CBCS SCHEME

USN 2VD22EE431 **21EE71**

Seventh Semester B.E./B.Tech. Degree Examination, Dec.2024/Jan.2025
High Voltage and 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. Mention the desired properties of gaseous dielectric for high voltage application. **(04 Marks)**

b. Derive an expression for the current in air gap $I = I_0 \,Exp\,(\alpha d)$ considering Townsends first ionization coefficient. **(08 Marks)**

c. Explain the following mechanism in liquid dielectric:
(i) Suspended particle mechanism
(ii) Thermal mechanism **(08 Marks)**

OR

2 a. What is Paschen's law? Discuss to measure minimum voltage for breakdown under a given P × d conditions. **(10 Marks)**

b. Explain the following mechanism in solid dielectric:
(i) Electronic Breakdown
(ii) Avalanche or Streamer Breakdown **(10 Marks)**

Module-2

3 a. With a neat sketch, explain the working of Cockeroft Walton Voltage Multiplier with waveforms. **(10 Marks)**

b. With a neat sketch, explain:
(i) Series Resistance Microammeter
(ii) Resistance Potential divider
for measurement of high dc voltage. **(10 Marks)**

OR

4 a. Explain in detail the components of Multistage impulse generator. **(10 Marks)**

b. Explain discharge detection using straight detectors. **(10 Marks)**

Module-3

5 a. With a neat diagram, explain zones of protection in a power system. **(08 Marks)**

b. List the types of faults and its effects. **(04 Marks)**

c. With a neat diagram, explain the construction and working of:
(i) Plunger or solenoid type relay
(ii) Reed Relay **(08 Marks)**

OR

6 a. Explain in detail about Primary and Backup protection. **(08 Marks)**

b. With a neat sketch, explain the working of Induction Cup relay. **(08 Marks)**

c. Write short notes on protection of parallel feeder. **(04 Marks)**

Module-4

7 a. With a neat sketch, explain the Operating Principle of impedance relay and its characteristics. (08 Marks)
b. Explain Balanced Voltage Scheme with a neat diagram. (08 Marks)
c. Explain in brief protection of transformer against overheating. (04 Marks)

OR

8 a. List the various type of differential relay and explain any one of them. (10 Marks)
b. Write a short note on stator overheating protection. (10 Marks)

Module-5

9 a. Explain with a neat sketch Air-break Circuit Breaker. (10 Marks)
b. Explain the causes of over voltages. (10 Marks)

OR

10 a. Explain in detail about direct testing and indirect testing of circuit breaker. (10 Marks)
b. With a neat diagram, explain the construction and working of klydonograph. (10 Marks)

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Solution of VTU QP Dec. 2024 | Jan. 2025

High Voltage and Power System Protection [21EE71]

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Module - 01

[1a] Mention the desired properties of gaseous dielectric for high voltage application. (04 Marks)

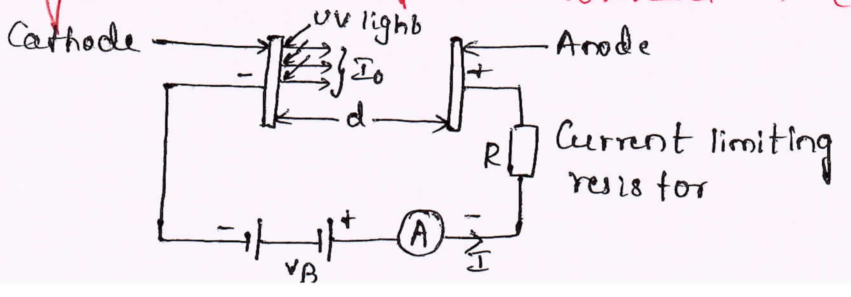
→ Desired properties of gaseous dielectric for high voltage application are,

* High dielectric strength
* High thermal stability.
* Chemical inertness.
* Non-inflammability.
* Good heat transfer capability
* Low cost.

Example of gaseous dielectric : Air, SF_6, Vacuum

[1b] Derive an expression for the current in air gap $I = I_0 \, Exp(\alpha d)$ considering Townsend's first ionization coefficient. (08 Marks)

→



* Referring to figure, let us assume that no electrons are emitted from the cathode. When one electron collides with a neutral particle, a positive ion and an electron are formed. This is called an ionizing collision.

* Let α be the average number of ionizing collisions made by an electron per centimetre travel in the direction of the field (α depends on gas pressure p & E/p, and is called the Townsend's first ionization coefficient).

* At any distance x from the cathode, let the number of electrons be n_x. When these n_x electrons travel a further distance of dx they give rise to the $(\alpha n_x dx)$ electrons.

At $x = 0,\ n_x = n_0$

Also, $\frac{dn_x}{dx} = \alpha n_x$; or $n_x = n_0 \exp(\alpha x)$

Then, the number of electrons reaching the anode $(x = d)$ will be

$$n_d = n_0 \exp(\alpha, d)$$

The number of new electrons created, on the average, by each electron is

$$\exp(\alpha d) - 1 = \frac{n_d - n_0}{n_0}$$

∴ The average current in the gap, which is equal to the number of electrons travelling per second will be.

$$I = I_0 \exp(\alpha d)$$

where I_0 is the initial current at the cathode.

[1 c] Explain the following mechanism in liquid dielectric:
(i) Suspended particle mechanism
(ii) Thermal mechanism.

(08 Marks)

→ (i) Suspended particle mechanism:

* In commercial liquids, the presence of solid impurities cannot be avoided. These impurities will be present as fibres or as dispersed solid particles.

* The permittivity of these particles (ε_2) will be different from the permittivity of the liquid (ε_1).

* If we consider these impurities to be spherical particles of radius r, & if the applied field is E, then the particles experience a force F, where,

$$F = \frac{1(\varepsilon_2 - \varepsilon_1)}{2r^3 2\varepsilon_1 + \varepsilon_2} \text{ grad } E^2.$$

* These force is directed towards areas of maximum stress, if $\varepsilon_2 > \varepsilon_1$. One the other hand, if only gas bubbles are present in the liquid i.e $\varepsilon_2 < \varepsilon_1$, the force will be in the direction of areas of lower stress.

(ii) Thermal mechanism:

* This mechanism is based on the experimental observations of extremely large currents just before breakdown.

* This high current pulses are believed to originate from the tips of the microscopic projections on the cathode surface with densities of the order of $1 A/cm^3$.

* This high density current pulses give rise to localised heating of the oil which may lead to the information of vapour bubbles.

* The vapour bubbles are formed when the energy exceeds

10^7 J/cm^2.

* This theory is only applicable at very small lengths ($\leq 100 \mu m$) and does not explain the reduction in breakdown strength with increased gap lengths.

OR

[2a] What is Paschen's Law? Discuss to measure minimum voltage for breakdown under a given P×d conditions. (10 Marks)

→ Paschen's studied breakdown voltage of different gaseous dielectric material - SF6, vacuum, CO_2, here the pressure and distance is varied.

He found that breakdown voltage is a function of product of pressure and distance.

∴ Breakdown voltage, $V = f(pd)$

This is called Paschen's law for gaseous dielectric.

* Breakdown criterion in gases is given as

$$\gamma[\exp(\alpha d) - 1] = 1$$

where the coefficients α and γ are functions of E/p. i.e.

$$\frac{\alpha}{p} = f_1\left(\frac{E}{p}\right)$$

& $$\gamma = f_2\left(\frac{E}{p}\right)$$

Also $$E = \frac{V}{d}$$

Substituting for E in the expressions for α and γ,

$$f_2\left(\frac{V}{pd}\right)\left[\exp\left\{pd f_1\left(\frac{V}{pd}\right)\right\} - 1\right] = 1$$

This equation shows a relationship between V and pd, and implies that the breakdown voltage varies as the product pd varies. Knowing the nature of functions f_1 and f_2 we can rewrite as $V = f(pd)$.

* The paschen's curve, the relationship between V and pd is shown as below figure.
It is seen that the relationship between V and pd is not linear and has a minimum value for any gas.

