It is a non directional relay as it will also operate for the negative values of *X*. The negative value of *X* means that the fault is behind the relay location, i.e. in the reverse direction. A directional unit, having a circular characteristic is used in conjunction with reactance relays. The directional unit also acts as the III unit of the distance scheme. The I and II units are reactance units as shown in Fig. (b). The I unit is a high speed unit to protect 80% to 90% of the protected line. The II unit protects up to 50% of the adjacent line. The III unit is a back-up unit to protect the whole of the adjacent line. The time-distance characteristic is a stepped characteristic, as shown in Fig.

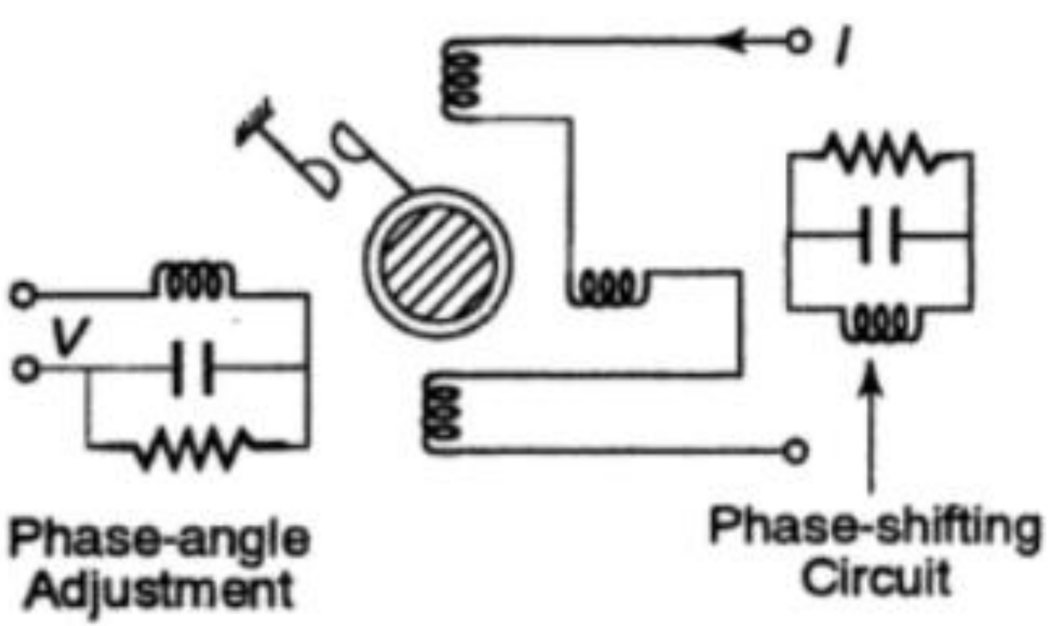


FIGURE 4.15 Induction cup type reactance relay

Why the directional unit used with reactance relays should have a circular characteristic needs further explanation. Under normal conditions, with a load of high power factor, the reactance measured by the reactance relay may be less than its setting. Such points have been shown in Fig. (b) by P_1 lying in the I zone of protection and P_2 in the II zone of protection. To prevent false trippings under such conditions, the reactance relay should be supervised by a fault-detecting unit (starting unit)which limits its area on the R-X diagram. Hence, its characteristic should be a circular one. A directional unit with a straight line characteristic, as used with an impedance relay cannot be used in this case. With this type of a directional unit, the reactance relay will not trip under conditions of a high power factor load.

