CMR INSTITUTE OF TECHNOLOGY

USN

Internal Assessment Test -II

Sub:	POWER SYSTEM PROTECTION							Code:	18EE72
Date:	4/12/2023	Duration:	90mins	Max Marks:	50	Sem:	7^{th} A & B	Branch:	EEE

Answer any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1.	With a neat circuit diagram explain the construction and working of MHO Relay.	10	CO2	L2
2.a	With neat diagram, explain static impedance relay using amplitude comparator.	6	CO2	L2
2.b	With a neat sketch explain frame leakage protection scheme.	4	CO4	L2
3.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.	4	CO4	L3
3.b	Explain the effect of Line length and source impedance on the performance of distance relay.	6	CO2	L2
4.a	Explain the working principle of Buchholz relay used for the protection of transformer.	4	CO4	L2

P.T.O

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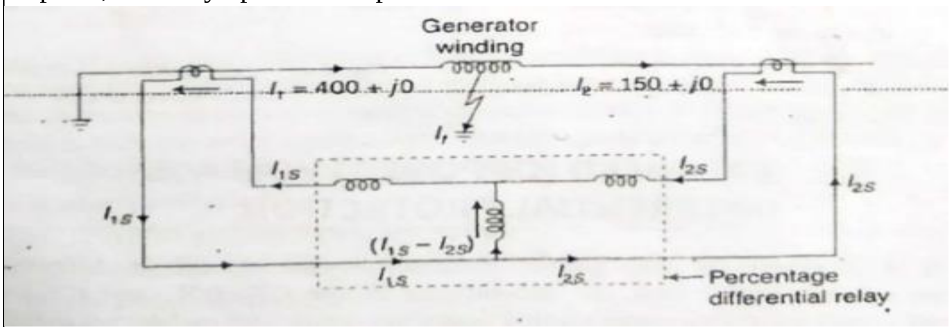
4.b	Explain balanced (opposed) voltage differential protection.	5	CO3	L2
5	With schematic diagram, explain protection of stator against overheating in an alternator.	10	CO3	L2
6.a	A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. 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? 	4	CO3	L3
6.b	Explain how reactance relay and MHO relay characteristics are realized using a sampling comparator.	6	CO3	L2

CCI **CI** **HOD**

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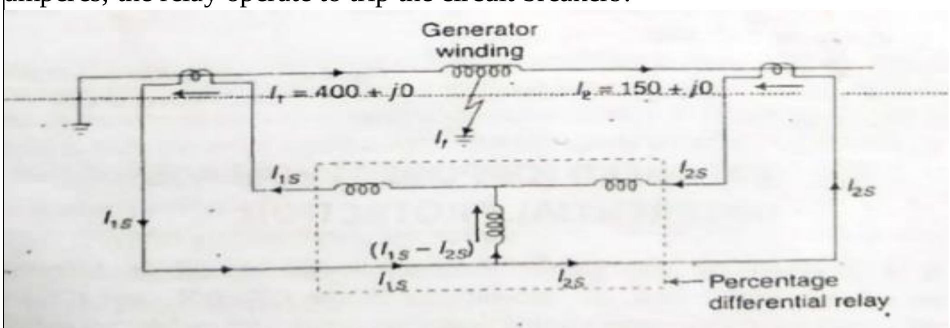
6.a	A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding are shown if fig.1. Assuming CT ratios of 500/5 amperes, the relay operate to trip the circuit breakers? 	4	CO3	L3
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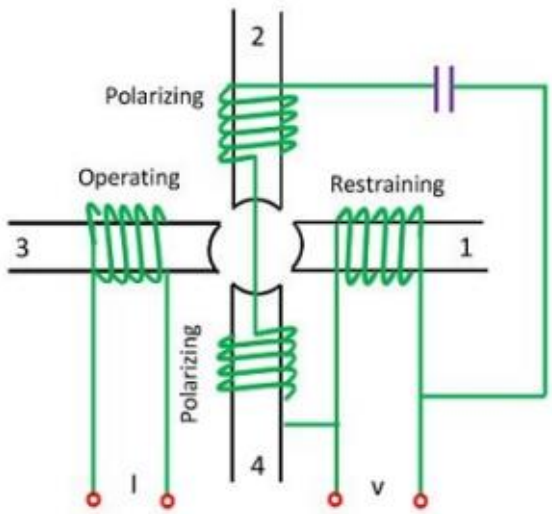
CCI **CI** **HOD**

PSP_IAT II_Solution

1.

