Modified

CBCS SCHEME

USN | | | | | | | | | | 17EE72

# Seventh Semester B.E. Degree Examination, Jan./Feb.2021
# Power System Protection

Time: 3 hrs. Max. Marks: 100

**Note:** ***Answer any FIVE full questions, choosing ONE full question from each module.***

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

## Module-1

1 a. With a neat diagram, explain zones of protection in a power system. **(06 Marks)**
b. Derive an expression for torque produced by an induction relay. **(08 Marks)**
c. List the merits and demerits of static relays. **(06 Marks)**

**OR**

2 a. Draw a neat sketch of an induction disc relay and discuss its operating principle. **(07 Marks)**
b. What are the various types of over current relays? Discuss their area of applications. **(06 Marks)**
c. Describe the realization of a overcurrent relay using numerical technique. Show its flowchart with neat diagram. **(07 Marks)**

## Module-2

3 a. With a neat schematic diagram, explain the construction and working of static reactance relay using an amplitude comparator. **(08 Marks)**
b. With a neat sketch, explain the construction and working principle of induction disc type reverse power relay. **(08 Marks)**
c. With neat diagram, explain induction cup type impedance relay. **(04 Marks)**

**OR**

4 a. Draw and explain the circuit connections of three MHO units used at a particular location for three zones of protection. **(07 Marks)**
b. With neat connection diagrams, explain the working of directional earth fault relay. **(07 Marks)**
c. With neat diagram, explain static impedance relay using amplitude comparator. **(06 Marks)**

## Module-3

5 a. With neat diagram, explain percentage differential protection of star-delta connected transformer. **(08 Marks)**
b. With neat diagram, explain the working of Buccholz relay. **(05 Marks)**
c. An 11 kV, 150 MVA alternator is provided with differential protection. The percentage of winding to be protected against phase to ground fault is 80%. The relay is set to operate when there is 20% out of balance current. Determine the value of the resistance to be placed in the neutral to ground protection. **(07 Marks)**

**OR**

6 a. Define the term 'pilot' with reference to power line protection. List the different types of wire pilot protection schemes and explain any one of the schemes. **(08 Marks)**
b. With neat diagram, explain harmonic restraint relay used to protect against magnetizing inrush current of transformer. **(08 Marks)**
c. With a neat circuit diagram, explain rotor earth fault protection of alternator. **(04 Marks)**

## Module-4

7 a. In a 132 kV system, reactance and capacitance upto the location of the circuit breaker is 4Ω and 0.02 μF respectively. A resistance of 500 Ω is connected across the break of the C.B. Determine the (a) natural frequency of oscillation (b) damped frequency of oscillation. (c) critical value of resistance. **(08 Marks)**

b. Explain working of $SF_6$ circuit breaker with the help of diagrams. Write two of its advantages. **(08 Marks)**

c. Explain recovery rate theory to explain the zero current interruption of the arc. **(04 Marks)**

**OR**

8 a. Derive expressions for restriking voltage and RRRV in terms of system voltage, inductance and capacitance during fault on feeder. **(08 Marks)**

b. With neat circuit diagram, explain the synthetic testing of circuit breaker. **(06 Marks)**

c. With neat diagram, explain Air-break circuit breaker. Write any two of its applications. **(06 Marks)**

## Module-5

9 a. Describe the construction and operation of the HRC cartridge fuse with indicator. Write any four of advantages of HRC fuses. **(08 Marks)**

b. Describe the phenomenon of lightning and explain the terms pilot streamer, stepped leader, return streamer, dart leader, cold lightning stroke and hot lightning stroke. **(08 Marks)**

c. Write short note on Arcing horn with diagram. **(04 Marks)**

**OR**

10 a. Describe the construction and principle of operation of valve type lightning arrester with detailed diagram. **(08 Marks)**

b. Write note on klydonograph and magnetic link. **(06 Marks)**

c. Describe the protection of stations and sub-stations against direct lightning strokes. **(06 Marks)**

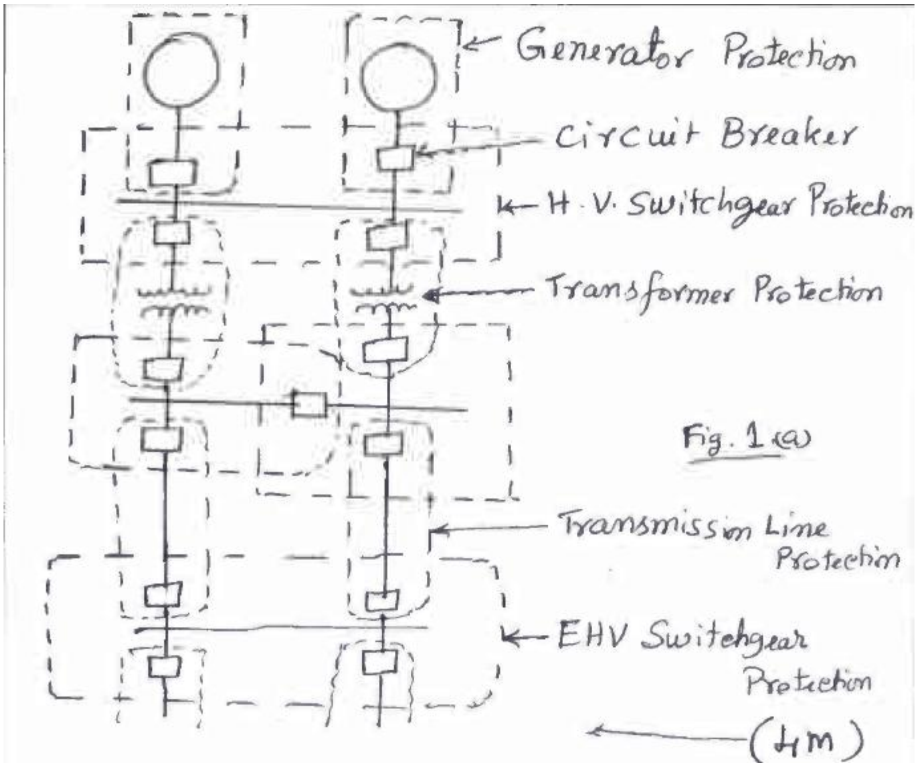
* * * * *

**Power System Protection**

**Scheme of valuation**

**Module I**

1. a) With a neat circuit diagram explain zones of protection in power system.




* Protection zone is that part of a power system, which is protected by certain protective scheme.

* Power system contains generators, transformers, bus bars, transmission & distribution lines etc. There is separate protective scheme for each of the elements in power system.

* Few of them are generator protection, transformer protection, transmission line protection, bus bar protection etc. Thus the power system is divided into a no: of zones of protection.

* Each protective zone covers one or at the most 2 elements of a power system. Thus the entire power system will be covered by protective zone. No part of the system is left unprotected.

* The various protective zones are shown in the figure below. Always the adjacent protective zones must overlap each other. This overlapping is unavoidable because even if one protective zone fails, always there is one another. If a fault occur in the overlapping zone more CB's than the minimum necessary would trip.

b) Derive an expression for torque produced by an induction relay.

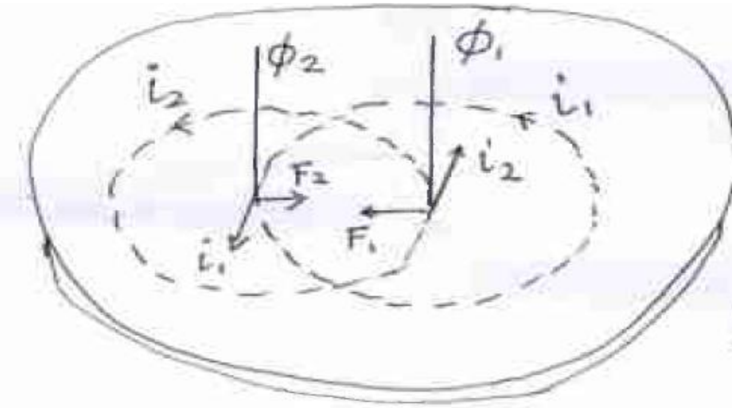



Fig. 1(b)

— (01m)

$$\phi_1 = \phi_{1m} \sin\omega t \quad ; \quad \phi_2 = \phi_{2m} \sin(\omega t + \theta)$$

$$e_1 \propto \frac{d\phi_1}{dt} \propto \phi_{1m} \cos\omega t$$

$$e_2 \propto \frac{d\phi_2}{dt} \propto \phi_{2m} \cos(\omega t + \theta)$$

$$i_1 \propto \phi_{1m} \cos\omega t$$

$$i_2 \propto \phi_{2m} \cos(\omega t + \theta)$$

(03 M)

$$F_1 \propto \phi_1 i_2$$

$$\propto \phi_{1m} \sin\omega t . \phi_{2m} \cos(\omega t + \theta)$$

$$\propto \phi_{1m} \phi_{2m} \cos(\omega t + \theta) . \sin\omega t$$

$$F_2 \propto \phi_2 i_1 \propto \phi_{2m} \sin(\omega t + \theta) . \phi_{1m} \cos\omega t$$

(03M)

$$F = F_2 - F_1 \propto \phi_{1m} \phi_{2m} [\sin(\omega t + \theta) \cos\omega t - \cos(\omega t + \theta) . \sin\omega t]$$

$$\Rightarrow \boxed{F \propto \phi_{1m} \phi_{2m} \sin\theta}$$

— (01M)

If same current produces $\phi_1$ & $\phi_2$, $F = K I^2 \sin\theta$

c) List the merits and demerits of Static relay.

STATIC RELAY:

MERITS: (1) Low burden on CTs & PTs
(2) Fast response
(3) Long life
(4) High resistance to shock and vibration
(5) Less maintenance
(6) Compact size (or others) } (03m)

Demerits: (1) They are Temperature Sensitive
(2) These are Sensitive to Voltage transients
(3) These relays need an auxiliary power supply } (03)

2. a) Draw a neat sketch of induction disc relay and discuss its operating principle.

