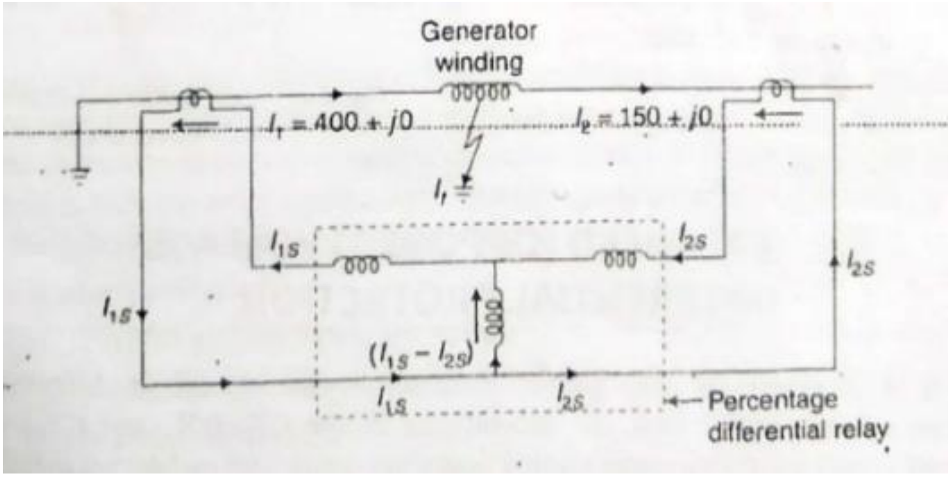
CMR INSTITUTE OF TECHNOLOGY	USN										

Internal Assesment Test - II

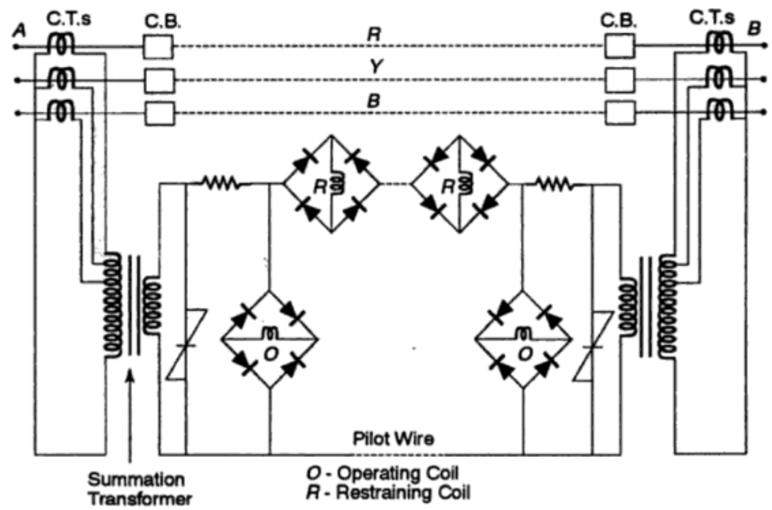
Sub:	POWER SYSTEM PROTECTION							Code:	17EE72
Date:	04/11/2020	Duration:	90 mins	Max Marks:	50	Sem:	7th(A & B)	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1a	What are the important operating principles which are used in wire pilot scheme? With schematic diagram explain the circulating current principle.	[6]	CO3	L2
1b	Explain the working principle of Buchholz relay used for the protection of transformer.	[4]	CO4	L2
2a	With a neat sketch explain frame leakage protection scheme.	[6]	CO4	L2
2b	With schematic diagram explain the protection of stator against overheating in an alternator.	[4]	CO4	L2
3a	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? 	[6]	CO4	L4
3a	Define Over Reach and Under Reach.	[4]	CO2	L1
4	With a neat circuit diagram explain the construction and working of MHO Relay.	[10]	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.	[4]	CO4	L3
5b	Explain the effect of Line length and source impedance on the performance of distance relay.	[6]	CO2	L1

6a	What is simple differential protection scheme? Explain its behavior during normal condition.	[4]	CO2	L2
6b	With a neat circuit diagram explain the construction and working of Impedance Relay.	[6]	CO2	L2
7a	With a neat circuit diagram explain the construction and working of Reactance Relay in details.	[5]	CO2	L2
7b	Explain the effect of power surge on the performance of distance relay.	[5]	CO2	L2