A mho Relay is a high-speed relay and is also known as the admittance relay. In this relay operating torque is obtained by the volt-amperes element and the controlling element is developed due to the voltage element. It means a mho relay is a voltage controlled directional relay.

A mho relay using the induction cup structure is shown in the figure below. The operating torque is developed by the interaction of fluxes due to pole 2, 3, and 4 and the controlling torque is developed due to poles 1, 2 and 4.



Schematic Diagram of Mho Relay

Circuit Globe

If the spring controlling effect is indicated by $-K_3$, the torque equation becomes,

$$T = K_1 VI\cos(\theta - 90^\circ) - K_3$$

Where Θ and τ are defined as positive when I lag behind V. At balance point, the net torque is zero, and hence the equation becomes

$$K_1 VI\cos(\theta - \tau) - K_2 V^2 - K_3 = 0$$

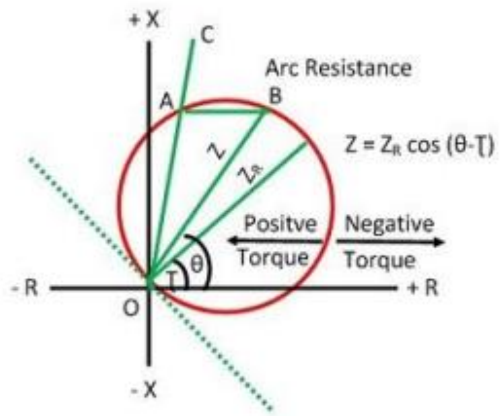
$$\frac{K_1}{K_2}\text{Cos}(\theta - \tau) - \frac{K_3}{K_2 VI} = \frac{V}{I} = Z$$

$$Z = \frac{K_1}{K_2}\text{Cos}\,(\theta - \tau)$$

If the spring controlled effect is neglected i.e., $k_3 = 0$.

Operating Characteristic of Mho Relay

The operating characteristic of the mho relay is shown in the figure below. The diameter of the circle is practically independent of V and I, except at a very low magnitude of the voltage and current when the spring effect is considered, which causes the diameter to decrease. The diameter of the circle is expressed by the equation as $Z_R = K_1 / K_2$ = ohmic setting of the relay

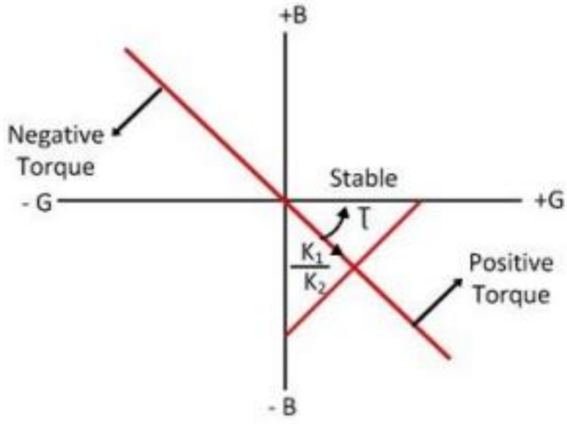


Operating Characteristic of Mho Relay

The relay operates when the impedance seen by the relay within the circle. The operating characteristic showed that circle passes through the origin, which makes the relay naturally directional. The relay because of its naturally directional characteristic requires only one pair of contacts which makes it fast tripping for fault clearance and reduces the VA burdens on the current transformer.

The impedance angle of the protected line is normally 60º and 70º which is shown by line OC in the figure. The arc resistance R is represented by the length AB, which is horizontal to OC from the extremity of the chord Z. By making the τ equal to, or little less lagging than Θ, the circle is made to fit around the faulty area so that the relay is insensitive to power swings and therefore particularly applicable to the protection of long or heavily loaded lines.

For a given relay the τ is constant, and the admittance phasor Y will lie on the straight line. The characteristic of mho relays on the admittance diagram is, therefore, a straight line and is shown in the figure below.