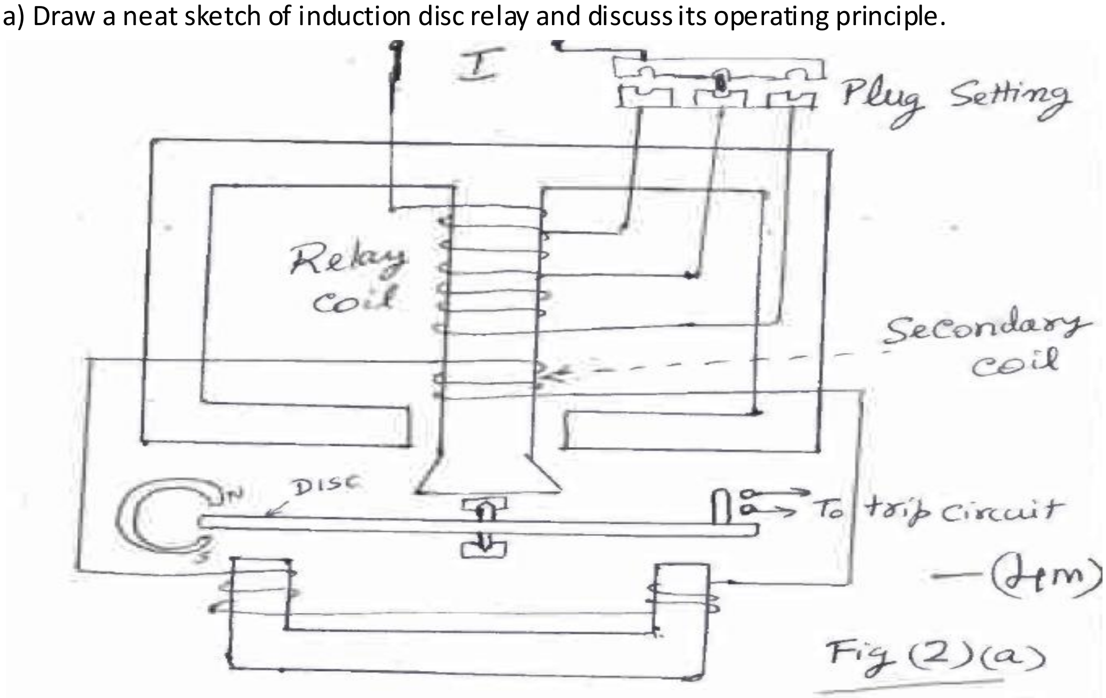



Fig (2)(a)
INDUCTION DISC Relay

In wattmetric type of construction (ii) two electromagnets are used upper and lower one. Each magnet produces an alternating flux which cuts the disc. To obtain a phase displacement between two fluxes produced by upper and lower magnets, their coils may be energised by two different sources. If they are energised by the same source the resistances and reactances of the two circuits are made different. so that there will be sufficient phase difference between two fluxes. It is used for over current protection. Disc type units give an inverse time current characteristic and are slow compared to induction cup and attracted armature type. It is used for slow speed relay. A spring is used to supply the resetting torque. The disc inertia should be as small as possible, so that it should stop rotating as soon as fault current disappears when circuit breaker operates at any other location or fault current for a short moment. The braking torque is proportional to the speed of the disc. At a current below pick-up value the disc remains stationary by the tension of control. The position of the backstop is adjustable and therefore the distance by which moving contact of relay travels before it closes contacts can be varied.

The disc carries an arm which is attached to its (simp) spindle. The spindle is supported by bearings.

2 b) What are the various type of overcurrent realy? Discuss their applications.

Types of overcurrent relays:

(1) Definite-time overcurrent relay:- Operating time is constant. Desired definite operation time can be set. -(1)-

2) Instantaneous overcurrent relay:- Can be used for very fast relays having operating times less than 0.1 s. -1-

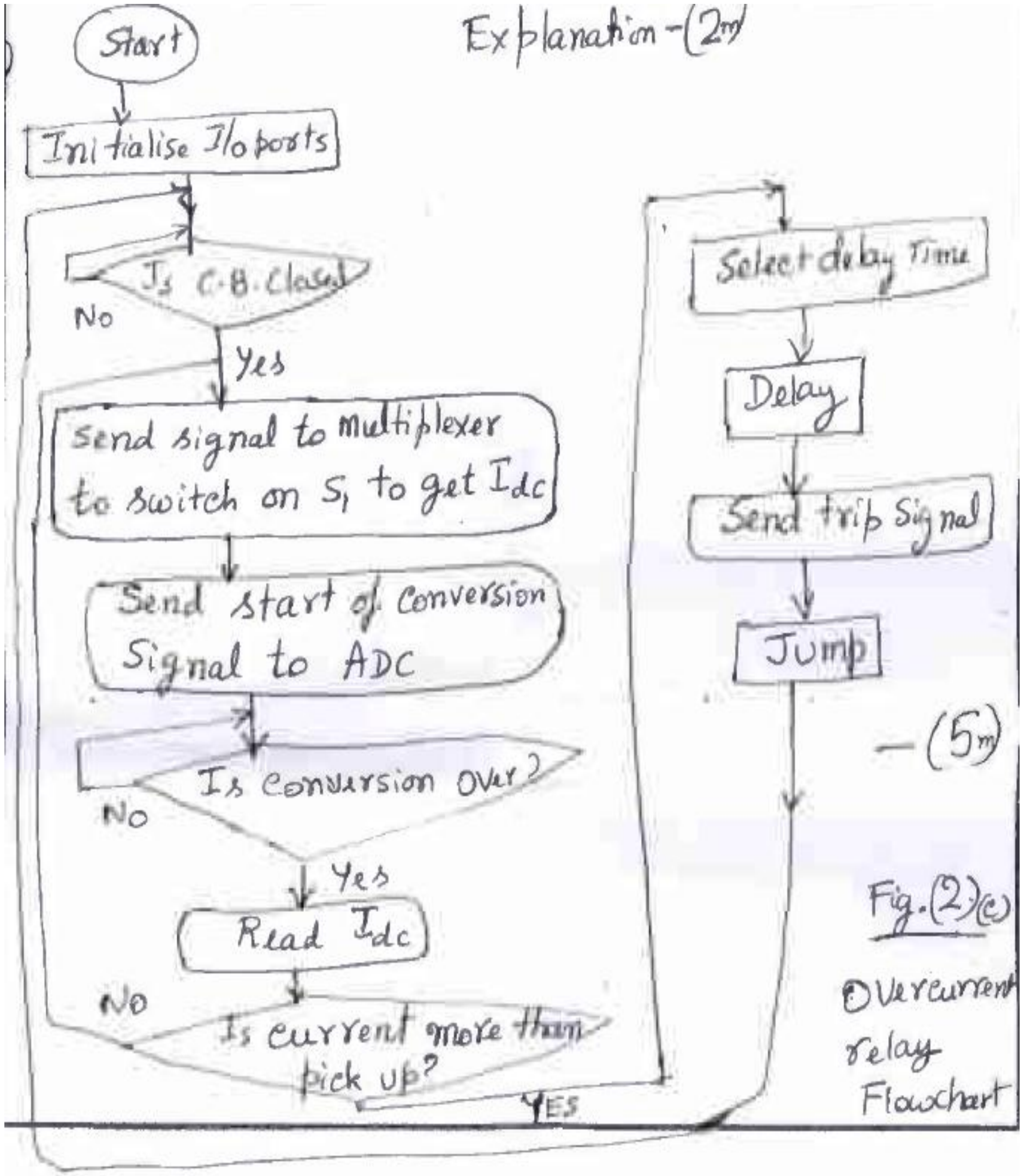
3) Inverse time overcurrent relay:- It operates when the current exceeds its pick-up value. Time depends on magnitude of current. -1-

4) Inverse Definite minimum Time overcurrent (IDMT) relay:- widely used for the protection of distribution lines. -1-

5) Very Inverse-time Overcurrent Relay:- It gives comparatively more inverse characteristic. It can be used where an IDMT relay fails to achieve good selectivity $t = \frac{13.5}{I-1}$ -1-

6) Extremely Inverse-time Overcurrent relay:- when IDMT and very inverse relays fail in selectivity, extremely inverse relays are employed. Very suitable for the protection of machines against overheating. $I^{3.5} t = K$ -1-

2 c) Describe the realization of overcurrent relay using numerical technique. Show its flow chart with neat diagram.




**Module II**

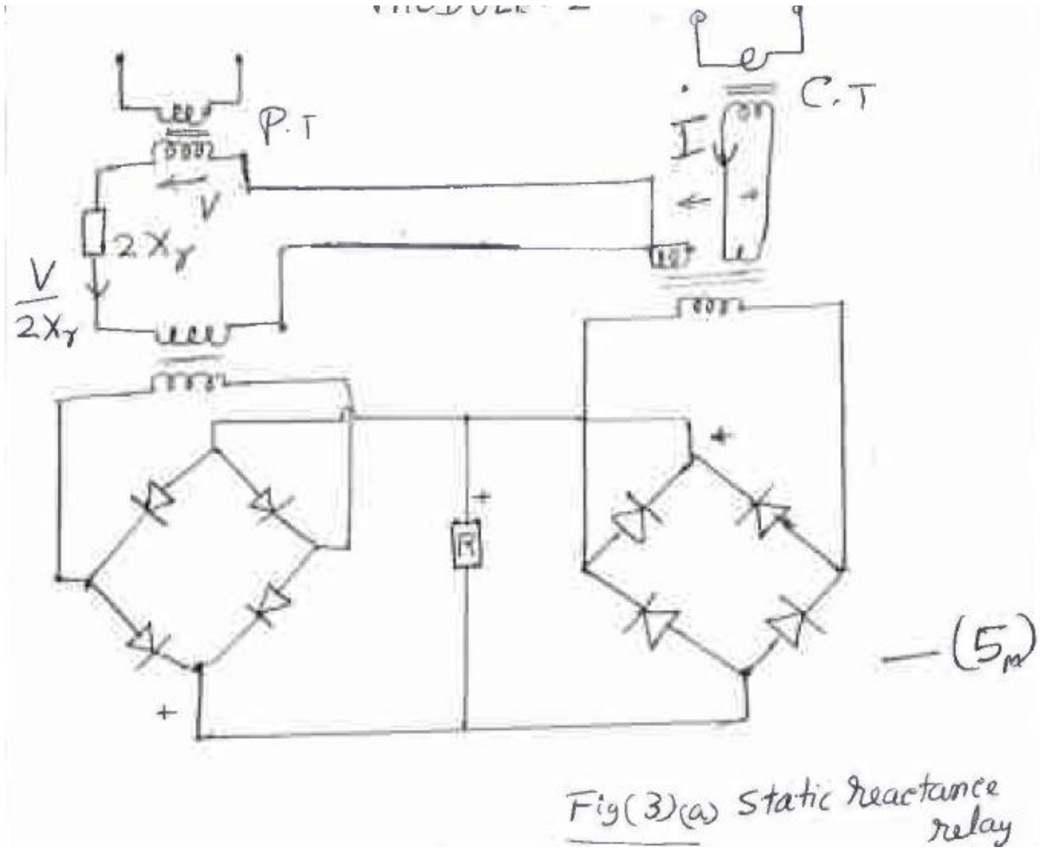
3. a) With a neat schematic diagram explain the construction and working of static reactance relay using an amplitude comparator.