1 (a) The operating principles used for wire pilot protection are circulating current scheme and Balanced (or Opposed Voltage) scheme (1 mark) [CO3, L2]



Practical scheme based on circulating current principle

(2 marks)

Explanation – 3 marks

1(b) [CO4, L2]

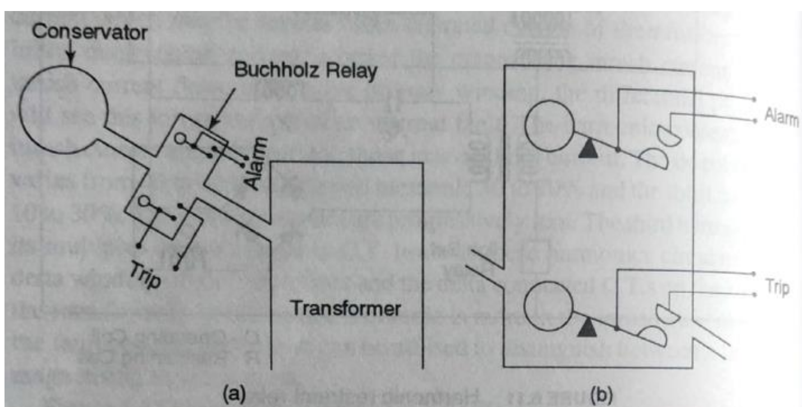


FIGURE 6.12 (a) Transformer tank, Buchholz relay and conservator
(b) Buchholz relay

(2 marks)

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.

Explanation- (2 marks)

2(a) [CO4, L2]

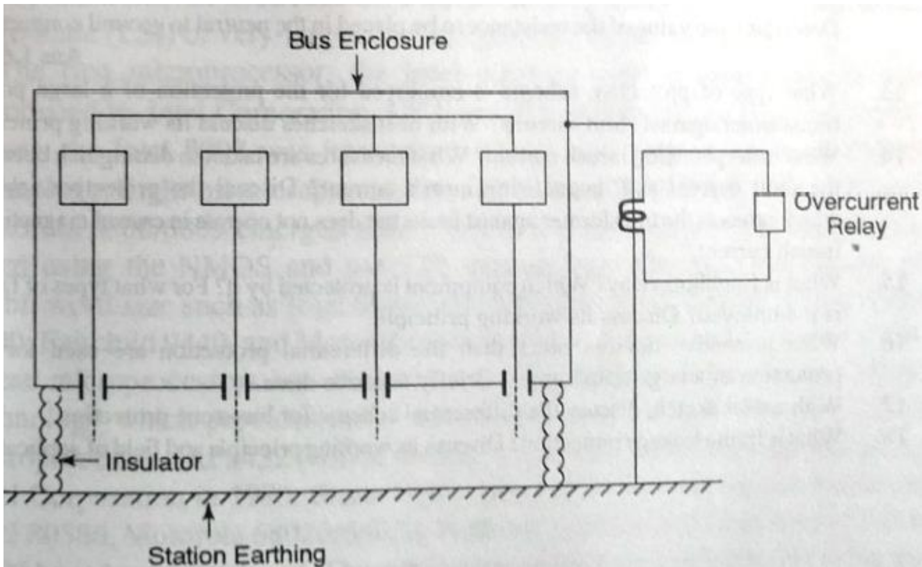


FIGURE 6.22 Frame leakage protection

(2 marks)

6.4 Frame Leakage Protection

Figure 6.22 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.

(4 marks)

2(b) [CO4, L2]