Characteristic of Mho Type Relay on Admittance Diagram

Circuit Globe

Mho relay is suitable for EHV/UHV heavily loaded transmission lines as its threshold characteristic in Z-plane is a circle passing through the origin, and its diameter is Z_R. Because of this, the threshold characteristic is quite compact enclosing faulty area compactly and hence, there is lesser chance to operate during power swing and also it is directional.

2. a

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

$$|2IX_r - V| > |V| \quad \Big\} (2m)$$

or $$|2X_r - Z| > |Z|$$

Explanation – (1m)

2.b

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.

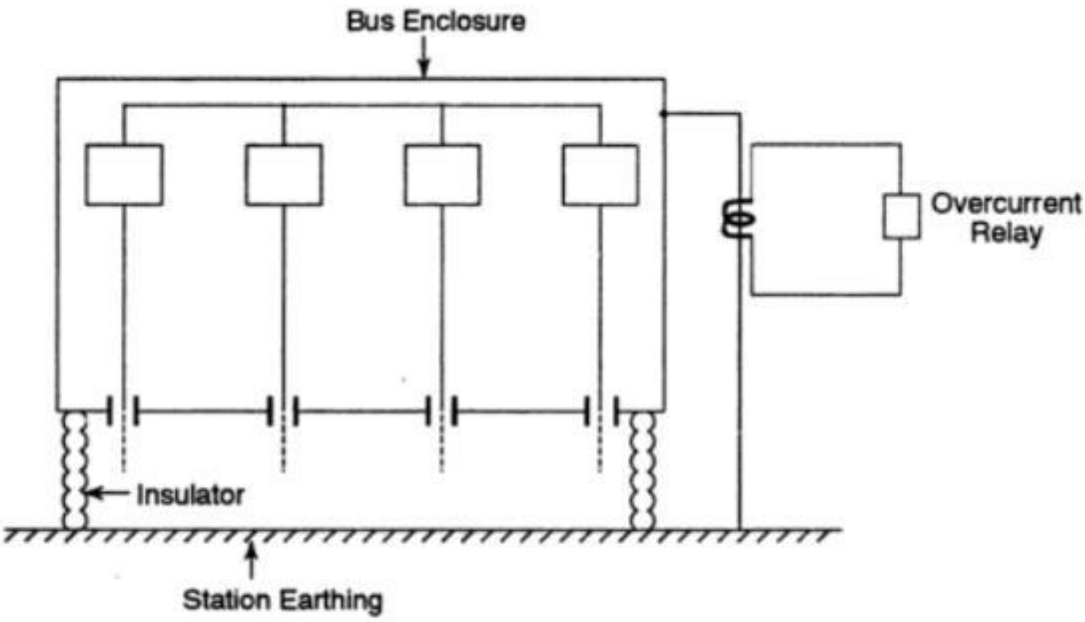


FIGURE Frame leakage protection

3.a

Solution:

Current at which relay operates =

$$\frac{10\times10^3}{\sqrt{3}\times13.2\times10^3}\times\frac{20}{100}=87.477\ A.$$

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

$$\text{The fault current} = \frac{P}{100}\times\frac{13.2\times10^3}{\sqrt{3}\,R}.$$

$$\frac{15}{100}\times\frac{13.2\times10^3}{\sqrt{3}\,R} = 87.477$$

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

$$R = 13.068\,\Omega$$

3. b

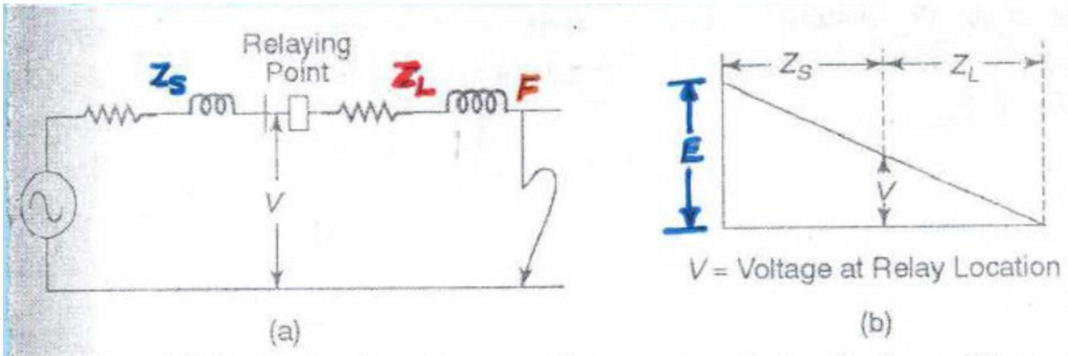


FIGURE 2.35 (a) Oneline diagram of the system during fault condition
(b) Voltage at the relaying point

→ Fig 2.35 shows a one-line diagram of the system during fault condition.