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

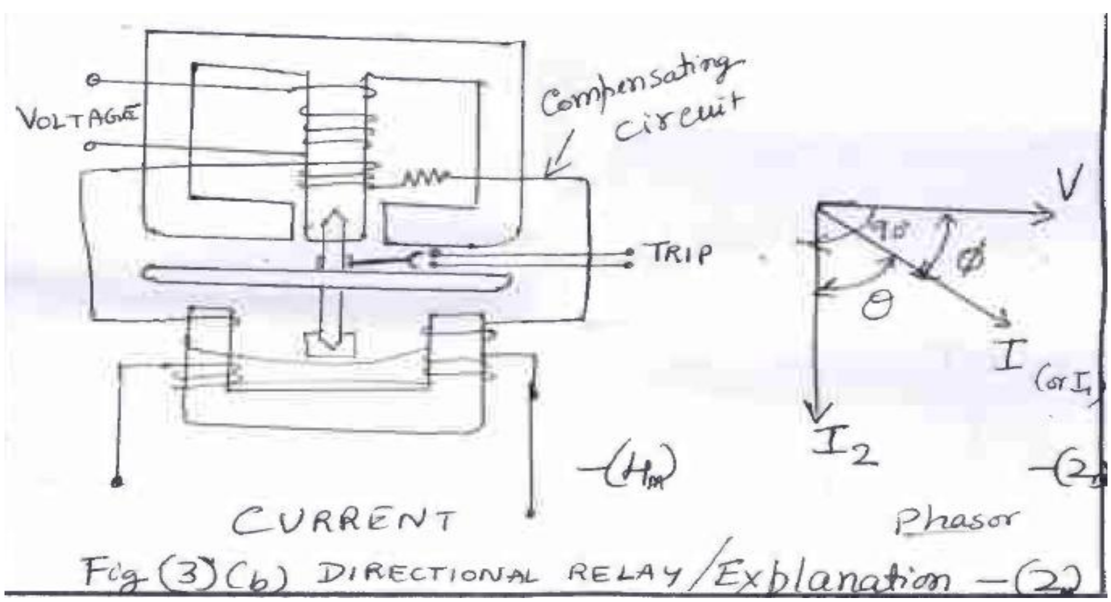
$$|2IX_r - V| > |V| \quad (2m)$$

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

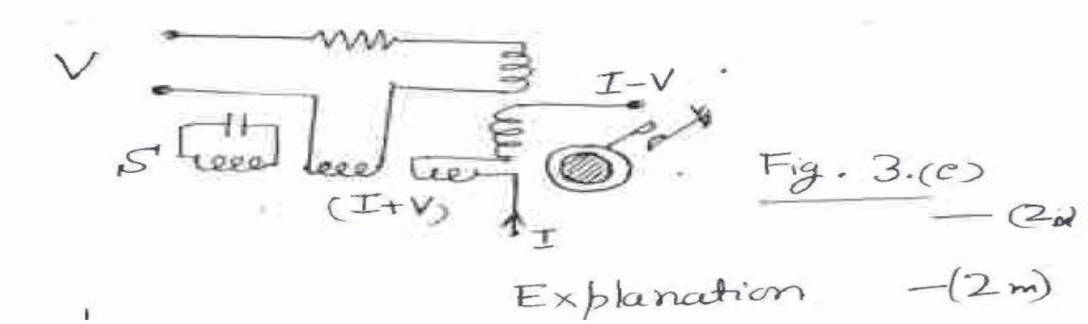
Explanation – (1m)




3. b) With a neat sketch, explain the construction and working principle of induction disc type of reverse power relay.

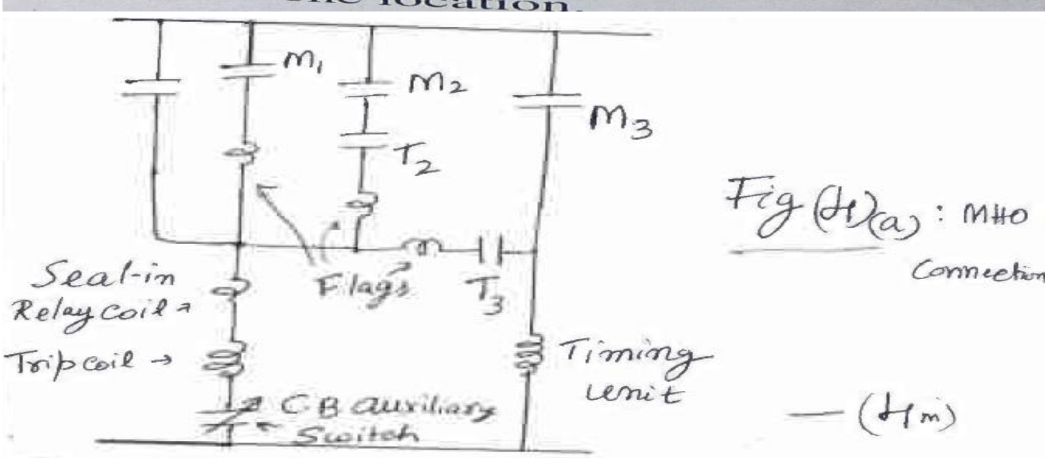



3.c)With neat diagram, explain induction cup type impedance relay.




4. a) Draw and explain the circuit connections of three MHO units used as a particular location for three zones of protection.

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. The time-distance characteristic is a stepped characteristic, as shown in Fig. 6.6. Figure 6.22 shows the connection diagram for MHO units placed at one location.




4.b) With neat connection diagrams, explain working of directional earth fault relay.

→ It contains 2 elements one directional element and one IDMT element.

→ Directional element has 2 coils, one coil is energized by current and another is energized by Voltage.

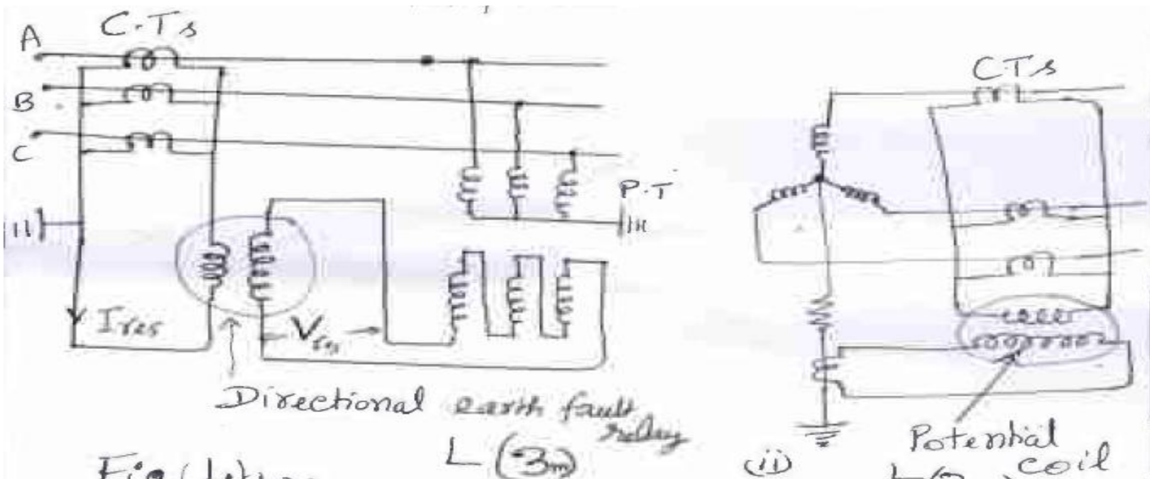



Fig (4)(b)(i)

Explanation –(2 m)

→ Current coil is energized by residual current (Ires) & Potenti[al]
coil by residual voltage as shown in Fig 2.14 (a).

→ Here residual current $I_{res} = I_a + I_b + I_c$
residual voltage $V_{res} = V_{ae} + V_{be} + V_{ce}$
where Vae, Vbe & Vce are phase or 2° voltages of PT

→ This connection is suitable for a place where neutral poi[nt]
is not available.

→ If neutral of an alternator or transformer is grounded,
then the connections are made as in Fig 2.14 (b).

→ If N point is grounded through a PT, then potential
coil of directional Earth fault relay may be connected to

4.c) With neat diagram ,explain static impedance relay using amplitude comparator.

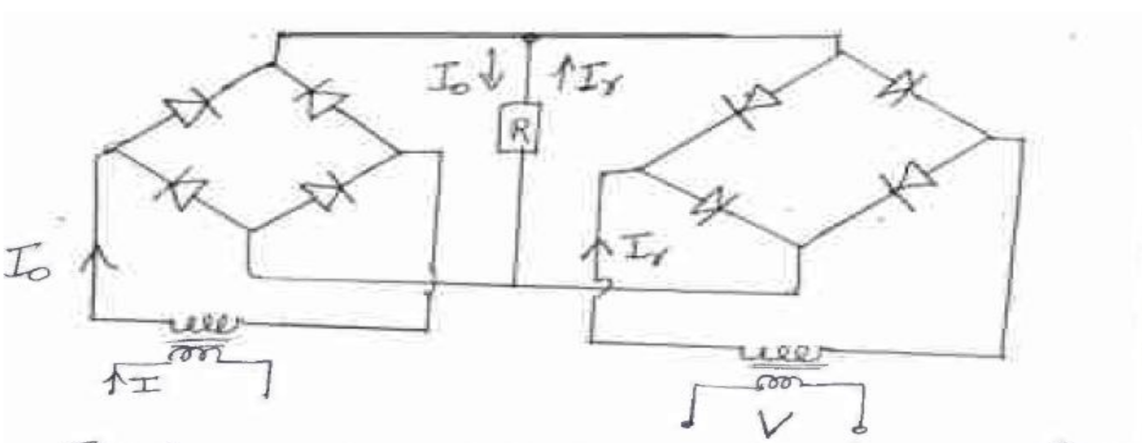



Fig. 4.(c): Static impedance relay (amplitude comparator) –(4m)

Explanation –( 2 m)

Rectifier bridge comparator is used to realise an impedance relay characteristic. Since it is an amplitude comparator, $I$ is compared with $V$. $I$ is an operating quantity and $V$ the restraining quantity. As the rectifier bridge arrangement is a current comparator, it is supplied with the operating current $I_0$ and restraining current $I_r$, as shown in Fig. 6.10. $I_0$ is proportional to the load current $I$, and $I_r$ is proportional to the sys

**MODULE III**

5.a)With neat diagram ,explain percentage differential protection of star-delta connected transformer.

