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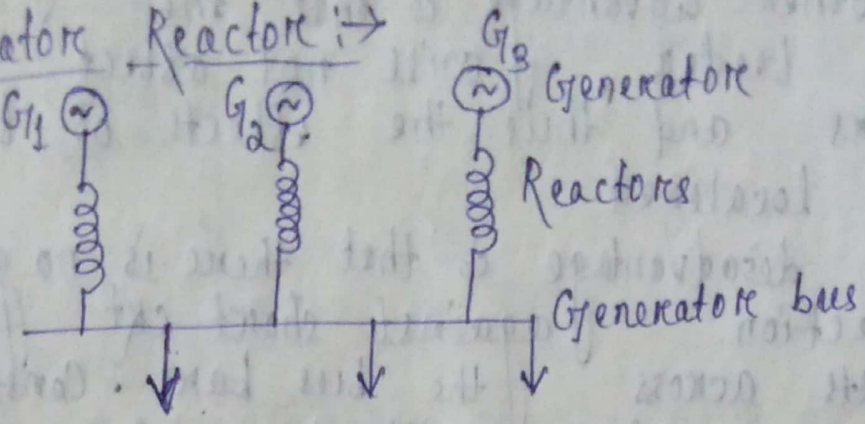
Different types of reactors:→

→ The types of reactors used in substation are:
(i) Generator Reactor
(ii) Feeder Reactor
(iii) Busbar Reactor

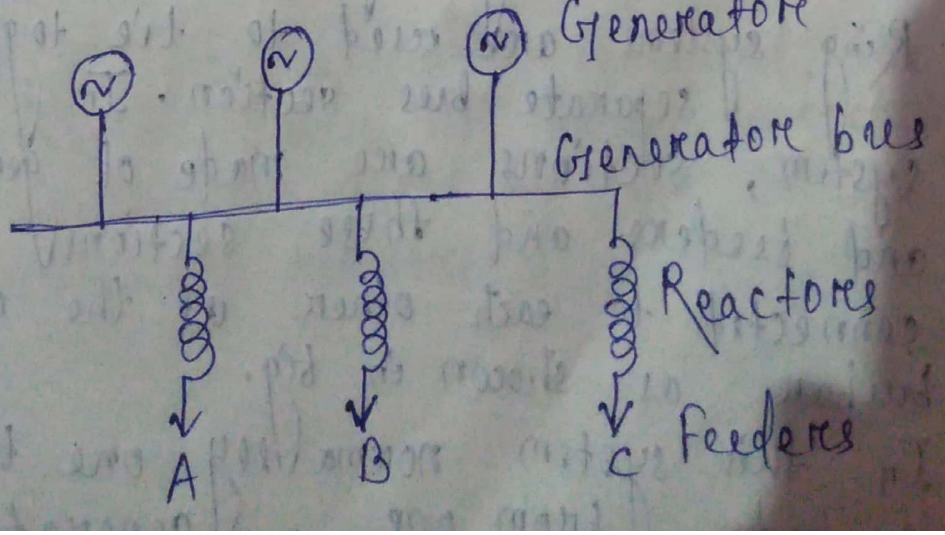
(i) Generator Reactor:→



→ Here the reactors are inserted between the generator and the generator bus, the reactors are known as generator reactors such reactors protect the machine individually. The magnitude of such reactors are about 5% or 0.05 PU.

→ The main disadvantage of such system is that if there is a S.C. In any feeder, the voltage at the generator bus may drop to such a value that the synchronous machine connected to the common bus bar may fall out of step.

(ii) Feeder Reactor:→

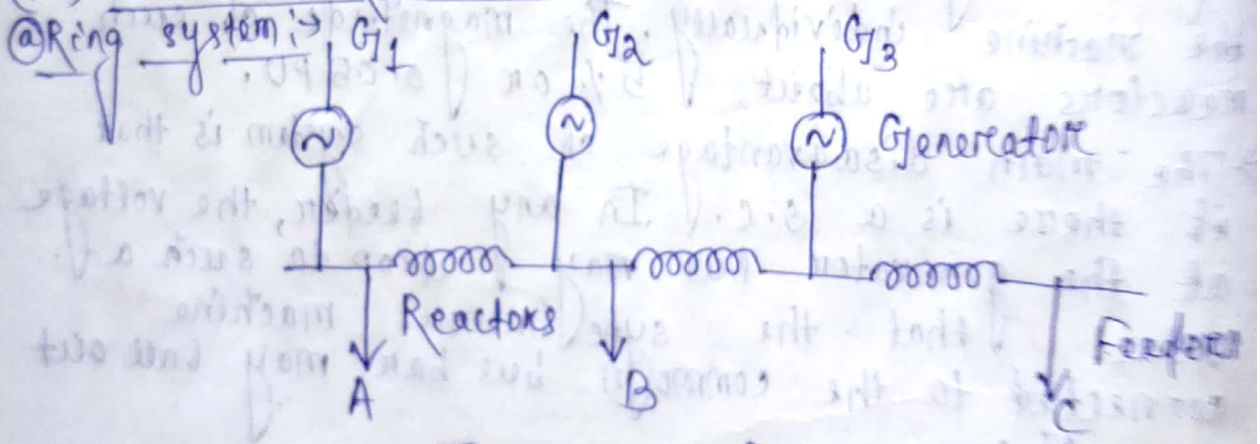


→ Here, the reactors are connected in series with the feeders. In the event of fault on any one feeder, the main voltage drop is in its reactor only and the bus bar voltage is not affected much hence other machines continue supplying load the other advantage is that the fault on a feeder will not affect other feeders and thus the effects of faults are localized.

→ The disadvantage is that there is no generator protection against short ckt (S.C) faults across the bus bars. Constant voltage and power loss will take place at the reactors under normal conditions.

(iii) Busbar Reactor :→

@Ring system :→



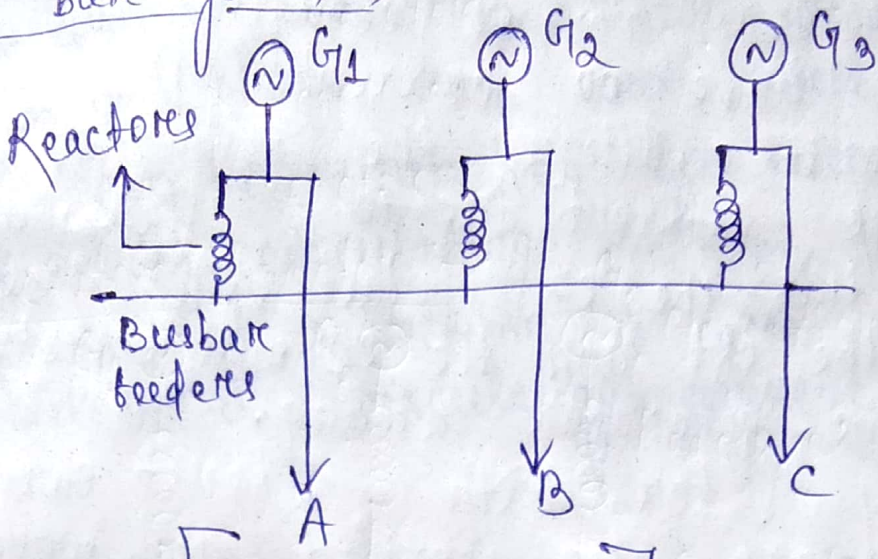
[Ring system]

→ Ring systems are used to tie together separate bus section. In this system, sections are made of generators and feeders and these sections are connected to each other at the common busbars as shown in fig.

→ In this system normally one feeder is fed from one generator.

→ Under normal conditions small amount of power flows through the reactors. Therefore voltage drop and power loss in the reactors is low.

(b) Tie bar system :→



[Tie bar system]

→ This is a modification of the ring system. In general, with this system the voltage regulation between feeder sections is better than the ring system. This system is ideally suited to the generating systems where frequently new generators are being added.

→ In this system the generators are connected to the common bus bar through the reactors but the feeder are fed from the generator side of the reactors.

→ If the no. of sections is increased, the fault current will not exceed a certain value, which is fixed by the size of the individual reactors.

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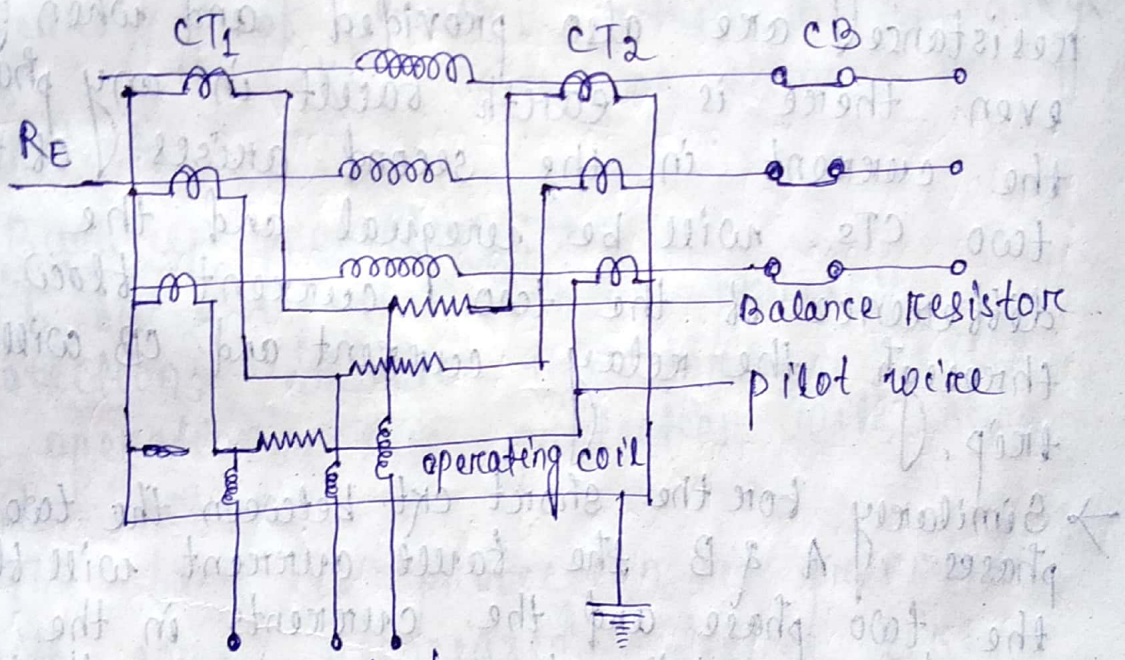
Differential protection of alternators :→

→ In alternators the most common type faults are taking place in stator winding i.e phase to phase and earth fault. and this can be minimized by using differential relay with circulating current preinciple.

→ This type of protection is called merz price protection of circulating current preinciple.



Working :→ There are two current T/Fs (CTs) in each side of the stator windings the secondary of the two CTs are connected in star and their ends are connected through pilot wires.

→ The operating coil or the relay coil are connected in star in which the neutral point of the CT connected to the relay coil to make a common ground.

→ The pilot wires are balancing resistances to make equipotential points to maintain the current in the pilot wire balance so that render normal condition the relay coil will have no current.

→ Under fault conditions the relay coil will take some current due to unbalancing and for this the CB contact will close to trip the ckt and the CB will operate to isolate the generator winding.

→ Similarly for earth fault earthing resistance are also provided and when even there is earth fault in any phase the current in the second arises of the two CTs will be unequal and the difference of the two current flow through the relay current and CB will be trip.

