CMR INSTITUTE OF TECHNOLOGY

USN

Internal Assessment Test - II

Sub:	POWER SYSTEM PROTECTION							Code:	18EE72
Date:	02/12/2022	Duration:	90 mins	Max Marks:	50	Sem:	7th A & B	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1.a	Explain operating principle and characteristics (R-X diagram) of an impedance relay.	10	CO2	L2
2.a	Draw and explain 3 stepped distance protection of transmission line.	6	CO4	L2
2.b	The neutral point of an 11KV an alternator is earthed through a resistance of 12Ω the relay is said to operate when there is out of balance of a 0.8A. The CT's have a ratio of 2000/5.What percentage of the winding is protected against earth fault? What must be the minimum value of earthing resistance required to give 90% of protection to earth phase.	4	CO4	L3
3.a	Define Over Reach and Under Reach.	4	CO2	L1
3.b	Explain the effect of Line length and source impedance on the performance of distance relay.	6	CO2	L2
4.a	What is simple differential protection scheme? Explain its behaviour during normal condition.	5	CO3	L2

P.T.O

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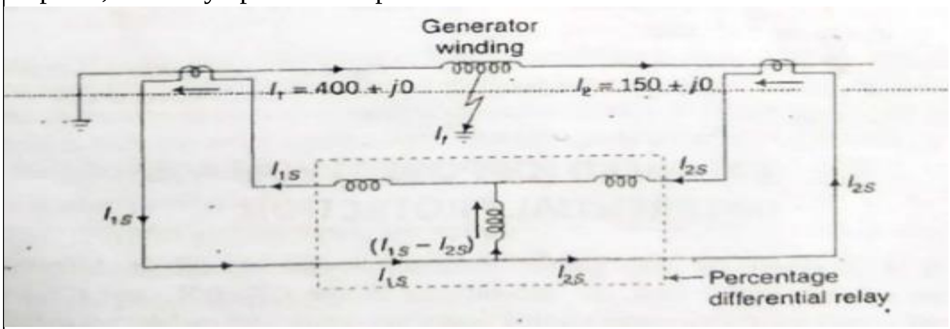
5.b	With schematic diagram, explain protection of stator against overheating in an alternator.	4	CO4	L2
6.a	A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding 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	CO4	L3
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CCI **HOD**

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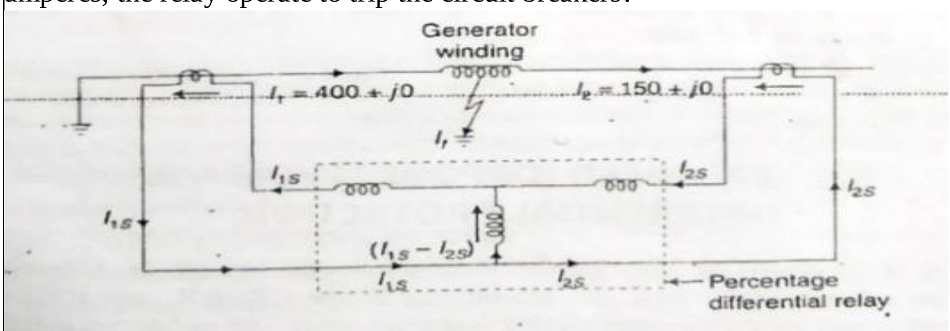
6.a	A generator winding is protected by using a percentage differential relay whose characteristics is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding while generator is carrying load. As a consequence, the currents flowing at each end of the winding are shown if fig.1. Assuming CT ratios of 500/5 amperes, the relay operate to trip the circuit breakers?  	4	CO4	L3
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Q.1.

Definition: The relay whose working depends on the distance between the impedance of the faulty section and the position on which relay installed is known as the impedance relay or distance relay. It is a voltage controlled equipment.

The relay measures the impedance of the faulty point, if the impedance is less than the impedance of the relay setting, it gives the tripping command to the circuit breaker for closing their contacts. The impedance relay continuously monitors the line current and voltage flows through the CT and PT respectively. If the ratio of voltage and current is less than the relay starts operating then the relay starts operating.