* Based on the experimental results, the breakdown potential of air is expressed as a power function in pd as

$$V = 24.22\left[\frac{293pd}{760T}\right] + 6.08\left[\frac{293pd}{760T}\right]^{1/2}$$

At 760 torr and 293 k

$$E = \frac{V}{d} = 24.22 + \left[\frac{6.08}{\sqrt{d}}\right] kV/cm$$

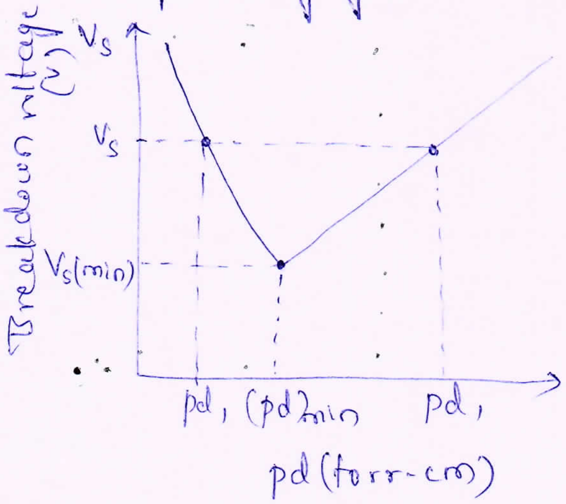


Fig: Breakdown voltage-pd curve

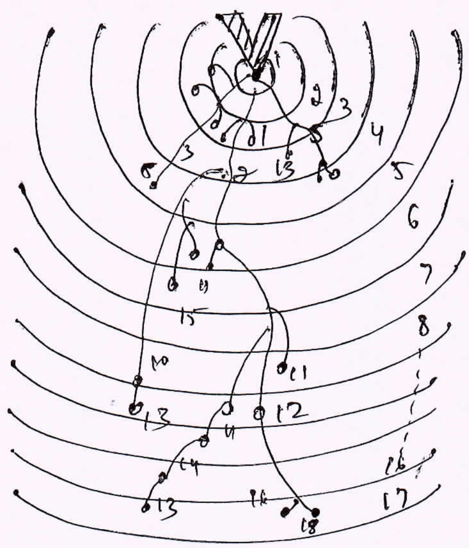
This equation yields a limiting value for E of 24 kV/cm for long gaps & a value of 30 kV/cm for $\left(\frac{293\,pd}{760T}\right)$ //.

[2b] Explain the following mechanism in solid dielectric:
(i) Electronic Breakdown.
(ii) Avalanche or Streamer Breakdown. (10 Marks).

→ (i) Electronic Breakdown:

* Intrinsic breakdown occurs in time of the order of 10^{-8} s and therefore is assumed to be electronic in nature.
* The initial density of conduction (free) electrons is also assumed to be large, and electron-electron collisions occur.
* When an electric field is applied, electrons gain energy from the electric field and cross the forbidden energy gap from the valency to the conduction band.
* When this process is repeated, more and more electrons become available in the conduction band, eventually leading to breakdown.

(ii) Avalanche or Streamer Breakdown:



* This is similar to breakdown in gases due to cumulative ionization. Conduction electrons gain sufficient energy above a certain critical electric field and cause liberation of electrons from the lattice atoms by collisions.

* Under uniform field conditions, if the electrodes are embedded in the specimen, breakdown will occur when an electron avalanche bridges the electrode gap.

* When the energy gained by an electron exceeds the lattice ionization potential, an additional electron will be liberated due to collision of the first electron.

* This process repeats itself resulting in the formation of an electron avalanche.

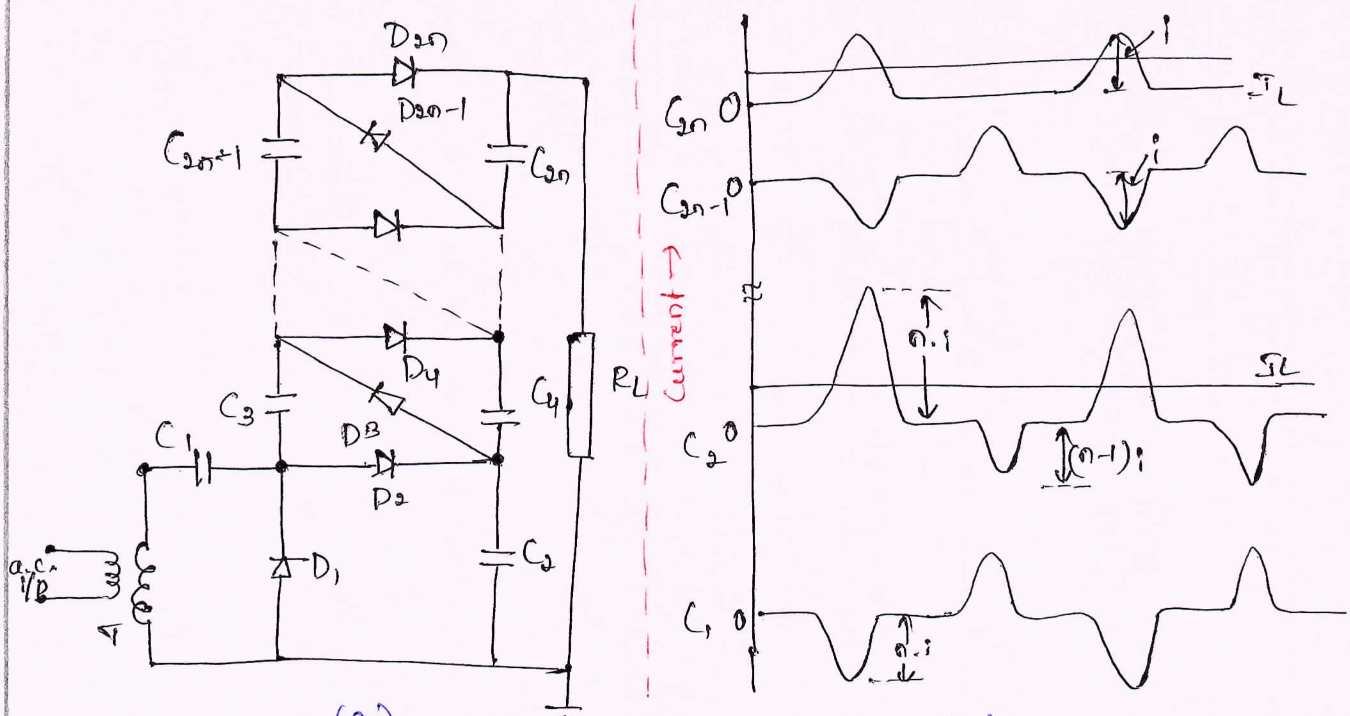
Module - 2

3a] With a neat sketch, explain the working of Cockcroft Walton voltage Multiplier with waveforms. (10 Marks)

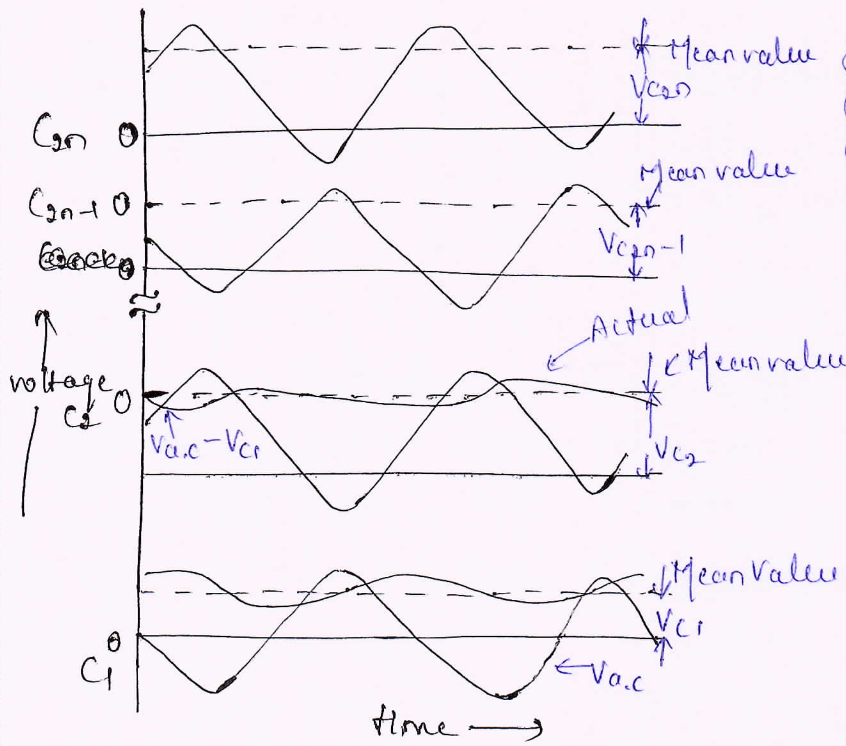
→ * Cascaded voltage multiplier circuits for higher voltages are cumbersome and require too many supply and isolating transformers.