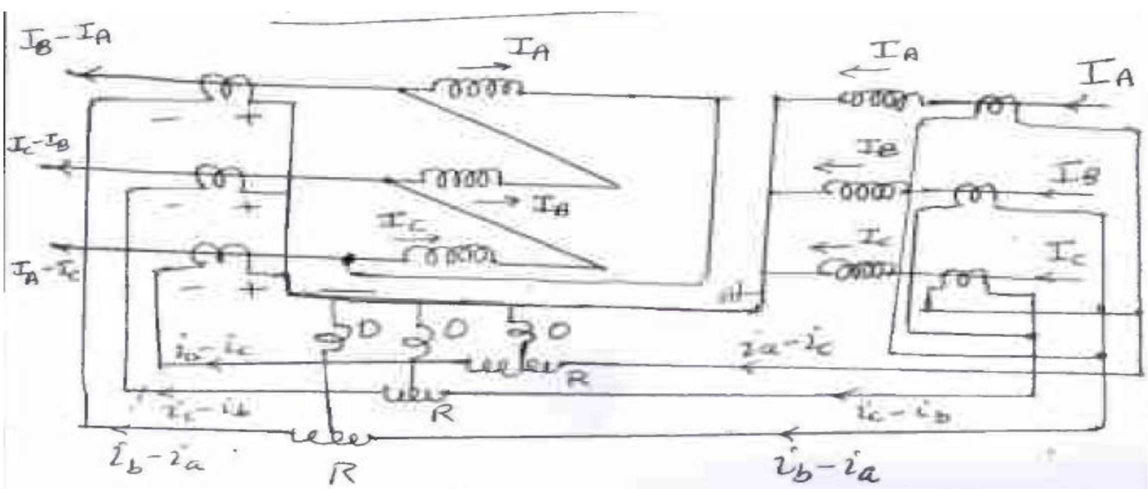



Fig. 5.(a) : Differential protection of transformer

L (5m)

* It is commonly used for protection above 1MW in generator.
* It protects against winding faults ie, Ph to Ph & Ph to Gr.
* The scheme is also called as biased differential protection or longitudinal differential protection.

* Currents at both ends are sensed using CTs.
* Wires connecting relay coils to the CT 2° are called Pilot wires.

* Normal conditions, current in pilot 2° fed from CT 2° are =.
* So differential current $I_1 - I_2$ through the operating coil of the relay will be zero.
* Hence Relay is inoperative and s/m is said to be BALANCED.

5.b) With neat diagram, explain Buccholz relay.

* Buchholz relay is a gas operated relay used for the protection of oil immersed transformer, against all type of internal fault.
* It is named after its inventor Buchholz
* Slow developing faults called incipient Faults occurring in transformer tank below the oil level, actuates buchholz relay which gives an alarm.
* If Fault are severe it disconnects the transformer from supply.
* It uses the principle that due to faults, oil in the tank decomposes, generating the gases.

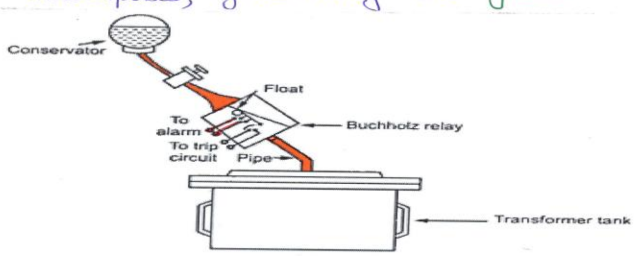



Fig.3.29 Basic arrangement of Buchholz relay

* Almost 70% component of such gases is hydrogen which is light & hence it will rise towards the conservator. through pipe
* Due to the gas collected in the upper portion of Buchholz relay, the relay operates and gives an alarm.
* Under normal conditions, the Buchholz relay is full of oil.
* It consist of a cast housing as shown in Fig (next page).
* It also contains a hingled float, which tilts down with the lowering of oil level.
* A mercury switch is attached to the float. Float is rotated in the upper part of the housing.

5.c)

11kV, 150MVA

Primary earth fault current $= \frac{150 \times 10^3}{\sqrt{3} \times 11} \times \frac{20}{100}$

$= 1,574.5$ A — (2)

p = unprotected portion $= 100 - 80 = 20\%$ — (1)

The fault current $= \frac{p}{100} \times \frac{11 \times 10^3}{\sqrt{3}\, R_n} = 1,574.5$ — (2)

$R_n = \frac{0.2 \times 11 \times 10^3}{\sqrt{3} \times 1574.5} = 0.8\, \Omega$ — (2)

where $R_n$ = Resistance in neutral

6 a. Define the term 'pilot' with reference to power line protection. List the different types of wire pilot protection schemes and explain any one of the schemes. **(08 Marks)**

b. With neat diagram, explain harmonic restraint relay used to protect against magnetizing inrush current of transformer. **(08 Marks)**

c. With a neat circuit diagram, explain rotor earth fault protection of alternator. **(04 Marks)**

(a) "Intereonneeting channel over which information can be transmitted from one end of transmission line to the other end is called pilot" —(1)m

[Types- (i) wire pilot (ii) carrier-current pilot (iii) microwave pilot.]

Wire Pilot types - (i) Circulating current scheme (ii) Balanced voltage scheme (iii) Transley scheme (iv) Transley S Protection (v) Half-wave Comparison scheme —(2)m

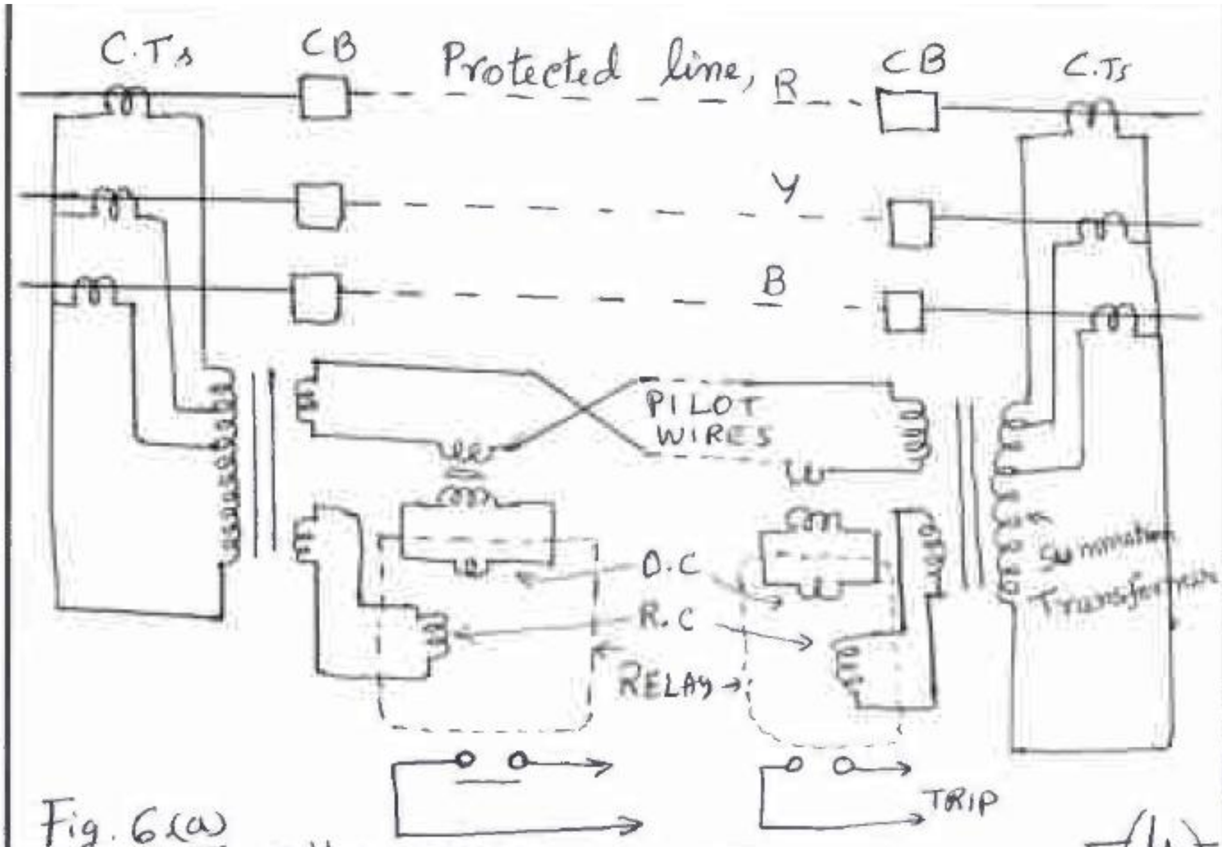



Fig. 6(a)
Balanced voltage scheme

# 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.

6. b.

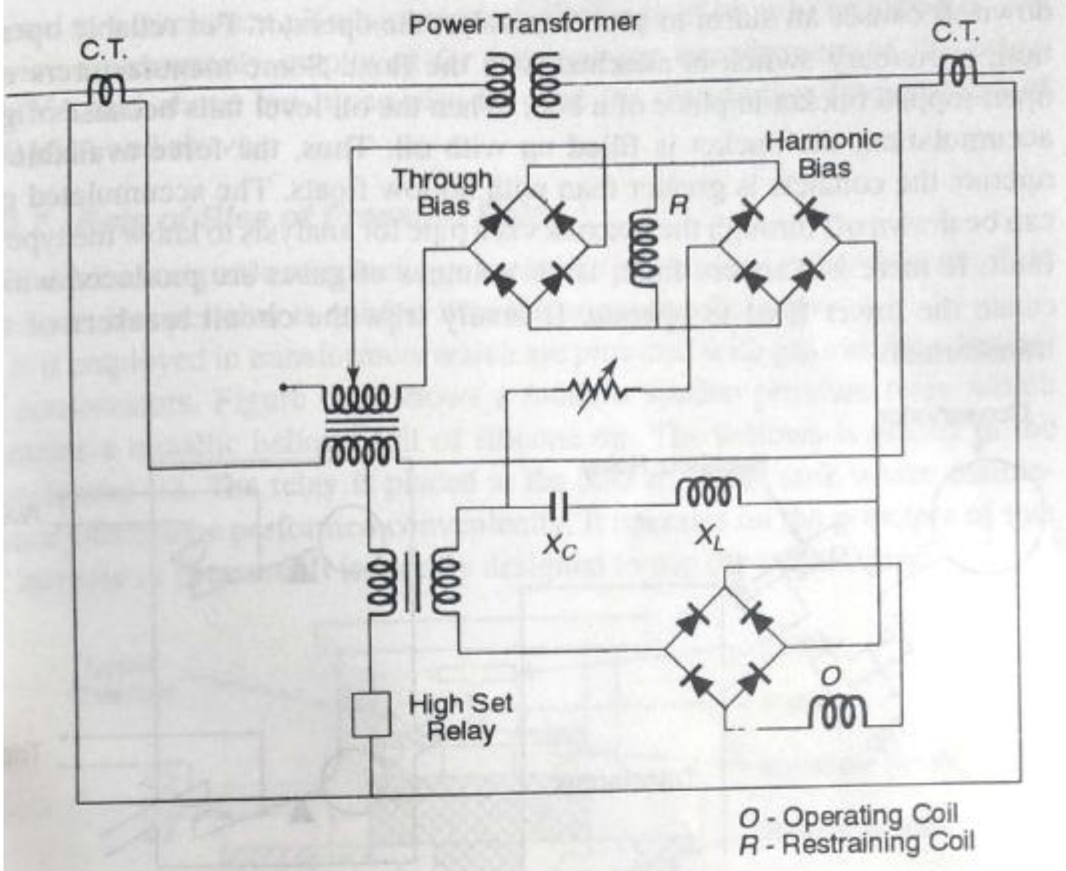



**FIGURE** Harmonic restraint relay

## Protection against Magnetising 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 the transformer. This initial magnetising current is called the magnetising inrush current. As the inrush current flows only in the primary winding, the differential protection will see this inrush current as an internal fault. The harmonic contents in the inrush current are different than those in usual fault current. The dc component varies from 40 to 60%, the second harmonic 30 to 70% and the third harmonic 10 to 30%. The other harmonics are progressively less. The third harmonic and its multiples do not appear in C.T. leads as these harmonics circulate in the delta winding of the transformer and the delta connected C.T.s on the $Y$ side of the transformer. As the second harmonic is more in the inrush current than in the fault current, this feature can be utilised to distinguish between a fault and magnetising inrush current.