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.

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 The -K 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. If the spring control effect becomes neglected, the equation becomes 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. 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 The impedance of the line is represented by the radius of the circle. The phase angle between the X and R axis represents the position of the vector. If the impedance of the line is less than the radius of the circle, then it shows the positive torque region. If the impedance is greater than the negative region, then it represents the negative tor

$$T = K_1 I^2 - K_2 V^2 - K_3$$

que region.

z

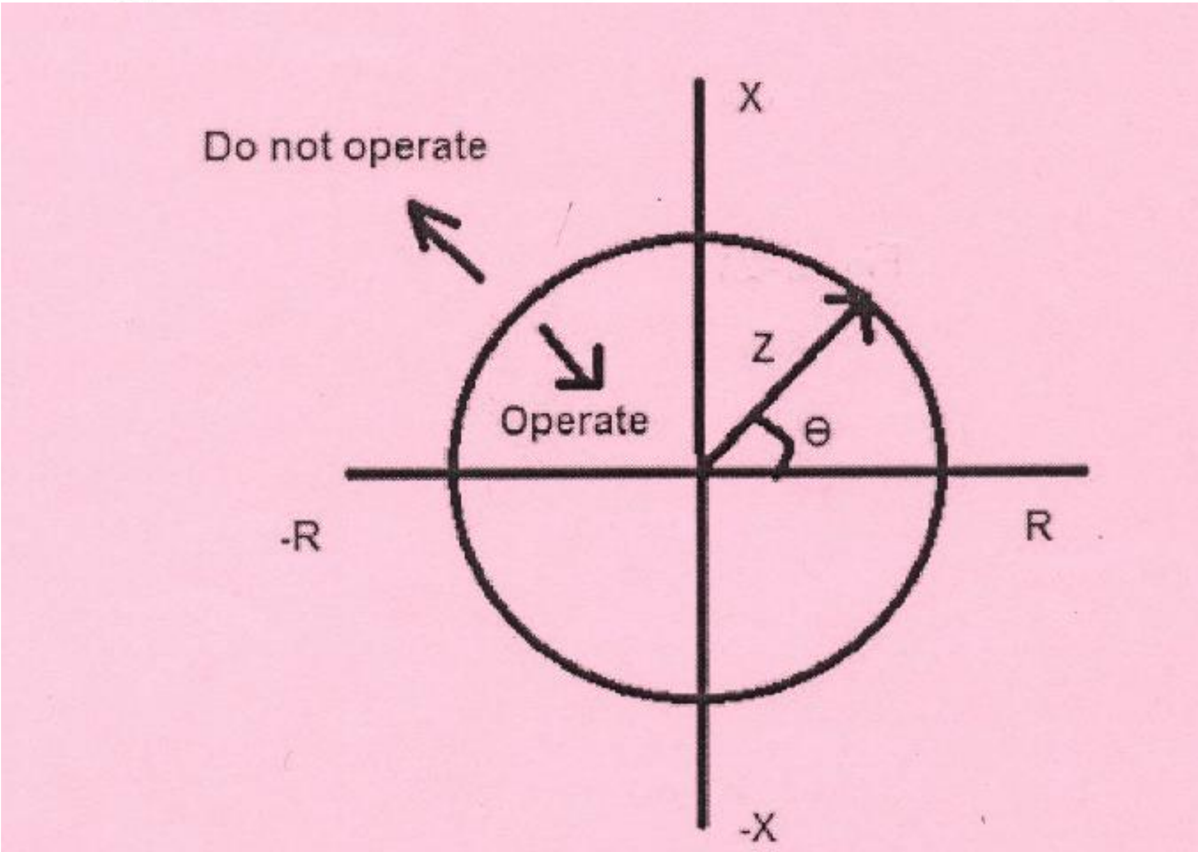
$$T = K_1 I^2 - K_2 V^2$$

$$K_1 I^2 > K_2 V^2 \quad \text{(or)} \quad K_2 V^2 < K_1 I^2$$

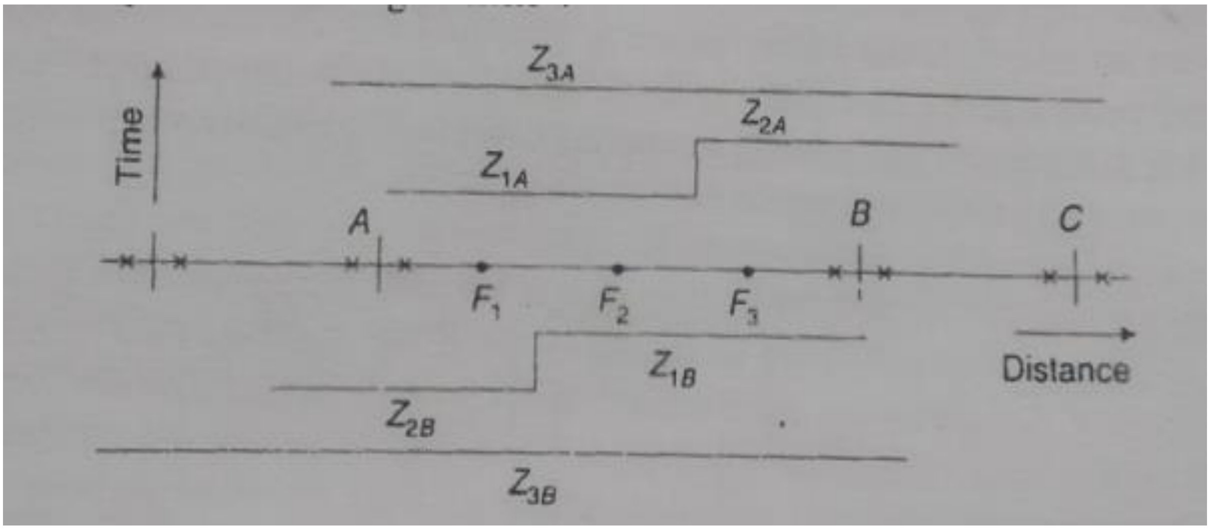
$$\frac{V^2}{I^2} < \frac{K_1}{K_2}$$

$\frac{V}{I} < K$ where K is a constant

$Z < K$ Z is a constant



Q.2 a



Q.2 b

1° current in CT = ?

out of balance current = 0.8 in pilot wire

$1^\circ I$ in CT = CT ratio × 0.8

$$= \frac{2000}{5} \times 0.8$$