* A trigger voltage pulse of triangular waveform (ramp) is given to make the valve switched on and off.

* Thus a voltage across the coil L is produced and is equal to $V_{max} = I\sqrt{L/C_p}$.



(a) (b)



(C)

* Voltage multiplier circuit using the Cockcroft-Walton principle is shown in fig (a)

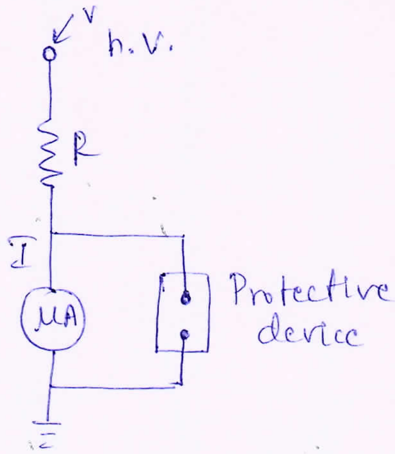
* The first stage, i.e D_1, D_2, C_1, C_2, and the transformer T are identical as in the voltage doubler shown in fig.

* The rectifiers $D_1, D_3 - D_{2n-1}$ shown in fig(a) operate and conduct during the positive half cycles while the rectifiers $D_2, D_4 -- D_{2n}$ conduct during the negative half cycles.

* Typical current & voltage waveforms of such a circuit are shown in fig(b) & fig(c) respectively.

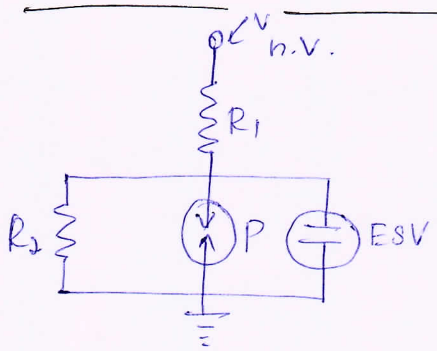
[3b] With a neat sketch, explain:
(i) Series Resistance Microammeter
(ii) Resistance Potential divider
for measurement of high dc voltage. (10 Marks)

→ (i) Series Resistance Microammeter:

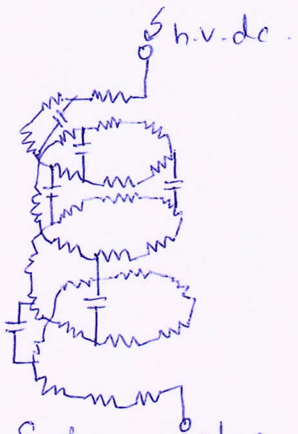


* High d.c. voltages are usually measured by connecting a very high resistance in series with a micro ammeter as shown in Figure.
* Only the current I flowing through the large calibrated resistance R is measured by the moving coil microammeter. The voltage of the source is given by V = IR.
* The voltage drop in the meter is negligible, as the impedance of the meter is only few ohms compared to few hundred mega-ohms of the series resistance R.

(ii) Resistance Potential divider:



(a) Resistance potential divider



(b) Series resistor.

* A resistance potential divider with an electrostatic or high impedance voltmeter is show in fig (a).
* The influence of temperature & voltage on the elements is eliminated in the voltage divider arrangement.
* The high voltage magnitude is given by $[(R_1+R_2)/R_2]V_2$, where V_2 is the d.c. voltage across the low voltage arm R_2.
* A series resistor with a parallel capacitor connection for linearization of transient potential distribution is shown in Fig (b).

4[a] Explain in detail the components of Multistage impulse generator. (10 Marks).

→ (i) d.c. Charging Set :

* The charging unit should be capable of giving a variable d.c voltage of either polarity to charge the generator capacitors to the required value.

(ii) Charging Resistors :

These will be non-inductive high value resistors of about 10 to 100 kilo-ohms. Each resistor will be designed to have a maximum voltage between 50 and 100 kV.

(iii) Generator Capacitors and Spark Gaps:

These are arranged vertically one over the other with all the spark gaps aligned. On dead short circuit, the capacitors will be capable of giving 10 kA of current.

(iv) Wave-shaping Resistors and Capacitors :

Resistors will be non-inductive wound type and should be capable of discharging impulse currents of 1000A or more. Each resistor will be designed for a maximum voltage of 50 to 100 kV.

(v) Triggering System :

This consists of trigger spark gaps to cause spark breakdown of the gaps.

(vi) Voltage Dividers :

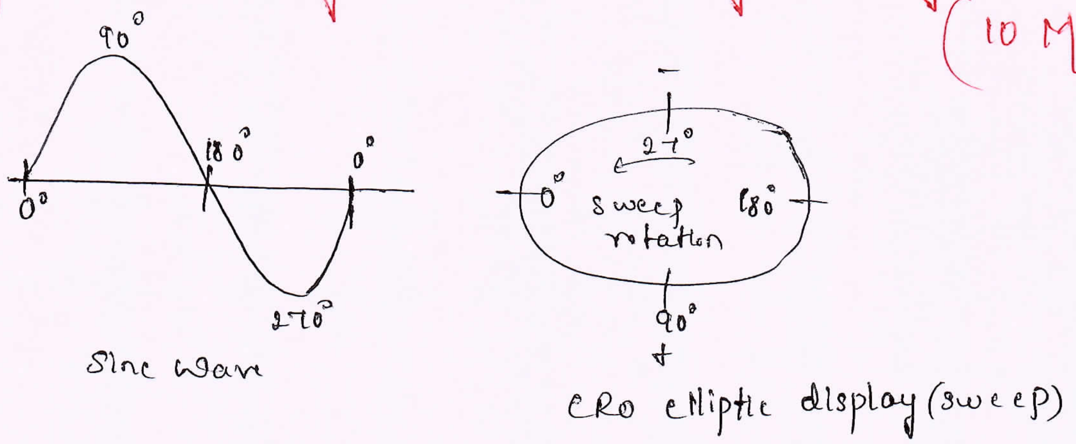
Voltage dividers of either damped capacitor or resistor type and an oscilloscope with recording arrangement are provided for measurement of the voltages across the test object.

(vii) Gas insulated impulse generators :

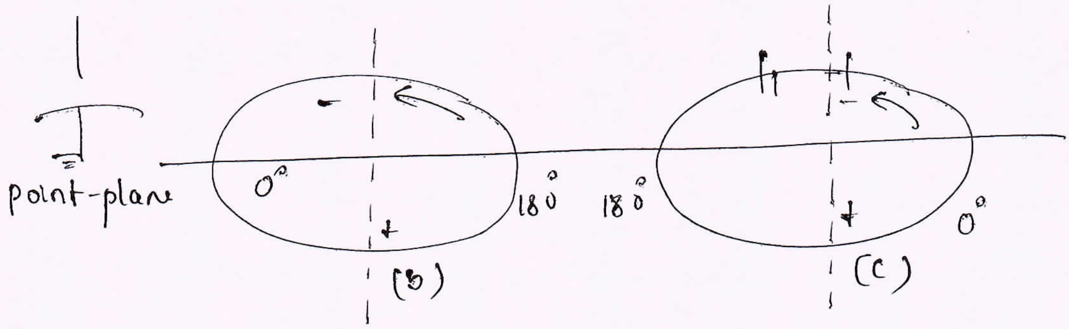
Impulse generators rated for 4 MV or above will be very tall & require large space. Impulse generators are needed to generate very fast transients having time duration of 0.5/5 or 0.1/1.0 μs waves for testing Gas Insulated systems (GIS) that are coming up.

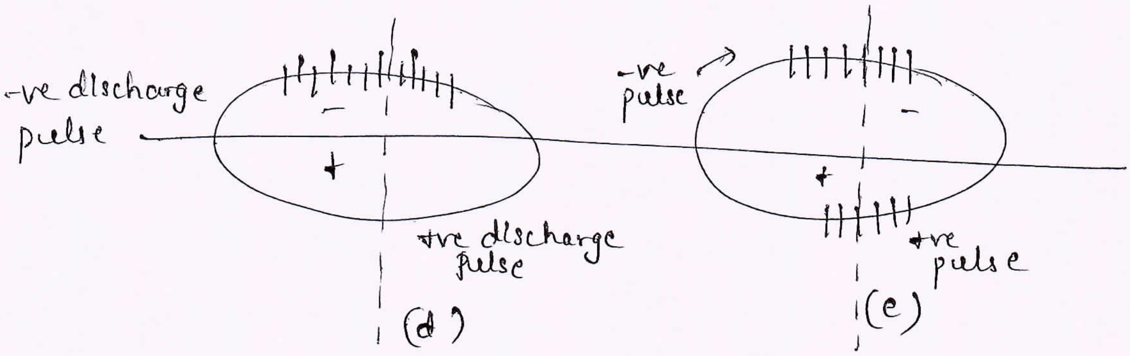
[4 b] Explain discharge detection using straight detectors. (10 Marks)

→



(a) Elliptic sweep display.