→ Z_S is the source impedance behind the relay.

→ Z_L is the line impedance from the relaying point to the fault.

→ Current flowing through the relay is given by

$$I = \frac{E}{Z_S + Z_L}$$

→ Voltage applied to the relay location

$$V = I Z_L = \frac{E Z_L}{Z_S + Z_L} = \frac{E}{\frac{Z_S}{Z_L} + 1}$$

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→ Relay manufacturers specify the minimum voltage for the relay operation

→ An induction cup MHO relay can operate down to 8 V within 5% accuracy.

5% accuracy.

$\therefore \quad 8 = \dfrac{E}{\dfrac{Z_s}{Z_L} + \ldots}$

E → can be taken as ...

$\left(\dfrac{Z_s}{Z_L} + 1 \right) = \dfrac{110}{8}$

$\therefore \quad \dfrac{Z_s}{Z_L} = \dfrac{110}{8} - 1 = 13.75 - 1 = 12.75 \cong 13$

→ If the value of $\frac{Z_s}{Z_L}$ is less than 13, the voltage at the relay point is more than 8 volts and the relay will operate.

→ If the value of $\frac{Z_s}{Z_L}$ is less than 13, the voltage at the relay point is more than 8 volts and the relay will operate.

→ If the ratio $\frac{Z_s}{Z_L}$ is more than 13, the voltage at the relay point is less than 8 volts and the relay will fail to operate.

So Source impedance Z_s is common for the system. the value of Z_L depends on the position of fault.

So we can conclude relay will fail to operate

if $\frac{Z_S}{Z_L} > 13$

or $Z_L < \frac{Z_S}{13}$

→ So there is a minimum length below which relay cannot protect the line. Such Z_L less than $\frac{Z_S}{13}$ relay fails to operate.

→ Modern induction cup relay can operate down to 3V.
So corresponding value $\frac{Z_S}{Z_L} \cong 36$ V. That relay will operate

if $Z_L < \frac{Z_S}{36}$

4.a

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.

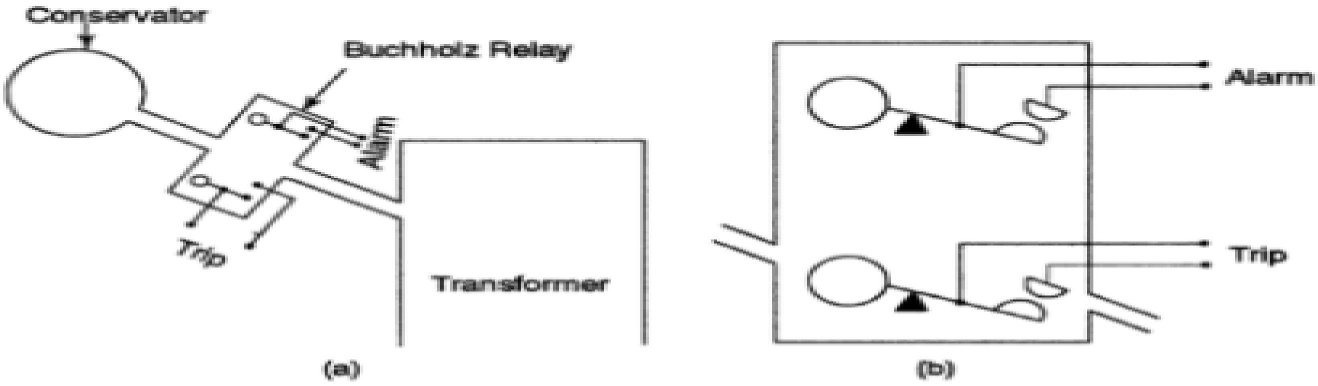

FIGURE 6.12 (a) Transformer tank, Buchholz relay and conservator
(b) Buchholz relay

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.