Figure shows a high speed biased differential scheme incorporating a harmonic restraint feature. The relay of this scheme is made insensitive to magnetic inrush current. The operating principle is to filter out the harmonics from the differential current, rectify them and add them to the percentage restraint. The tuned circuit $X_C X_L$ allows only current of fundamental frequency to flow through the operating coil. The dc and harmonics, mostly second harmonics in case of magnetic inrush current, are diverted into the restraining coil. The relay is adjusted so as not to operate when the second harmonic (restraining) exceeds 15% of the fundamental current (operating). The minimum operating time is about 2 cycles.

6.c.

Fig: 6.c
Rotor earth fault Protection

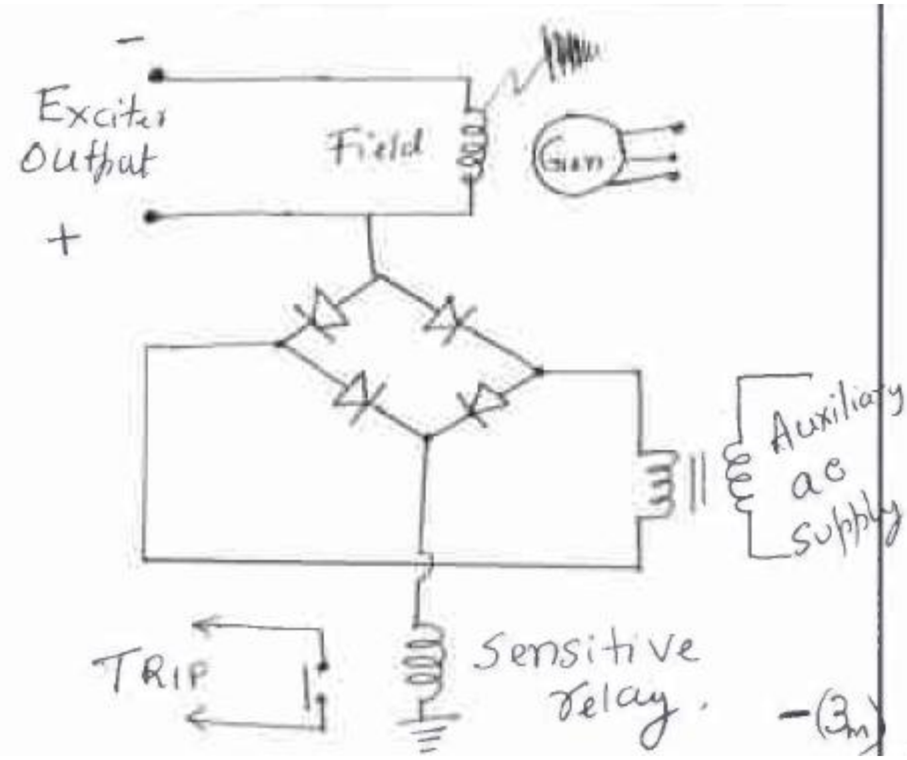



Figure shows the schematic diagram of rotor earth fault protection. A dc voltage is impressed between the field circuit and earth through a polarised moving iron relay. It is not necessary to trip the machine when a single field earth fault occurs. Usually an alarm is sounded. Then immediate steps are taken to transfer the load from the faulty generator and to shut it down as quickly as possible to avoid further problems.

In case of brushless machines, the main field circuit is not accessible. If there is a partial field failure due to short-circuiting of turns in the main field winding, it is detected by the increase in level of the field current. A severe fault or short-circuiting of the diode is detected by a relay monitoring the current in the exciter control circuit.

## Module-4

7 a. In a 132 kV system, reactance and capacitance upto the location of the circuit breaker is 4Ω and 0.02 μF respectively. A resistance of 500 Ω is connected across the break of the C.B. Determine the (a) natural frequency of oscillation (b) damped frequency of oscillation. (c) critical value of resistance. **(08 Marks)**

b. Explain working of $SF_6$ circuit breaker with the help of diagrams. Write two of its advantages. **(08 Marks)**

c. Explain recovery rate theory to explain the zero current interruption of the arc. **(04 Marks)**

(a) $X_L = 4$ ; $L = \frac{4}{2\pi f} = 0.0127H$ —(1)m

(a) Natural frequency of oscillation $= \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$

$= \frac{1}{2\pi}\sqrt{\frac{1}{0.0127 \times 0.02 \times 10^{-6}}} = 9.986\ kHz$ —(2)m

(b) Frequency of damped oscillation $= \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{1}{4C^2R^2}}$

$= \frac{1}{2\pi}\sqrt{\frac{1}{0.0127 \times 0.02 \times 10^{-6}} - \frac{1}{4(0.02\mu)^2 \times 500^2}}$

$= \frac{1}{2\pi}\sqrt{3.937 \times 10^9 - 2.5 \times 10^9} = 6.033\ kHz$

(c) The value of critical resistance —(3)m

$R = \frac{1}{2}\sqrt{\frac{L}{C}} = \frac{1}{2}\sqrt{\frac{0.0127}{0.02 \times 10^{-6}}}$

$\Rightarrow R = 398.4\ \Omega$ —(2)m

7.(b)

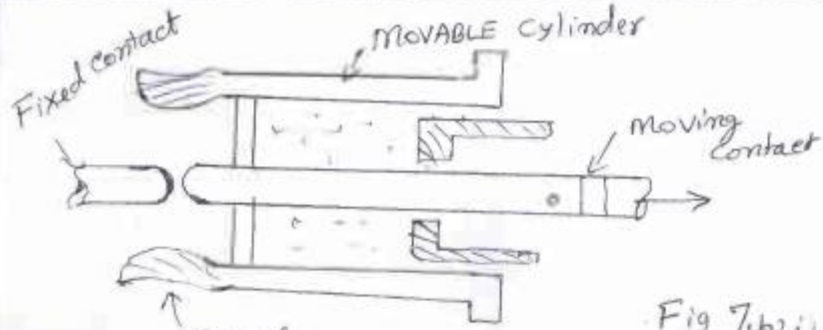



Fig 7(b)(i)

— (3)M

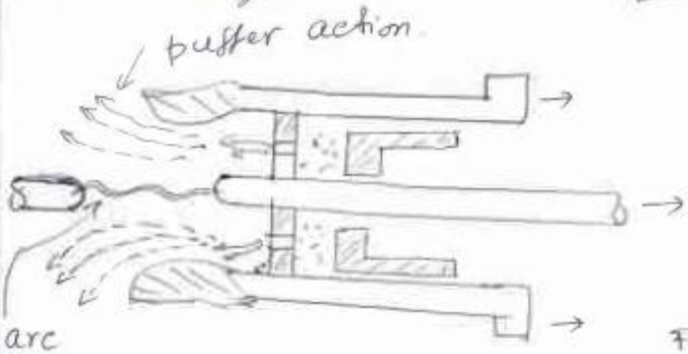



Fig 7(b)(ii)

Puffer type $SF_6$ Circuit breaker. — (3)M

Explanation — (2)M

[08]

ADvantage : 1) Excellent arc quenching
2) Good dielectric strength ($SF_6$)

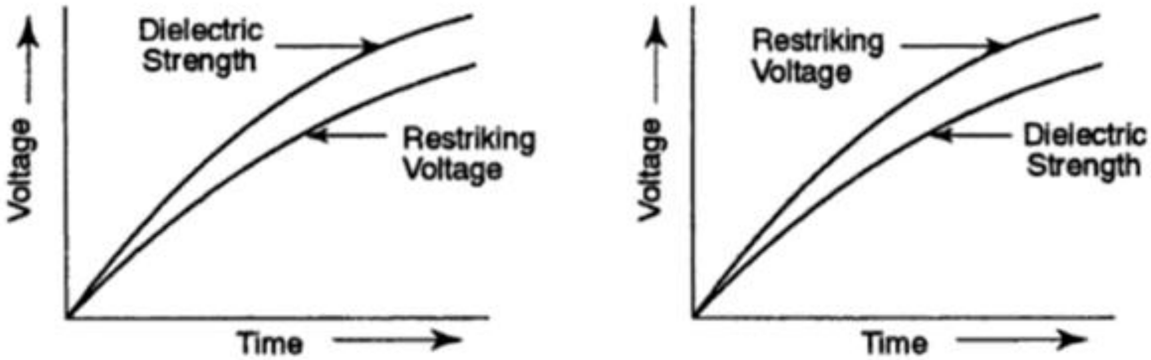
## Sulphur Hexafluoride (SF6) Circuit Breaker

- It contains an arc interruption chamber containing $SF_6$ gas.
- In closed position the contacts remain surrounded by $SF_6$ gas at a pressure of 2.8 kg/cm2.
- During opening high pressure $SF_6$ gas at 14 kg/cm2 from its reservoir flows towards the chamber by valve mechanism.
- $SF_6$ rapidly absorbs the free electrons in the arc path to form immobile negative ions to build up high dielectric strength.
- It also cools the arc and extinguishes it.
- After operation the valve is closed by the action of a set of springs.
- Absorbent materials are used to absorb the byproducts and moisture.

7.c.