* In above figures, the discharge pattern displayed on the CRO screen of a partial discharge detector with an elliptical display is shown.

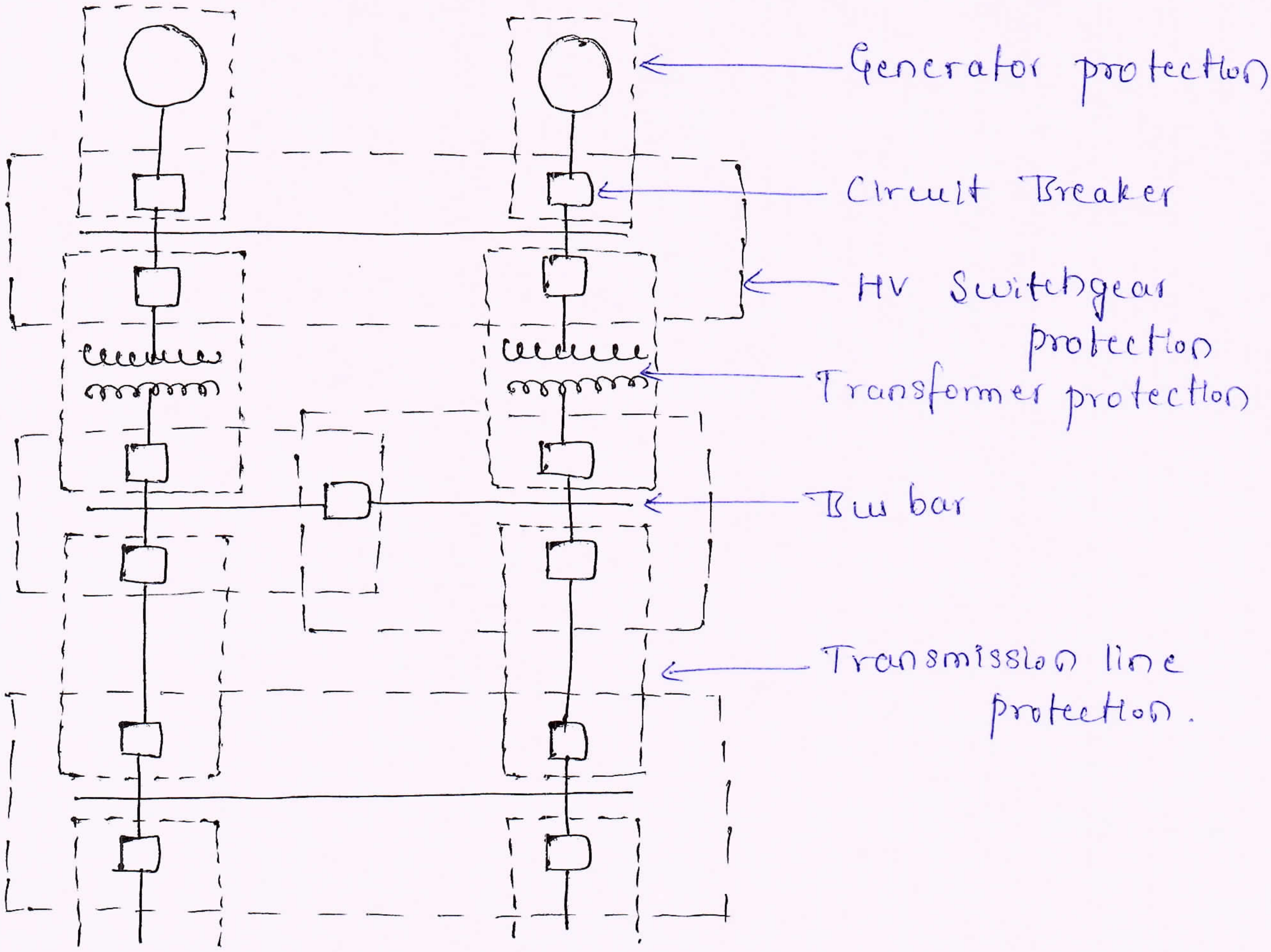
* The sinusoidal voltage and the corresponding ellipse pattern of the discharge are shown in Fig (a) ~~& (b)~~ and a sigal corona pulse in a point-plane spark gap geometry as shown in fig(b) and (c).

* When the voltage applied is greator than that of the critical inception voltage, multiple pulses appear in fig (c) and all the pulses are of equal magnitude.

* A typical discharge pattern in cavities inside the insulation is shown in Fig (d).

Module - 3

[5a] With a neat diagram, explain zones of protection in a power system (08 Marks)



* A power system contains generators, transformers, busbar, transmission & distribution lines etc,
* There is a separate protective scheme for each piece of equipment of power system such as generator protection, transforme-r protection, transmission line protection etc.
* The power system is divided into no. of zones of protection etc. ~~The~~
* The protective zones are planned in such a way that the entire power system is collectively covered by them & no part of the power system is left unprotected.
* Adjacent protective zones must overlap each other, failing which a fault on boundry of a zone may not lie in any of the zones & hence no circuit breaker ~~is~~ would trip.
* Thus overlapping between adjacent zones is unavoidable

[5 b] List the types of faults and its effects (04 Marks)

→ Types of faults are.

1) Symmetrical faults

2) Unsymmetrical faults.

i) Single -phase to ground (L-G) fault

ii) Two -phase to ground (L-L-G) fault

iii) Phase-to-phase fault (L-L)

iv) Open-circuited phases:

v) Winding faults.

3) Simultaneous faults.

Effects of faults:

* Heavy short circuit current may cause damage to equipment or any other element of the system due to overheating & high mechanical forces set up due to heavy current.

* Arcs associated with short circuits may cause fire hazards such fires, resulting from arcing, may destroy the faulty element of the system.

* There may be reduction in the supply voltage of the healthy feeders, resulting in the loss of industrial loads

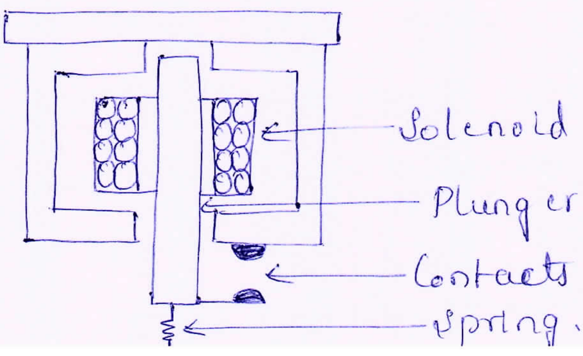
* There may be loss of system stability.

[5 c] With a neat diagram, explain the construction and working of:

(i) Plunger or solenoid type relay.

(ii) Reed Relay. (08 Marks)

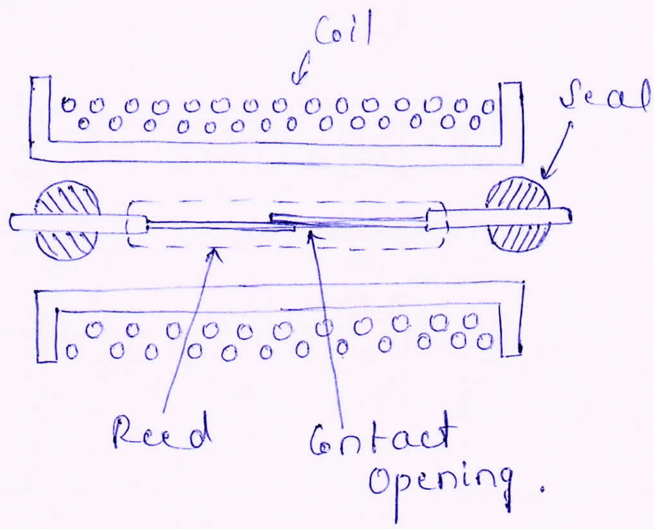
→ (i) Plunger or solenoid type relay:



* Figure shows a plunger-type relay.
* In this type of relay, there is solenoid & an iron plunger which moves in & out of the solenoid to make & break the contact.
* The movement of the plunger is controlled by spring.
* This type of construction has become absolete as it draws more current.