$$I_0 = 320\ A$$

$$\%\ \text{winding unprotected} = \frac{R \times I_0}{V} \times 100$$

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{11000}{\sqrt{3}} = 6{,}350.85$$

$$R = 12\ \Omega$$

$$\%\ \text{unprotected} = \frac{12 \times 320}{6350.85} \times 100$$

$$= 60\%$$

∴ % of winding protected = 100 − 60

$$= 40\%.$$

Q.3 a

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**.

$$Z_{sec} = Z_{prm}\left(\frac{\text{CT ratio}}{\text{PT ratio}}\right)$$

To convert primary impedance (impedance of the line referred to the line voltage and current) to a secondary value (line impedance referred to the relay side) for use in adjusting a distance relay the following relation is used: where the CT ratio is the ratio of the HV phase current to the relay phase current, and the PT ratio is the ratio of the HV phase-to-phase voltage to the relay phase-to-phase voltage all under balanced conditions.
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**.
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:

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

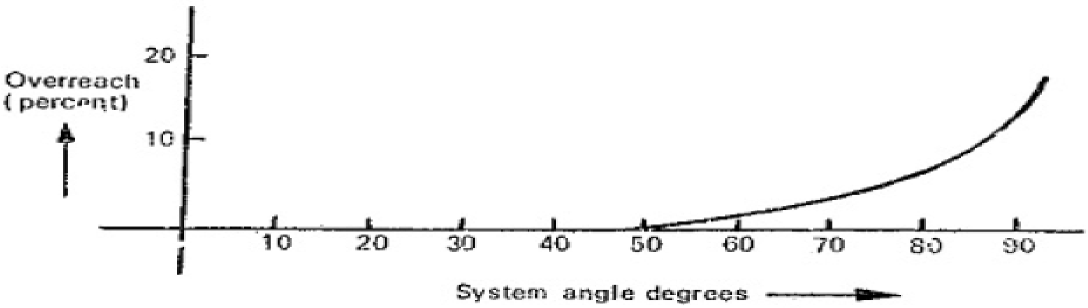


FIGURE 5.20 Overreach characteristics.