4.b

BALANCED VOLTAGE DIFFE... Protection based on

* Fig 3.18 shows the principle of differential Protection balanced voltage principle.
* In this scheme CT 2° are connected such that for normal condition & through fault conditions, 2° currents of CT's on both sides oppose each other and their voltage are balanced.

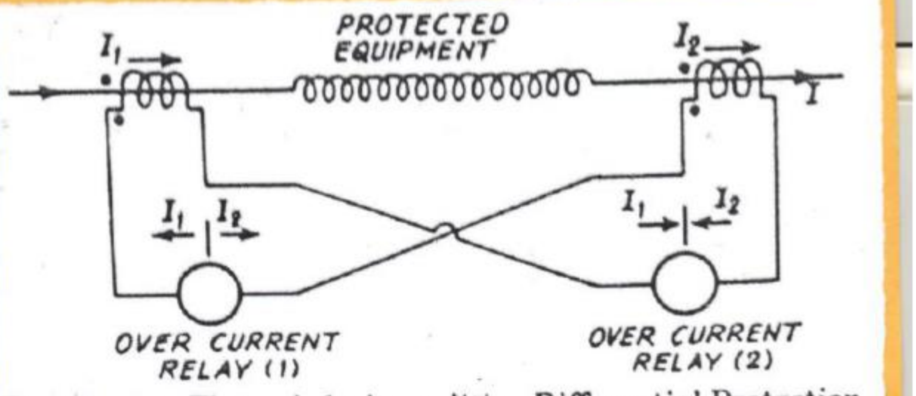

Fig. 3.18 . Through fault condition Differential Protection based on balanced voltage principle.

* During internal falt, the condition changes as shown in Fig 3.19.
* Current flowing through the relays will be $(I_1 + I_2)/2$ at each end & the direction of flow is as shown.

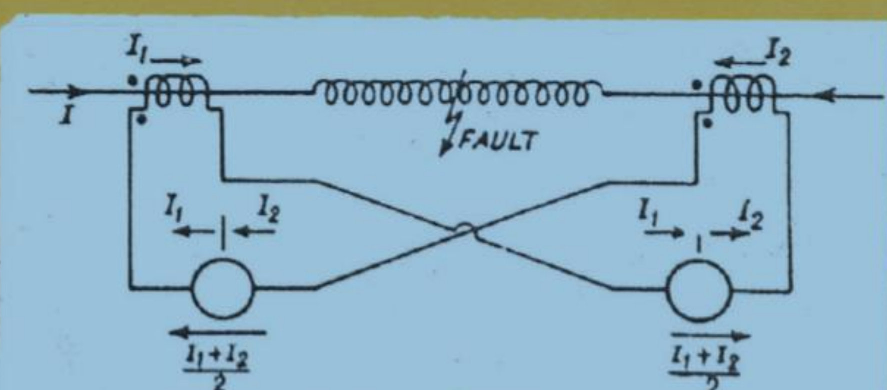

Fig. 3.19 . Internal fault condition.

* CTs used in such protection are with air gap core so that core do not get saturated and overvoltages are not produced during zero 2° current under normal working conditions.

Balanced Voltage Scheme

- In this scheme current does not normally circulate through pilot wires
- The operating coil is placed in series with the pilot wire so the current does not flow through it under normal conditions and external faults
- During internal faults , the polarity of the remote end CT is reversed, hence current flows through pilot wires and operating coil of the relay.
- Practical scheme is called Solkar system (Reyrolle)
- Capacitor is used to tune the operating circuit to the fundamental frequency component
- This scheme is suitable for 7/0.029 pilot loops up to 400Ω.

5.

