CBCS SCHEME

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18EE72

Seventh Semester B.E. Degree Examination, Feb./Mar.2022
Power System Protection

Time: 3 hrs. Max. Marks: 100

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

Module-1

1 a. With a neat diagram, explain zones of protection in a power system. **(06 Marks)**

b. Discuss the essential qualities of a protective relay. **(08 Marks)**

c. Explain various methods of back up protection. **(06 Marks)**

OR

2 a. Define the following terms :
(i) Relay
(ii) Operating force
(iii) Pick up level
(iv) Reset
(v) Current setting **(10 Marks)**

b. Write a short note on Automatic reclosure. **(05 Marks)**

c. Write the advantage and disadvantages of the static relay. **(05 Marks)**

Module-2

3 a. What is an impedance relay? Explain its operating principle, torque equation and operating characteristics of impedance relay. **(08 Marks)**

b. Explain the operating principle of reverse power or directional relay with neat diagram. **(06 Marks)**

c. Why IDMT relays are widely used for over current protection? **(06 Marks)**

OR

4 a. Discuss a protection scheme for parallel feeder. **(06 Marks)**

b. Distinguish between earth fault relay and an over current relay. **(06 Marks)**

c. Write and explain 3 stepped distance protection of transmission line. **(08 Marks)**

Module-3

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

b. Explain balanced (opposed) voltage differential protection. **(06 Marks)**

c. The neutral point of a 11 KV an alternator is earthed through a resistance of 12 Ω the relay is said to operate when there is out of balance of a 0.8 A. 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. **(06 Marks)**

OR

6 a. With a neat sketch explain the working of frame leakage protection used for bus-zone protection. **(08 Marks)**

b. With neat diagram, explain construction and operation of Burhholz relay. **(12 Marks)**

Module-4

7 a. With a neat sketch, explain the recovery rate theory and energy balance theory of arc interruption in a circuit breaker. **(10 Marks)**

b. Explain the terms: restriking voltage, recovery voltage and RRRV. Derive expression for restriking voltage and RRRV interms of system voltage, inductance and capacitance. **(10 Marks)**

OR

8 a. What are the different types of air blast circuit breaker? Discuss their operating principle and area of application. **(08 Marks)**

b. With a neat sketch, explain the direct testing of circuit breaker. **(06 Marks)**

c. What are the merits and demerits of SF_6 circuit breaker? **(06 Marks)**

Module-5

9 a. Define the following terms:
(i) Fuse
(ii) Fuse element
(iii) Rated current
(iv) Minimum fusing current
(v) Fusing factor. **(06 Marks)**

b. Describe the construction and operation of the HRC cartridge fuse with indicator. Write applications of the HRC fuse. **(08 Marks)**

c. Write discrimination between fuse and over-current protective devices. **(06 Marks)**

OR

10 a. Write note on Klydonograph and magnetic link. **(08 Marks)**

b. What is a Gas Insulated Substation? Discuss its advantages and disadvantages as compared to conventional air insulated substation. **(08 Marks)**

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

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Karnatak Law Society's

Vishwanathrao Deshpande Institute of Technology, Haliyal.

Department of Electrical & Electronics Engineering

Semester : VII

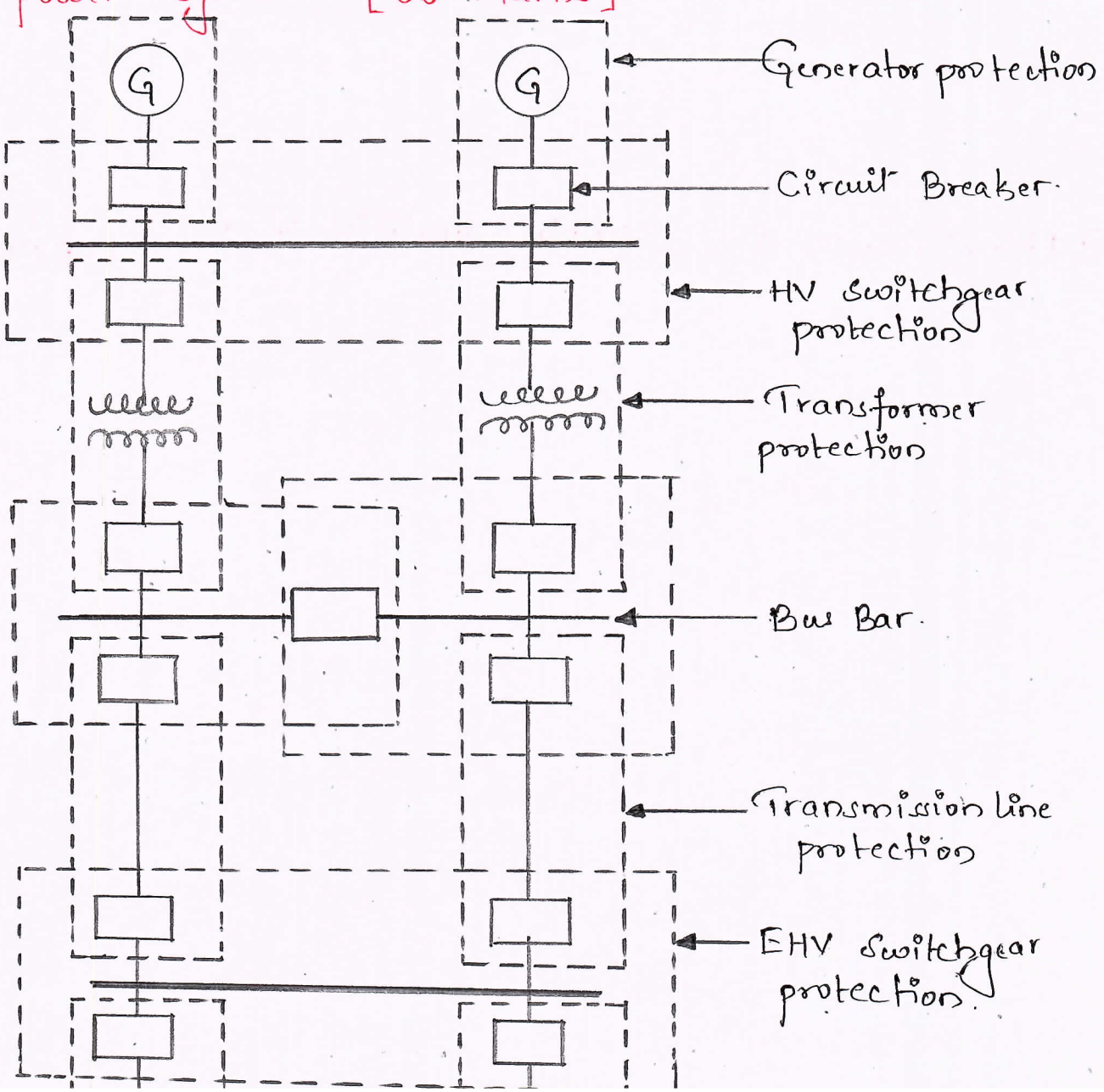
Subject : Power System Protection.

Code : 18EE72

Prepared by,
Prof. Rajeshwari N.

Module - 01.

Q1 a) With a neat diagram, explain zones of protection in a power system. [06 Marks]



A power system contains generators, transformers, busbars, transmission & distribution lines etc., There is a separate protective scheme for each piece of equipment or element of the power system such as generator protection, transformer protection, transmission line protection, bus bar protection etc., Thus power system is divided into no. of zones ~~of~~ for protection. The protective zone are planned in such a way that the entire power system is collectively covered by them & thus no part of the system is left unprotected. Adjacent protective zones must overlap each other, failing which a fault on boundary of a zone may not lie in any of the zones & hence no CB would trip. Thus overlapping between the adjacent zones is unavoidable. If a fault occurs in the overlapping zone in a properly protected scheme more CB than the minimum necessary to isolate the faulty element of the system would trip.

Q 1b) Discuss the essential qualities of protective relay. [08 Marks]

The essential qualities of protective relays are,

1) Selectivity or Descrimination.

Selectivity is the quality of a protective relay by which it is able to discriminate between fault in the protected section & normal condition. When fault occurs on a power system, only the faulty part of the system should be isolated, no healthy part should be deprived of electric supply & hence should be intact. The protective relay should be able to distinguish between a fault or power surge either by its inherent characteristic or with the help of an auxiliary relay.

2) Reliability.

A protective system must operate reliably when a fault occurs in its zone of protection.

To achieve a high degree of reliability, greater attention should be given to the design, installation, maintainance & testing of the various elements of the protective system. A typical value of reliability of protective scheme is 95%.

3) Sensitivity:
A protective relay should operate when the magnitude of the current exceeds the preset value. This value is called the pick up current. The relay should not operate when the current is below its pick-up value. A relay should be sufficiently sensitive to operate when the operating current just exceeds its pick-up value.

4) Stability:
A protective ~~relay~~ system should remain stable even when a large current is flowing through its protective zone due to an external fault, which does not lie in its zone.

5) Fast Operation:
A protective system should be fast enough to isolate the faulty element of the system as quickly as possible to minimize damage to the equipment & to maintain the system stability. The operating time of protective relay is usually one cycle. Half cycle relays are also available.