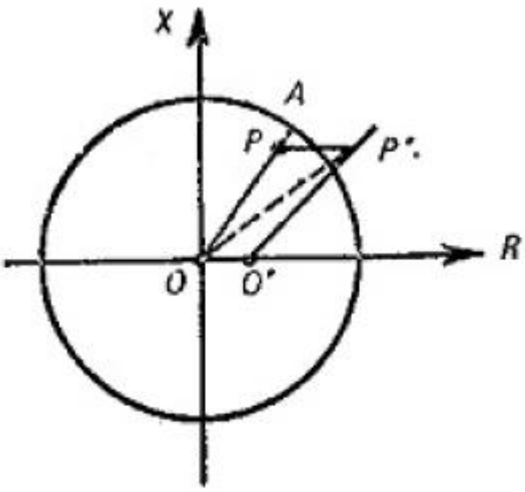


FIGURE 5.21 Underreach of distance relay.

Q. 3.b

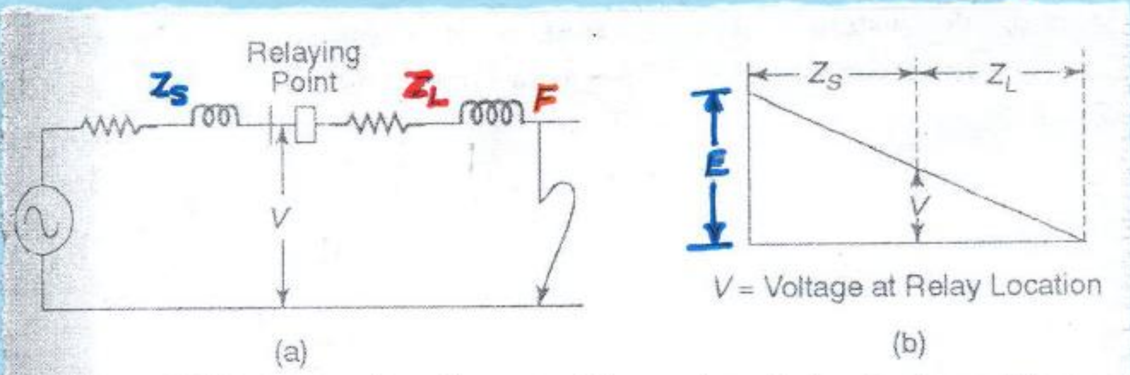


FIGURE 2.35 (a) Oneline diagram of the system during fault condition
(b) Voltage at the relaying point

→ 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

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

→ Relay manufactorers specify the minimum voltage for the relay operation

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

→ ∴ $$8 = \frac{E}{\frac{Z_s}{Z_L} + 1}$$

E → can be taken as normal 2° CT voltage → 110V

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

41.

$$\left(\frac{Z_S}{Z_L} + 1\right) = \frac{110}{8}$$

$$\therefore \frac{Z_S}{Z_L} = \frac{110}{8} - 1 = 13.75 - 1 = 12.75 \cong 12$$

→ If the value of $\frac{Z_S}{Z_L}$ is less than 12, 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 12, 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 $$\frac{Z_S}{Z_L} > 12$$

or $$Z_L < \frac{Z_S}{12}$$

→ 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 $\frac{Z_S}{Z_L} \cong 36V$. That relay will operate

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

→ if min Voltage is 3.5V, $\frac{Z_S}{Z_L} \cong 30V$.
42.