→ Similarly for the short ckt between the two phases A & B the fault current will flow the two phase and the currents in the secondary of the two CTs will be affected and the current will be unequal and the differential current will flow to the relay coil and the circuit Breaker will trip to isolate the ckt.

Q:→ What are the various types of protection in a power system? (5 marks)

Ans:→ There are two types of protection used are:-

(i) primary protection

(ii) Back up protection.

(i) Primary protection:→

→ It is the first line of defence and ensures quick arcing and selective clearing of faults within the boundary of the ckt, section or element it protects.

(ii) Back up protection:→

→ It backs up the main or primary protection, whenever the former fails in operation, this protection will come into action.

→ The back up protection is provided with some associated devices like current transformer (C.T), potential-transformer (P.T), and the circuit breaker (CB) etc.

→ This system is provided either on the same CB which would be normally opened by the main protection or different circuit breaker (CB) in the second line protection.

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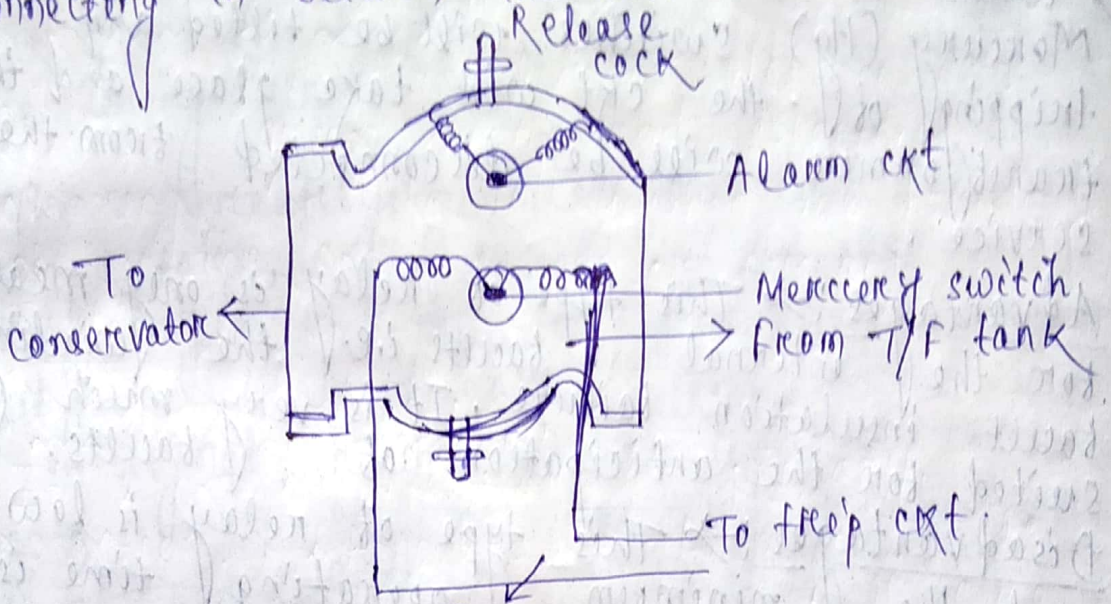
Buchholz relay :→

→ It is a gas actuated relay which is used in oil immersed transformers having rating more than 500 KVA.

→ This relay is connected in between the main tank and conservator tank with a pipe connecting in between the two.



(Buchholz relay)

→ It consists of two floats in a metallic chamber located in between the conservator and the main tank.

→ One of the float is near the top of the chamber and other is in the bottom. The two floats are consisting of Hg switches and one Hg switch is connected to the alarm ckt and other is to the tripping ckt.

Working :→ During a minor fault the oil of the tank gets over heated and gases are formed and this gas vapours will be collected in the top of the chamber and the oil level will fall.

→ The high pressure gas vapours will help to tilt the mercury switch of the top float and due to the tilting of this mercury (Hg) switch the alarm ckt will ring and the operator can know that the fault arises and immediately the transformer will be shut down.

→ When a severe fault arises, the bottom float Mercury (Hg) switches will be tilted and tripping of the ckt will take place and the transformer will be disconnected from the service.

Advantages :→ This type of relay is only meant for the internal faults i.e. the winding fault insulation failure. It is very much suited for the anticipation of faults.

Disadvantages :→ This type of relay is low and the minimum operating time is 1 sec. and average time 2 second which is not desirable.

Static Relay

Static Relay :→ In electrical systems, a static relay is a type of relay, an electrically operated switch, that has no moving parts.

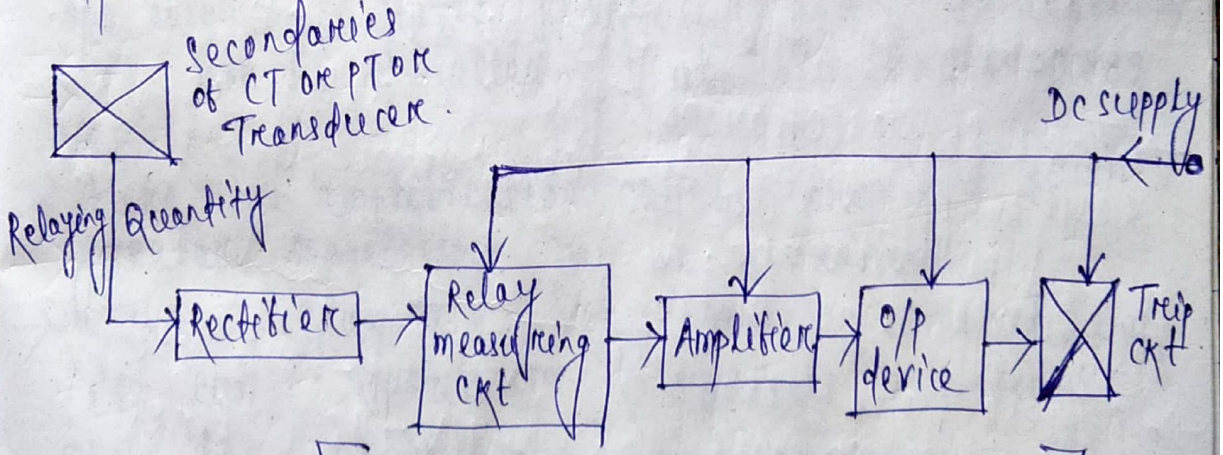
→ Static relays are contrasted with electromechanical relays which use moving parts to create a switching action.

→ The relay which does not contain any moving parts is known as the static relay.

→ In such type of relays, the output is obtained by the static components like magnetic and electronic ckt etc.

→ The input of the current transformer is connected to the transmission line and their output is given to the rectifier. The rectifier was rectifying the input signal and pass it to the relaying measuring unit.

→ The rectifying measuring unit has the comparators, level detector and the logic ckt. The o/p signal from relaying unit obtained only when the signal reaches the threshold value. The o/p of the relaying measuring unit acts as an i/p to the amplifier.



Block diagram of static Relay

→ The amplifier amplifies the signal and gives the output to the o/p devices. The o/p device activates the trip coil only when the relay operates. The o/p device is activated and gives the tripping command to the trip ckt.

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Advantages of static Relay :→

→ The power consumption of the static relay is usually very low as compared to the electromechanical relay. Therefore the burden on the current transformer (C.T) and the potential transformer (P.T) are reduced and the accuracy is increased.

→ It is shock proof, long life, quick response, less maintainance and high reliability.

→ As there are no moving contacts, so the problems of arcing contact bounce and replacement of contacts are avoided.

→ It does not have any thermal storage problems.

→ It has quick reset action and it is due to the absence of mechanical inertia.

→ There is no effect of gravity on the operation of static relay and therefore it can be installed at aircraft and vessels.

→ Here the amplification can be provided with greater sensitivity can be obtained.

→ This relay is very much compact and it can perform various functions i.e. for controlling and protection etc.

→ The risk of unwanted tripping is less with the static relay.

→ The static relay can easily operate in earthquake-prone areas because they have high resistance to shock.

Limitations of static Relay :→

→ The components used by the static relay are very sensitive to the electrostatic discharges. The electrostatic discharges mean sudden flows of electrons between the charged objects. Thus special maintainance is provided to the components so that it does not affect by the electrostatic discharges.

→ The relay is easily affected by the high voltage sureges. Thus, precaution should be taken for avoiding the damages through voltage spikes.

→ The coorking of the relay depends on the electrical components.

→ The relay has less overloading capacity.

→ The static relay is more costly as compared to the electromagnetic relay.

→ The construction of the relay is easily affected by the surrounding interference.

Applications of static Relay :→

→ These are used in ultra-high speed protection schemes of EHV-AC lines utilizing distance protection.

→ over current schemes.

→ Used in earth fault protection schemes.

IDMT Relay :→

→ This is known as Inverse Definite Minimum Time over current relay or simply IDMT relay.

→ IDMT relays are the protection relays. They are used on transmission lines to see to that the line current does not exceed safe values and if it does, triggers the ckt breaker (CB). So as the current keeps increases, the relay takes minimum time to trip the ckt.

→ These relays in which the time of operation is approximately inversely proportional to the smaller values of current or other quantity causing operation and tends to definite minimum time as the value increase without limit.

Q:→ What is a distance Relay ? 2 marks

Ans:→ This is the relay whose operation depends upon the ratio of the voltage to the current.

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Protection Against over voltage and lightening :→

Voltage surge :→ It is defined as the sudden reise in excessive voltage which damages the electrical equipment of an installation.

→ The overe voltage in the lines occures because of a reise in voltage between both phases and between phase and ground also.

→ The voltage sureges are mainly classified under two heading ; internal and external voltages.

Types of voltage surge :→

→ The overevoltage in the powere station can be caused either by the internal disturbance ore by the atmospheric eruption. On the basis of the generation of overevoltages the voltage surge are classified in to two categories. These are :→

(1) Internal overevoltage and
(2) External overevoltage

(1) Internal overvoltage :→

→ When the voltage in the system raises itself beyond the rated voltage, then such type of voltage is called the internal overevoltage.

→ The internal overvoltage may be transient, dynamic or stationary in nature. If the overvoltage wave is transient in nature, then there frequency is unrelated to the normal frequency, and it will persist few cycles only.

→ Transient overvoltage can be caused by the operation of the ckt breakers when switching inductive or capacitive loads.

→ These voltages can also be generated by interrupting very small current or by the sudden grounding of one phase of a system with an insulated neutral.

→ Dynamic overvoltage occures at the normal frequency and persists only for a few seconds. These voltages may be generated by the disconnection of a generator or because of suddenly thrown off a large portion of the load.

→ Stationary overvoltage occures at system frequency and remains for sometimes may be for an hours. Such type of voltages is generated when an earth fault on one line is continued for a long time. This voltage can also be caused when the neutral is grounded through an arc suppression with suppression coil, thereby leading to the overvoltage on the sound phase.

→ These voltages exceed three to five times the normal phase to neutral peak voltage of the system and relatively

harmless. for equipment having proper insulation.

→ The internal overvoltage mainly causes because of the following reasons :-

(a) Switching operation on unloaded line :-

→ During the switching operation, the line is connected to a source of voltage and travelling waves are set up which rapidly charge the line. These waves instantly attained the voltage of the magnitude not exceeding twice the supply voltage at the instant of disconnection.