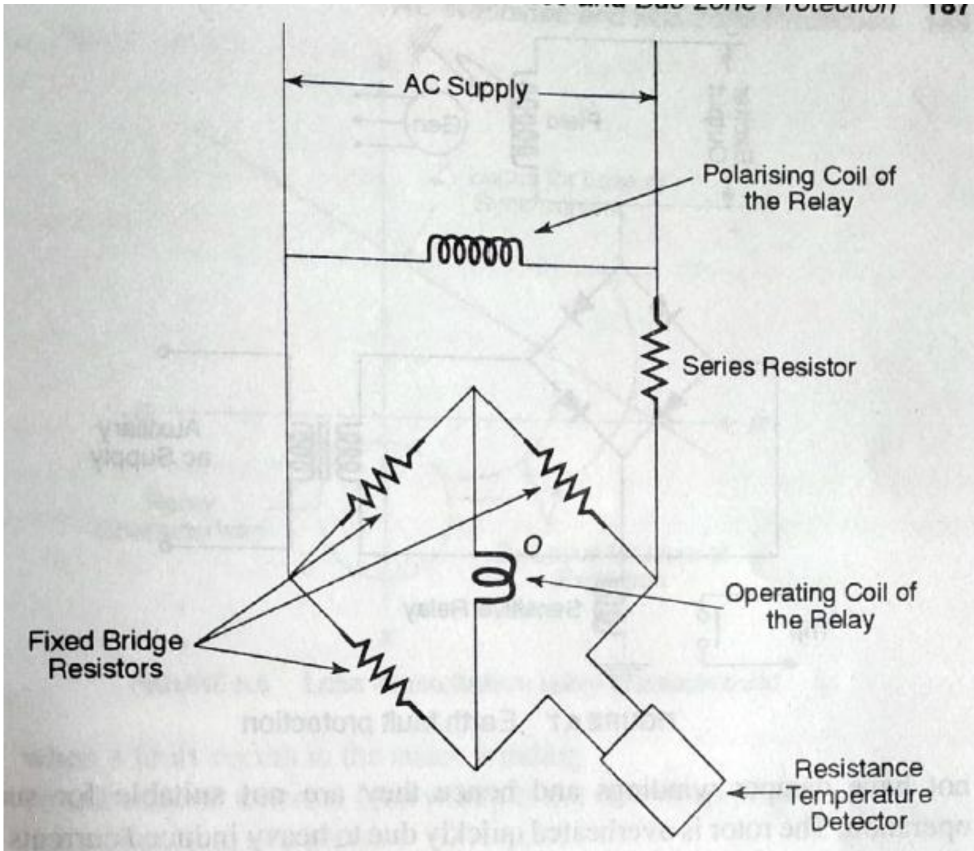


FIGURE 6.6 Stator overheating protection

(2 marks)

(c) 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 6.6 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.

(2 marks)

3(a) [CO4, L4]

Solution:

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

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

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

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

(3 marks)

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

$K = 0.1 \implies K I_r = 0.1 \times 2.75 = 0.275\text{A}$

For relay operation; $I_d > K I_r$.

So relay operates and trip the C.B.

(3 marks)

3 (b) [CO2, L1]

The tendency of a Reach of Distance Relay to operate at impedance larger than its setting value is known as **overreach** and similarly the tendency to restrain at the set value of impedance or impedances lower than the set value is known as **underreach**.

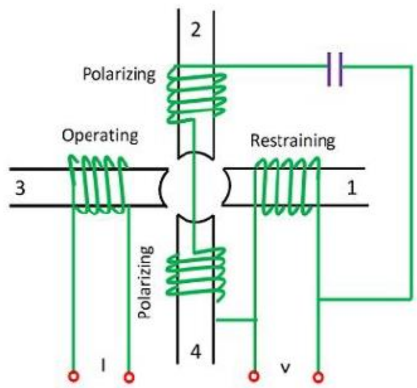
(4 marks)

4.

[CO2, L2]

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

(3 marks)

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

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

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

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

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

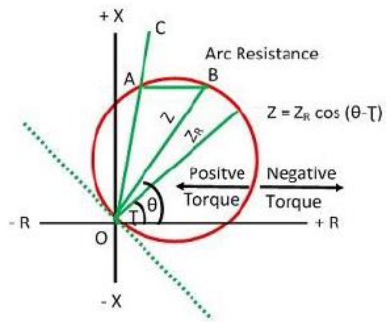
$$Z = \frac{K_1}{K_2} \text{Cos}\,(\theta - \tau)$$

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

(3 marks)