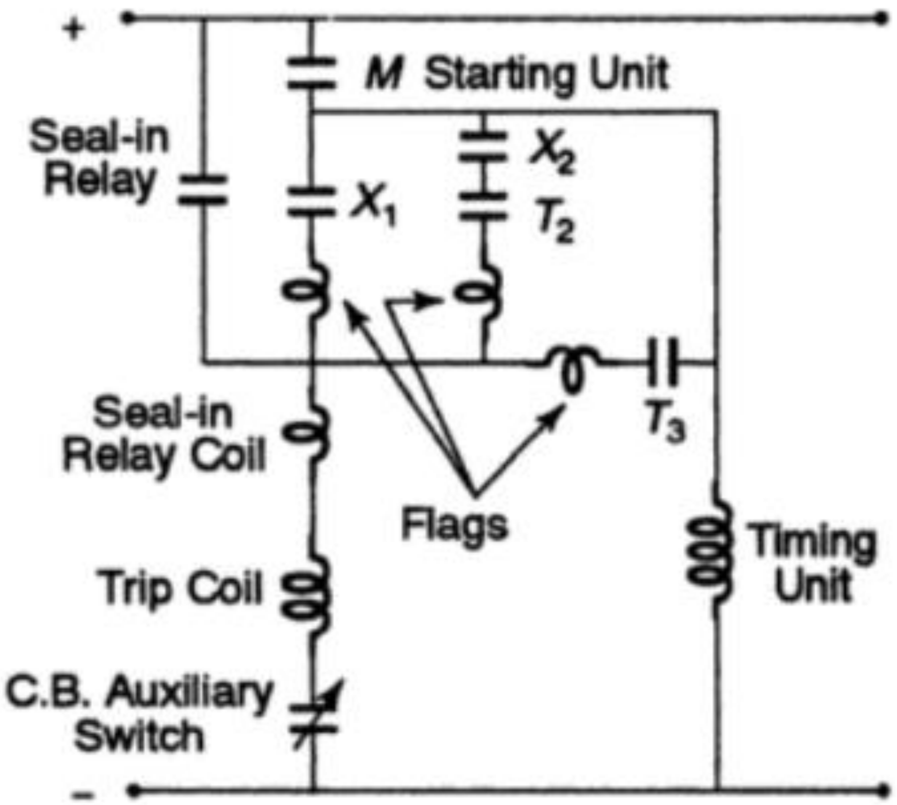


FIGURE Connections of reactance relay

Static Reactance Relay Using an Amplitude Comparator

Figure shows a rectifier bridge type amplitude comparator to realise a reactance relay. The actuating quantities to be compared are $(I - V/2X_r)$ and $V/2\,X_r$. The relay operates when

$$\left| I - \frac{V}{2X_r} \right| > \left| \frac{V}{2X_r} \right|$$

Multiplying both sides by $2\,X_r$, we get,

$$|2\,IX_r - V| > |V|$$

Dividing both sides by I, we get

$$\left| 2X_r - \frac{V}{I} \right| > \left| \frac{V}{I} \right| \quad \text{or} \quad |2X_r - Z| > |Z|$$

where X_r is the reactance of the line to be protected.

When the above condition is satisfied, the characteristic realised is a reactance relay characteristic. Proof of this will be given later on while discussing the angle impedance relay as the reactance relay is a special case of an angle impedance relay.