Q1. c) Explain various methods of back-up protection [06 Marks]

There are 3 types of back-up protection.

1) Remote Backup:
When a backup relays are located at a neighbouring station, they backup the entire primary protection scheme which includes relay, CB, CT, PT & other elements. It is the cheapest & simplest form of backup protection & widely used for transmission lines.

it is most desirable because of the fact that, it will not fail due to factors causing the failure of primary protection.

2) Relay Backup:

This is kind of local backup in which additional relay is provided for back-up protection. It trips the same CB if the primary relay fails & this operation takesplace without delay.

3) Breaker Backup:

This kind of backup is necessary for a busbar system where no. of CB's are connected to it. When a protective relay operates in response to a fault but the circuit breaker fails to trip, the fault is treated as busbar fault. In such situation it becomes necessary that all other CB on that busbar should trip. After a time delay, the main relay closes the contact of backup relay which trips all other CB on the bus if the proper breaker doesnot trip within a specified time after its trip coil is energized.

Q2 a) Define the following terms.
i) Relay. ii) Operating force iii) Pick-up level.
iv) Reset v) Current setting. [10 Marks]

i) Relay: A relay is an automatic device by means of which an electrical circuit is indirectly controlled & is governed by a change in the same or another electrical circuit.

ii) Operating force: A force or torque which tends to close the contacts of the relay.

iii) Pick-up level : The threshold value of the actuating quantity (current, voltage etc.,) above which the relay operates.

iv) Reset : It is the time which elapses from the moment the actuating quantity falls below its reset value to the instant when the relay comes back to its normal position.

v) Current setting : The value of the actuating quantity at which the relay is set to operate.

Q4 b) Write a short note on Automatic Reclosure [05 Marks]

About 90% of faults on overhead lines are of transient in nature. These are caused by lightning or external bodies falling on the lines & always associated with arcs. If the line is disconnected from the system for a short time, the arc is extinguished & fault disappears. Immidiately after this, CB can be reclosed automatically to restore the supply.

Most faults on EHV lines are caused by lightning. Flashover across insulators takesplace due to overvoltage caused by lightning & exist for short time. Hence only one instantaneous reclosure is used in EHV lines. On lines upto 33kV, most faults are caused by external objects such as tree branches etc., falling on the overhead lines. The external objects may not be burnt clear at the first reclosure & may require additional reclosure. Usually three reclosure at 15-20 second interval are made to clear the faults. Statistical report shows that over 80% of faults are cleared after the first reclosure, 10% require the second reclosure & 2% need the 3rd reclosure; while remaining 8% are permanent faults.

Q 2 c) Write the advantages & disadvantages of static relay. [05 Marks]

* Advantages:

1) Low burden on CTs & PTs. The static relay consumes less power & in most of the cases they draw power from auxiliary DC supply.
2) Fast Response.
3) Long Life.
4) High resistance to shock & vibration.
5) Less mentainance due to the absence of moving parts & bearings.
6) Frequent operation causes no deterioration.
7) Quick resetting & absence of overshoot.
8) Compact size.
9) Greater sensitivity as amplification can be provided easily.
10) Complex relaying characteristics can easily be obtained.
11) Logic circuits can be used for complex protective schemes.

* Disadvantages:

1) Static relays are temperature sensitive.
2) Static relays are sensitive to voltage transients.
3) Static relays need an auxiliary power supply.

Module - 02

Q3a) What is an impedance relay? Explain its operating principle, torque equation & operating characteristics of impedance relay. [08 Marks]

An impedance relay measures the impedance of the line at the relay location. When a fault occurs on the protected line section, the measured impedance is the impedance of line section between the relay location & the point of fault. It is proportional to the length of the line & hence the distance along the line. The term impedance includes both resistance & reactance.

* Operating Principle:

To realize the characteristic of an impedance relay current is compared with voltage at the relay location. The current produces +ve operating torque & voltage produces -ve restraining torque. The operating torque eqn. is given by,

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

where, K_1, K_2 & K_3 are constants, K_3 being torque due to control spring effect. Neglecting K_3,

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

for the operation of the relay, following condition should be satisfied.

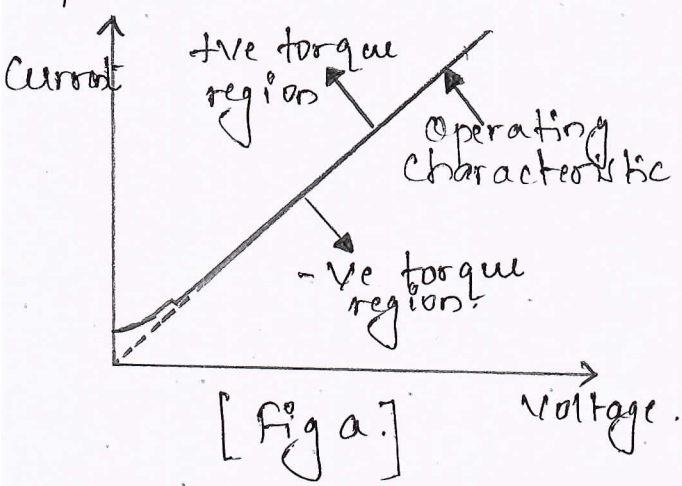
$$K_1 I^2 > K_2 V^2 \quad \text{or} \quad K_2 V^2 < K_1 I^2$$

or $$\frac{V^2}{I^2} < \frac{K_1}{K_2} \Rightarrow \frac{V}{I} < K \Rightarrow Z < K$$

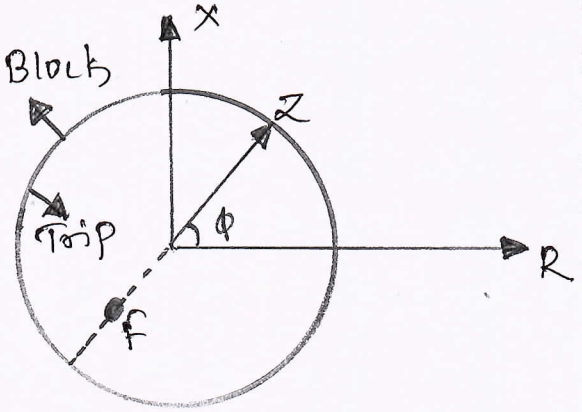
The above expression explains that the relay is on the verge of operation when the ratio of V/I i.e Z is equal to the given constant K. The relay operates if the measured impedance Z is less than given constant.

* Relay Operating Characteristics.

Below figures shows operating characteristics of impedance relay interms of voltage & current [Fig a]. [fig b] shows an relay characteristics on R-X diagram where $Z = K$ represents a circle. & $Z < K$ indicates the area within the circle which is operating zone of relay. K is impedance of the line which is to be protected.



[Fig a.]



[Fig b]

Q3 b) Explain the operating principle of reverse power or directional relay with neat diagram. [06 Marks]

A directional relay [Fig a] is energized by two quantities namely voltage & current & produces fluxes ϕ_1 & ϕ_2 respectively. Eddy current induced in disc by ϕ_1 interacts with ϕ_2 & produces torque. Similarly, eddy current induced in disc by ϕ_2 interacts with ϕ_1 & produces torque. The resultant torque ~~produces~~ the rotates the disc. The torque is proportional to $VI\cos\phi$, where ϕ is phase angle between V & I. Fig [b]. The torque eqn. is given by,

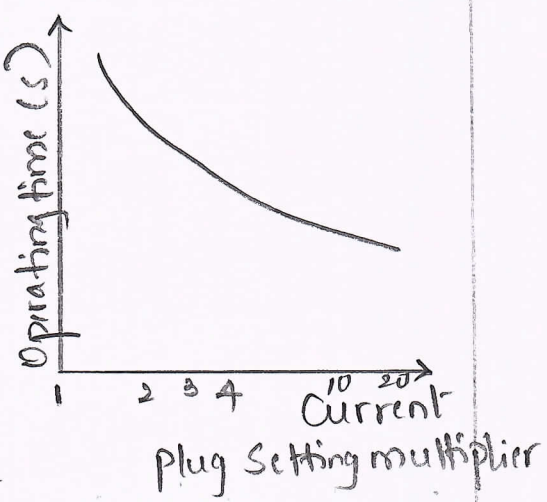
$$T = I_1 I_2 \sin(90-\phi) \propto I_1 I_2 \cos\phi \propto VI\cos\phi$$

Torque produced is +ve when $\cos\phi$ is +ve ie $\phi < 90^\circ$. when $\phi > 90^\circ$ the torque is -ve.

Q3c) Why IDMT relays are widely used for over-current protection? [06 Marks]

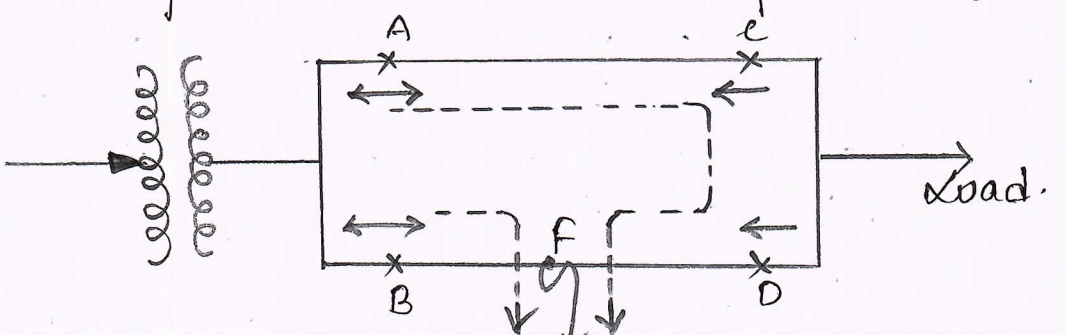
Inverse Definite Minimum Time over current relay [IDMT] gives an inverse time current characteristics at higher values of fault current.