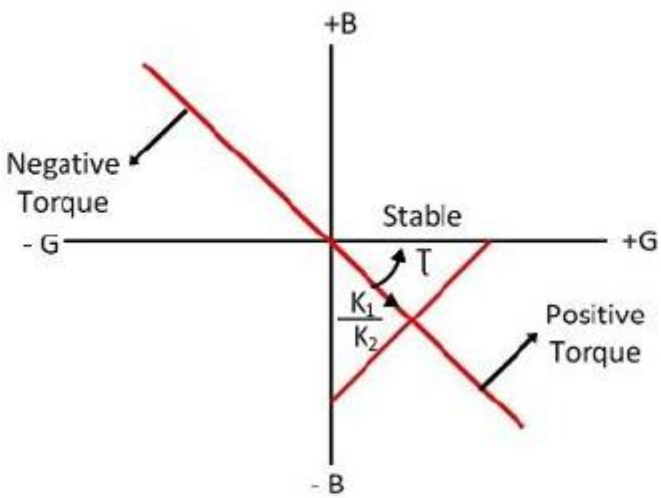
Operating Characteristic of Mho Relay

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

(3 marks)



Characteristic of Mho Type Relay on Admittance Diagram

(1 mark)

5 (a) [CO4, L3]

Solution:

Current at which relay operates =

$$\frac{10 \times 10^{6}}{\sqrt{3} \times 13.2 \times 10^{3}} \times \frac{20}{100} = 87.477\ A.$$

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

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

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

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

$$R = 13.068\,\Omega$$

(4 marks)

5(b) [CO2, L1]

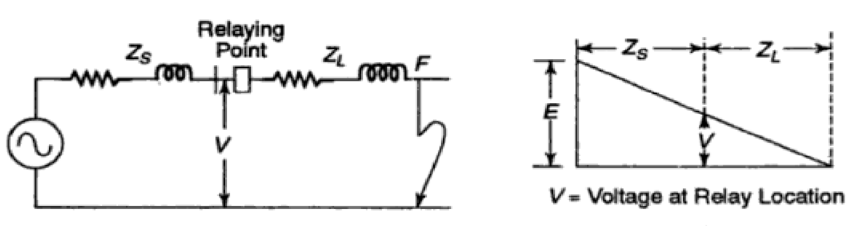


FIGURE 4.46 (a) Oneline diagram of the system during fault condition
(b) Voltage at the relaying point

(1 mark)

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

The voltage at the relay location which is applied to the distance relay is

$$V = IZ_L = \frac{EZ_L}{Z_S + Z_L}$$

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

(2 marks)

We can find the limiting value of Z_S/Z_L for $V = 8$ V.

$$8 = \frac{E}{\frac{Z_S}{Z_L} + 1}$$

E can be taken equal to the normal secondary C.T. voltage, which is 110 V

$$8 = \frac{110}{\frac{Z_S}{Z_L} + 1}$$

$$\frac{Z_S}{Z_L} = \frac{110}{8} - 1 = 13.75 - 1 \cong 13$$

If the value of 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 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. Z_S is constant for the system under consideration. The value of Z_L depends on the position of the fault point.

(2 marks)

The relay will fail to operate if

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

or

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

Thus, there is a minimum length of the line, below which the relay cannot protect the line. If the fault point is too close to the relay location, such that Z_L is less than $Z_S/13$, the relay will fail to operate.

Modern induction cup relays can operate down to 3 volts. Corresponding to this value of voltage, $Z_S/Z_L = 36$ V. The relay will fail to operate if

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

For a rectifier bridge comparator with a sensitive polarised relay, the minimum operating voltage is 3.5 V, and correspondingly, $Z_S/Z_L \cong 30$.

(1 mark)

6 (a) [CO2-L2]

8.3 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.

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 $(I'_L) = I_L/n$.

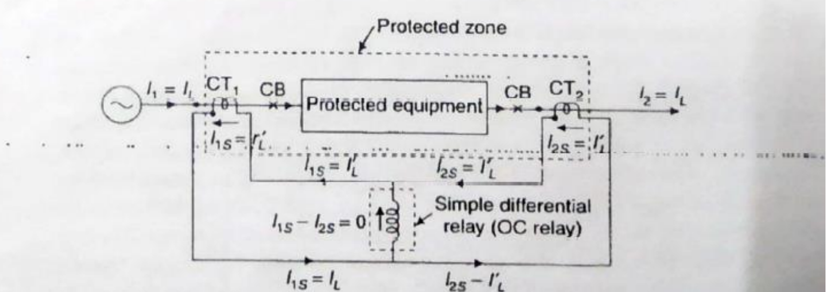


Fig. 8.1 *Simple differential protection scheme behaviour under normal condition.* $(I_1 = I_2 = I_L$ *and* $I_{1S} = I_{2S} = I_L$, *hence* $I_{1S} - I_{2S} = 0)$