(ii) Reed Relay:

* A reed relay consists of coil & nickel-iron strips (reeds) sealed in a closed glass capsule as shown in Fig.
* The coil surrounds the reed contact.
* When a coil is energized, the magnetic field is produced which cause the reeds to come together & close the contact.



* Reed relays are reliable & maintenance free.
* They serve as static relays & used for control & other purposes.

6a] Explain in detail about Primary and Backup protection (08 Marks)

→ * Primary protection is the first line of defense & is responsible to protect all the power system elements from all the types of faults.
* The backup protection comes into play when the primary protection fails.

The backup protection is provided as the main protection can fail due to many reasons,

i) failure in circuit breaker.
ii) failure in protective relay.
iii) failure in tripping circuit
iv) failure in dc tripping voltage.
v) Loss of voltage or current supply to the relay.

Thus if the backup protection is absent & main protection fails then there is possibility of severe damage to the system.

There are 3 types of backup relays.

a) Remote backup
b) Relay backup
c) Breaker backup.

a) Remote Backup → when backup relays are located at a neighbouring station, they backup the entire primary protective scheme which includes relay, CB, CT, PT & other elements.

b) Relay backup → This is kind of local backup in which additional relay is provided for backup protection. It trips the same CB if the primary relay fails & this operation takeplace without delay.

c) Breaker Backup → This is also kind of local backup. This type of backup is necessary for a busbar system where a no. of CB. are conneted to it.

[6b] With a neat sketch, explain the working of Induction Cup relay. (08 Marks)

→ * Figure shows an induction cup relay.

* A stationary Iron core is placed inside the rotating cup to decrease the air gap without increasing inertia.

* The spindle of the cup carries an arm which closes contacts.

* A spring is employed to provide a reseting torque.
* When two actuating quantities are applied, one way produce an operating torque while the other may produce restraining torque.
* Brake magnets are not used with induction cup type relays.

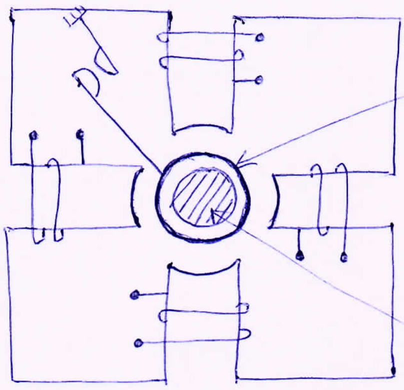
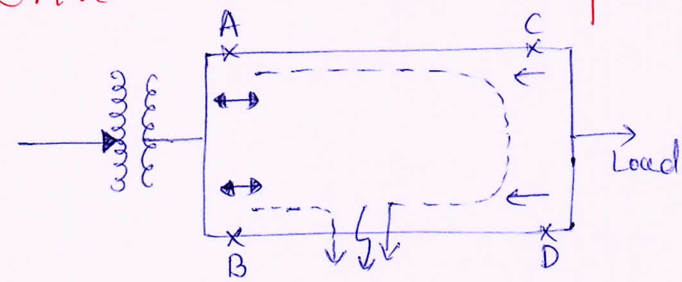


Fig: Induction cup relay.

* It operates on the same principle as that of an induction motor. It employs a 4 or 8-pole structure.
* The rotor is a hollow cylinder (inverter cup).
* Two pairs of coils, as shown in the figure, produce a rotating field which induces current in the rotor.
* A torque is produced due to the interaction between the rotating flux and the induced current, which causes rotation.

6C] Write short notes on protection of parallel feeder. (04 Marks)



* Figure shows an overcurrent protective scheme for parallel feeders.
* At the sending end of the feeders (at A + B) non-directional relays are required.
* The symbol ↔ indicates a non-directional relay.
* At the other end of feeders (at C + D), directional overcurrent relays are required.
* The arrow mark for directional relays placed at C + D indicates 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.

Module-4

[1a] With a neat sketch, explain the Operating principle of impedance relay and its characteristics! (08 Marks)

Operating Principle:

→ To realise the characteristics of an impedance relay, current is compared with voltage at the relay location. The current produces a +ve torque (operating torque) & voltage produces a negative torque (restraining torque).

The eqn for the operating torque of an electromagnetic relay can be written as,

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

where, k_1, k_2 & k_3 are constants, k_3 being torque due to the control spring effect.

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

$$k_1 I^2 > k_2 V^2 \quad \text{or} \quad k_2 V^2 < k_1 I^2$$

$$\text{or} \quad \frac{V^2}{I^2} < \frac{k_1}{k_2}$$

$$\text{or} \quad \frac{V}{I} < k \quad \text{where } k \text{ is constant}$$

$$\text{or} \quad Z < k.$$

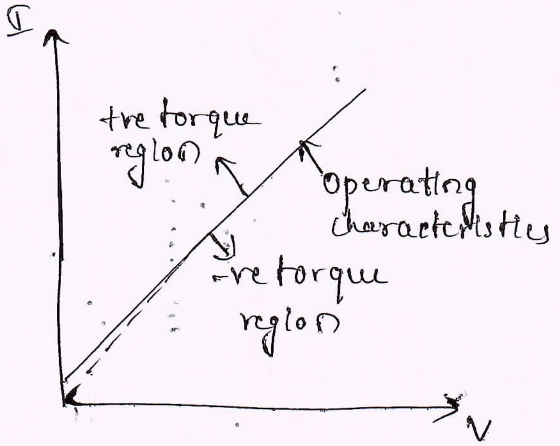
For the operation of the relay, the following condition should be satisfied $k_1 I > k_2 V$ or $k_2 V < k_1 I$

$$\frac{V}{I} < \frac{k_1}{k_2} \Rightarrow Z < k.$$

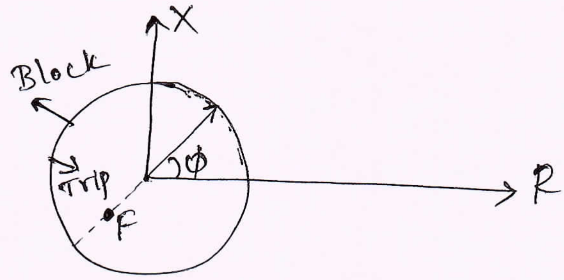
The relay operates if the measured impedance Z is less than given constant.

Impedance Relay Characteristics.

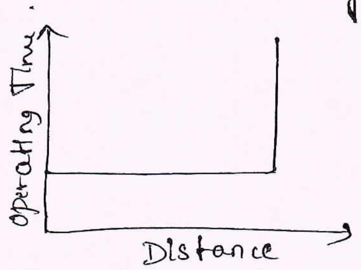
* Fig (a) shows the operating characteristic of an impedance relay in terms of voltage & current.
* Fig (b) shows an impedance relay characteristic on R-X diagram where Z = k represents a circle & Z<K indicates the area within the circle, which is setting of the relay, k is the impedance of lines which is to be protected.
* φ is the phase angle between V & I. The relay operation is independent of φ & depends on magnitude of Z.
* The operating time of the relay is constant irrespective of the fault location within the protected section as shown in fig (c).



(a) Operating characteristics



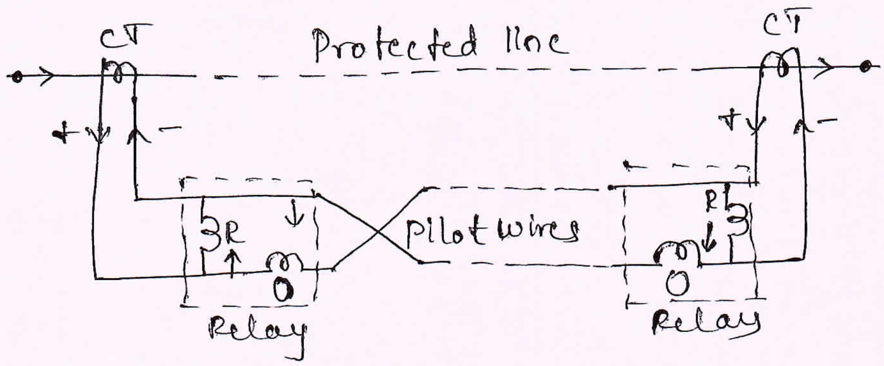
(b) Operating characteristics on R-X diagram.