An inverse-time characteristic is obtained if the value of the PSM is below 10. For values of PSM between 10 & 20, characteristic tends to become straight line. ie towards the definite time characteristics. shown in fig. Hence IDMT relays are widely used for over-current protection, protection of distribution lines.



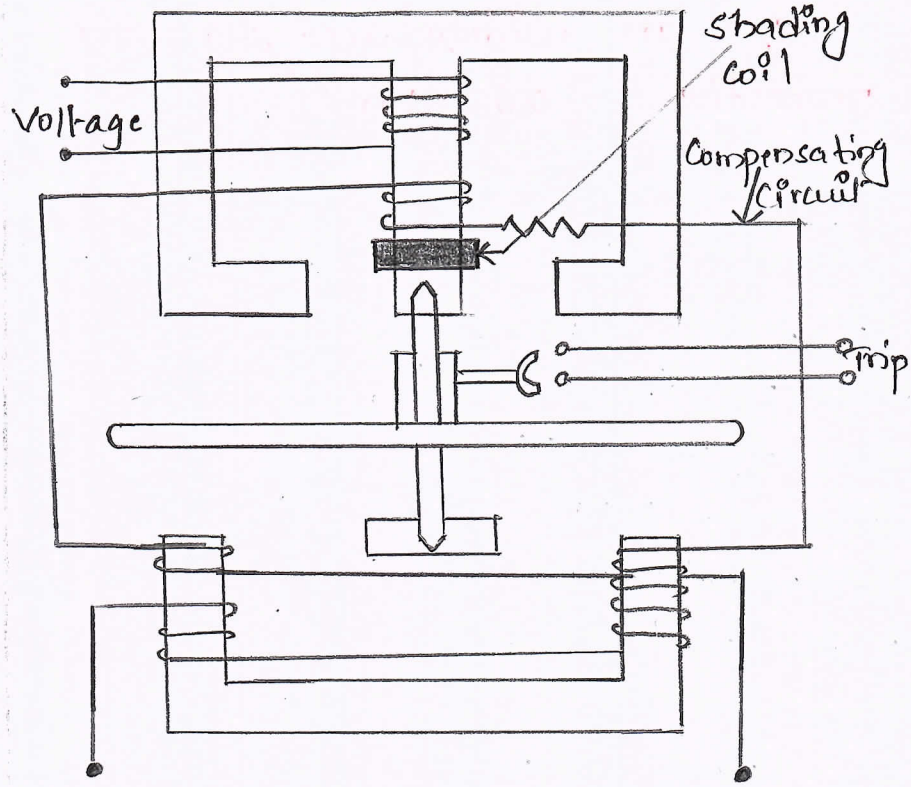
Q4a) Discuss protection scheme for parallel feeder. [06 Marks]

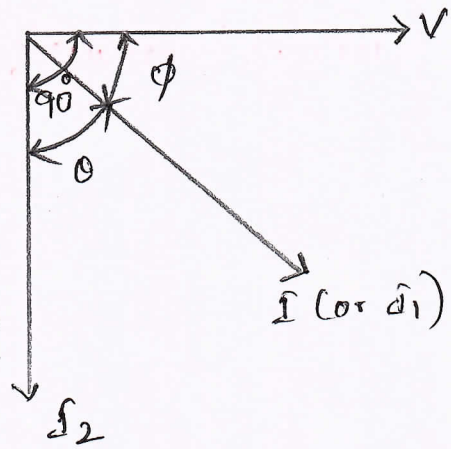
Fig. shows protection scheme for parallel feeder.



At the sending end of the feeders (at A & B) non-directional (↔) relays are required. At the other end of feeders (at C & D) directional overcurrent relays are required. The arrow mark for directional relays placed at C & D indicate that the relay will operate if current flows in the direction shown by the arrow.

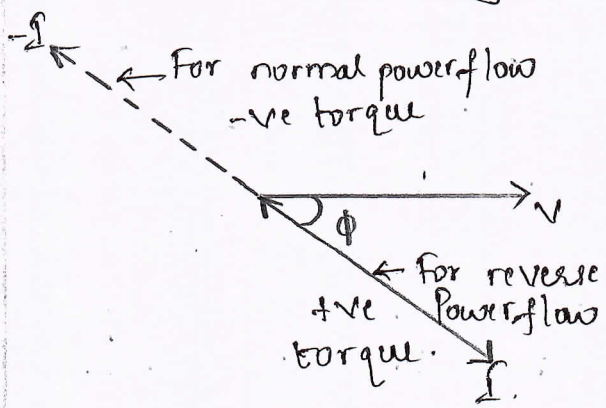
If fault occurs at F, the directional relay at D trips, as the direction of the current is reversed. The relay at C does not trip as current flows in normal direction.



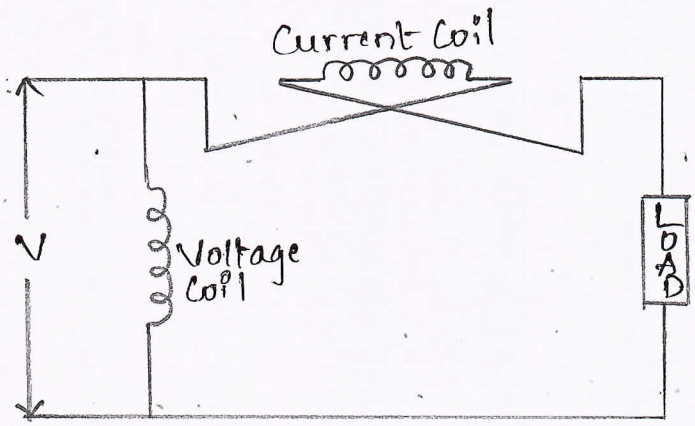


At a particular relay location, when power flows in the normal direction, the relay is connected to produce -ve torque. If due to any reason, the power flows in the reverse direction, the relay produces +ve torque & it operates. In this condition angle ϕ is kept less than 90° to produce +ve torque shown in [fig c.]

For normal flow of power, relay is supplied with V & -I. For reverse flow the actuating quantities become V & I, torque becomes $VI\cos\phi$ i.e +ve. This can be achieved easily by reversing the current coil as shown in [fig d.]



[fig c]



[fig d]

The relay at B trips for a fault at F. Thus the feeder is isolated & the supply of the healthy feeder is maintained.

Q4b) Distinguish between an earth fault relay & an over-current relay. [06 Marks]

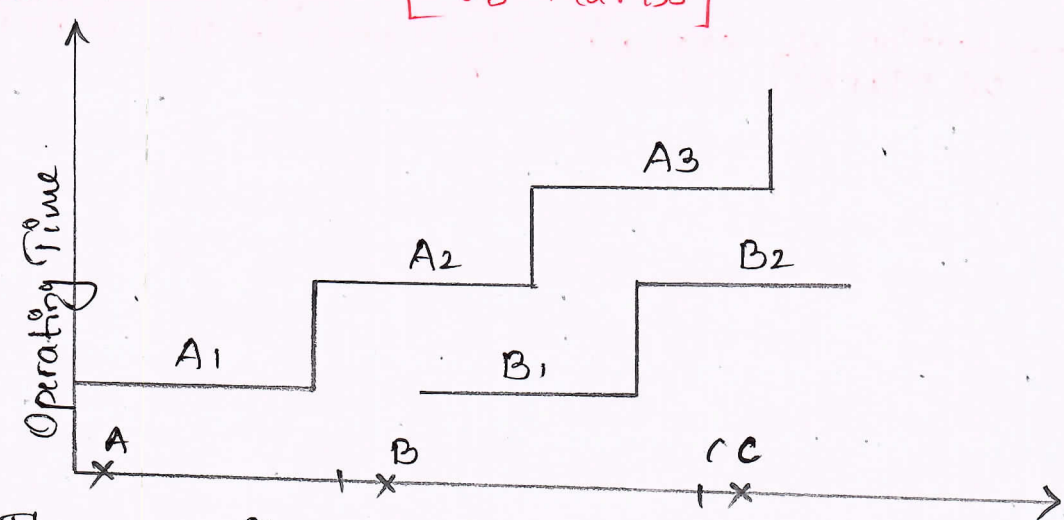
Relays which are used for the protection of a section or element of the power system against earth faults are called earth fault relays. & relays used for the protection of section of power system against phase faults are called phase fault relays or overcurrent relays.

The construction & operating principle of both the relays are same but differ only in the current levels of their operation.