(2 MARKS)

Figure 8.1 shows the combination of the two CTs and an instantaneous overcurrent relay (acting as simple differential relay) in the difference or spill circuit, as the constituents of the simple differential protection scheme. The normally open contacts of this overcurrent (OC) relay are wired to trip the circuit breakers. Under normal conditions the secondary currents I_{1S} and I_{2S} of CT_1 and CT_2 respectively are equal to the secondary load current I_L'. The secondary currents, under normal conditions, simply circulate through the secondary windings of the two CTs and the pilot leads connecting them, and there is no current through the spill or difference circuit, where the instantaneous overcurrent (OC) relay is connected. Hence, the OC relay does not operate to trip the circuit breakers (CBs). Since the currents circulate in the CT secondaries this differential protection scheme is called "circulating current differential protection scheme" or "Merz-Price protection scheme". The boundaries of the protected zone is determined by the locations of the CTs.

(2 MARKS)

6(b) [CO2, L2]

Principle of Operation of Impedance Relay

In the normal operating condition, the value of the line voltage is more than the current. But when the fault occurs on the line the magnitude of the current rises and the voltage becomes less. The line current is inversely proportional to the impedance of the transmission line. Thus, the impedance decreases because of which the impedance relay starts operating.

The figure below explains the impedance relay in much easier way. The potential transformer supplies the voltage to the transmission line and the current flows because of the current transformer. The current transformer is connected in series with the circuit.

Consider the impedance relay is placed on the transmission line for the protection of the line AB. The Z is the impedance of the line in normal operating condition. If the impedances of the line fall below the impedance Z then the relay starts working.

Let, the fault F1 occur in the line AB. This fault decreases the impedance of the line below the relay setting impedance. The relay starts operating, and its send the tripping command to the circuit breaker. If the fault reached beyond the protective zone, the contacts of the relay remain unclosed.

(2 marks)

Operating Characteristic of an Impedance Relay

The voltage and the current operating elements are the two important component of the impedance relay. The current operating element generates the deflecting torque while the voltage storage element generates the restoring torque. The torque equation of the relay is shown in the figure below

$$T = k_1 I^2 - k_2 V^2 - k_3$$

The $-K_3$ is the spring effect of the relay. The V and I are the value of the voltage and current. When the relay is in normal operating condition, then the net torque of the relay becomes zero.

$$k_2 V^2 = k_1 I^2 - k_3$$

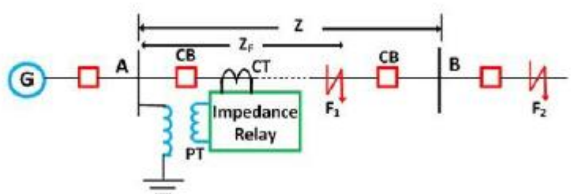
$$\frac{V}{I} = Z = \sqrt{\frac{k_1}{k_2} - \frac{k_3}{k_2 I^2}}$$

If the spring control effect becomes neglected, the equation becomes

$$Z = \sqrt{\frac{k_1}{k_2}} = Constant$$

(2 marks)

The operating characteristic concerning the voltage and current is shown in the figure below. The dashed line in the image represents the operating condition at the constant line impedance.