(b) Sudden opening of load line :-

→ When the load on the line is suddenly opened a transient voltage of the value of $e = iz_0$ is set up, where 'i' is the instantaneous value of the current at the instant of opening of the line and z_0 is the ~~natural~~ ~~one~~ natural one the surge impedance of the line.

→ The transient overvoltage of the line does not depend on the line voltage and therefore low voltage transmission system is liable to overvoltage of the same magnitude as compared to the high voltage system.

(C) Insulation Failure :- → The failure of insulation between the line and the earth is very frequent.

→ When the insulation breakdown occures the potential at fault suddenly

falls from maximum to zero and therefore a negative voltage wave of very steep front in the form of surges are generated in both the directions.

(2) External overvoltages :→

→ The overvoltage which is caused by the atmospheric discharge such as static discharge or lightning strokes, such type of voltage is called external overvoltage. It can cause considerable stress on the insulation. The intensity of the voltage is varied in the case of the lightning.

→ The installation in the power station is mainly classified in to 2 types, the one which is electrically exposed, resulting in the apparatus being subjected to overvoltages of the atmospheric origin and another which is electrically non-exposed and therefore not subject to this type of overvoltage.

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Causes of overvoltage :→

→ The overvoltage of a power system may be broadly divided into two main categories. i.e. :-

(A) Internal causes :→

(1) Switching surges :→ The overvoltages produced on the power system due to switching operations are known as the switching surges.

(2) Insulation Failure :→ The most common case of insulation failure in a power system is the grounding of conductors (i.e. insulation failure between line and earth) which may cause overvoltages in the system.

(3) Arcing ground :→ The phenomenon of intermittent arc taking place in line-to-ground fault of a 3-phase system with consequent production of the transients is known as the arc ground.

→ This happens when there is the presence of a sporadic arc in line-to-ground fault belonging to three-phase system.

→ Here, short-live oscillations are produced in the system due to some changes in the voltage and the current load.

This phenomenon may lead to the serious problems like breakdown of

the insulation and may harm the equipment connected to the power system.

(4) Resonance :→ This one occures when the value of the inductive resistance in the power system becomes equal with the value of capacitive resistance.

(B) External causes :→ This type of overe voltages originates from atmospheric disturbances mainly due to lightning. This takes the form of a surge and has no direct relationship with the operating voltage of the line. It may be due to any of the following causes :-

(i) Direct lightning stroke.

(ii) Electromagnetically induced overe voltages due to lightning discharge taking place near the line, called "side stroke".

(iii) Voltages induced due to atmospheric charges along the length of the line.

(iv) Electrostatically induced voltages due to presence of charged clouds nearby.

(v) Electrostatically induced overvoltages due to the frictional effects of small particles like dust or dry snow in the atmosphere or due to change in the altitude of the line.

Lightning stroke :→

Definition :→ Lightning stroke is the direct discharge of an electrical charge between the atmosphere and the object of earth. It is a sudden flow of electric charge between the electrical charge area of a cloud also called int rea-cloud and another cloud called (cc lightning) or between the charged cloud and the ground (CG lightning).

→ The charge region of the cloud is equal to the electric discharge. When the cloud charge is discharged on the ground, then it is called a strike, and if the discharge is hit on the object, then it is called the flash. The lightning occures in the form of the plasma and sound in the form of thunder.

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Mechanism of the lightning Discharge :→

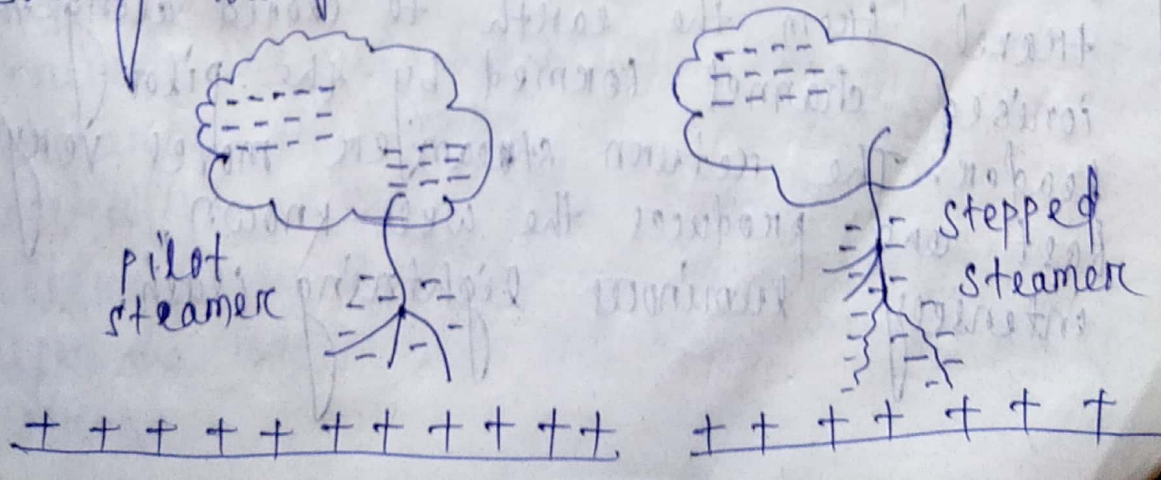
→ In the atmosphere, the positive as well as the negative ions in the aire, attach themselves to the small dust particles. The water dreops present in the aire also get charged because of polarisation by induction. These charged particles and watere dreops charged the clouds.

→ The positive ions are collected in the uppere regeion, and the negative ions are collected in the lowere regeion of the cloud because of their mass.

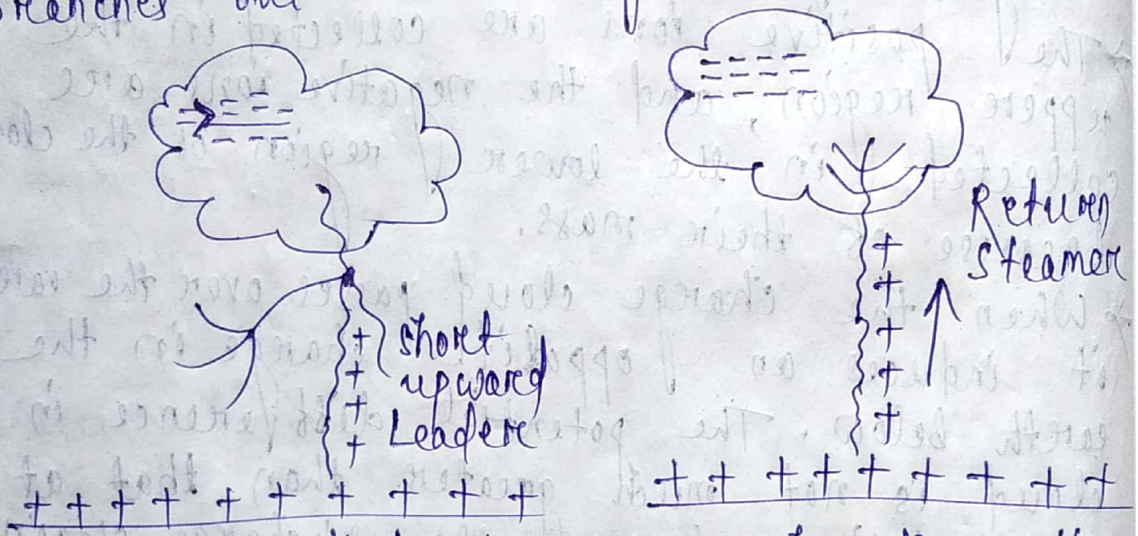
→ When the charge cloud passes over the eareth, it induces an oppotite charge in the eareth below. The potential difference in the cloud is not much greatere than that at the eareth's surface, the discharge obtains and oreginates in the clouds.

→ The potential gradient of the clouds is not uniforem, and it is of the ordere of 10-30 KV/cm in any part of the cloud.

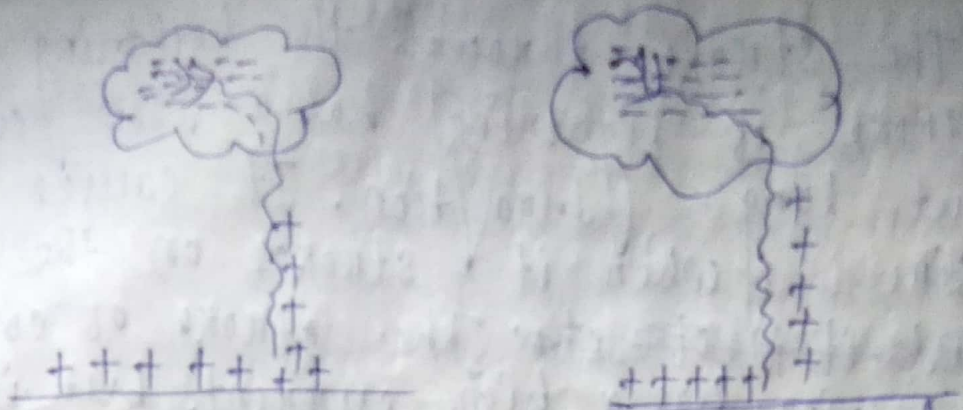
The initial discharge which is also called pilot discharge or pilot leadere moves slowly towareds it from the eareth.



→ The first discharge moves to earth in steps of about 50 meters each and is therefore, termed as the stepped leader. The pilot leader carries a charge with it, and the potential gradient at its tips is very high. It ionises the air and provides a path or channel for the pilot leader. The channel also becomes charged. The pilot leader carries secondary streamer which branches out from it.



→ When the pilot streamer reaches near the earth, the electric field intensity decreases and due to this, the charges of an opposite polarity in the form of a short stream rises from the earth to meet the tip of downward leader. When a contact is made between the pilot leader and the short upward streamer, a return streamer travel from the earth to cloud along the ionised channel formed by the pilot leader. The return streamer moves very fast and produces the well known, intensely luminous lightning flash.



→ The potential of the portion of the cloud from where the discharge originated is lowered by the passage of the charge through the ionised channel to the earth. But the other portion of the clouds remains charged. Therefore, a high potential develops between the original charge centre and another charge centre in the clouds.

→ The charge of the other charge centre is first transferred to the first one, and then it passes to the earth through the ionised channel made by the first discharge. The second's discharge is unbranched and without steps. Its velocity is more than that of the pilot leader. This is known as the dart leader, and it is also followed by the return strokes.

→ Similarly, the other charges are discharged to the earth in the form of leader and return strokes along the same ionised channel. Lightning strokes with any discharge are known as multiple or repetitive strokes. The lightning is called referred to as hot or cold depending upon the magnitude and duration of the stroke.