(c) Operating time characteristic

1b] Explain Balanced Voltage Scheme with a neat diagram (08 Marks)

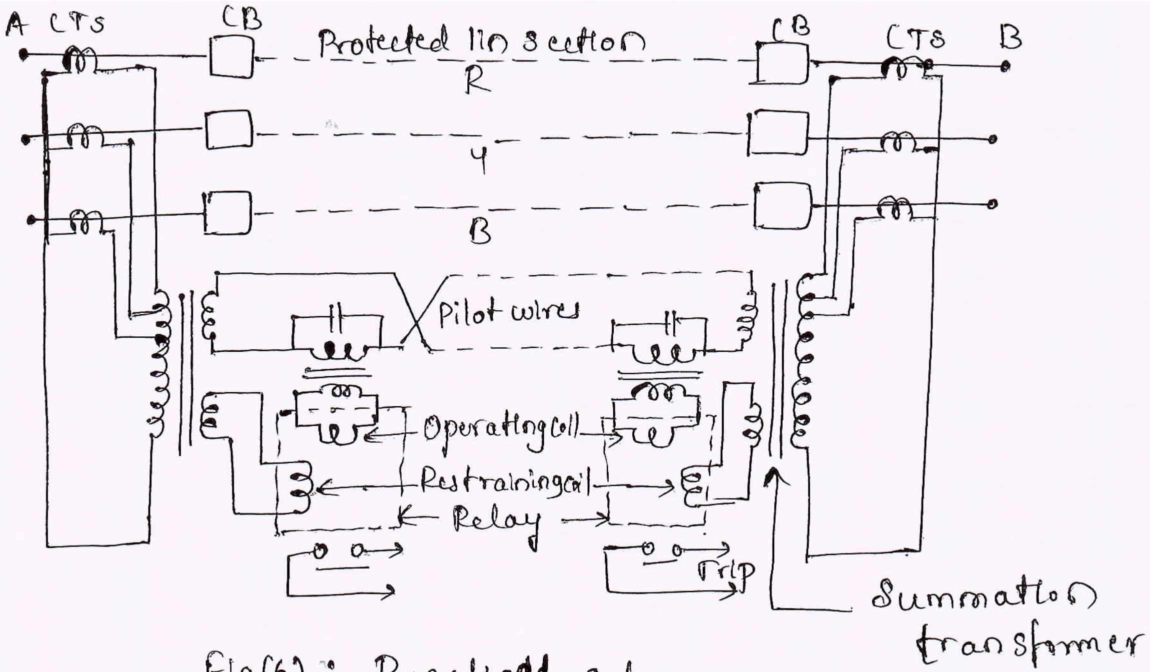
→



O - Operating coil

R - Restraining coil

Fig(a): Schematic diagram of balanced voltage principle



Fig(b) : Practical scheme.

* Fig(a) shows schematic diagram of the balanced voltage principle.
* Polarities of CTs & direction of currents shown in fig(b) are for normal condition or external faults.
* In this scheme, current does not normally circulate through pilot wires.
* The operating coil of the relay is placed in series with pilot wire & hence current doesnot flow through the pilot wires under normal conditions & in case of external faults.
* Fig (b) shows practical scheme known as solkar system (Reyrolle).
* The capacitor shown in fig is used to turn the operating circuit to the fundamental frequency component.
* The scheme is suitable for 7/0.029 pilot loops upto 400Ω.

[7c] Explain in brief protection of transformer against overheating (04 Marks)

→ * The rating of a transformer depends on the temperature rise above an assumed maximum abient temperature.
* Sustained overload is not allowed if the ambient

temperature is equal to the assumed ambient temperature.

* At lower ambient temperature, some overloading is permissible.

* The overloading will depend on the ambient temperature prevailing at the time of operation.

* The maximum safe overloading is that which does not overheat the winding.

* The maximum allowed temperature is about 95°C.

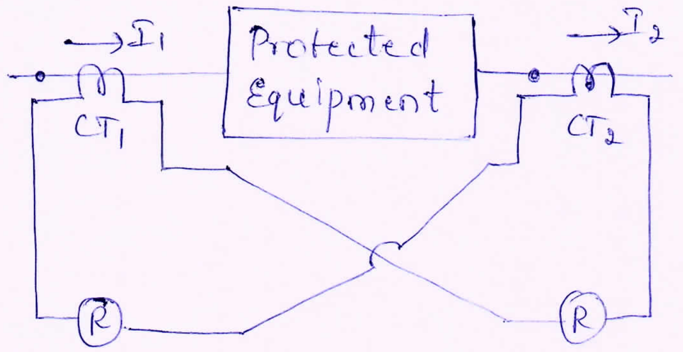
* Thus the protection against overload depends on the winding temperature which is usally measured by thermal image technique.

[8a] List the various type of differential relay and explain any one of them (10 Marks)

→ Various type of differential relays are.

1) Simple (Basic) differential relay/Protection.
2) Percentage (Biased) differential relay/ protection.
3) Balanced (opposed) voltage differential relay/ protection.

Balanced (Opposed) Voltage differential relay



R: Instantaneous OC relay.

* Figure illustrates the principle of balanced voltage differential protection scheme.

* In this case, the secondaries of the CT_1 & CT_2 are connected in such a way that under normal operating conditions & during external faults, the secondary currents of the CTs on two sides oppose each other

& their voltages are balanced.

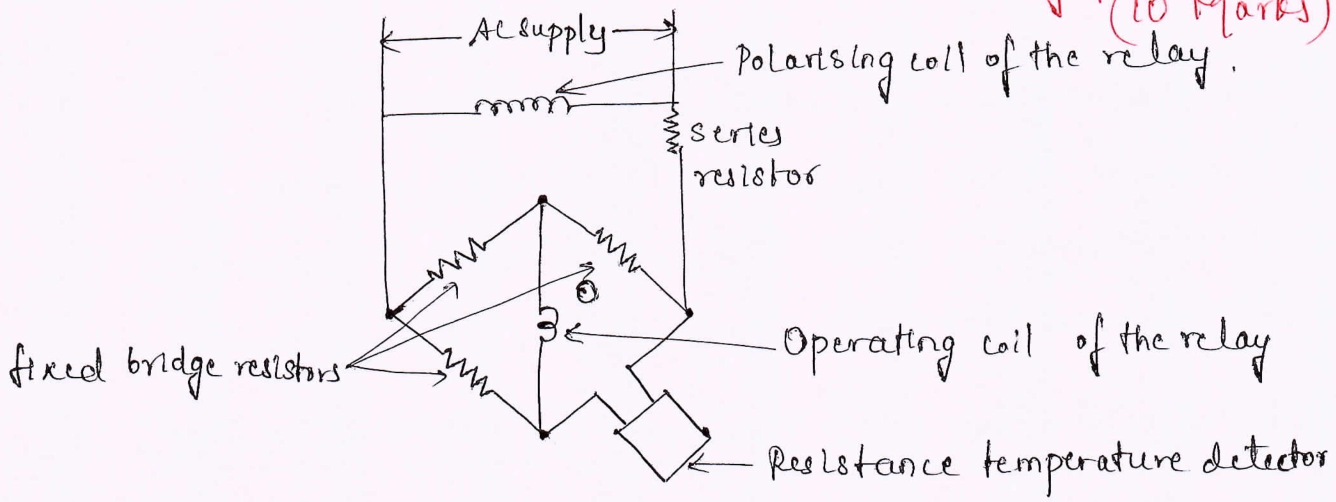
* Hence no current flows in pilot wires & relay.

* During internal fault, a differential current proportional to $(I_1 - I_2)$ in case of single end fed system & proportional to $(I_1 + I_2)$ in case of double end fed system flows through the relay coils.

* If this differential current is higher than the pickup value, the relay operates to isolate the protected equipment from the system.

* Since no current flows through the secondaries of the CTs under normal operating conditions, the whole of the primary ampere-turns are used in exciting the CTs.

8b] Write a short note on stator overheating protection. (10 Marks)



* Overheating of the stator may be caused by the failure of the cooling system, overloading or core faults like short-circulated laminations & failure of core-bolt insulation.

* Modern generators employ two methods to detect overheating both being used in large generators (above 2MW).

* In one method, the inlet & outlet temperatures of the cooling medium which may be hydrogen/water are compared for detecting overheating.