**Recovery rate theory**

The arc is a column of ionised gases. To extinguish the arc, the electrons and ions are to be removed from the gap immediately after the current reaches a natural zero. Ions and electrons can be removed either by recombining them into neutral molecules or by sweeping them away by inserting insulating medium (gas or liquid) into the gap. The arc is interrupted if ions are removed from the gap at a rate faster than the rate of ionisation. In this method, the rate at which the gap recovers its dielectric strength is compared with the rate at which the restriking voltage (transient voltage) across the gap rises. If the dielectric strength increases more rapidly than the restriking voltage, the arc is extinguished. If the restriking voltage rises more rapidly than the dielectric strength, the ionisation persists and breakdown of the gap occurs, resulting in an arc for another half cycle. Figure explains the principle of recovery rate theory.




(a) Arc extinguishes (b) Arc does not extinguishes

**FIGURE** Recovery rate theory

8 a. Derive expressions for restriking voltage and RRRV in terms of system voltage, inductance and capacitance during fault on feeder. **(08 Marks)**

b. With neat circuit diagram, explain the synthetic testing of circuit breaker. **(06 Marks)**

c. With neat diagram, explain Air-break circuit breaker. Write any two of its applications. **(06 Marks)**

8.(a) natural frequency of oscillation is

$$f_n = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$$

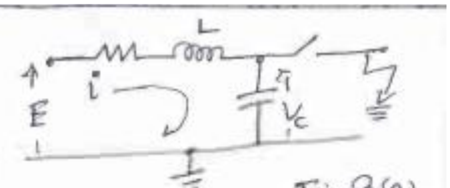



Fig 8(a)

$$L\frac{di}{dt} + \frac{1}{C}\int i\,dt = E$$

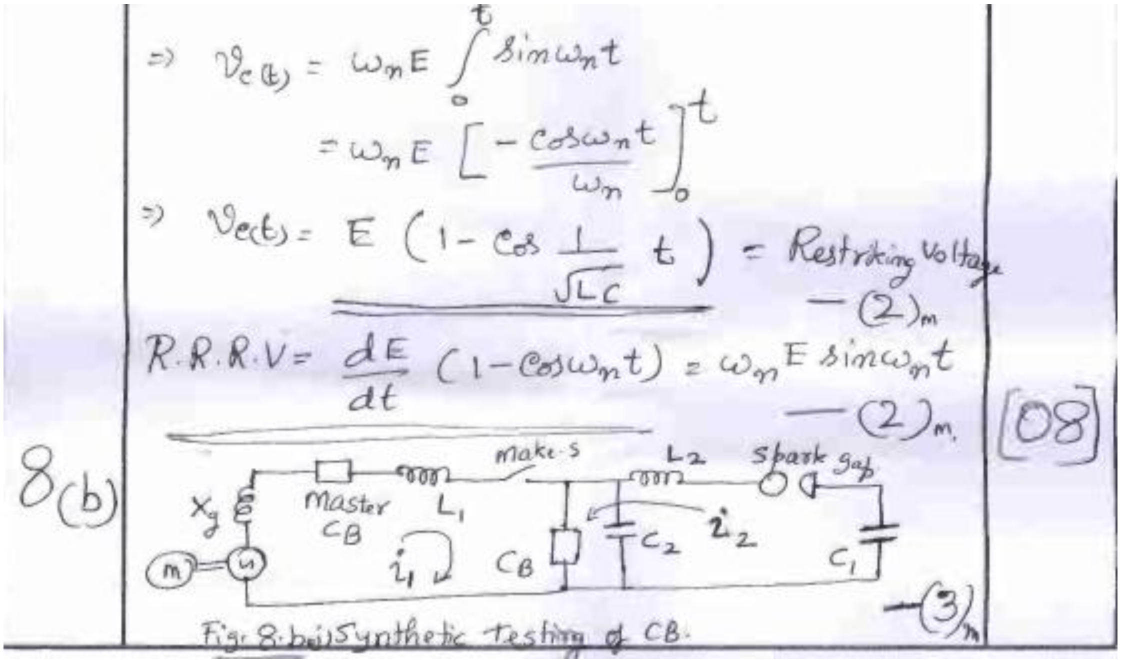
$$i = \frac{dq}{dt} = \frac{d(Cv_c)}{dt}\ ;\ \frac{di}{dt} = C\frac{d^2v_c}{dt^2}$$

$$\therefore LC\frac{d^2v_c}{dt^2} + v_c = E \qquad -(2)_m$$

$$\Rightarrow LC\,s^2 v_c(s) + v_c(s) = \frac{E}{s}$$

$$\Rightarrow v_c(s) = \frac{E}{s[LCs^2+1]} = \frac{E}{LCs\left(s^2+\frac{1}{LC}\right)}$$

$$\omega_n = \frac{1}{\sqrt{LC}}\ ;\ v_c(s) = \frac{\omega_n^2 E}{s(s^2+\omega_n^2)} \qquad -(2)_M$$



$$\Rightarrow v_c(t) = \omega_n E \int_0^t \sin\omega_n t$$

$$= \omega_n E \left[ -\frac{\cos\omega_n t}{\omega_n} \right]_0^t$$

$$\Rightarrow v_c(t) = E\left(1 - \cos\frac{1}{\sqrt{LC}}\, t\right) = \text{Restriking voltage}$$ —(2)m

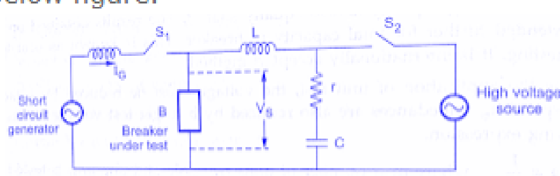
$$R.R.R.V = \frac{dE}{dt}(1-\cos\omega_n t) = \omega_n E \sin\omega_n t$$ —(2)m [08]

8(b)

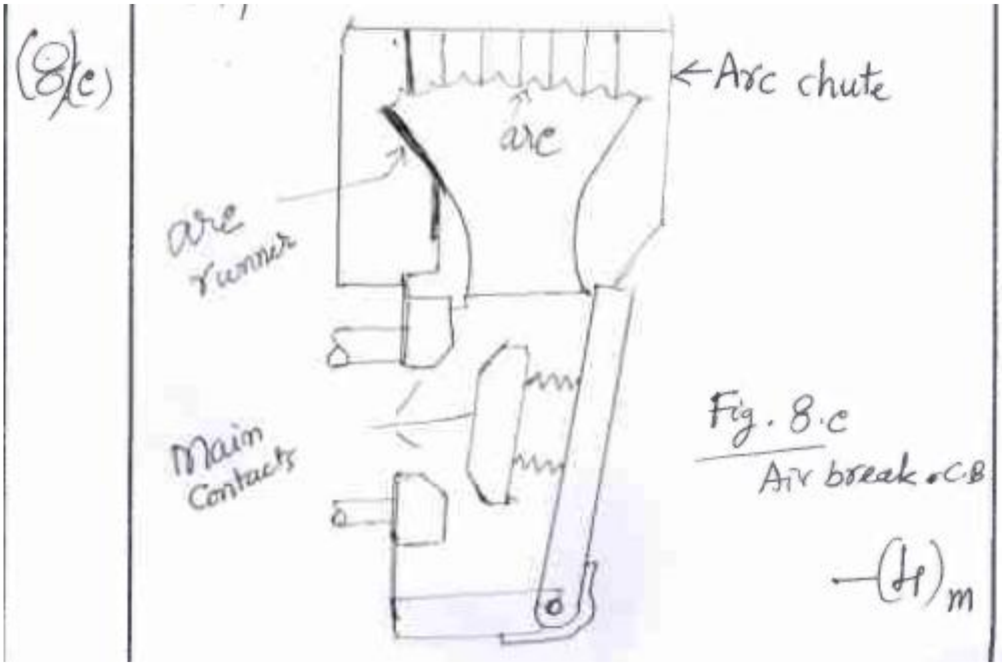


Fig. 8.b(i) Synthetic testing of CB. —(3)m

Every circuit breaker undergoes testing to make sure whether it is working properly or not.So now we will learn about the **testing of circuit breakers**.**Synthetic testing** is one of the indirect testing methods used.Synthetic testing is the popular method which permits testing of circuit breaker.It consists of current source and voltage source with relatively low voltage and low current respectively.The **principle of synthetic testing** can be explained from below figure.




The current source provides short circuit current.The voltage source provides restriking voltage and recovery voltage.**Synthetic testing** conditions are given by L, r, C.The short circuit current $I_G$ is supplied by closing switch $S_1$. At final current zero, switch $S_2$ is closed and voltage contains transient as it contains L and C.




## Working Principle Air Break Circuit Breaker

When the fault occurs, the main contacts are separate first, and the current is shifted to the arcing contacts. Now the arcing contacts are separate, and the arc is drawn between them. This arc is forced upwards by the electromagnetic forces and thermal action. The arc ends travel along the arc runner. The arc moves upward and is split by the arc splitter plates. The arc is extinguished by lengthening, cooling, splitting, etc.

## Applications of Air Break Circuit Breaker

Air break circuit breaker is suitable for the control of power station auxiliaries and industrial plants. They do not require any additional equipment such as compressors, etc. They are mainly used in a place where there are possibilities of fire or explosion hazards. Air break principle of lengthening of the arc, arc runners magnetic blow-up is employed for DC circuit breakers up to 15 KV.

## Module-5

9 a. Describe the construction and operation of the HRC cartridge fuse with indicator. Write any four of advantages of HRC fuses. **(08 Marks)**

b. Describe the phenomenon of lightning and explain the terms pilot streamer, stepped leader, return streamer, dart leader, cold lightning stroke and hot lightning stroke. **(08 Marks)**

c. Write short note on Arcing horn with diagram. **(04 Marks)**

9.a.

**High-Rupturing capacity (H.R.C.) cartridge fuse:** The primary objection of low and uncertain breaking capacity of semi-enclosed rewireable fuses is overcome in H.R.C. cartridge fuse. Fig. shows the essential parts of a typical H.R.C. cartridge fuse. It consists of a heat resisting ceramic body having metal end-caps to which is welded silver cuirent-carrying element. The space within the body surrounding the element is completely packed with a filling powder. The filling material may be chalk, plaster of paris, quartz or marble dust and acts as an arc quenching and cooling medium.

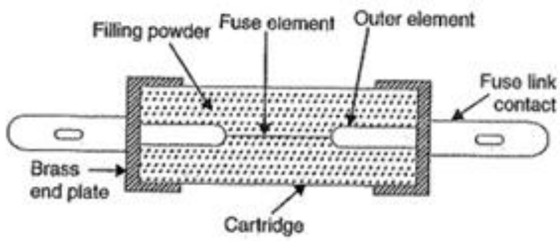



**Fig.**

Under normal load conditions, the fuse element is at a temperature below its melting point.