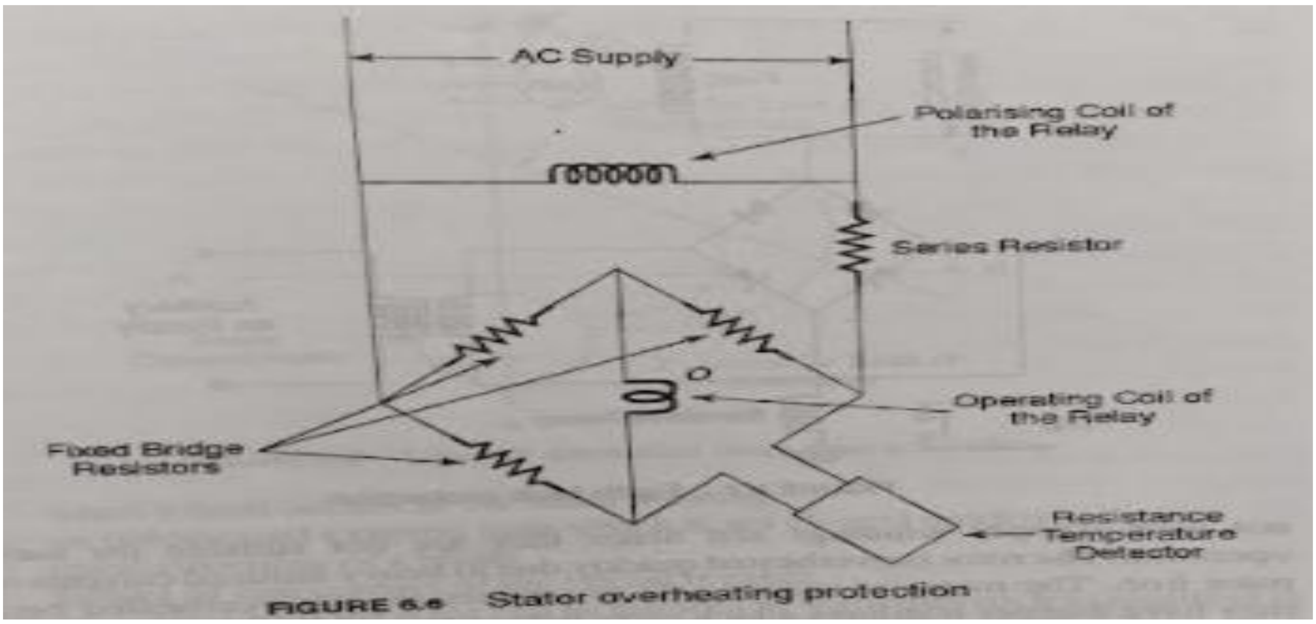

FIGURE 6.6 Stator overheating protection

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.

6.a

Solution:

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

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

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

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

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

$$K = 0.1 \Rightarrow K I_r = 0.1 \times 2.75 = 0.275\,A$$

For relay operation; $I_d > K I_r$.

So relay operates and trip the C.B.