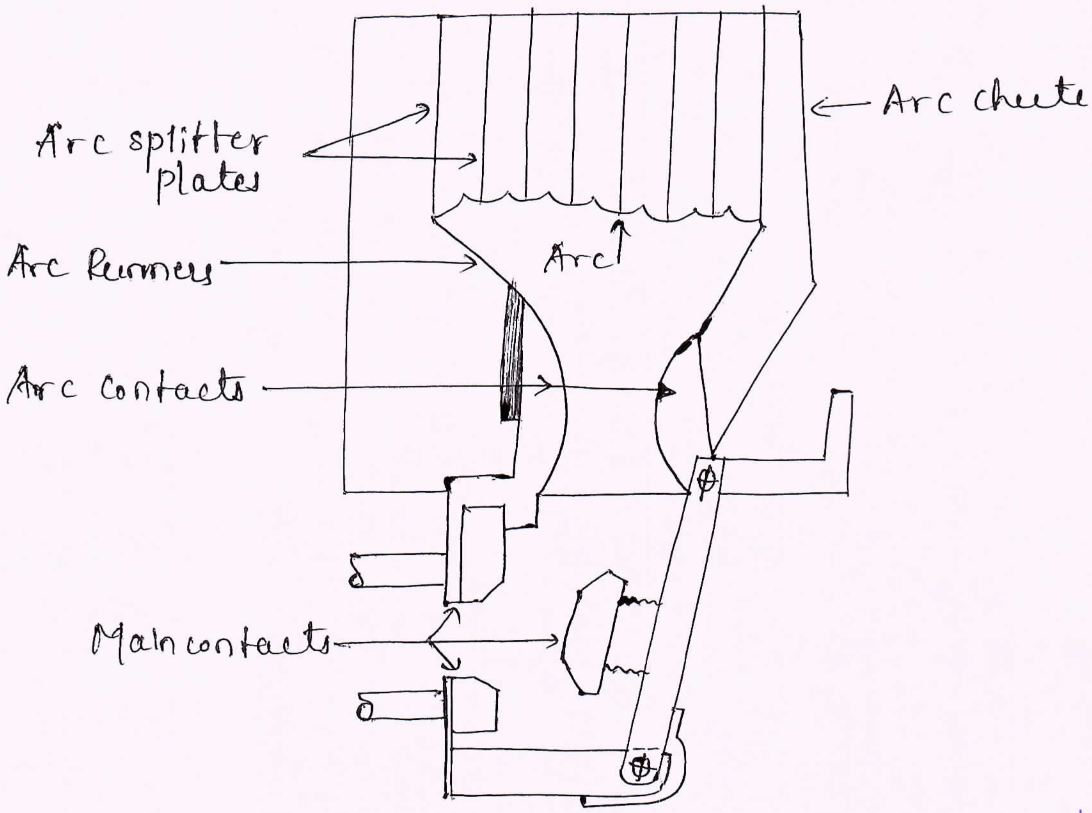
* In the second method, temperature sensing elements

are embedded in the stator slots to sense the temperature.
Fig shows a stator overheating relaying scheme.

* when temperature exceeds a certain preset max. temp limit, the relay sounds an alarm.
* The scheme employs temperature detector unit, relay & wheatstone bridge for the purpose.
* The temperature sensing elements may either be thermistors, thermocouples or resistance temperature indicator.
* They are embedded in the stator slots at different locations

Module - 5

9a] Explain with a neat sketch Air-break Circuit Breaker. (10 Marks)



* Air break circuit Breakers are quite suitable for high current interruption at low voltage.
* In this type of CB, air at atmospheric pressure is used as an arc extinguishing medium.

* Figure shows an air-break circuit breaker.
* It employs two pairs of contacts: main contact & arcing contacts.
* The main contacts carry current when the breaker is in closed position.
* They have low contact resistance, when contacts are opened, the main contacts separate first, the arcing contacts still remain closed.
* Therefore, the current is shifted from the main contacts on the arcing contacts.
* The arcing contacts separate later on & the arc is drawn between them.
* In air-break circuit breaker, the principle of high resistance is employed for arc interruption.
* Ac air-break CB are available in the voltage range 400 to 12 kV.
* They are extensively used with electric furnaces, with large motors requiring frequent starting, in a place where chances of fire hazard exists. etc, Air-Break CB are also used in dc CB upto 12kV.

[9b]. Explain the causes of over voltages. (10 Marks)

→ * Overvoltages (OV) or surges on power systems are due to various causes.
* The normal operating voltages of the system do not stress the insulation severely.
* But the voltage stresses due to overvoltages can be so high that they may become dangerous to both lines as well as the connected equipment & may cause damage, unless some protective measures against those overvoltages are taken.

External Overvoltages :

* These overvoltages originate from atmospheric disturbances, mainly due to lightning.
* These overvoltages take the form of a unidirectional impulse (surge) whose maximum possible amplitude has no direct relationship with the operating voltage of the system. They may be due to any of the following causes.

i) direct lightning stoke
ii) Electromagnetically induced overvoltages due to lightning discharge taking place near the line.
iii) voltages induced due to changing atmospheric condition along the line length.
iv) Electrostatically induced overvoltages due to the presence charge clouds nearby.

Internal Overvoltages :

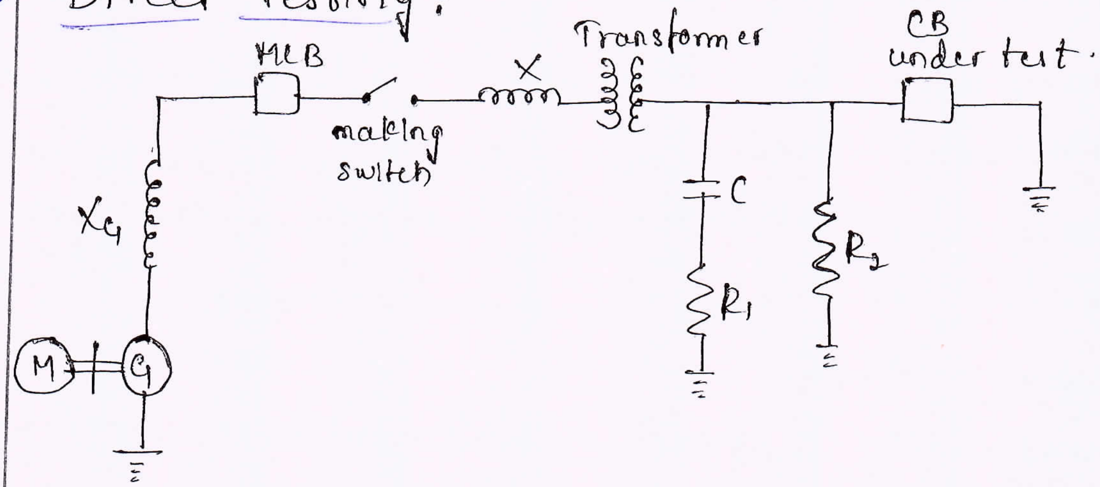
These overvoltages are caused by changes in the operating conditions of the network. Internal ov can be further divided into two groups as below.

i) Switching overvoltages (transient or of high frequency).
These ovs are caused by the transient phenomenon which appear when the state of the network is changed by a switching operation or fault conditions.

ii) Temporary Overvoltages (steady-state or of power frequency)
These ovs are the steady-state voltages of power system frequency which may result from the disconnection of load, in case of long transmission line.//

[10 a] Explain in detail about direct testing and indirect testing of circuit breaker. (10 Marks).

→ Direct Testing:



* In direct testing, CB is tested under the conditions which actually exist on power system.

* Fig. shows an arrangement for direct testing.

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 as follows.

Test for breaking capacity:

First, the Master CB & the CB under test are closed. Then short circuit current is passed by closing the making switch. The short circuit current is interrupted by opening the breaker under test at the desired moment.

The following measurements are taken.

i) Symmetrical breaking current

ii) Asymmetrical breaking current.

iii) Recovery voltage.

iv) Frequency of oscillation & RRRV.

Test for making capacity.

The master CB & making switch are closed first, then the short circuit is initiated by closing the CB under test.

Duty Cycle test :

The following duty cyle 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.

iii) B-3-B-3-B tests are perfomed at not less than 100%.