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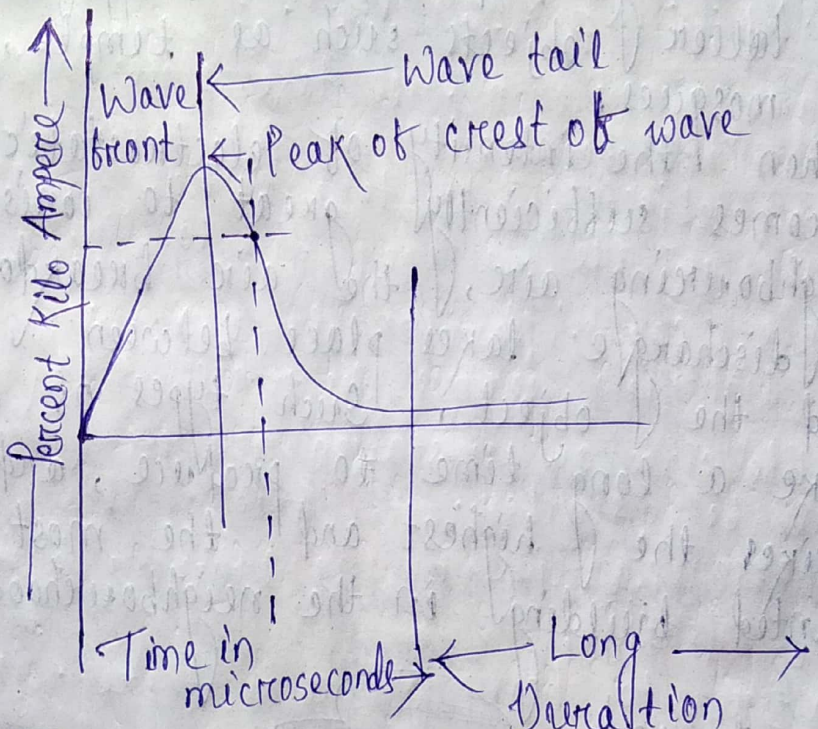
Wave shapes of stroke currents :→

→ The wave shapes consist of a portion showing the steep rise of voltage up to a peak or crest value called the wavefront, and the other portion showing the decay of voltage called the wave tail. Such a wave shape may be represented as the difference of two exponentials, thus :-



Impulse wave form

$$e = E(\varepsilon^{-\alpha t} - \varepsilon^{-\beta t})$$

→ Where the α and β show the constants which determine the shapes. The waves are defined by times t_1 and t_2 in milliseconds. The times to reach the impulse current or voltage to its maximum amplitude is denoted by t_1, while t_2 denotes the times when the current or voltages has fallen to one-half of its peak value.

Types of Lightning stroke :→

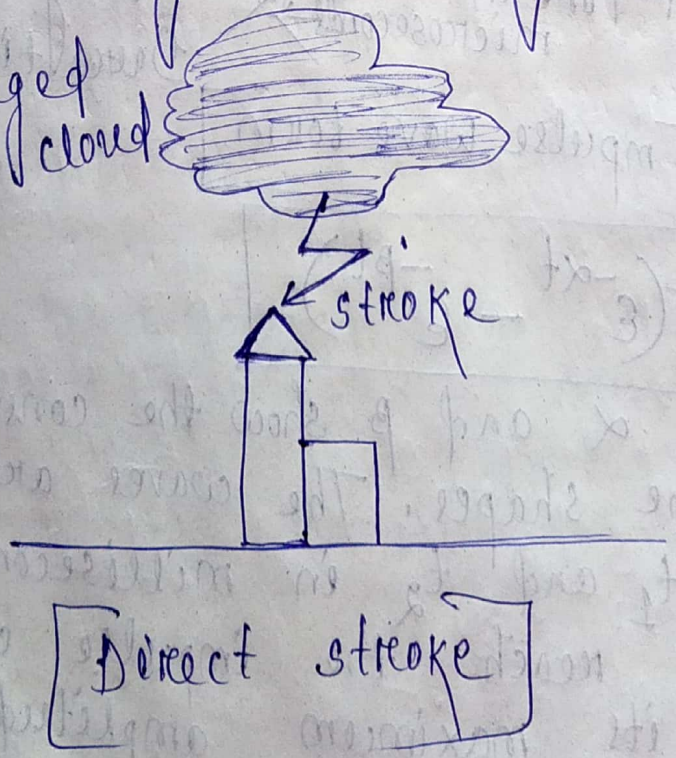
→ The lightning stroke affects the lines in 2 ways. These are :→

(1) Direct stroke

and (2) Electrostatic induction.

(1) Direct stroke :→ In the direct lightning strokes, the cloud attains a large amount of charge and induces an opposite charge on taller objects such as temple, churches, are mosques.

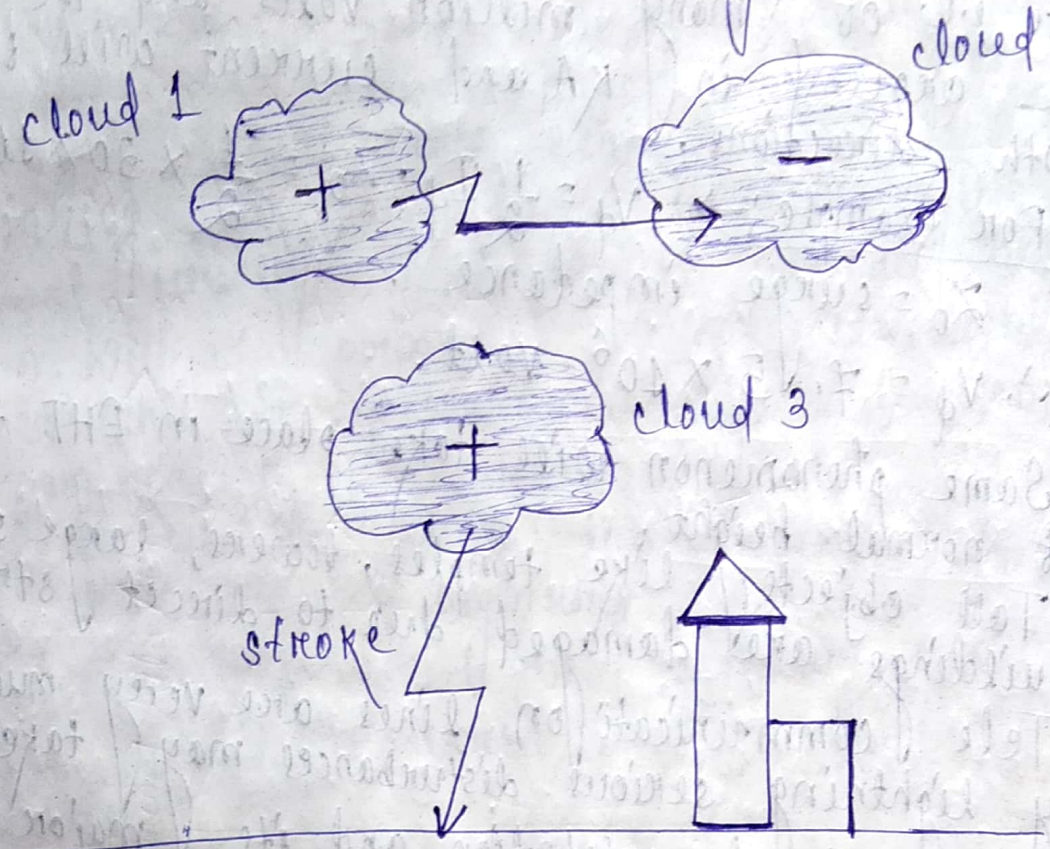
→ When the intensity of electrostatic field becomes sufficiently great to ionise the neighbouring air, the air breakdown and discharge takes place between the cloud and the object. Such types of discharge take a long time to produce, and it strikes the highest and the most sharply pointed building in the neighbourhood.



Direct stroke

(2) Electrostatic Induction stroke :→

→ Consider the 3 clouds, clouds 1 and 3 are positively charged, and cloud 2 is negatively charged as shown in the figure below :→



Electrostatic Induction stroke

→ The potential of cloud 3 is reduced due to the presence of the charged cloud 2. On the flash over from cloud 1 to cloud 2, both these clouds are discharged rapidly, and class 3 assumes a much potential and flashes to earth very rapidly.

→ It is the most dangerous strokes because it ignores taller building and reaches directly to the ground. This stroke is called the induced strokes or the induction stroke.

Other harmful effects of lightning :→

(i) There will be over voltages due to lightning and in over head line when there is direct stroke there will be considerable voltage rise i.e. of many million volts and the current be around in KA and current will flow in both directions.

For example :→ $V_d = \frac{1}{2} I_d Z_0 = \frac{1}{2} \times 30 \times 10^3 \times 500$

Z_0 = surge impedance.

$\therefore V_d = 7.5 \times 10^6$ volt.

(ii) Same phenomenon will take place in EHT towers of normal height.

(iii) Tall objects like temples, towers, large storied buildings are damaged due to direct strokes.

(iv) Tele communication lines are very much affected by lightning serious disturbances may take place.

(v) Electrical substation and its major components will be disturbed.

(vi) persons outside during lightning have danger of death.

(vii) Due to heavy currents there will possibility of failure of insulations in electrical ckts, machines etc.

Harmful effects of lightning :→ The kind of lightning that usually hits people is cloud to ground lightning. Lightning can affect all organs in the body. A lightning strike can give you cardiac arrest which is when your heart stops beating.

→ Lightning can change the hearts rhythm but the heart usually resumes its normal heart rhythm. With a power of 300 kilovolts, lightning can heat the air up to 50,000 degrees Fahrenheit. This combination of power and heat can cause serious damage to the human body. Being struck by lightning may lead to burns, rupturing of the eardrum, eye damage, cardiac arrest, and respiratory arrest.

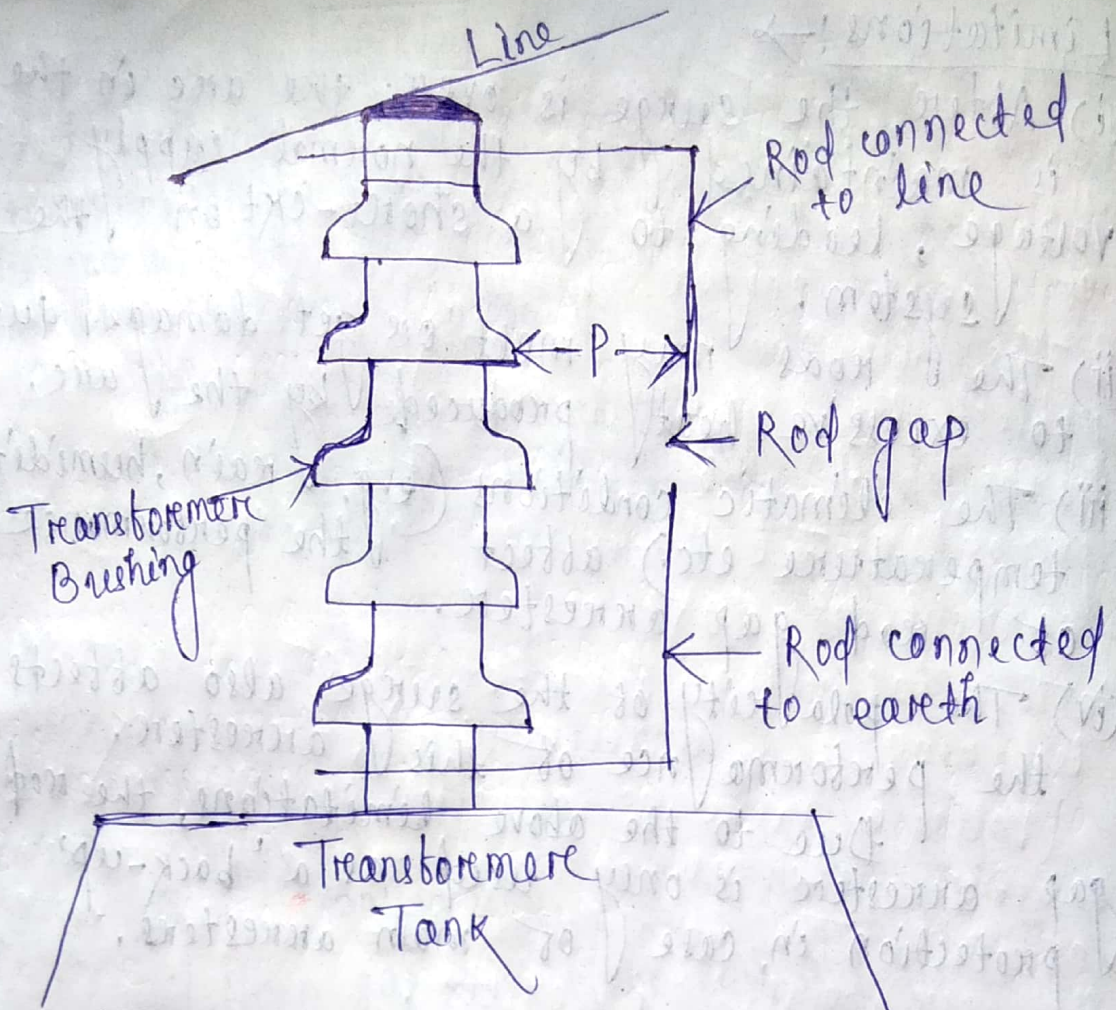
Causes and effects of lightning :→ Heavier, negatively charged particles sink to the bottom of the cloud. When the positive and negative charges grow large enough, a giant spark, - lightning - occurs between the two charges within the cloud. Most lightning happens inside a cloud, but sometimes it happens between the cloud and the ground.