Q.4.a

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

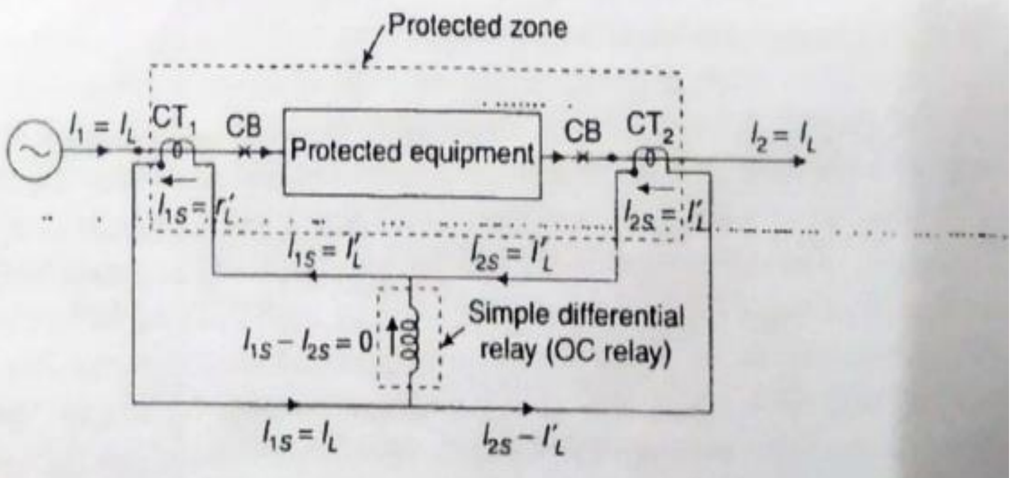


Fig. 8.1 *Simple differential protection scheme behaviour under normal condition.* *($I_1 = I_2 = I_L$ and $I_{1S} = I_{2S} = I_L$, hence $I_{1S} - I_{2S} = 0$)*

Q.4.b

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.

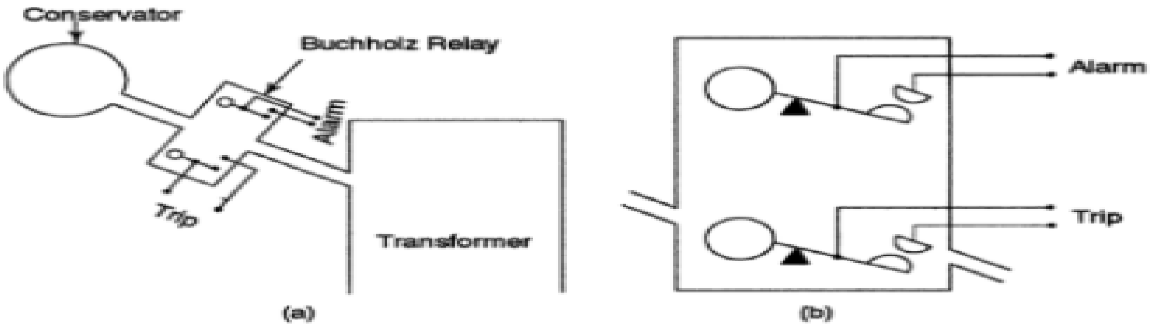


FIGURE 6.12 (a) Transformer tank, Buchholz relay and conservator
(b) Buchholz relay

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.

Q.5.a

PROTECTION AGAINST MAGNETIC INRUSH CURRENT

* When an unloaded transformer is switched on, it draws a large initial magnetising current which may be several times the rated current of transformer.
* This initial magnetising current is called magnetising inrush current.
* This inrush current flows in primary winding, hence the differential protection will see the inrush current as an internal fault.
* The inrush current have a high component of even & odd harmonics.

Harmonic component in magnetizing current.	Amplitude as % of fundamental
2nd	63.0
3rd	26.8
4th	5.1
5th	4.1
6th	3.7
7th	2.4

* 3rd harmonic and its multiples do not appear in CT leads as they circulate in delta winding of transformer. & if transformer is star, they circulate in delta of their CT.