The plug setting for earth fault relays varies from 20% to 80% of the CT secondary rating in steps of 10%

The plug setting for over current relays varies from 50% to 200% of the CT secondary rating insteps of 25%

Q4c) Write & explain 3 stepped distance protection of transmission line. [08 Marks]



Three units of impedance relays are required at a particular location for three zones of protection. It is normal practice to adjust first unit to protect only upto 80% to 90% of protected line which is

called first zone of protection. It is high speed unit, its operation is instantaneous about 1 to 2 cycles. This unit is not set to protect entire line to avoid undesired tripping due to overreach.

The purpose of second unit is to protect the rest of the protected line which is beyond the reach of first unit. The normal practice in second zone is to set second zone reach upto 50% of the shortest adjoining line section. Its operating time is usually 0.2 to 0.5 sec.

The third zone of protection is provided for back-up protection of the adjoining line. Its reach should extend beyond the end of the adjoining line. The setting of 3rd zone covers the first line ie protected line + longest second line + 25% of 3rd line. The time delay of 3rd zone is 0.4 to 1 sec.

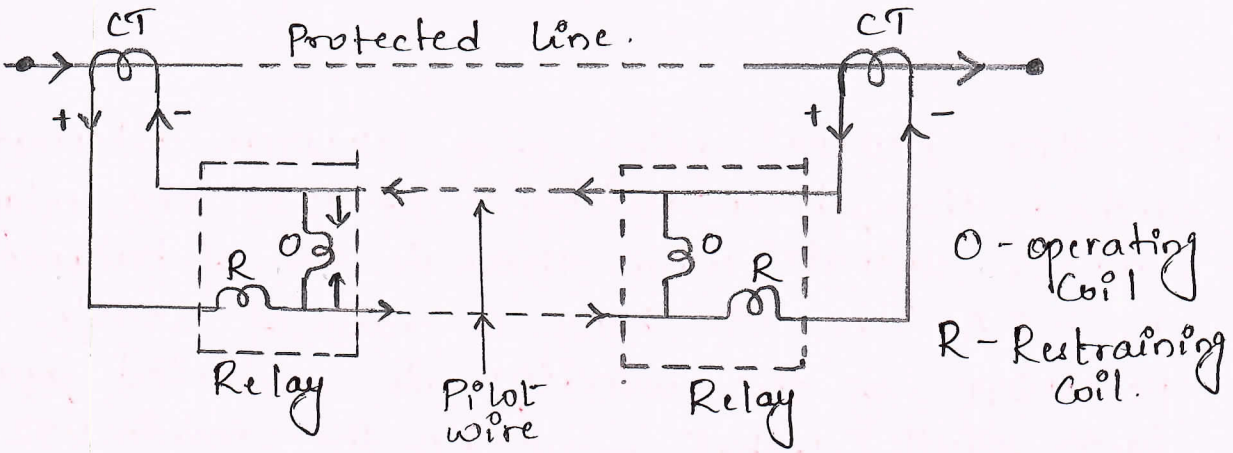
Module - 03

Q5 a) Define the term pilot with reference to power line protection. List the different types of wire pilot protection. & explain any one of the scheme. [08 Marks]

Pilot relaying schemes are used for the protection of transmission line sections. In these schemes, some electrical quantities at the two ends of the transmission line are compared & hence they require some sort of interconnecting channel over which information can be transmitted from one end to the other. Such an interconnecting channel is called a "pilot".

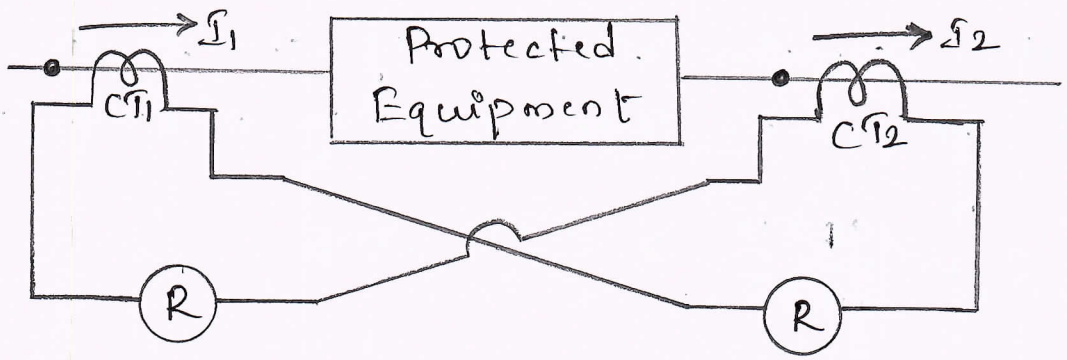
Different types of wire pilot protection are,
i) Circulating Current scheme.
ii) Balanced voltage scheme.
iii) Transley scheme.
iv) Half-Wave comparison scheme.

* Circulating Current scheme :



In a circulating current scheme, the current circulates normally through the terminal CT & pilot wire. Under normal conditions & in case of external faults Current does not flow through the operating coil. In case of internal faults, the polarity of the remote end CT is reversed & hence current flows through the operating coil of the relay.

Q5b) Explain balanced (opposed) voltage differential protection. [06 Marks]



In this scheme, the secondaries of the CT_1 & CT_2 are connected in such a way that under normal operating condition & during external faults, the secondary currents of the CT's on two sides oppose each other & their voltages are balanced. Hence no current flows in pilot wires & relays.

During internal fault, a differential current proportional to $(I_1 - I_2)$ in case of single end fed system or $(I_1 + I_2)$ in case of double end fed system flows through the relay coils. If this differential current is higher than the pick-up value, the relay operates to isolate the protected equipment from the system.

Q5 c) The neutral point of a 11kV an alternator is earthed through a resistance of 12Ω the relay is said to operate when there is out of balance of a 0.8 A. The CTs 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? [06 Marks]

Primary earth-fault current at which relay operates

$= 2000/5 * 0.8 = 320$ A.

Suppose p% of winding from the neutral remains unprotected.

The fault current $= \frac{p}{100} \times \frac{11 \times 10^3}{\sqrt{3} \times 5}$

For the operation of the relay, the fault current must be greater than the relay pick-up current.

$$\frac{p}{100} \times \frac{11 \times 10^3}{\sqrt{3} \times 5} > \frac{2000}{5} \times 0.8$$

Or $p > 25.2$

This means that 25.2% of the winding from the neutral is not protected. In other words, $100 - 25.2 = 74.8\%$ of the winding from the terminal is protected.

b) Suppose that the % of winding which remains unprotected is,

$$P = 100 - 90 = 10\%.$$

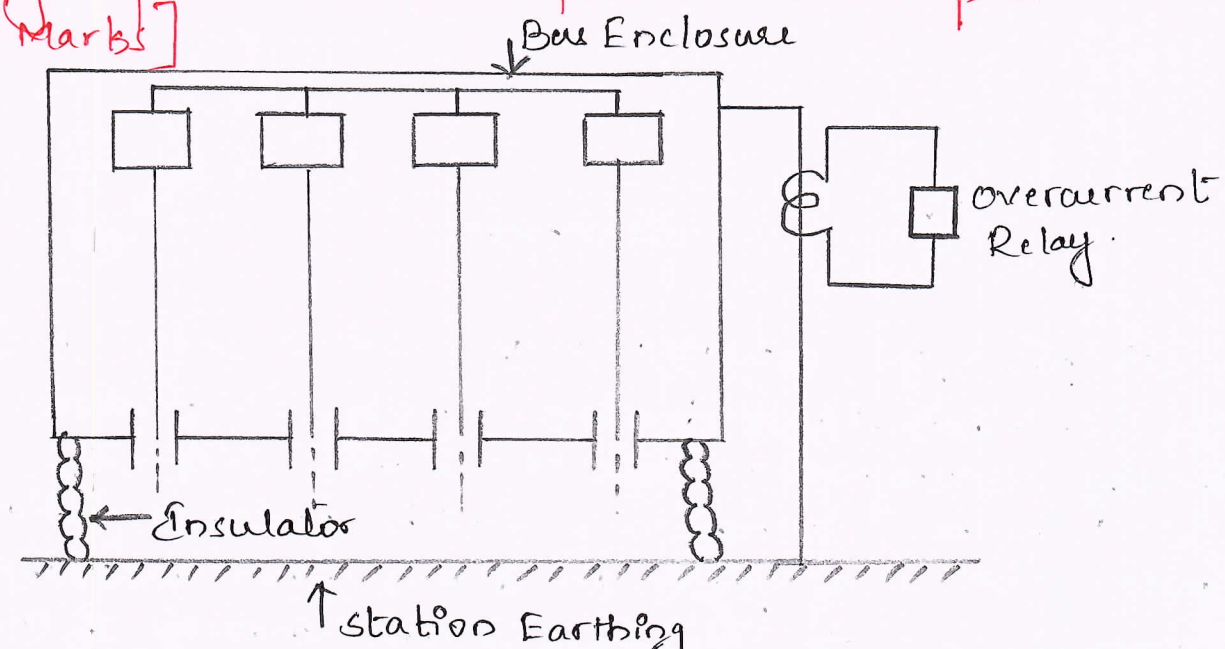
$$\text{The fault current} = \frac{P}{100} \times \frac{11 \times 10^3}{\sqrt{3} R_n}$$

$$\frac{10}{100} \times \frac{11 \times 10^3}{\sqrt{3} R_n} = 320.$$

$$1/R_n = \frac{320 \times 100 \times \sqrt{3}}{10 \times 11 \times 10^3} = 0.50$$

$$\boxed{R_n = 2\ \Omega.}$$

Q6a) With a neat sketch explain the working of frame leakage protection used for bus-zone protection. [08 Marks]