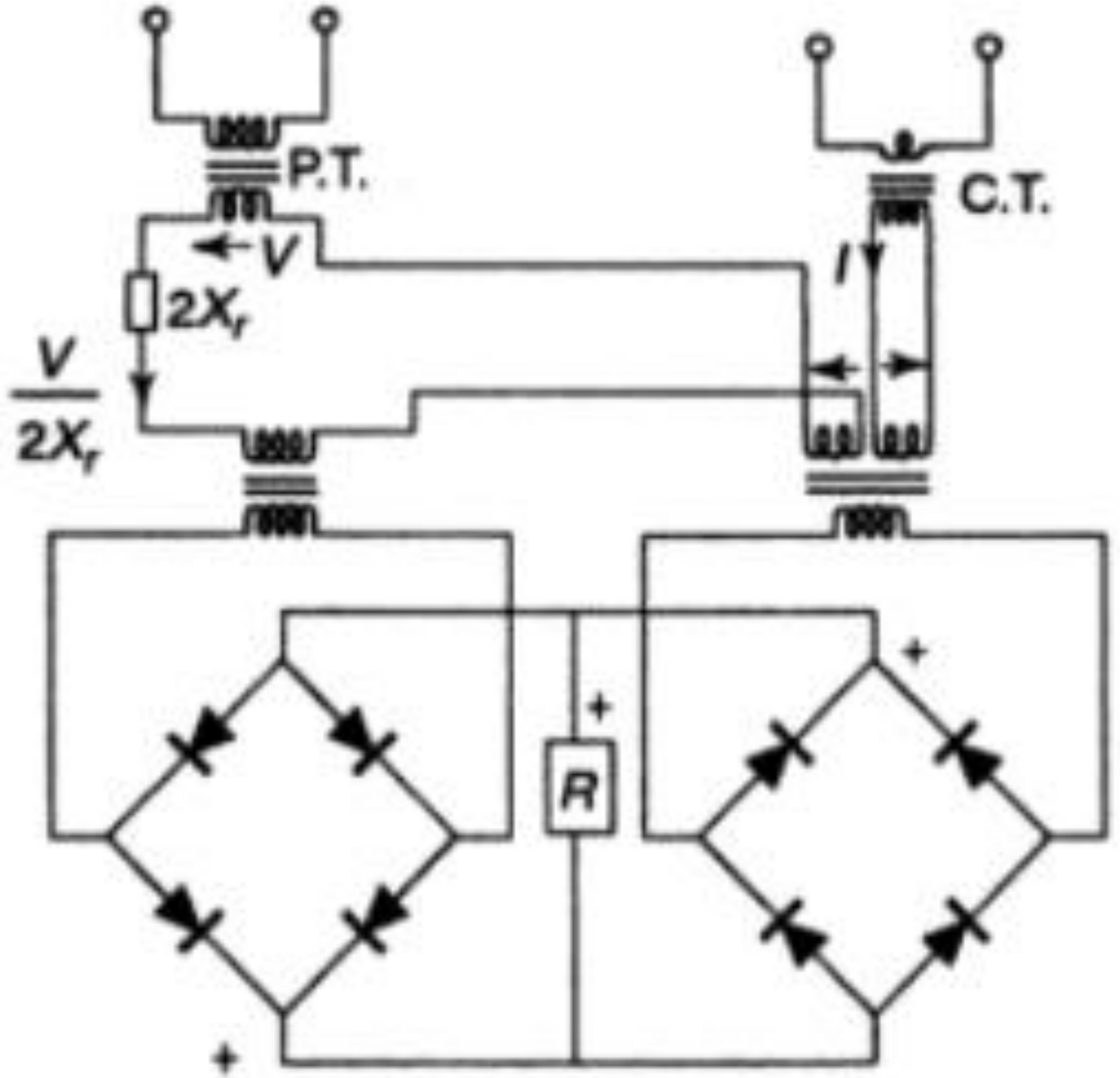


FIGURE Static reactance relay

Static Reactance Relay Using a Phase Comparator

Figure (a) shows a vector diagram showing voltage, current and voltage drops. If we divide all vectors by I, the vectors of Fig. (b) are obtained. A perpendicular line MK is drawn from the point M. A horizontal line LN is drawn through the point M. As MK is parallel to IX_r, the phase angle between IX_r and $(IZ_r - V)$ is equal to the angle between MK and $(IZ_r - V)$, i.e. θ. If the point P is below the horizontal line LN, θ is less than $\pm 90°$. If P is above LN, θ is greater than $\pm 90°$. Therefore, a reactance relay characteristic can be realised by comparing the phase angle between IX_r and $(IZ_r - V)$ with $\pm 90°$.

The reactance relay characteristic can also be realised if the phase angle between IX_r and $(IX_r - V)$ is compared with $\pm 90°$. The vector diagram for this condition has been shown in Fig. 4.19.