→ Climatologist have warned that due to climate change, the likelihood of being struck by lightning has increased, partly due to thunderstorms becoming more explosive as a consequence of warming temperatures. So, lightning is a combination of clouds becoming electronically charged.

Lightning Arresters:→ The lightning arrester protects the electrical equipment from lightning. It is placed very near to the equipment and when the lightning occures the arrester diverts the high voltage wave of lightning to the ground. The selection of the arrester depends on the various factors like voltage, current and reliability etc.

Types of lightning arresters:→

(a) **Rod-gap lightning arrester:→** It is a very simple type of diverter and consists of two 1.5 cm. rods which are bent at right angles with a gap inbetween as shown in the figure below. One rod is connected to the line ckt and the other rod is connected to earth. The distance between the gap and the insulator (i.e. distance P) must not be less than one-third of the gap length so that the arc may not reach the insulator and damage it. Generally, the gap length is so adjusted that breakdown should occur at 80% of the sparkover voltage in order to avoid cascading of very steep wave fronts across the insulators. The string of insulators for an overhead line or the bushing of transformer has frequently a rod gap across it. Here, the figure shows the rod gap across the bushing of a transformer.



Rod gap on an insulator string

→ The difficulty with the rod arrester is that once the spark having taken place it may continue for sometime even at low voltages. To avoid it a current limiting reactor in series with the rod is used. The resistance limits the current to such an extent that it is sufficient to maintain the arc. Another difficulty with the rod gap is that the rod gap is liable to be damaged due to the high temperature of the arc which may cause the rod to melt.

→ Under normal operating conditions, the gap remains non-conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way, excess charge on the line due to the surge is harmlessly conducted to earth.

Limitations :→

(i) After the surge is over, the arc in the gap is maintained by the normal supply voltage, leading to a short-ckt on the system.

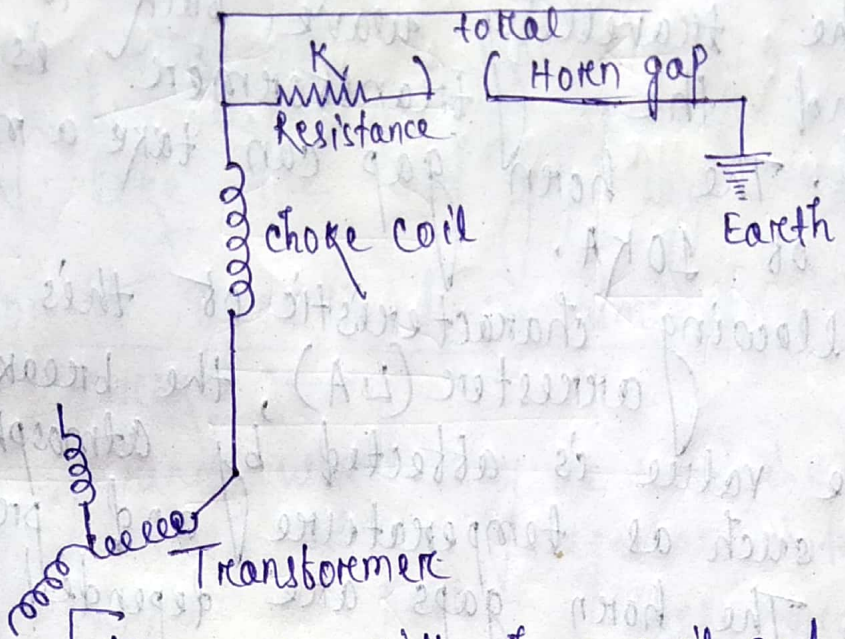
(ii) The rods may melt or get damaged due to excessive heat produced by the arc.

(iii) The climatic conditions (e.g. rain, humidity, temperature etc.) affect the performance of rod gap arrester.

(iv) The polarity of the surge also affects the performance of this arrester.

Due to the above limitations, the rod gap arrester is only used as a 'back-up' protection in case of main arresters.

(b) Horn-gap arrester :→ This type of the lightning arrester is developed both for low voltage and high voltage purpose and its diagram is given below:-



Horn gap with choke coil and Resistance

→ It consists of two horn shaped metallic pieces separated by a small air gap. It is connected between each conductor of earth.

→ The distance of the gap between the two electrode ~~normal~~ under normal condition will always open but if the travelling wave surge voltage is abnormally high i.e. slightly less than twice of the normal operating voltage will breakdown the gap and find a conducting path to the earth and there will be also an arc produced by the horn. So, that will be extinguished due to the presence of the air.

→ The time of complete operation is about 3 to 5 sec. The choke coil is connected between the arrester and apparatus and it consists of bare copper with several turns.

→ The function of the choke is that it will reflect the travelling wave back to the horns and the transformer is protected. The horn gap can take a maximum current of 10KA.

→ The following characteristic of this type of lightning arrester (L.A), the break down voltage value is affected by atmospheric condition such as temperature and pressure of air. The horn gaps are depended upon the air density inversely.

Advantages :→

(i) The arc is self-clearing. Therefore, this type of arrester does not cause short-circuiting of the system after the surge is over as in the case of rod gap type lightning arrester.

(ii) Series resistance helps in limiting the follow current to a small value.

Limitations :→

(i) The bridging of gap by some external agency (e.g. birds) can render the device useless.

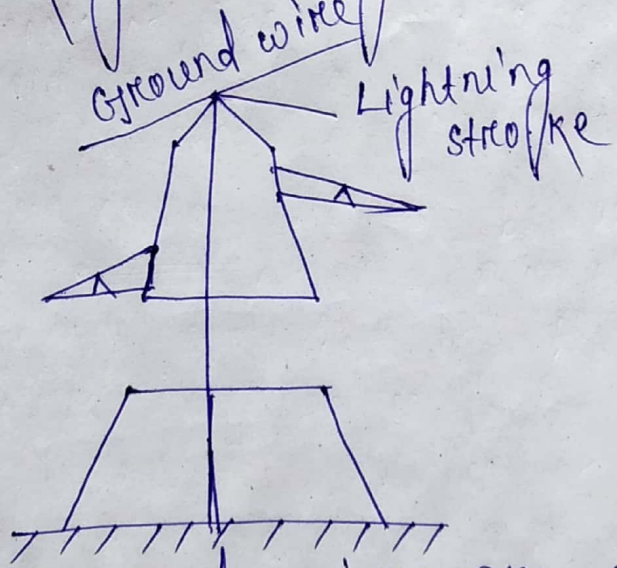
(ii) The setting of horn gap is likely to change due to corrosion or pitting. This adversely affects the performance of the arrester.

(iii) The time of operation is comparatively long, say about 3 seconds. In view of the very short operating time of both of the modern protective gear for the feeders, this time is fare long.

Due to the above limitations, this type of arrester is not reliable and can only be used as a second line of defence like the rod gap lightning arrester.

Protection of Over Head Transmission line from Direct strokes :→

(i) Here ground wires may be used i.e. they will be grounded at regular intervals at each support or pole. These ground wires are making an angle of 20° to 30°.



(ii) These ground wires are extensively used for the direct strokes in transmission line for voltages of 110 KV and above.

(iii) Protector tubes may be added against the direct lightning strokes. These tubes are producing the internal gap between the line conductors.

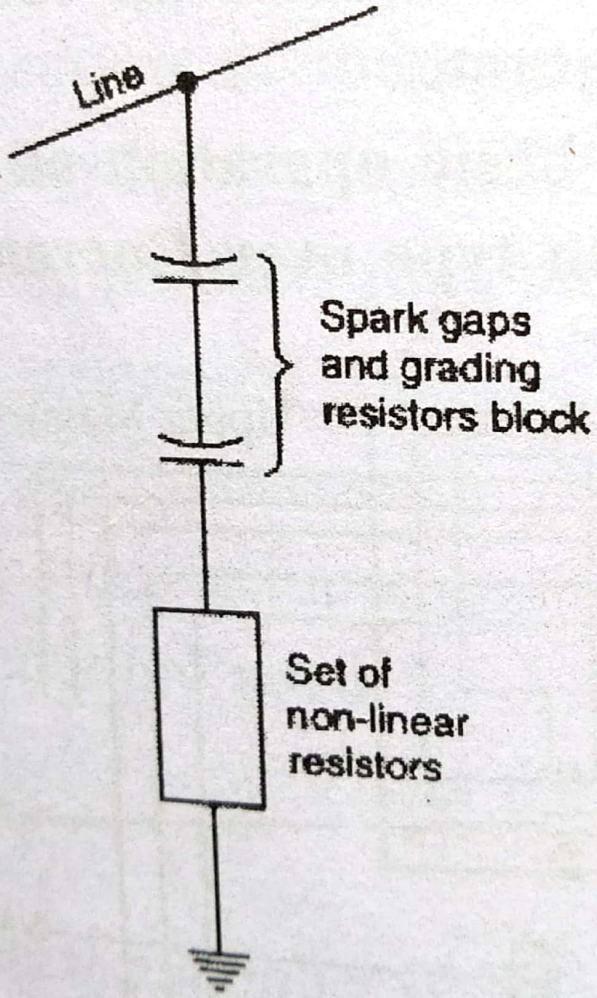
Protection against travelling waves :→

(i) Against these types of faults, the surge diverters may be used. These surge diverters are rod gap type arrester, sphere gap arrester, horn gap arrester, Lucke arrester, multi-gap arrester, valve type arrester, expulsion type arrester etc.

for pro...

(c) Explain valve type arrester.

Ans.Valve type lightning arrester. It is also known as



non-linear type lightning arrester.
It is very cheap, effective and robust and is,

therefore extensively used for high voltage systems.

Figure shows the schematic arrangement of a valve type lightning arrester.

Construction. It consists of a stack of spark gaps and resistor discs, the later having the unique characteristics and their ohmic value decreases rapidly as the magnitude of current flowing through them increases. Both assemblies, i.e., spark gaps and set of resistors, are accommodated in series within a completely tight porcelain housing ensuring reliable protection against atmospheric moisture, condensation and humidity.