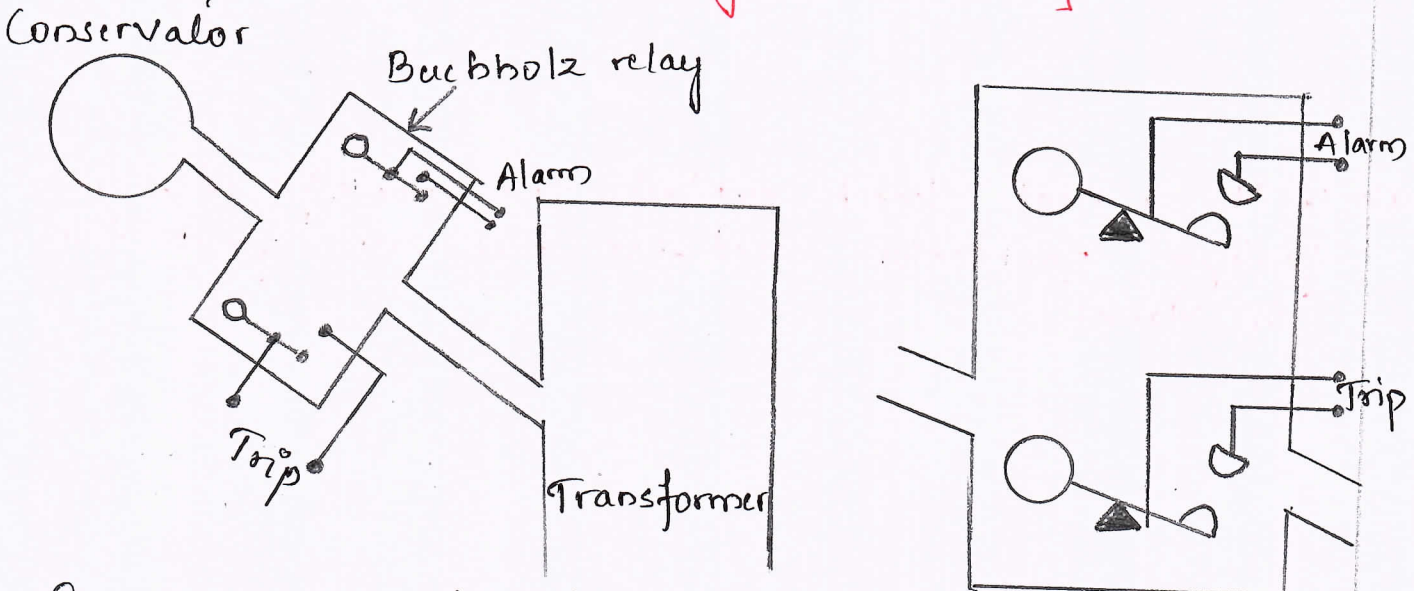


This protection scheme is more favoured for indoor than outdoor installation. This is applicable to metal clad type switchgear installations.

The frame work is insulated from the ground. The insulation is light, anything over 10Ω is acceptable. This scheme is most effective in case of isolated phase construction type switchgear installations in which all faults involves ground.

To avoid the undesired operation of the relay due to spurious currents, a check relay energized from a CT connected in the neutral of the system is employed. An instantaneous over current relay is used in this scheme, if a neutral check relay is incorporated. If neutral check relay is not employed an inverse time delay relay should be used.

Q6b) With a neat diggram explain construction & operation of Buchholz Relay [12 Marks]



It is a gas actuated relay used to detect incipient faults. When fault develops slowly, it produces heat thereby decomposing solid or liquid insulating material in the transformer which produces inflammable gases. The relay gives an alarm when a specified amount of gas is formed. The analysis of the gas collected in the relay chamber indicates type of fault.

There is chamber to accomodate Buchholz relay in between transformer & conservator as in [fig a].

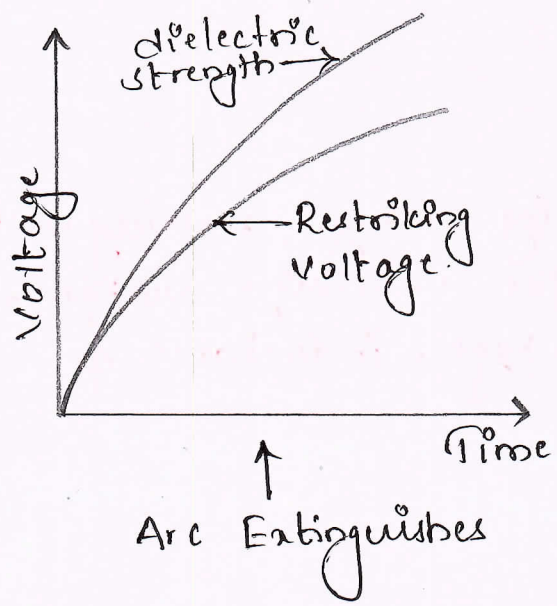
When gas accumulates, the oil level falls down & thus float also comes down. It causes an alarm to sound & alert the operator. For reliable operation mercury switch is attached with the float.

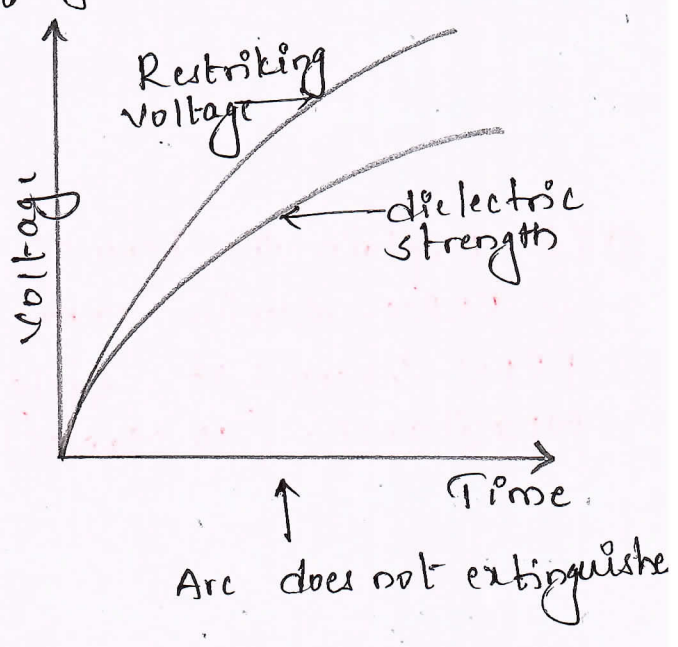
The accumulated gas can be drawn off through the petcock via a pipe for analysis. If there is a severe fault, large volume of gases are produced which causes the lower float to operate & finally trips the circuit breaker of the transformer.
The relay is slow operating device with minimum operating time of 0.1sec & average operating time of 0.2sec

Module - 04

Q 7 a) With a neat sketch explain the recovery rate theory & energy balance theory of arc interruption in a circuit breaker. [10 Marks]

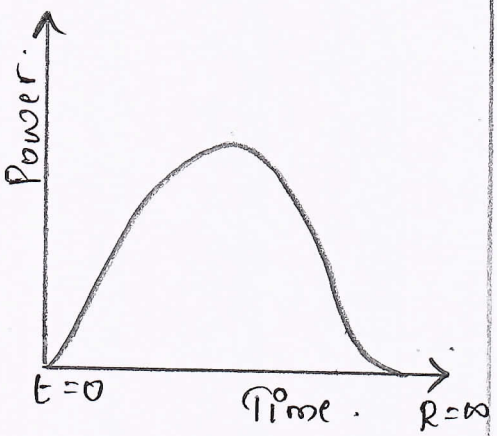
* Recovery Rate Theory:
In this theory, the rate at which the gap recovers its dielectric strength is compared with rate at which restriking voltage across the gap rises. If the dielectric strength increases more rapidly than the restriking voltage, the arc is extinguished. If the restriking voltage rises more rapidly than the dielectric strength, resulting in an arc for another half cycle.





* Energy Balance Theory:

The space between the contacts contains some ionised gas immidiately after current zero & hence it has finite post-zero resistance. At the current zero moment, power is zero because restriking voltage is zero. When arc is finally extinguished, the power again becomes zero, the gap is fully deionized & its resistance is infinitely high.



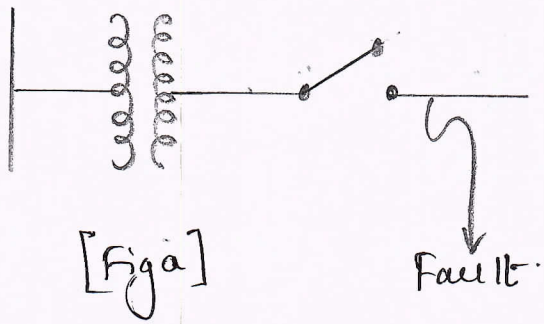
In between these two limits, first the power increases, reaches max. value, then decreases & finally reaches zero. Due to the rise of restriking voltage & associated current, energy is generated in the space between contacts. The energy appears in the form of heat & CB is designed to remove this generated heat as early as possible by cooling the gap, giving a blast of air or flow of oil at high velocity & pressure. If rate of removal of heat is faster than rate of heat generation, the arc is extinguished. If the rate of heat generation is more than the rate of heat dissipation, the space breaks down again resulting in an arc for another half-cycle.