Therefore, it carries the normal current without overheating. When a fault occurs, the current increases and the fuse element melts before the fault current reaches its first peak. The heat produced in the process vaporizes the melted silver element The chemical reaction between the silver vapour and the filling powder results in the formation of a high resistance substance which helps in quenching the arc.

## Advantages

- **They are capable of clearing high as well as lo**
- **They do not deteriorate with age.**
- **They have high speed of operation.**
- **They provide reliable discrimination.**
- **They require no maintenance.**
- **They are cheaper than other circuit interrupting devices of equal breaking capacity.**
- **They permit consistent performance.**

9)(b)

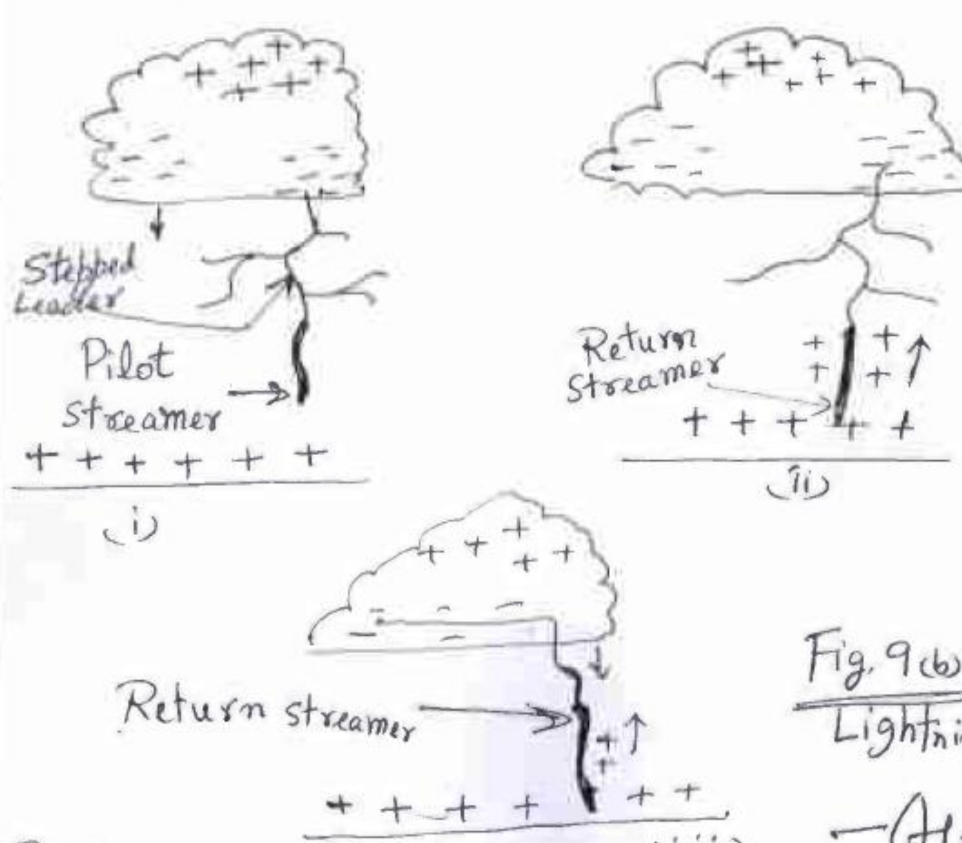



Fig. 9(b) Lightning

—(4M)

(iii) —(4M)

<u>Pilot streamer</u> : when potential gradient of 10kV/cm is set in the cloud, the surrounding air gets ionised & a streamer called pilot streamer starts from the cloud.

<u>Return streamer</u>: when one of the stepped leaders strikes the ground, an extremely bright return streamer propagates upward from the ground.

9b Contd

Stepped leader: Zig-Zag shaped leader branching into several paths.

Dart leader: Discharge from another charge centre making use of already ionised path, having single branch and higher energy current is dart leader.

Cold lightning stroke - lightning due to return streamer

hot lightning stroke - lightning due to dart leader.

— (1m)

(a).

9.c.

### Arcing Horn

The damage to line insulators from heavy arcs formed due to overvoltages is a serious maintenance problem. Several protective devices have been developed to keep an insulator string free from the arc. Arcing horn is one of such protective devices. It consists of small horns attached to the clamp of the line insulator string. Horns with a large spread, both at the top of the insulator and at the clamp are required to be effective, as shown in Fig. 11.14. In the case of lightning impulse, the arc formed tends to cascade the string. In order to avoid this cascading, the gap between horns should be considerably less than the length of the string. Protection of line insulators by arcing horns thus results in reduced flashover voltage. In any event, flashover persists as a power arc until the line trips out. The protection of line insulators by arcing horns is especially used in hilly areas.

The grading ring when used in conjunction with an arcing horn fixed at the top of the insulator string serves the purpose of an arcing shield. In the event of an arc forming following a flash-over caused by some type of overvoltage, the arc will usually take the path between the horn and the shield and the insulator string will remain clear from the arc.

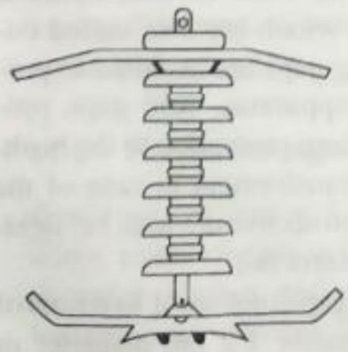


**FIGURE** Suspension string with arcing horns

10 a. Describe the construction and principle of operation of valve type lightning arrester with detailed diagram. **(08 Marks)**

b. Write note on klydonograph and magnetic link. **(06 Marks)**

c. Describe the protection of stations and sub-stations against direct lightning strokes. **(06 Marks)**

10. a.