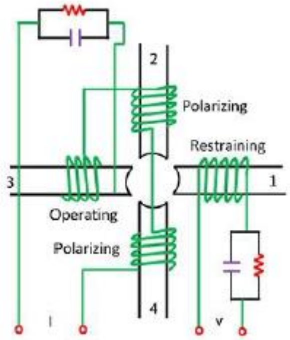


Principle of operation of an Impedance Relay

The operating characteristic of the impedance relay is shown in the figure below. The positive torque region of the impedance relay is above the operating characteristic line. In positive torque region, the impedance of the line is more than the impedance of the faulty section. Similarly, in negative region, the impedance of the faulty section is more than the line impedance

(2 marks)

7 (a) [CO2, L2]



Reactance Type Distance Relay

Circuit Globe

The operating torque will be proportional to the square of the current while the restraining torque will be proportional to VI cos (Θ – 90°). The desired maximum torque angle is obtained with the help of resistance-capacitance circuits, as illustrated in the figure. If the control effect is indicated by $-k_3$, the torque equation becomes

(1 marks)

$$T = K_1 I^2 - K_2 VIcos(\theta - 90^{\circ}) - K_3$$

$$T = K_1 I^2 - K_2 sin\theta - K_3$$

where Θ, is defined as positive when I lag behind V. At the balance point net torque is zero, and hence

$$K_1 I^2 - K_2 VIcos(\theta - 90^{\circ}) - K_3$$

$$K_1 I^2 = K_2 VIsin\theta + K_3$$

$$K_1 = K_2 \frac{V}{I} sin\theta + \frac{K_3}{I^2}$$

$$\frac{V}{I} sin\theta = \frac{K_1}{K_2} - \frac{K_3}{K_2 I^2}$$

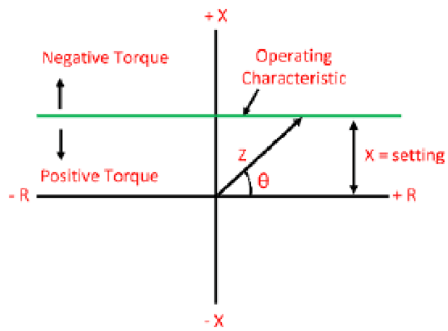
$$Zsin\theta = \frac{K_1}{K_2}$$

The spring control effect is neglected in the above equation, i.e., $K_3 = 0$.

(2 marks)

Operating Characteristic of Reactance Relay

The operating characteristic of a reactance relay is shown in the figure below. X is the reactance of the protected line between the relay location and the fault point, and R is the resistance component of the impedance. The characteristic shows that the resistance component of the impedance has no consequence on the working of the relay, the relay reacts solely to the reactance component. The point below the operating characteristic is called the positive torque region.

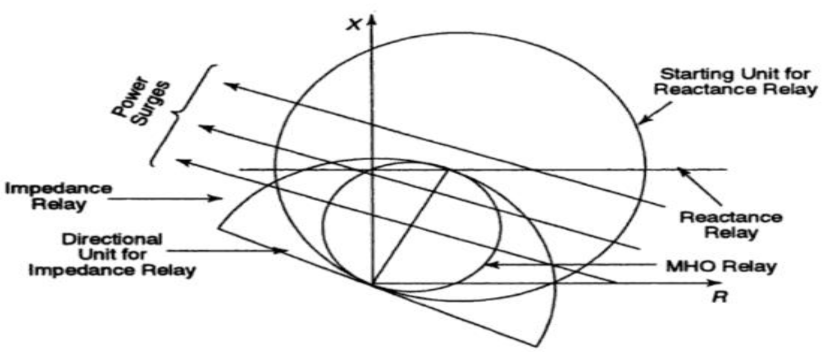


Operating Characteristic of Reactance Type Distance Relay

If the value of τ, in the general torque equation, expressed below is made any other 90º, a straight line characteristic will still be obtained, but it will not be parallel to R-axis. Such a relay is called an angle impedance relay.

(2 marks)

7 (b) [CO2, L2]



(2 marks)

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

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

$$V = E_A - IZ_A$$

The impedance 'seen' by the relay is given by

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

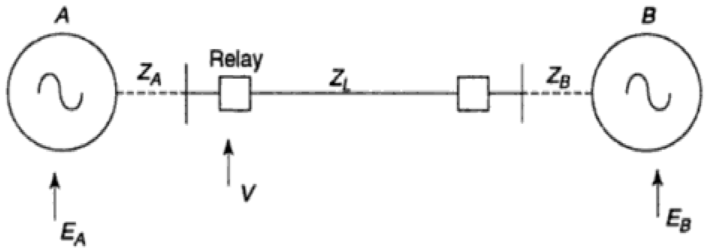


FIGURE 4.39 One line diagram of a system to illustrate loss of synchronism

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

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

(3 marks)