Q7 b) Explain the terms: Restriking voltage, recovery voltage & RRRV. Derive expression for restriking voltage & RRRV interms of system voltage, inductance & capacitance. [10 Marks]

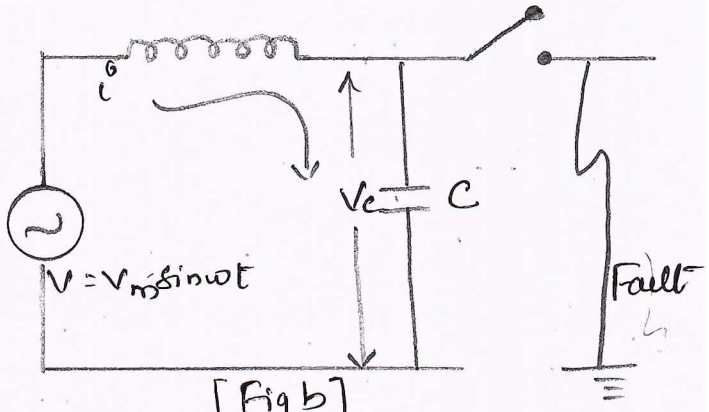
* Restriking Voltage: The transient voltage which appear across the breaker contacts at the instant of arc being extinguished.

* Recovery Voltage: The power frequency rms voltage which appears across the breaker contacts after the arc is finally extinguished & transient oscillations dieout.

* Expression for restriking voltage & RRRV.



[Fig a]



[Fig b]

[Fig a] shows short circuit (fault) on a feeder beyond the location of CB. [Fig b] shows an equivalent electrical circuit with L & C. The resistance of circuit is neglected. When CB contacts are opened & the arc is extinguished, the current i is diverted through the capacitance C resulting in a transient condition. The L & C form a series oscillatory circuit. The voltage across C which is restriking voltage rises & oscillates.

The natural frequency of oscillation is given by,

$$f_n = \frac{1}{2\pi\sqrt{LC}} \quad \text{— (1)}$$

& the natural angular frequency is,

$$\omega_n = \frac{1}{\sqrt{LC}} \quad \text{— (2)}$$

The mathematical expression for the transient condition is as follows.

$$L \cdot \frac{di}{dt} + \frac{1}{C}\int i\,dt = V_m \cos \omega t \quad \text{— (3)}$$

Since the natural frequency of oscillation is a fast phenomenon, it persist only for a short period of time. During this short period, the change in the power frequency term is very little & hence negligible because $\cos \omega t = 1$.

$$\therefore L \cdot \frac{di}{dt} + \frac{1}{C}\int i\,dt = V_m \quad \text{— (4)}$$

$$i = \frac{dq}{dt} = \frac{d(CV_c)}{dt} \quad \text{— (5)}$$

Therefore, $\frac{di}{dt} = \frac{d^2(CV_c)}{dt^2} = C \cdot \frac{d^2 V_c}{dt^2}$ — (6)

$$\frac{1}{C}\int i\,dt = \frac{q}{C} = V_c \quad \text{— (7)}$$

Substituting these values in eqn. (4) we get,

$$LC\frac{d^2V_c}{dt^2} + V_c = V_m \quad \text{— (8)}$$

Taking Laplace transform on both sides of eqn. (8)

$$LCs^2 V_c(s) + V_c(s) = \frac{V_m}{s}$$

or $$V_c(s)\left[LCs^2 + 1\right] = \frac{V_m}{s}$$

or $$V_c(s) = \frac{V_m}{s\left[LCs^2+1\right]} = \frac{V_m}{LCs\left[s^2 + \frac{1}{LC}\right]}$$

We have, $\omega_n = \frac{1}{\sqrt{LC}}$ therefore $\frac{1}{LC} = \omega_n^2$.

$$V_c(s) = \frac{\omega_n^2 V_m}{s(s^2+\omega_n^2)} = \frac{\omega_n V_m}{s}\left[\frac{\omega_n}{s^2+\omega_n^2}\right] \quad \text{— (9)}$$

Taking inverse Laplace of eqn. (9)

$$V_c(t) = \omega_n V_m \int_0^t \sin\omega_n \cdot t$$

$$V_c(t) = \omega_n V_m \left[\frac{-\cos\omega_n t}{\omega_n}\right]_0^t$$

As $V_c(t) = 0$ at $t = 0$, constant $= 0$.

$$\therefore V_c(t) = V_m\left[1 - \cos\omega_n t\right] \quad \text{— (10)}$$

Eqn. (10) is the expression for restriking voltage. The max. value of restriking voltage occurs at

$t = \pi/\omega_n = \pi\sqrt{LC}$.

Hence max. value of restriking voltage $= 2V_m$

$= 2 \times$ peak value of system voltage.

The rate of rise of restriking voltage [RRRV]

$$= \frac{d}{dt}[V_m(1-\cos\omega_n t)]$$

or $RRRV = V_m \omega_n \sin\omega_n t$ —— (11)

The max. value of RRRV occurs when $\omega_n t = \pi/2$ ie when $t = \pi/2\omega_n$.

Hence max. value of $RRRV = V_m \omega_n$.

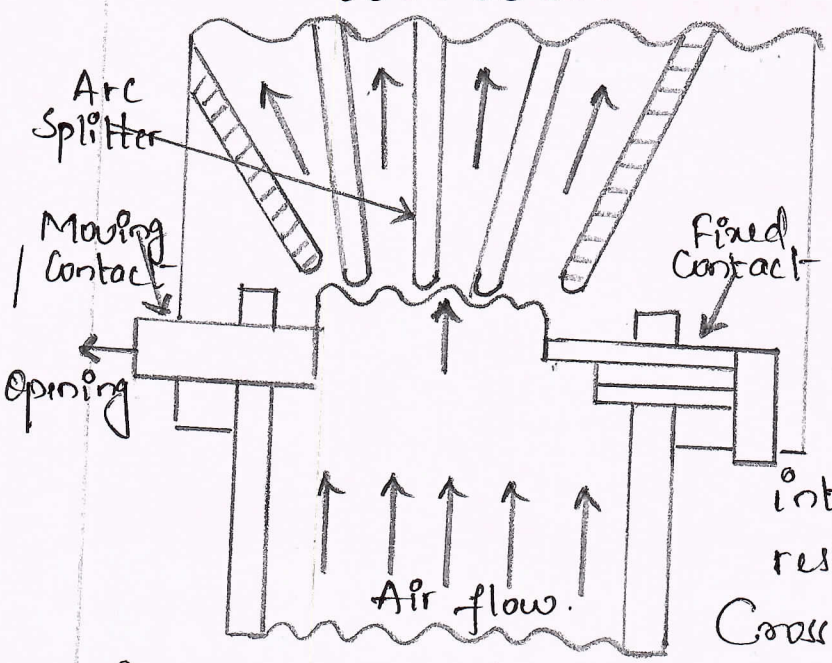
Q8a) What are the different types of air-blast circuit breaks Discuss their operating principle & area of application. [08 Marks]

Types of air-blast circuit breakers are,

i) Cross blast CB

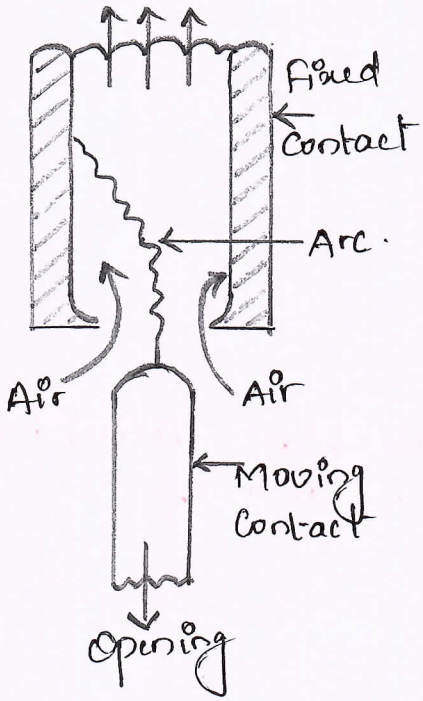
ii) Axial blast CB.