Working. Under normal operating conditions, the normal system voltage is insufficient to cause the breakdown of air gap assembly. However, when overvoltageoccurs, the breakdown of the series spark gap takes place and the surge current is conducted to earth via the non-linear resistors. As the magnitude of surge current is very large, the non-linear elements will offer a low resistance to the passage of surge. Consequently the surge will rapidly move to earth instead of being sent back over the line. When the surge is over, the non-linear resistors assume high resistance and flow of the current ceases.

Advantages:

(i) These arresters provide very effective protection against surges (especially for transformers and cables).

(ii) The impulse ratio (ratio of breakdown voltage under surge conditions to breakdown voltage under low frequency conditions) is practically unity.

(iii) Operate very rapidly, taking less than a second.

Drawbacks.

Although these arresters possess very superior characteristics, they suffer from the following drawbacks:

(i) The performance characteristic is adversely affected by the ingress of moisture into the enclosure.

(ii) These arresters may fail to respond quick enough to check the surge voltage of very steep wavefront from finding access into the station equipment.

The various types of valve type arresters and their applications are:

(i) Station type:

* These are the most efficient and most expensive type. The word 'station' indicates their general application in large station.

* They are generally used for the protection of important power equipment in the circuits of 2.2 kV to 400 kV and higher.

(ii) Line type:

* These are constructed in a way similar to that of the station type arresters but are smaller in cross-section and weight and less in cost. They permit higher surge voltages across their terminals than do the station types and have lower surge current capacity.
* They are seldom used on system voltage above 66 kV.
* The designation 'line type' is confusing as these are not used for the protection of lines.
* They are generally used for protecting large transformers and immediate sub-stations. Ratings are available upto 5000 A.

(iii) Arresters for the protection of rotating machines:

* These are designed particularly for the protection of motors and generator.
* The usual circuit voltages are 2.2 to 22 kV.

(iv) Distribution type arresters:

* These are available for voltages varying between 2.2 to 15 kV.
* These are mostly pole mounted and employed for protecting distribution circuits/transformers.

(v) Secondary arresters:

* These are available for protection of low voltage apparatus (120 to 750 V).

5.(a) What are the causes of overvoltage ?

Ans. The causes of over-voltages are of two types i.e., External causes and internal causes.

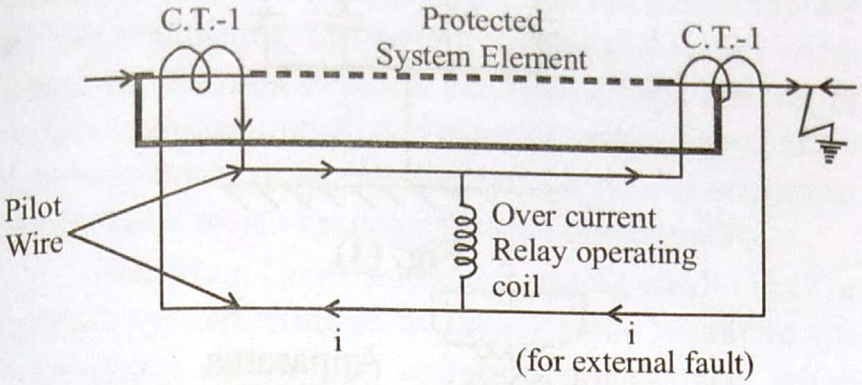
The external causes of over-voltages is due to lightning, surge phenomenon.

The internal causes are due to insulation failure, arcing ground, short-circuit, resonance etc.

(b) Explain different types of

(b) Explain current differential relay.

Ans.



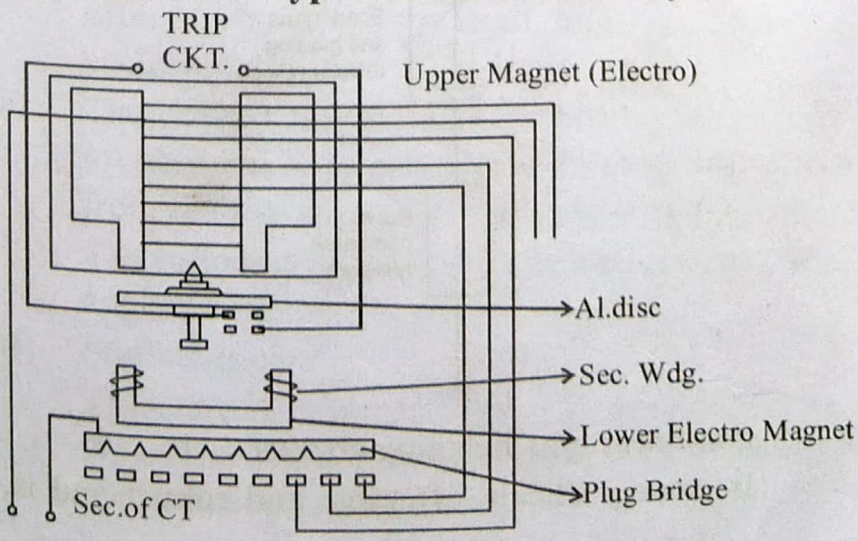
An arrangement of an over current relay connected to operate as differntial relay is shown in figure. This system is meant for external fault. This system element might be a length of circuit, a portion of the bus or a winding of a generator or that of a transformer. A pair of CTS are fitted on either end of the section to be protected. The secondaries of the C.T.S are connected in series with the help of pilot wires in such a way that they carry the induced currents in the same direction. The operating coil is connected across the C.T. secondary circuit.

Normally when there is no fault the currents in the two C.T. sencondaries are equal & the relay operating coil therefore doesnot carry any current.

But at the time of fault either external or intenal there will be a differential current flowsthrough thedifferential relay or operating coil. This current is propertiaonal to the phasor difference between the current entering & leaving the protected element. If the differential current exceeds the valay's pick-up value the relay will operate.

(c) Explain basic operation on Induction relay.

Ans. Induction type over Current relay :



Operations. The plug bridge usually arranged to give seven section of tappings to give over current range from 50% to 200% in steps of 25%.

Let rated current of CT = 5Amp. and Therefore the pickup value will be 1.5 × 5A = 7.5 A.

It means that above current setting the relay will actually operate for a relay current equal to or greater then 7.5 A (for 150% setting) for 200% setting it is 2 × 5 = 10A. Adjustment of current setting is made by inserting a pin between the spring loaded jaw of the bridge socket at the top.

The secondary wdg. is energized by induction from the pri. & is connected in series with the wdg. on the lower magnet. Therefore the fluxes of upper and lower electro magnets are sufficient displaced in space and phase in set up a rotational torque

$$T = K_1 I^2_{rms} - K_2.$$

Where K_1 and K_2 are the spring const. the disc spindle rotates through a pre-set angle 0 to 360° and Thus giving a desired time setting. Time setting multiplier (TMS) is an adjustable back-stop which decides the actual operating time. Its range is from 0 to 1. in steps of 0.05.

Calculation of plug setting multiplier (PSM)

$$PSM = \frac{\text{Fault Current in relay}}{\text{Pick up Value of current}}$$

$$= \frac{I_R}{\text{C.T. ratio of sec. rated current} \times \text{Current setting}}$$

$$= \frac{I_R}{\frac{I_P}{100} \times y} = \frac{I_R \times 100}{I_P \times y}$$

$$= \frac{I_f \times 100 \times y}{x \times I_P \times y} = \frac{I_f \times 100}{x I_P}$$

I_P = % current setting of the relay.

$$TSM = \frac{\text{Actual time of operation}}{\text{Time of operation corresponding to PSM}}$$

(b) Explain Surge Absorber.

Ans. Surge Absorber : These are the protective devices which reduce the steepness of wave front of a surge by absorbing surge energy.

The schematic diagram of the surge absorber is drawn below :

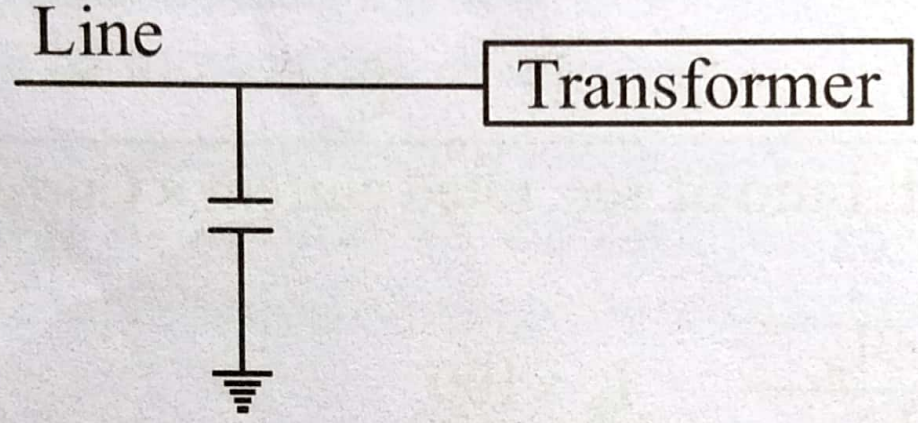


Fig. (1)

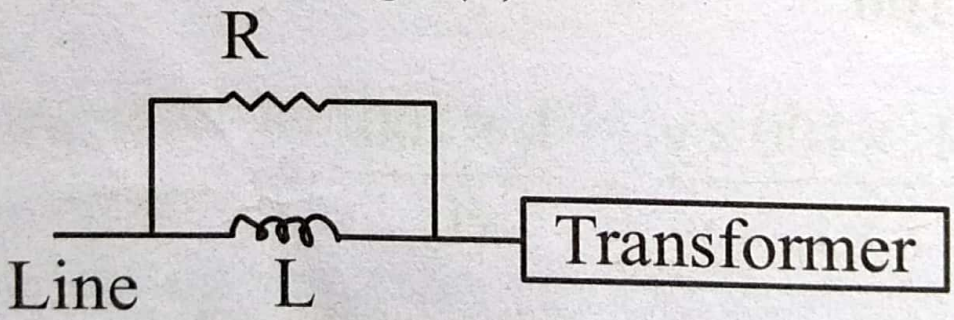


Fig. (2)

In figure-(1), a condenser (c) is connected between line and ear th and acts as a S.A. reactance of a condenser (X_C) is inversely proportional to frerquency, 'X_C' will be low at high frequency and high at low frequency. Since surges are of high frequencies, capacitor acts as a S.C. and passes directly to earth. Thus the transformer wdg. is protected. In figure-(2), there is a

choke coil (L) and a resistor (R) is connected across 'L'. The choka offers high reactance to surge frequencies $(\because X_L \alpha f)$. The surges are forced to flow through 'R' where they are dissipated.