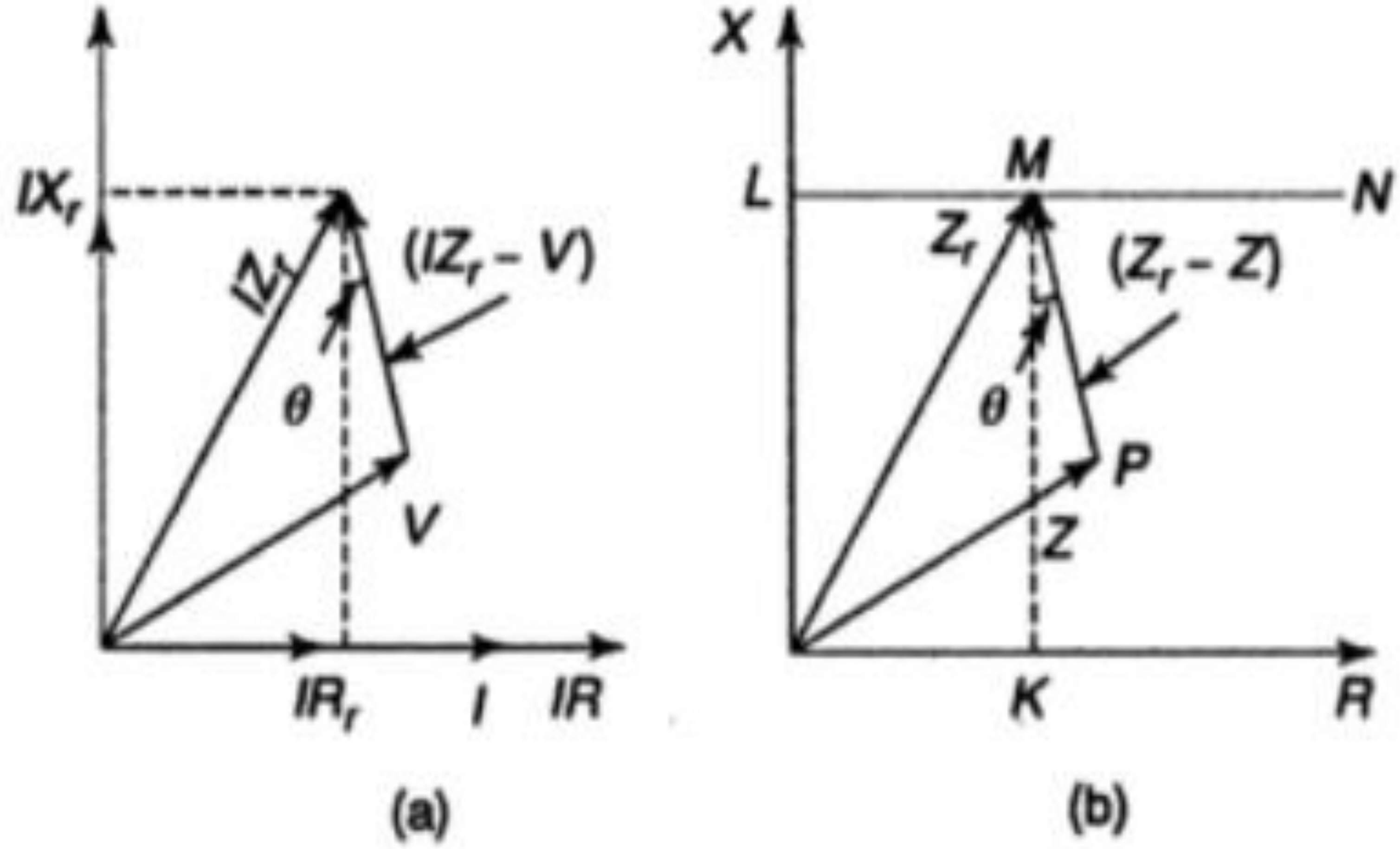


FIGURE (a) Phasor diagrams showing V, I and voltage drop
(b) Phasor diagram for reactance relay