* Cross-blast CB:



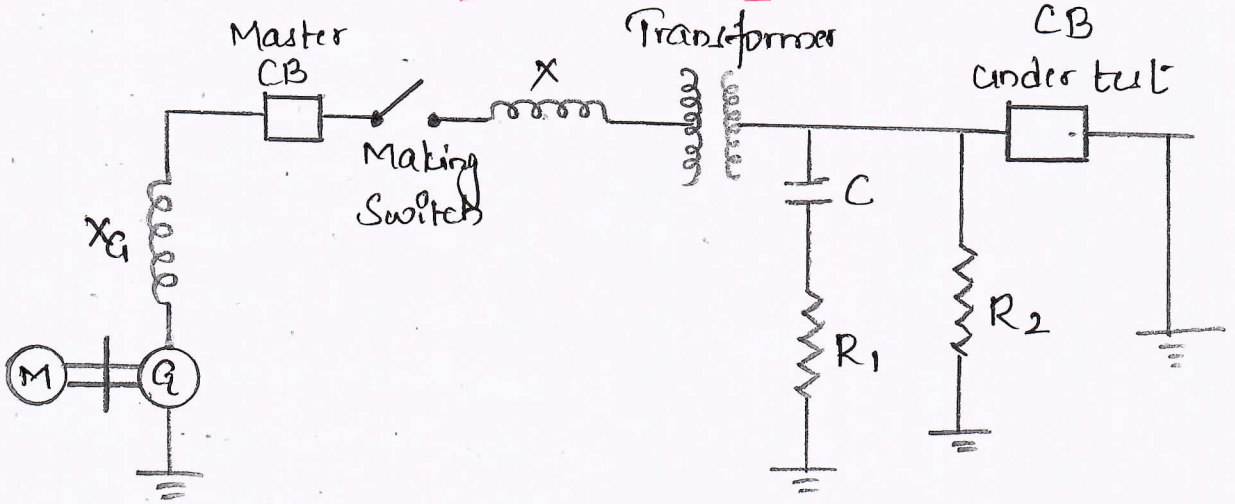
In this CB, a high pressure blast of air is directed perpendicularly to the arc for its interruption. The arc is forced into a suitable chute. Sufficient lengthning of arc is obtained, resulting in the introduction of appreciable resistance in the arc itself. Cross-blast CB are suitable for interrupting high current (upto 100kA) at comparati-vely lower voltages.

* Axial Blast CB:



In an axial blast CB, a high-pressure blast of air is directed longitudinally, ie in line with the arc. These are suitable for EHV & super high voltage application.

Q8b) With a neat sketch explain direct testing of circuit breaker. [06 Marks]



In direct testing, the CB is tested under the conditions which actually exists on power systems. It is subjected to restriking voltage which is expected in practical situation. The reactor X is to control short circuit current, C, R_1 & R_2 are to adjust transient restriking voltage.

Short-circuit tests to be performed are,

1) Test for Breaking Capacity.

First Master CB & CB under test are closed. Then short-circuit current is passed by closing the making switch. The S.C. current is interrupted by opening the breaker under test at the desired moment & following measurements are taken.

i) Symmetrical breaking current.
ii) Asymmetrical breaking current.
iii) Recovery Voltage.
iv) Frequency of oscillation & RRRV.

2) Test for Making Capacity.

The master CB & making switche are closed first then the short circuit is initiated by closing the CB under test. The rated making current ie, the peak value of the first major loop of the S.C. current wave is measured.

3) Duty Cycle test.

Following duty cycle tests are performed.

i) B-3-B-3-B tests are performed at 10%, 30% & 60% of the rated symmetrical breaking capacity.

ii) B-3-MB-3-MB tests are performed (a) at not less than 100% of the rated symmetrical breaking capacity
(b) at not less than 100% of the rated making capacity.

iii) B-3-B-3-B tests are performed at not less than 100% of the rated asymmetrical breaking capacity.

Q8 c) What are the merits & demerits of SF_6 CB. [06 Marks]

* Merits of SF_6 CB:

1) Low gas velocities & pressures employed in SF_6 CB prevent current chopping & capacitive currents are interrupted without restriking.

2) These CB are compact, having smaller overall dimension & shorter contact gaps., requires less maintenance.

3) Since the same gas is recirculated in the circuit, requirement of SF_6 gas is less.

4) Operation of the CB is noiseless because there is no exhaust to atmosphere.

5) Because of inertness of SF_6 gas, contact corrosion is small hence contacts do not suffer oxidation.

6) Since the gas is non-inflammable & chemically stable & the products of decomposition are not explosive, there is no danger of fire or explosion.

* Demerits of SF_6 CB:

1) Problems of perfect sealing.

2) SF_6 gas is suffocating to the operator to some extent.

3) Arced SF_6 gas is poisonous & should not be inhaled or let out.

4) Influx of moisture in the breaker is very harmful to SF_6 CB.

5) Internal parts should be cleaned thoroughly during periodic maintainance.

6) Special facilities are required for transporting gas.

Module-05

Q9a) Define the following terms.
i) Fuse
ii) Fuse Element
iii) Rated Current
iv) Minimum fusing current
v) Fusing Factor.
[06 Marks]

i) **Fuse**: A fuse is protective device used for protecting cables & electrical equipment against overloads and/or short circuits. It breaks the circuit by fusing the fuse element when the current flowing in the circuit exceeds a certain predetermined value.

ii) **Fuse Element**: It is that part of the fuse which melts when the current flowing in the circuit exceeds a certain predetermined value & thus breaks the circuit.

iii) **Rated Current**: It is the current fuse can carry indefinitely without fusing.

iv) **Minimum Fusing Current**: It is the minimum current (rms value) at which the fuse element will melt.

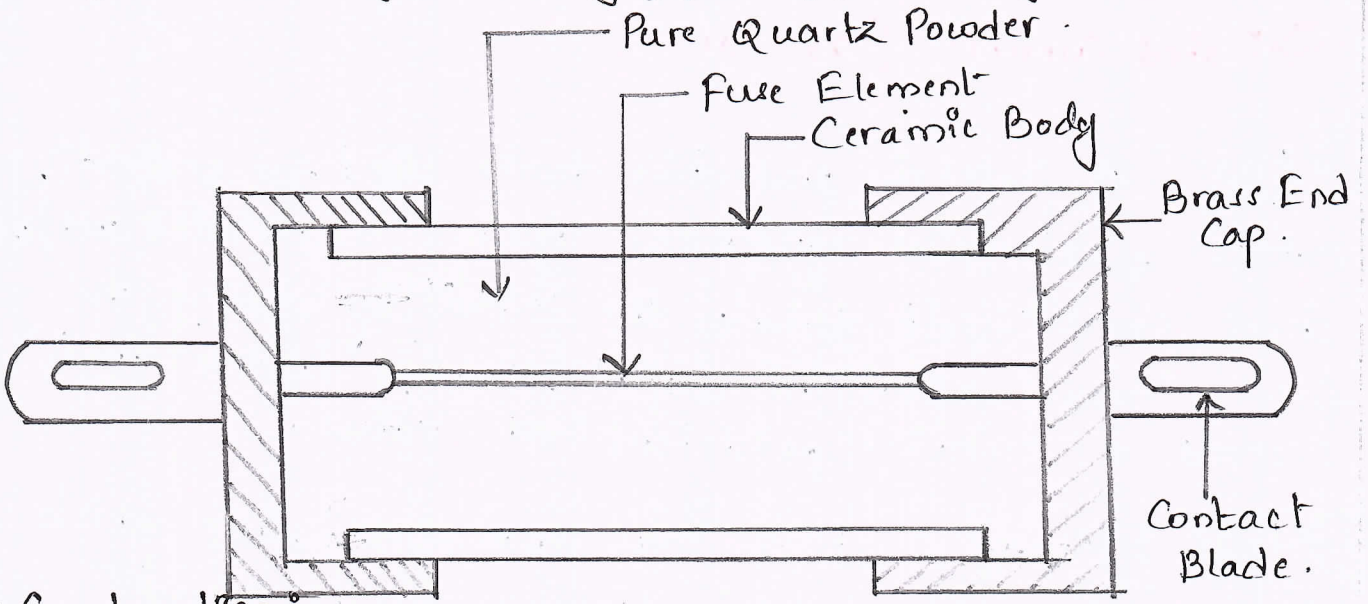
v) **Fusing Factor**: It is defined as the ratio of the minimum fusing current to rated current.

$$\text{i.e. Fusing Factor} = \frac{\text{Minimum fusing current}}{\text{Rated Current}}$$

This factor is always more than unity.

Q9 b) Describe the construction & operation of the HRC cartridge fuse with indicator. Write the applications of HRC fuse. [08 Marks]

High Rupturing Capacity (HRC) Cartridge Fuse.



* Construction:

The HRC fuse consist of cylindrical body of ceramic material usually pure silver element, pure quartz powder, brass end cap & copper contact blades. The fuse element is fitted inside the ceramic body & space within the body surrounding the element is completely filled with pure powdered quartz. The ends of the fuse element are connected to the metal end caps which are screwed to the ceramic body by means of special forged screws. The fuse element has two or more sections joined together by means of a tin joint which prevent silver from attaining a high temperature.

* Operation:

When fuse carries normal rated current, the heat energy generated is not sufficient to melt the fuse element. But when fault occurs, the fuse element melts before fault current reaches its first peak. As the element melts, it vapourizes & disperses.

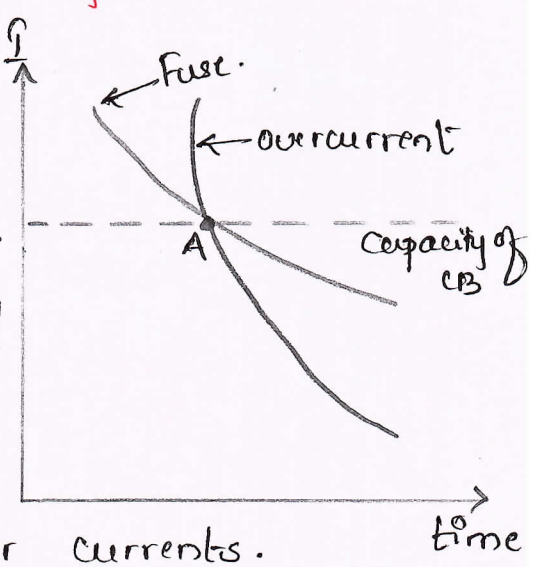
During the arcing period, the chemical reaction between the metal vapour & quartz powder forms a high resistance which helps in quenching the arc. Thus the current is interrupted.