* 2nd harmonic is more in inrush current than the fault current, hence we can easily distinguish inrush current & fault current from each other.

→ Fig 3.28 shows a high speed biased differential scheme.

→ Harmonic restraint relay is made insensitive to magnetic inrush current.

→ The operating principle is to filter out the harmonics from the differential current, then rectify them.

→ Operating coil of the relay receives only fundamental component of current only. The restraining coil receives rectified sum of fundamental component and harmonic component.

→ Thereby inrush current have more harmonic content and thus it gives more restraining Torque. and do not operate.

→ Tune circuit Xc XL allows only current of fundamental frequency to flow through the operating coil.

→ DC & harmonics (2nd harmonics) in case of magnetic inrush are diverted into restraining coil.

→ Relay operates when 2nd harmonic exceeds the fundamental current (15%). Minimum operating time is about 2 cycles.

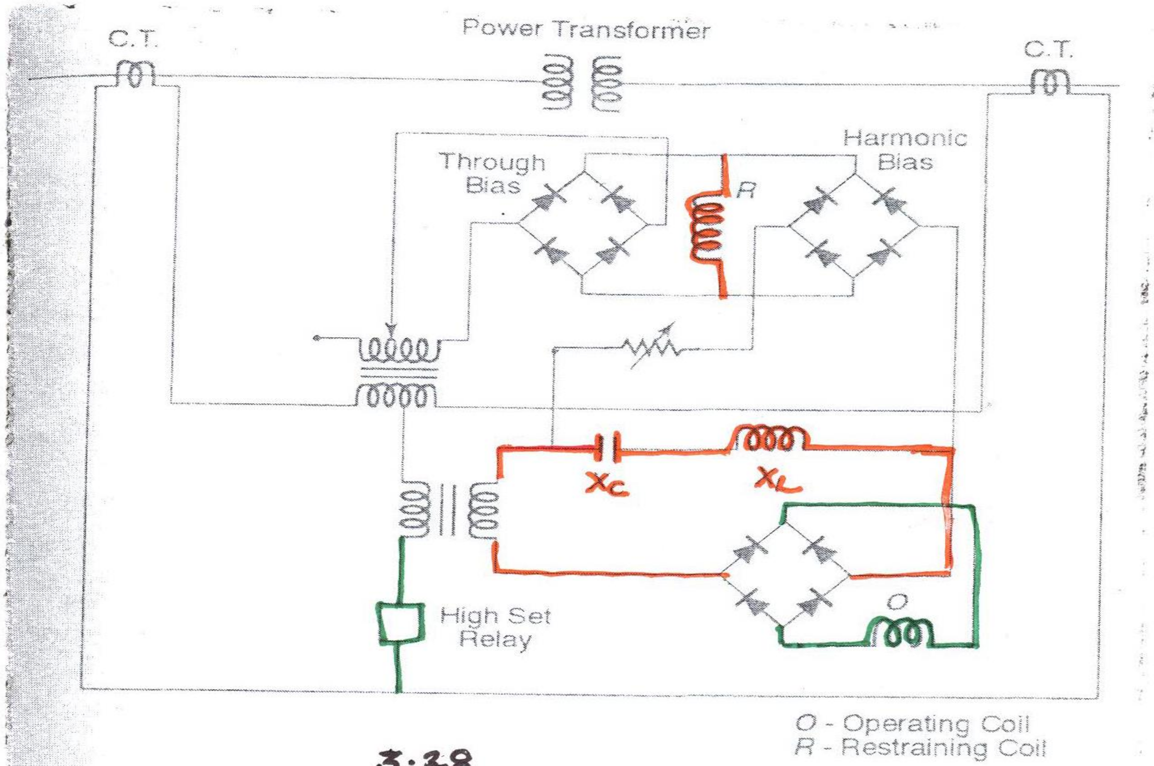


FIGURE 3.28 Harmonic restraint relay

Q.5.b

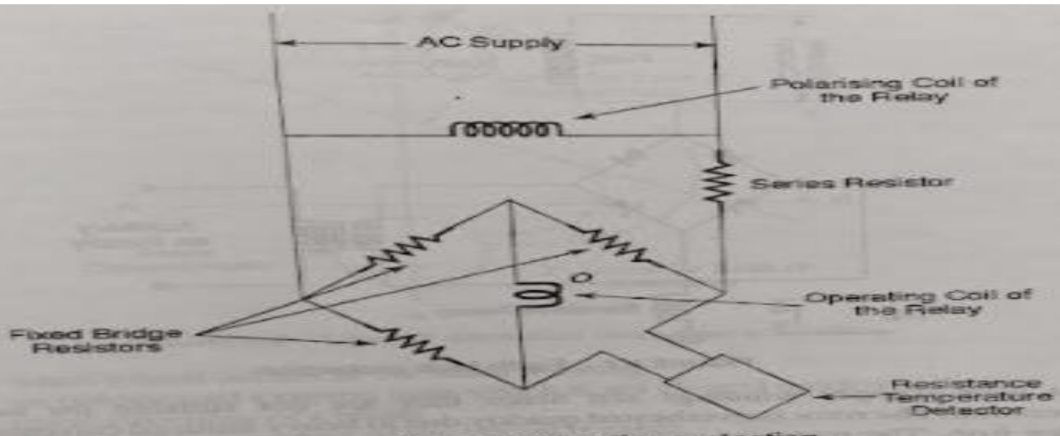