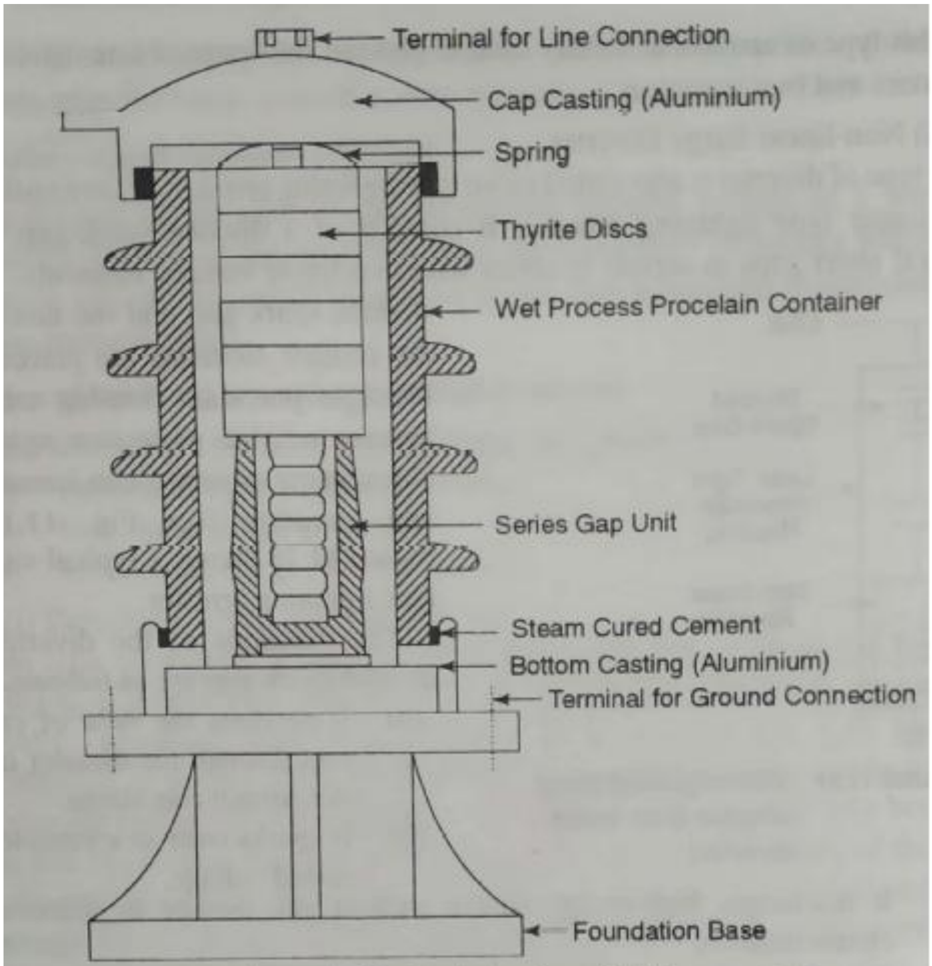


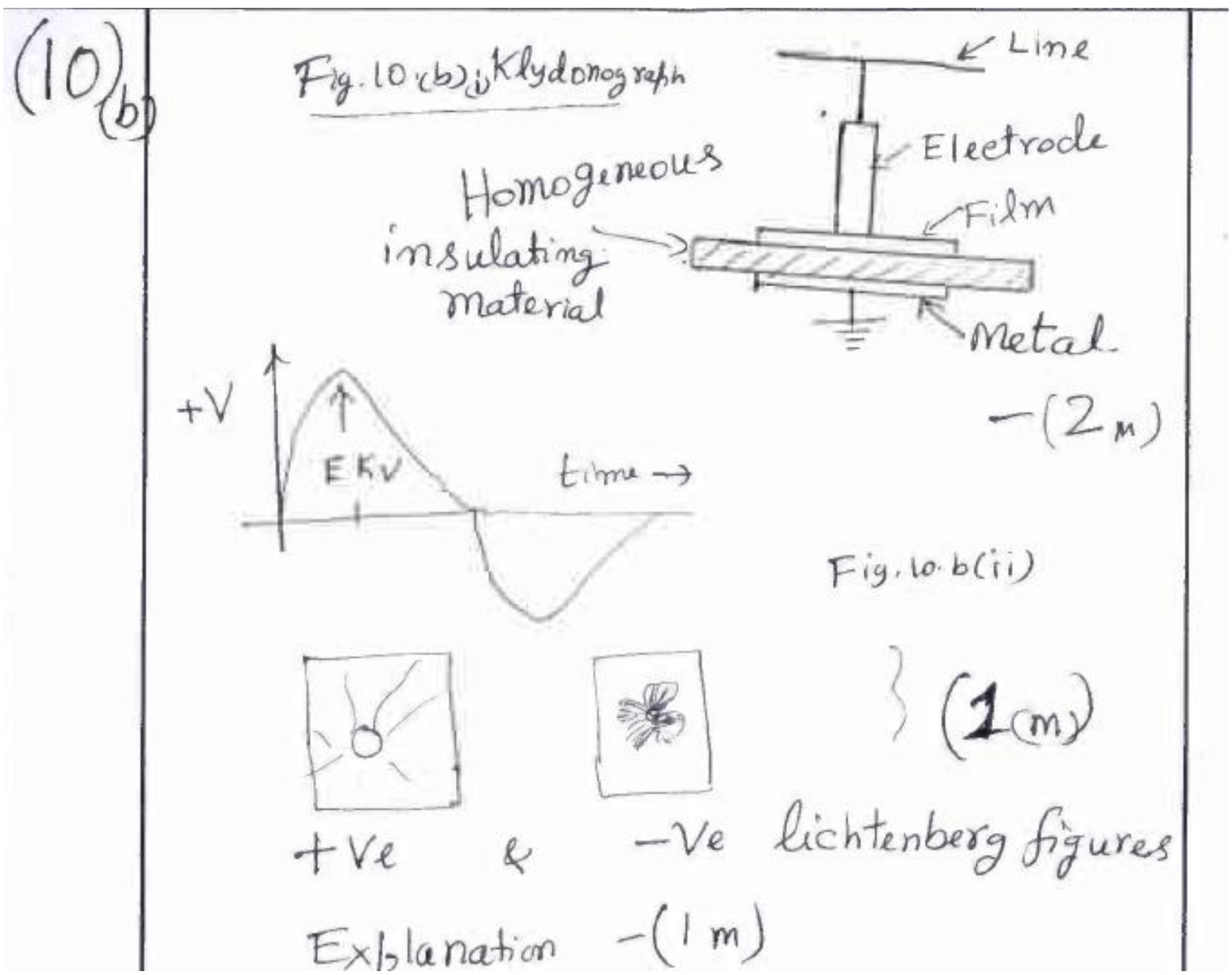

FIGURE A typical valve-type lightning arrester

## Working of Valve Type Lightning Arrester

For low voltage, there is no spark-over across the gaps due to the effect of parallel resistor. The slow changes in applied voltage are not injurious to the system. But when the rapid changes in voltage occur across the terminal of the arrester the air gap spark of the current is discharged to ground through the non-linear resistor which offers very small resistance.

After the passage of the surge, the impressed voltage across the arrester falls, and the arrester resistance increases until the normal voltage restores. When the surge diverter disappears, a small current at low power frequency flow in the path produced by the flash over. This current is known as the power follow current.

The magnitude of the power follows current decreases to the value which can be interrupted by the spark gap as they recover their dielectric strength. The power follow current is extinguished at the first current and the supply remains uninterrupted. The arrester is ready for the normal operation.This is called resealing of the lightning arrester.



- Since lightning surges are infrequent and random in nature, it is necessary to install a large number of recording devices to obtain a reasonable amount of data regarding these surges produced on transmission lines and other equipments. Some fairly simple devices have been developed for this purpose. Klydonograph is one such device which makes use of the patterns known as Lichtenberg figures which are produced on a photographic film by surface corona discharges.
- The Klydonograph (Fig. above) consists of a rounded electrode resting upon the emulsion side of a photographic film or plate which is kept on the smooth surface of an insulating material plate backed by a plate electrode. The minimum critical voltage to produce a figure is about 2 kV and the maximum voltage that can be recorded is about 20 kV, as at higher voltages spark overs occurs which spoils the film.
- The device can be used with a potential divider to measure higher voltages and with a resistance shunt to measure impulse current. There are characteristic differences between the figures for positive and negative voltages. However, for either polarity the radius of the figure (if it is symmetrical) or the maximum distance from the centre of the figure to its outside edge (if it is unsymmetrical) is a function only of the applied voltage.
- The oscillatory voltages produce superimposed effects for each part of the wave. Thus it is possible to know whether the wave is unidirectional or oscillatory. Since the size of the figure for positive polarity is larger, it is preferable to use positive polarity figures. This is particularly desirable in case of measurement of surges on transmission lines or other such equipment which are ordinarily operating on a.c. voltage and the alternating voltage gives a black band along the centre of the film caused by superposition of positive and negative figures produced on each half cycle.
- For each surge voltage it is possible to obtain both positive and negative polarity figures by connecting pairs of electrodes in parallel, one pair with a high voltage point and an earthed plate and the other pair with a high voltage plate and an earthed point.
- Klydonograph being a simple and inexpensive device, a large number of elements can be used for measurement. It has been used in the past quite extensively for providing statistical data on magnitude, polarity and frequency of voltage surges on transmission lines even though its accuracy of measurement is only of the order of 25 per cent.

<u>Magnetic link</u>: It is an instrument for the measurement of surge currents due to lightning. It contains a small bundle of laminations made of cobalt-steel inserted in a cylindrical molded plastic container. ...(etc) —(2m)

10. c.

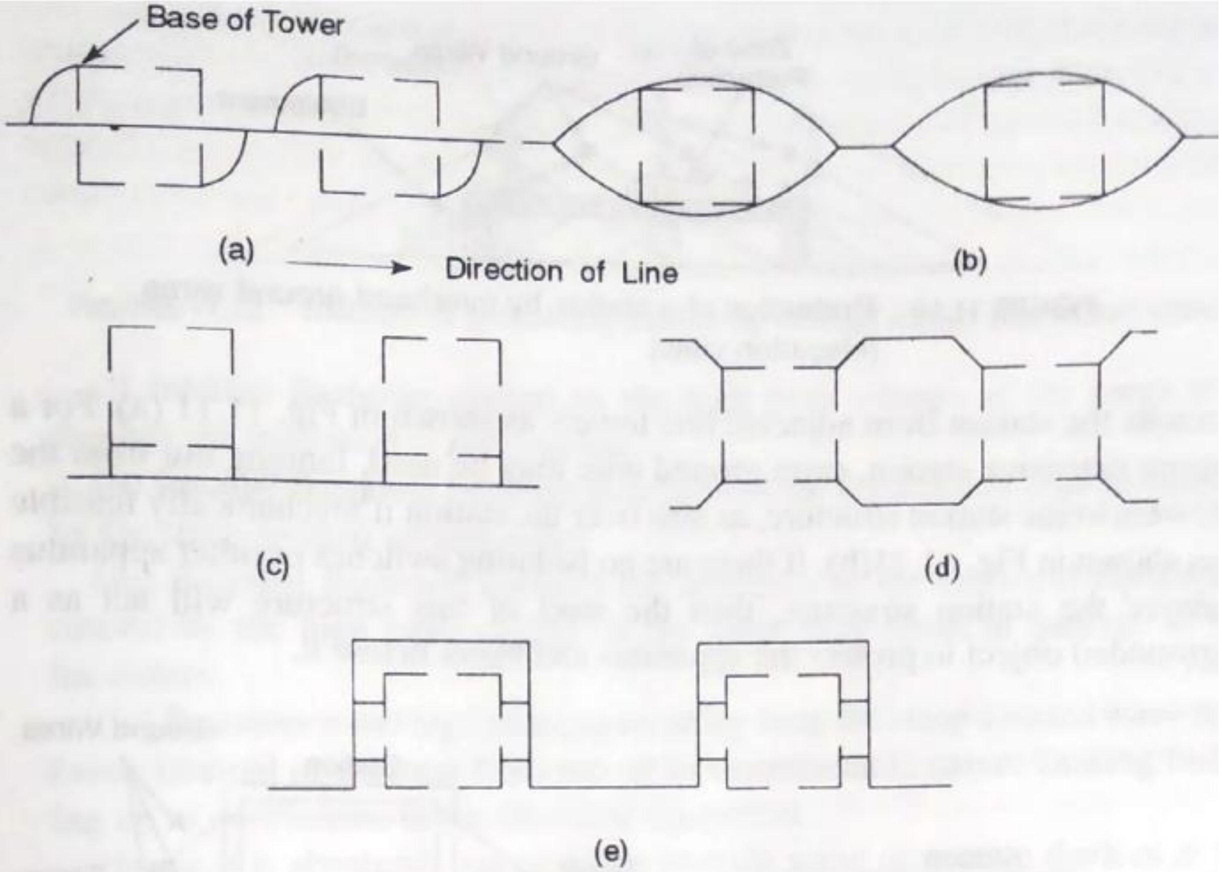
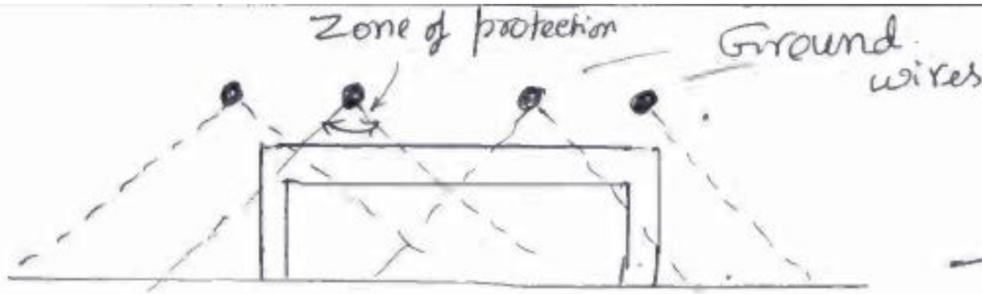



**FIGURE** Typical arrangements of tower-to-tower (continuous) counterpoise wires

The task of protection of such stations can be resolved into two parts. The first being the protection of stations (including sub-stations) from direct lightning strokes, and the second is the protection of electrical equipment of stations from travelling waves coming in over the lines. The protection of stations from direct strokes will be discussed in this section and the protection of equipment from travelling waves will be discussed in the subsequent section.

Wherever it is likely for direct strokes of lightning to strike the line at or near the station, there is a possibility of exceedingly high rates of surge-voltage rise and large magnitude of surge-current discharge. If the stroke is severe enough, the margin of protection provided by the protective device may be inadequate. The installation may, therefore, require shielding of the station and the incoming lines enough to limit the severity of surges particularly in the higher voltage class of 66 kV and above. This can be done by properly placed overhead ground wires, masts, or rods.

10 (c) Contd.



—(2)M

Fig 10.c(ii) Protection of station by overhead ground wire

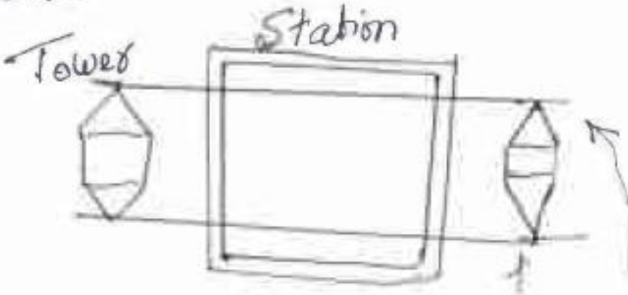



Fig 10.c(iii) Between adjascent towers

Ground wires —(1)M

Explanation –(2 m)