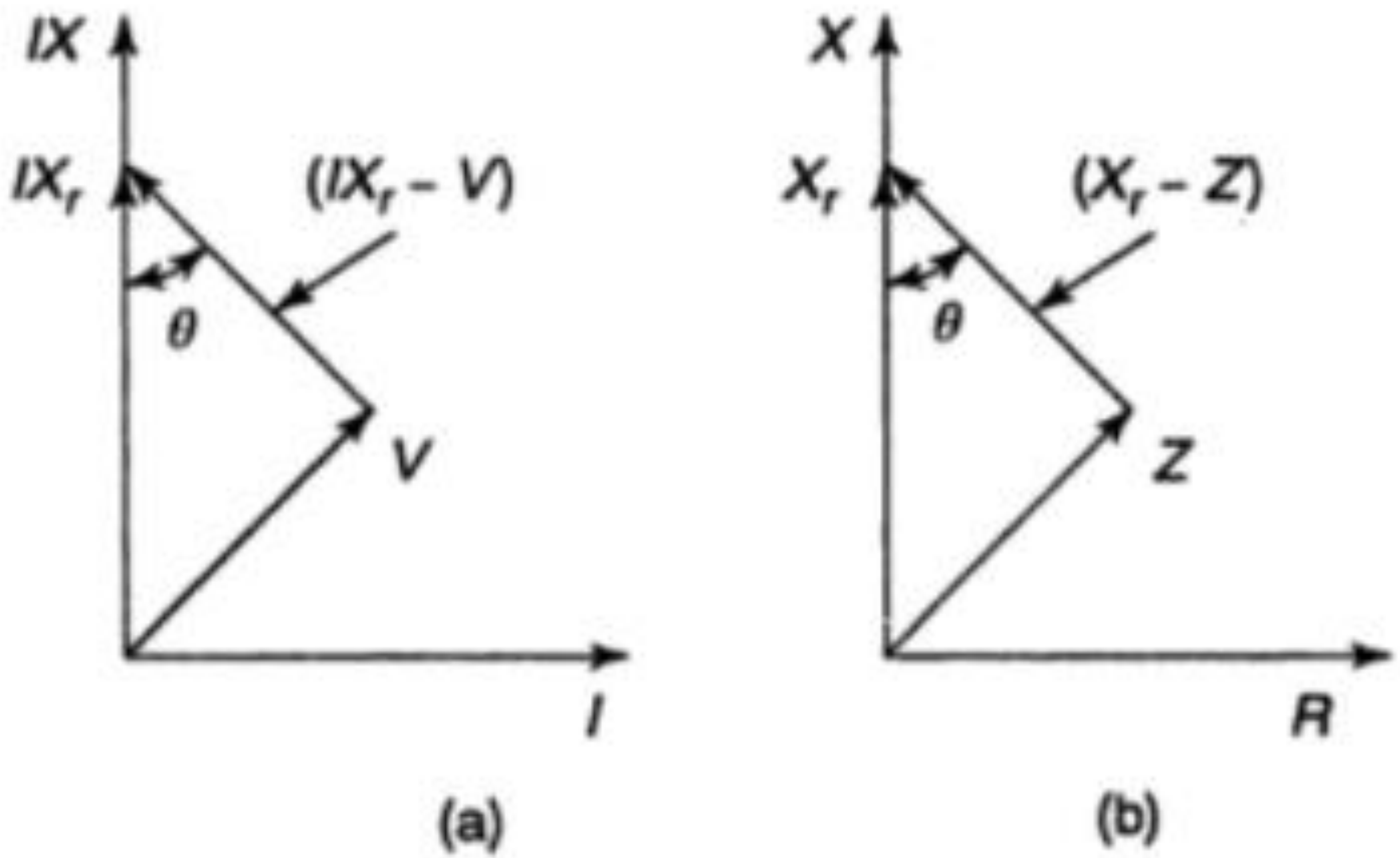


FIGURE 4.19 Realisation of reactance relay by comparing IX_r and $(IX_r - V)$