Short time Current test

The rated short time current is passed through the CB under test for specified short duration (1 sec or 3 sec) & current is measured by taking an oscillograph of the current wave.

$$I = \sqrt{\frac{1}{3}\left[I_0^2 + 4\left(I_1^2 + I_3^2 + I_5^2 + I_7^2 + I_9^2\right) + 2\left(I_2^2 + I_4^2 + I_6^2 + I_8^2 + I_{10}^2\right)\right]}$$

Indirect Testing:

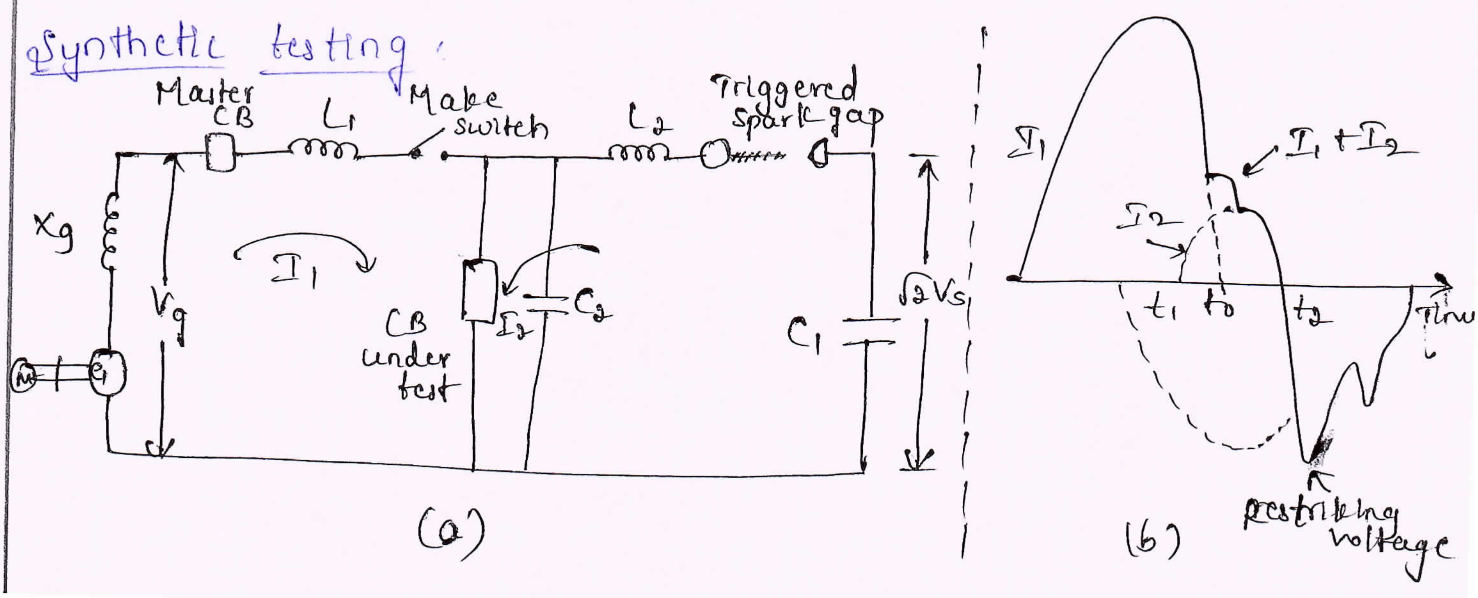
The testing of HV CB of large capacity also requires very large capacity of the testing station, which is uneconomical. The important indirect methods of testing are

i) Unit testing ii) Synthetic testing.

Unit testing :

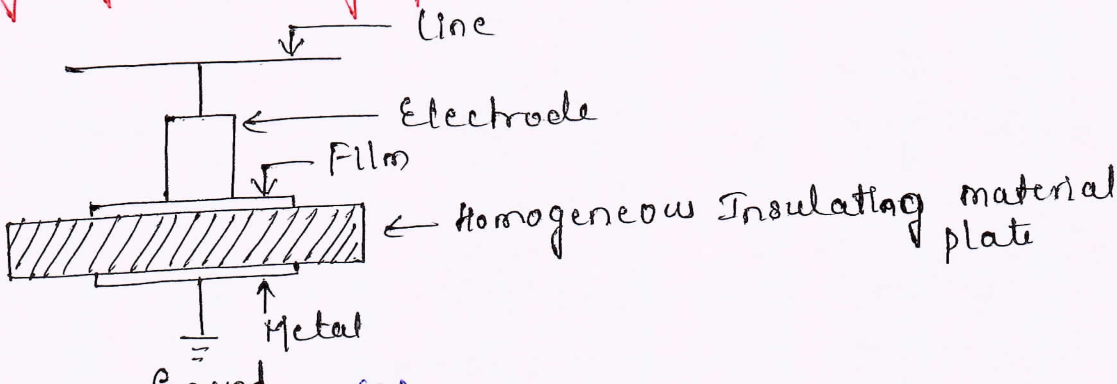
High voltage CB are designed with several arc interrupter units in series. Each unit can be tested seperately. This type of testing is known as unit testing.

Synthetic testing :



* In this method of testing, there are two sources of power supply for the testing, a current source & voltage source.
Fig (a) shows a circuit for synthetic testing. It is a circuit for parallel method.
* The capacitor C_1 is a high voltage source to provide recovery voltage.
* There is a control circuit to fire the triggered spark gap at the appropriate moment.
* Fig (b) shows waveforms during synthetic testing.

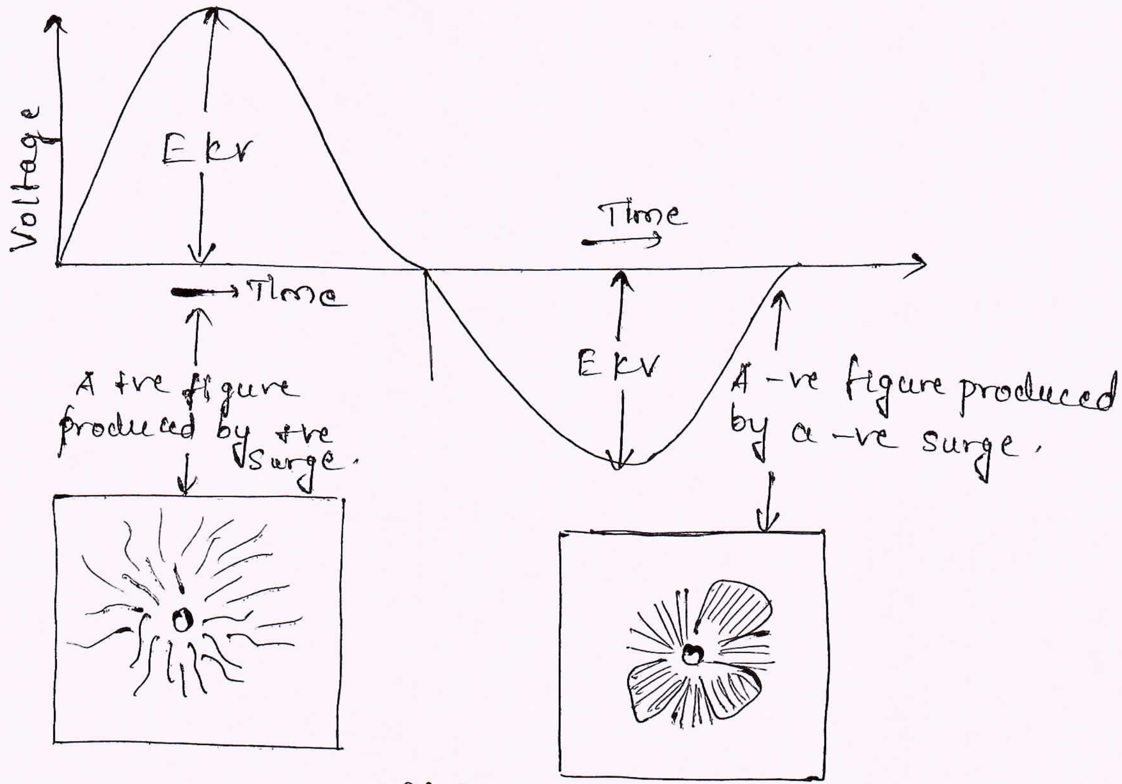
9b] With a neat diagram, explain the construction and working of klydonograph. (10 Marks).



(a)

* The klydonograph is an instrument for the measurement of surge voltage on transmission lines caused by lighting.
* It measures voltage by means of Lichtenberg figures, when suitably coupled to the line whose surge voltage is to be measured.

* The electrode rests on a emulsion side of a photographic film or plate, which inturn rests on the smooth surface of an insulating plate made of homogeneous insulating material, backed by a metal plate electrode as shown in fig (a).



(b)

* The photographic plate or the film is turned or moved by a clockwork mechanism for bringing in the element of time These assemblies are generally placed in the same box, for simultaneously measuring the voltages on the three phases of a transmission line.

With this arrangement, a +ve lichtenberg figure is produced by +ve surge & -ve Lichtenberg figure by a -ve surge as in Fig (b).

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