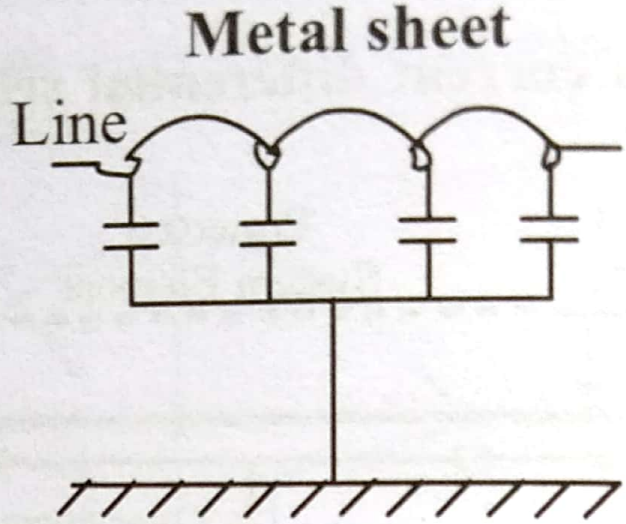


Fig. (3)

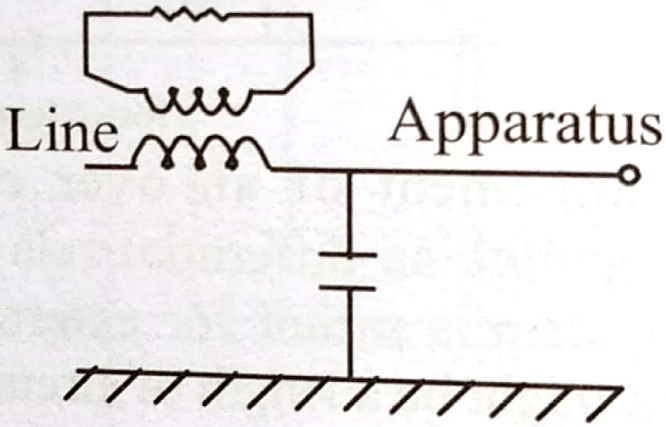


Fig. (4)

Fig (3) and (4) show another type of S.A. which is called Ferranti S.A. It consists of air cored inductor connected in series with the line. The inductor is sorrounded by but insulated from an earthed metallic sheet called dissipator. The energy of the surge is used up in the form heat generated in the dissipator due to transformer action. These type of S.A. are mainly used for protection of transformer.

CKt Breakers

Defination of CB:→ A ckt breaker is an automatically operated electrical switch designed to protect an electrical ckt from damage caused by excess current from an overload or short ckt. Its basic function is to interrupt current flow after a fault is detected.

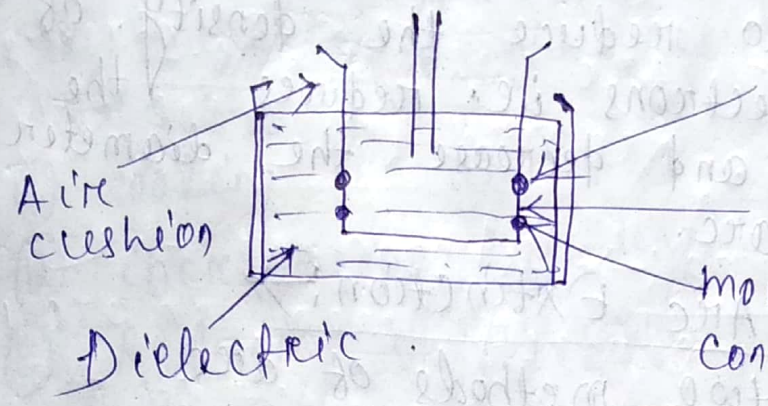
→ A ckt breaker is a switching device that interrupts abnormal or fault current. The ckt Breaker is mainly designed for closing or opening of an electrical ckt, thus protects the electrical system from damage.

Working principle of ckt Breaker :→

→ CKt breaker essentially consists of fixed and moving contacts. These contacts are touching each other and carrying the current under normal conditions when the ckt is closed.

→ When the ckt breaker is closed the current carrying contacts called the electrodes, engaged each other under the pressure of a spring.

→ During the normal operating cond, the arms of the ckt breaker can be opened or closed for a switching and maintenance of the system. To open the CB, only a pressure is required.



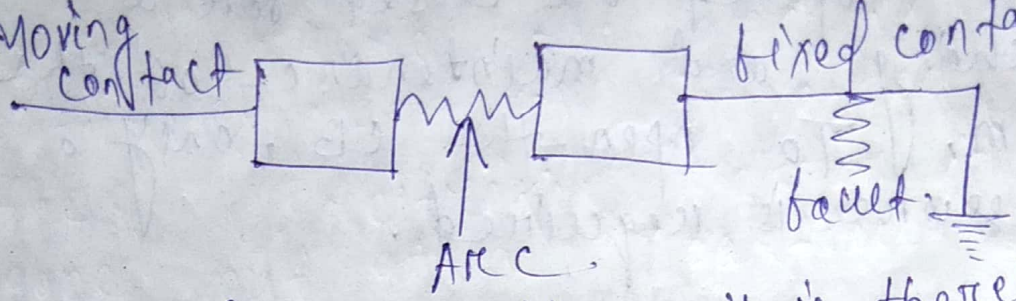
→ Whenever a fault occures in any part of the system, the trip coil of the breaker gets energized and the moving contacts are getting apart from each other by some mechanism, thus opening the ckt.

Arc phenomenon and prinicple of Arc extinction :→

Arc extinction :→ When the current carrying contacts of the CB are moved apart, an arc is formed, which insist for a short period after the separation of contacts.

→ This arc is dangerous on account of the energy generated in it in the

form of heat which may result in excessive forces.



→ For arc extinction, it is therefore necessary to reduce the density of free electrons i.e. reduces the ionisation and decrease the diameter of the arc.

Methods of Arc Extinction :→

→ There are two methods of arc extinction in CKt breakers. These methods are :→

1. High resistance Method.
2. Low resistance or zero current interruption method.

① High Resistance Method :→

→ In this method, the arc is controlled in such a way that its effective resistance increase with the time, so that the current is reduced to such a value that heat formed by it is not sufficient to maintain the arc or thus arc is extinguished.

→ Because of the resistive nature of the arc discharge, most of the energy in the system will be dissipated within the ckt breaker. This is the main drawback of this method of arc extinction.

→ The following are the reasons which can increase the resistance of the arc :→

① cooling of arc.
② increasing the length of the arc.
③ Reducing the cross section of the arc.
④ splitting of arc.

② Low Resistance or zero current Interruption Method :→

→ This method is applicable only in Ac ckt interruption because there are natural zero of current, 100 times in a second for 50 Hz. 3-ϕ supply system. This is one of the most significant advantages of Ac ckt for arc interruption purpose because the current is not allowed to rise again.

→ In this method, the arc resistance is kept low until the current is zero where the arc extinguishes naturally and its prevented from restriking after it has gone out at a particular arc. ckt.

Defination of Arc voltage, Re-striking voltage and Recovery voltage :→

Arc voltage :→ As soon as the breaker contacts open, an arc is formed between the contacts of the CB. The voltage which appears across the contacts of the breaker during this arcing period is called the arc voltage.

→ Its value is low but when the value of arc current reaches to zero, arc voltage will shoot up to its peak value which in turn will try to main the arc across the contacts.

→ So here we come to a voltage which shoots up to peak when the current crosses to its zero. Actually this is the origination of Restriking voltage.

Restriking voltage :→

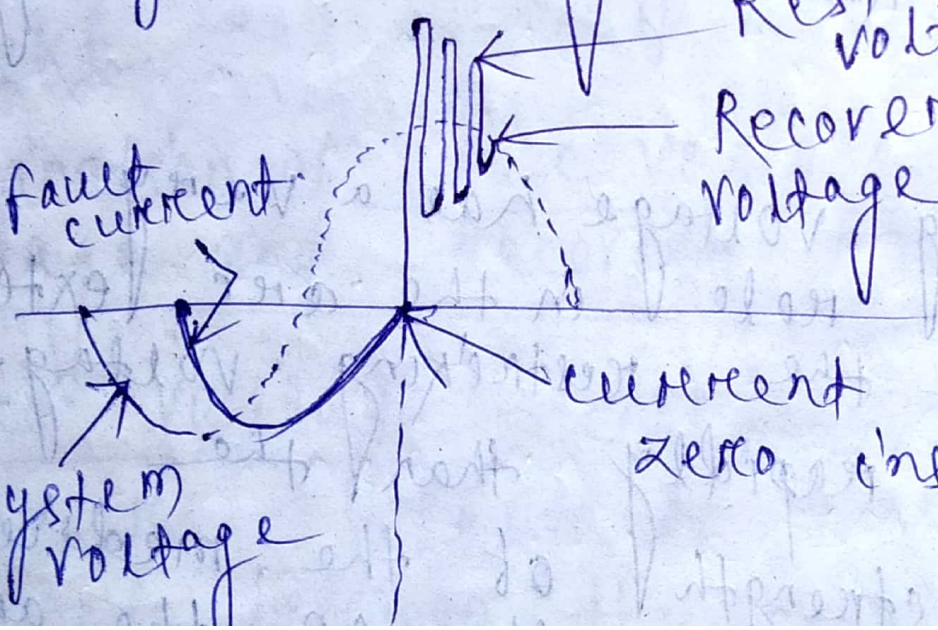
→ As the arcing current crosses zero, a high frequency transient voltage appears across the contacts of the CB. This transient voltage is known as the Restriking voltage.

→ Restriking voltage has a very important role in the arc extinction process. If the restriking voltage rises more rapidly than the dielectric strength of the medium bet' the contacts of the CB, the arc will persists for next half cycle and after next half cycle, arcing current will again reach to its zero and we again get a chance.

→ If this time the rate of rise of dielectric strength of medium bet' the contacts is more than the rate of rise of restriking voltage then arc will extinguish.

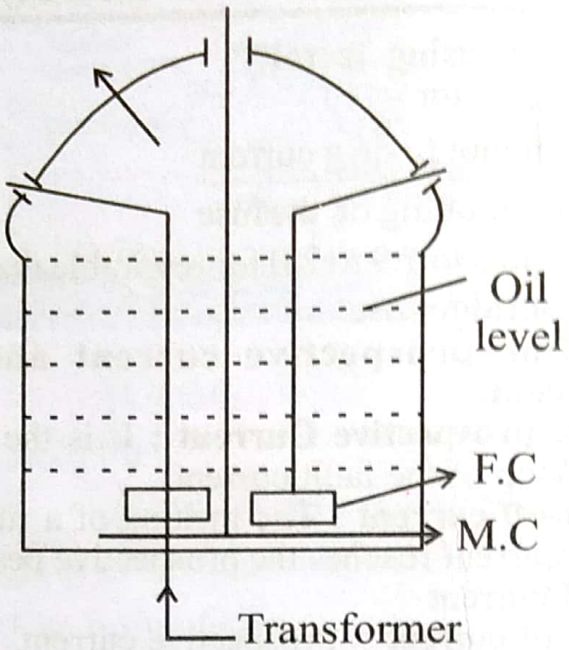
→ Therefore, for arc extinction,
Rate of Rise of Restriking voltage < Rate of rise of dielectric strength.

Recovery voltage ⇒ It is the normal frequency RMS voltage that appears across the contacts of the CB after final arc extinction. It is equal to the system voltage.



(c) Explain plain brake oil circuit-breaker.

Ans. Plain break O.C.B. : This circuit-breaker involves the simple process of separating the contacts under the whole of the oil in the tank. The arc is extinguished when a certain critical gap between the contacts is increased.