6. b

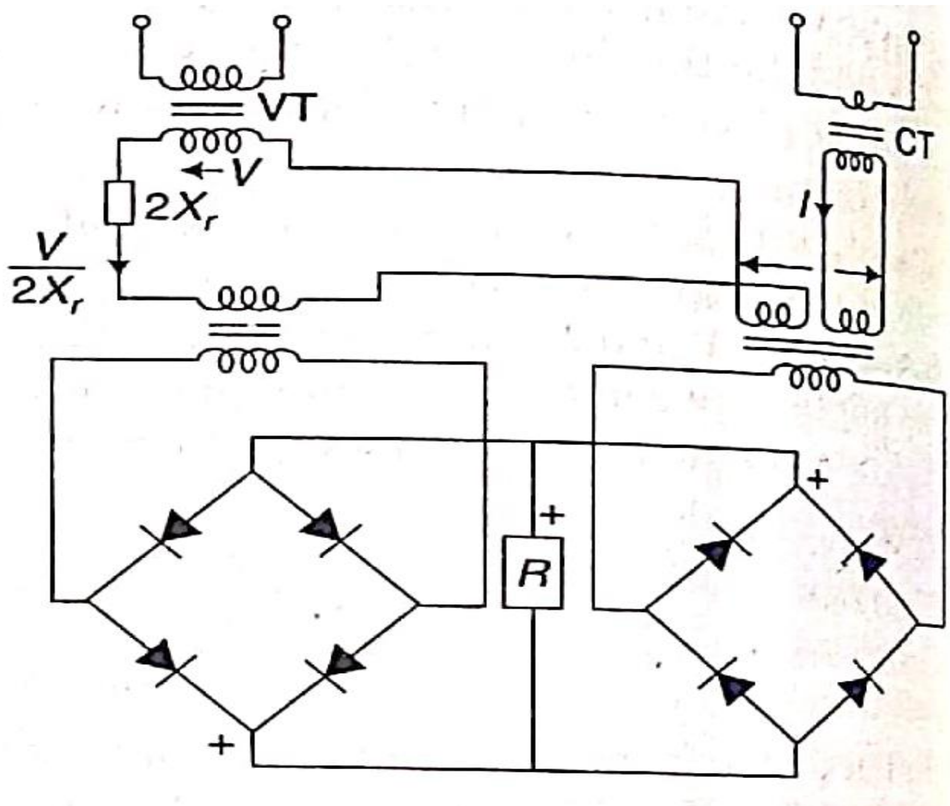

Fig. 6.17 Static reactance relay

Static Reactance Relay:

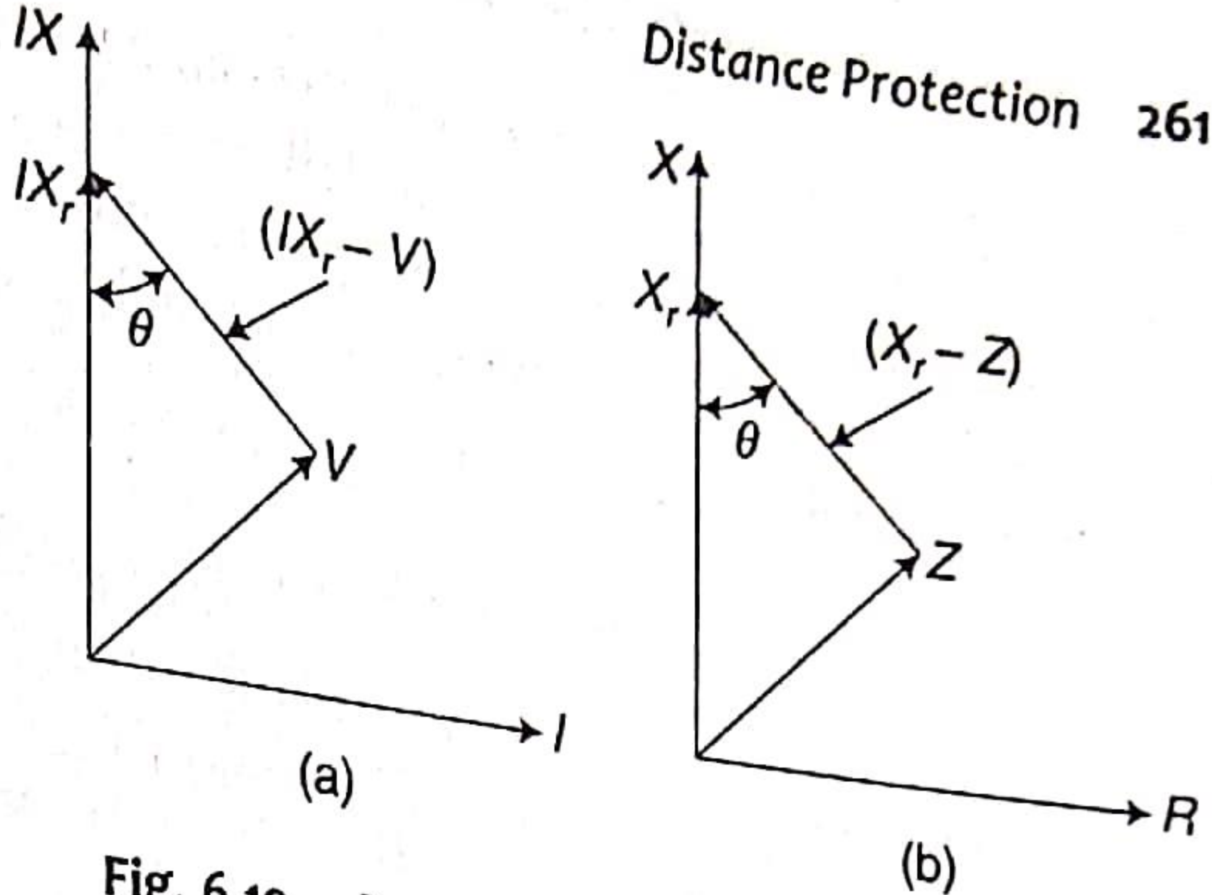

Fig. 6.19 Realisation of reactance relay by comparing IX_r and $(IX_r - V)$

MHO relay:

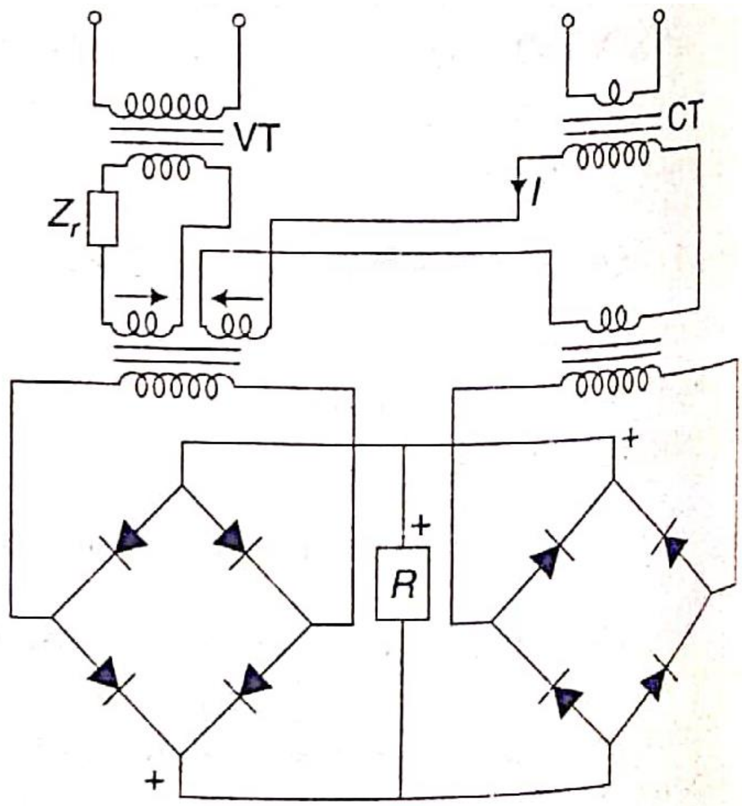

Fig. 6.23 *Schematic diagram of a static MHO relay*

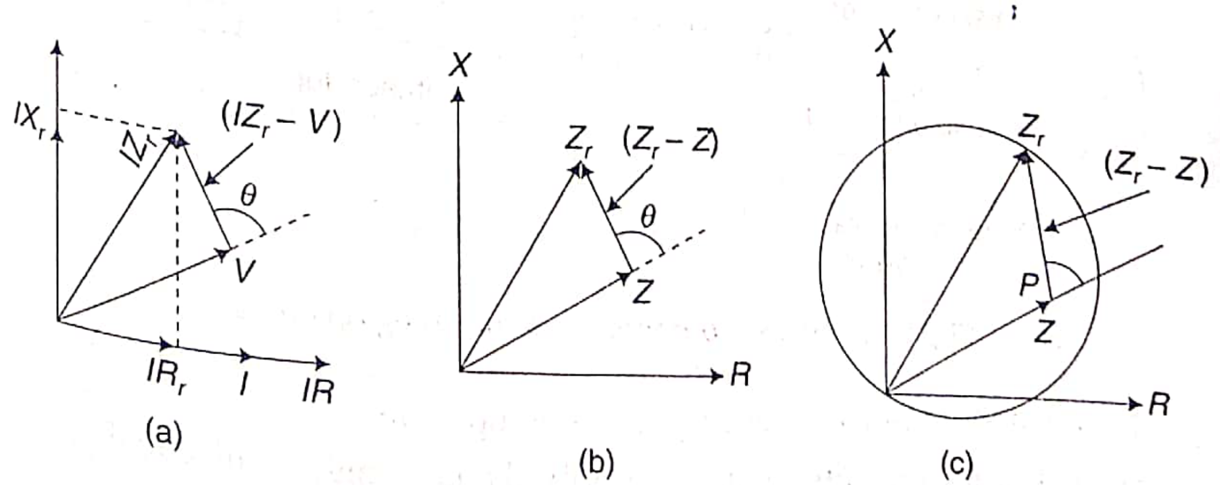

Fig. 6.25 *(a) Phasor diagram showing V, I and voltage drop (b) Impedance diagram (c) MHO characteristic*

MHO relay