FIGURE 6.6 Stator overheating protection

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.

Q. 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.

$k = 0.1 \Rightarrow kI_r = 0.1 \times 2.75 = 0.275$ A

For relay operation; $I_d > kI_r$.

So relay operates and trip the C.B.

Q.6.b

BALANCED VOLTAGE DIFFERENTIAL PROTECTION

* Fig 3.18 shows the principle of differential Protection based on balanced voltage principle.
* In this scheme CT 2^0 are connected such that for normal condition & through fault conditions, 2^0 currents of CT's on both sidest oppose each other and their voltage are balanced.
*

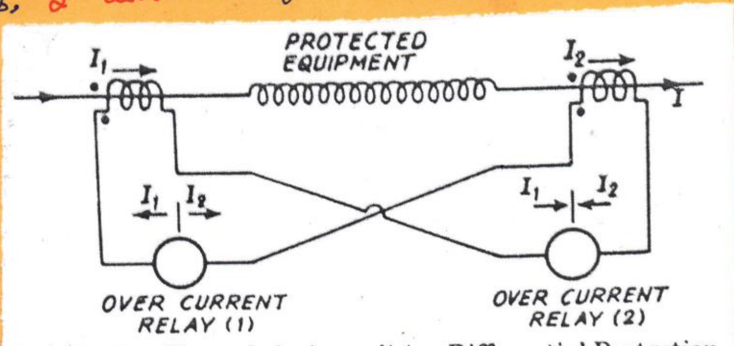


Fig. 3.18 . Through fault condition Differential Protection based on balanced voltage principle.

* During internal fault, 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.

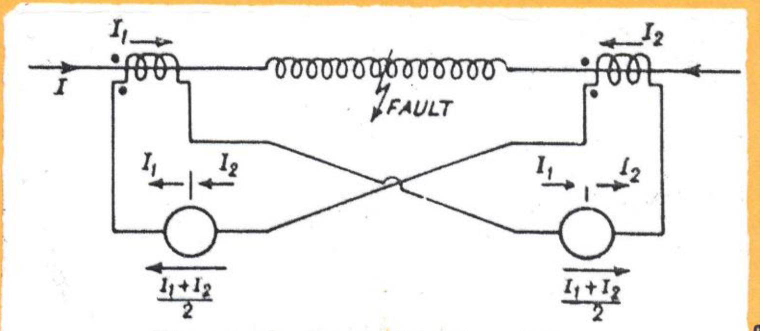


Fig. 3.19 . Internal fault condition.

* CTs used in such protection are with air gap core so that core do not get saturated and overvoltages are not produced during zero 2^0 current under normal working conditions.