*Applications of HRC Fuse:

1) Protection of low voltage distribution system against overloads & short circuits.
2) Protection of cables.
3) Protection of busbars.
4) Protection of motors.
5) Protection of semiconductor devices.
6) Backup protection to CB.

Q9c) Write discrimination between fuse & over-current protective devices. [06 Marks]

In motor circuits, fuse provide short-circuit protection & overcurrent relay provides overcurrent protection. The characteristics of fuse & OC relay are coordinated in such a way that OC relay operates for currents within the breaking capacity of CB & fuses operates for faults of larger currents. For this purpose the characteristic of OC protective device should be below that of the fuse as shown in fig.

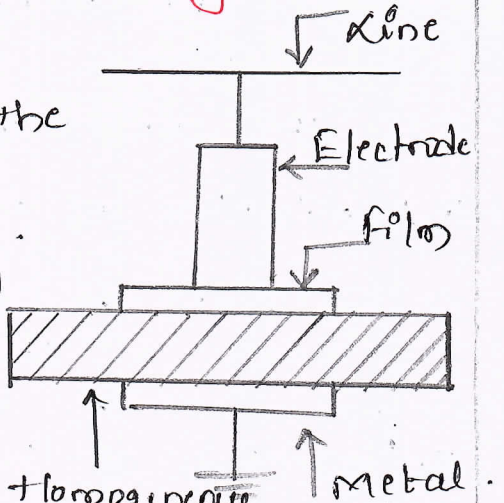


The fuse is so selected that, the intersection of the characteristics of these two protective devices must takes place at point (A) corresponding to six time the full-load current, keeping in view that the protective devices do not operate unduly during starting. In this case, the fuse provides backup protection to the motor & is connected on the supply side.

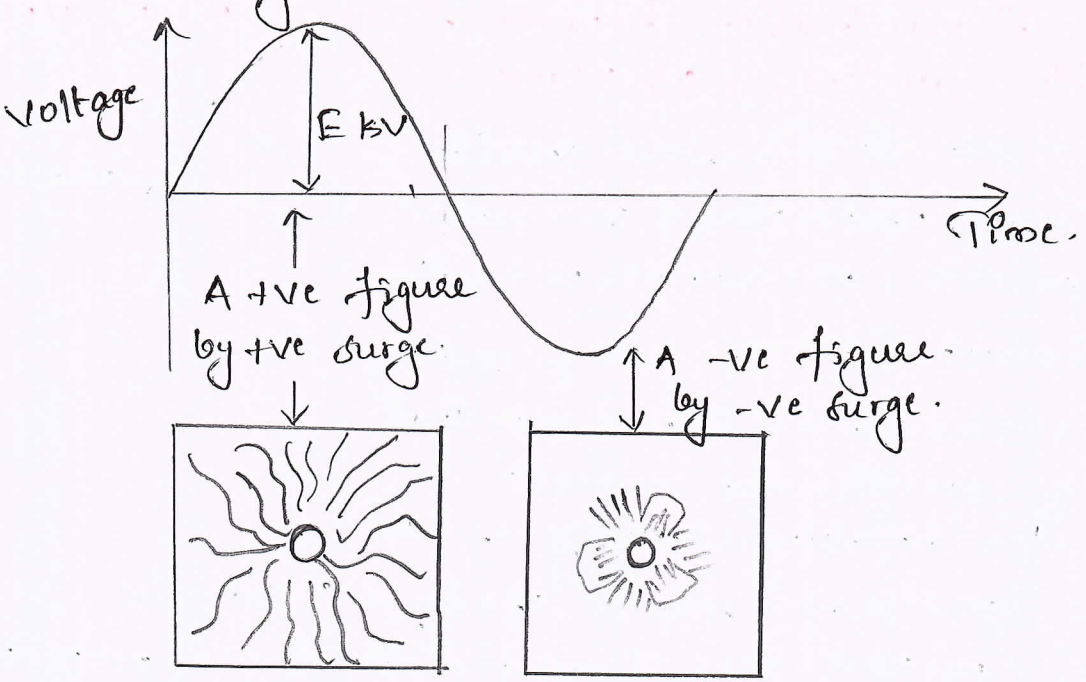
Q 10. a) Write a note on Klydonograph & Magnetic Links. [08 Marks]

* Klydonograph:

Klydonograph is an instrument for the measurement of surge voltage on transmission lines caused by lightning.



The photographic plate or the film is turned or moved by a clockwork mechanism for bringing in the element of time. With this arrangement, a +ve Lichtenberg figure is produced by +ve & -ve Lichtenberg figure by a -ve surge as shown below.



The +ve Lichtenberg figure is found to be superior to the -ve ones for voltage measurement purpose, since they are much larger than -ve figures for the same voltage.

* Magnetic Link:

The magnetic link 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, with open end sealed in.

it is placed in an unmagnetized state in the vicinity of the conductor whose surge current is desired to be measured.

When the current flows through the conductor, a magnetic field is setup around it which is proportion to the current. The magnetizing force of this field magnetizes the magnetic link placed in the vicinity of the conductor. After the current has passed, the link is left with residual magnetism which is function of magnitude of the current producing it for unidirectional surges. The residual magnetism may be measured by a suitable instrument & the magnitude of the current which produces it may be determined by an experimentally obtained calibration curve of current vs. residual magnetism.

The magnetic link is extensively used to measure current in direct strokes, in transmission line - tower legs, ground wires, phase conductors, & in ground leads of arresters.

Q10b) What is Gas Insulated substation? Discuss its advantages & disadvantages as compared to conventional air insulated substation. [08 Marks]

The various substation equipments such as CBs, bus bars, earthing switches, isolators, instrument transformers (CT & PT) etc., are housed in separate metal-encapsulated modules filled with pressurized SF_6 gas, the assembly of such equipment at a substation is defined as GIS.

* Advantages:

1) Compactness: GIS are compact in size & the space occupied by them is about 15% of that of conventional air insulated outdoor substation.

2) Cost-effective, reliable & maintenance free:
GIS offers cost effective, reliable & maintenance free alternative to conventional air insulated substation.

3) Protection from pollution: The moisture, pollution, dust etc., have little influence on GIS.

4) Reduced Installation Time: The modular construction reduces the installation time to a few weeks.

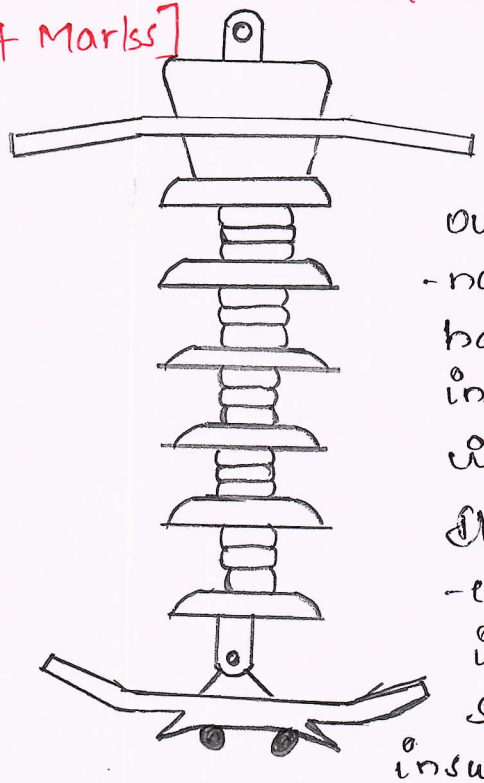
5) Superior Arc Interruption: SF_6 gas used in the CB has superior arc quenching property.

6) Reduced Switching Overvoltages: The overvoltages while closing & opening line, cables, motors, capacitors etc., are low.

7) Increased safety: As the metal enclosures of the various modules are at ground potential, there is no possibility of accidental contact by service personnel to live parts.

* Disadvantages:
1) GIS has high cost as compared to conventional outdoor substation.
2) Requirement of Cleanliness in GIS are very stringent as dust or moisture can cause internal flashover.
3) Since GIS are generally indoor, they need separate building which is generally not required for conventional substation.
4) GIS can have excessive damage in case of internal fault & there may be long outage periods as repair of damaged part may be difficult at site.

Q10C) Write a short note on Arcing horn with diagram. [04 Marks]



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 arc & is known as Arcing Horn. It consist of small horns attached to the clamp of the line insulator string. Horns with large spread, both at the top of the insulator & at the clamp are required to be effective. 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 string. Protection of Line insulators by arcing horns thus results in reduced flashover voltage. 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 insulator string serves the purpose of arcing shield. In the event of an arc forming following a flashover caused by some type of overvoltage, the arc will usually take a path between the horn & shield & insulator string will remain clear from the arc.

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