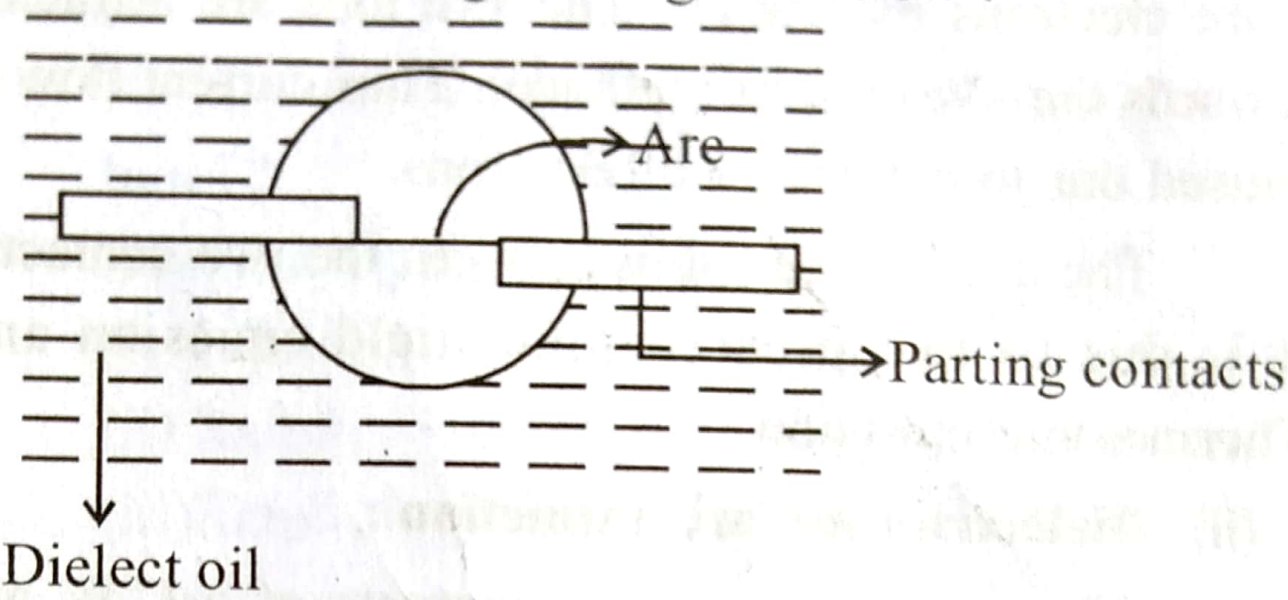


There are two contacts known as F.C. and M.C. and the transformer oils are filled in a strong weather tight earthed tank and the oil is upto same level. Air cushion is present to allow for the reception of the gases so that there will be no excess pressure generated inside the chamber.

Under normal operating conditions, both F.C. and M.C. remain closed and circuit-breaker carries normal circuit current. When a fault occurs, the M.C. are pulled down by the protective system and an arc is struck which vapourizes the oil mainly into 'H_2' gas. The 'H_2' gas bubbles generated around the arc cools the arc column and aids the deionisation of the medium between contacts. The gas sets up turbulence in the oil and helps in eliminating the arcing products from the arc path, the arc lengthens due to separating contacts, the dielectric strength of the medium is increased. Thus the arc is extinguished due to some critical gap length. These circuit-breaker are mainly used for L.V. low speed operation and there is no control over the arc.

(b) Write the construction and working of oil CB with neat sketch in brief.

Ans. This type of CB has oil as the insulating material and the diagram is given below :



On occurrence of fault the CB contacts i.e. fixed and moving contacts will open under oil, the arc is struck between them and the heat of the arc evaporates the surrounding oil and dissociates it into a substantial volume of gaseous hydrogen, methane, ethylene etc at high pressure. The pressure built-up & flow of gases is influenced by the design of arc control device, speed of contact travel etc. The arc extinction process is conducted in to manners, firstly the 'Hg' as high heat conductivity and cools the arc. Secondly the gas sets up turbulence in oil and forces it into the space between the contacts after the final arc interruption at a current zero & thus arcing products from the arc path are eliminated. The result is that arc is extinguished & the circuit current is interrupted the various types of OCB used are

(i) Bulk oil CB (ii) Low oil CB

In bulk oil CB – The quantity of oil is large. This CB is used for indoor and outdoor applications. Similarly low oil CB the quantity of oil required is small or minimum.

(c) State and explain the various important components common to most of the circuit breaker and their function. Show the components.

Ans. The various important components common to most of the C.B. are :

(i) Moving contacts and fixed contacts.

(ii) Dielectric materials.

(iii)Trip circuit materials.

(iv)Container for dielect.

(i) Contacts i.e. Fixed or Moving Contacts :

In order to produce the arc Phenomenon in C.B. these contacts are necessary. The electrons being negatively charged are attracted towards the +ve contact i.e. anode with a high velocity and on the way they detach more electrons by impact. The +ve ions are attracted towards the –Ve contact (cathode). Thus current flow is caused dur to movement of electrons.

The arc is initiated in between the two contacts. It is due to two processes i.e. field emission and Thermoionic emission.

(ii) Dielectrics for arc extinction :

When current carrying contacts of a C.B. are parted, an arc is formed, which persists during the brif period after separation of contacts. In order to extinguish the arc or to cool it dielectric are present in betwen the contacts of the C.B. These dielectrics are oil, air, SF_6, Vacuum etc.

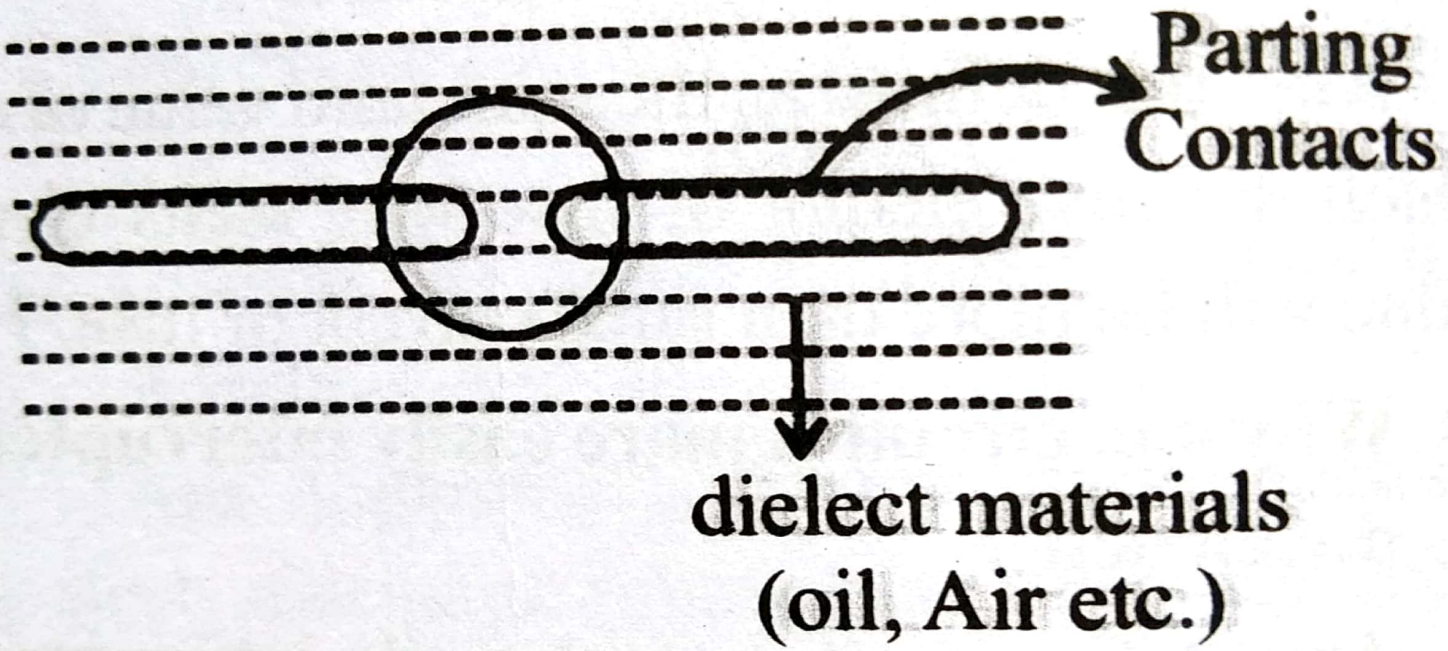
(iii) Trip Circuit :

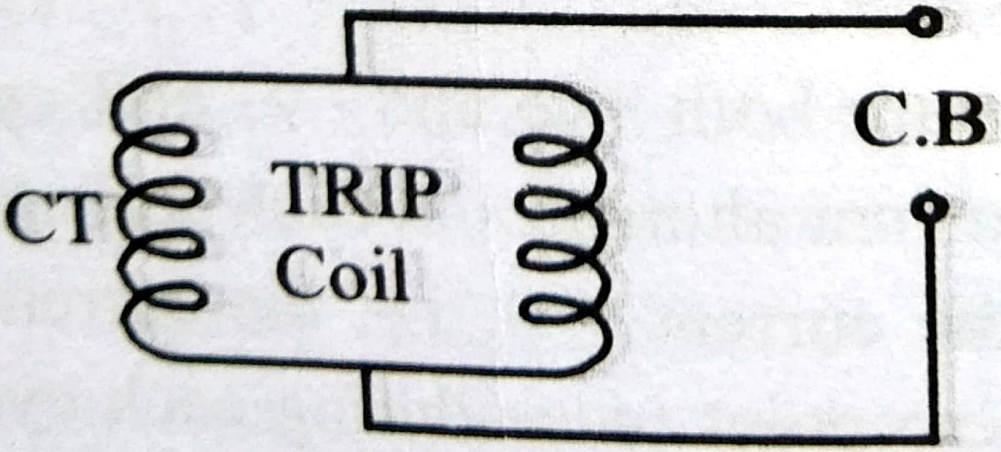
All the C.B. are being connected with trip coil & relay. The trip coils of the C.B. get energized & the moving contacts are pulled apart by some mechanism thus opening the Ckt. at fault conditions.

(iv) Containers :

There are containers which are meant for the storing of some of the dielect. materials such as oil, Air, SF_6, Vacuum etc.

The Components shown are :





(b) Explain various ratings of a circuit breaker in brief ?

Ans. Rating of a C.B are :

(i) Rated voltage

(ii) Rated current.

(iii) Rated frequency.

(iv) Operating duty

(v) Breaking capacity

(vi) Making capacity

(vii) Short time current rating.

Rated Voltage : The rated maximum voltage of a C.B. is the highest rms voltage above nominal system voltage for which the C.B. is designed and is the upper limit of operation. The rated voltage = kV_{rms} and refer phase to phase voltage for '3' phase Ckt.

Rated Current : It is the rms value of the current which the C.B. shall be able to carry at rated frequency and at the rated voltage continuously, under specified conditions. It is very much related with temperature. The important condition for normal working of an oil C.B. is that temperature of oil should not be more the 40°C and that of contact should not exceed 35°C.

Operating Duty : It consists of the prescribed no. of unit operations at stated intervals.

Breaking Capacity : It is the highest rms vaue of s.c. current that the C.B is capable of breaking under specified conditions of transient recovery voltage and power frequency voltage. It is expressed in kA rms at contact separation.

Conventionally breaking capacity :

$= \sqrt{3} \times$ rated voltage $\times$ rated breaking current in kA.

Hence it is expressed in MVA.

There are two breaking capacities.

(i) Symmetrical breaking capacity.

(ii) Asymmetrical breaking capacity.

Making Capacity : It depends upon its ability to withstand the effects of electro magnetic forces which are propertional to the square of peak value of making on Current. The making current when closed on s.c. is the peak value of I_{max}(including dc component) in the 1st cycles of current after the circuit is closed by C.B.

Making current = $1.8 \times \sqrt{2}$ rated s.c. breaking current

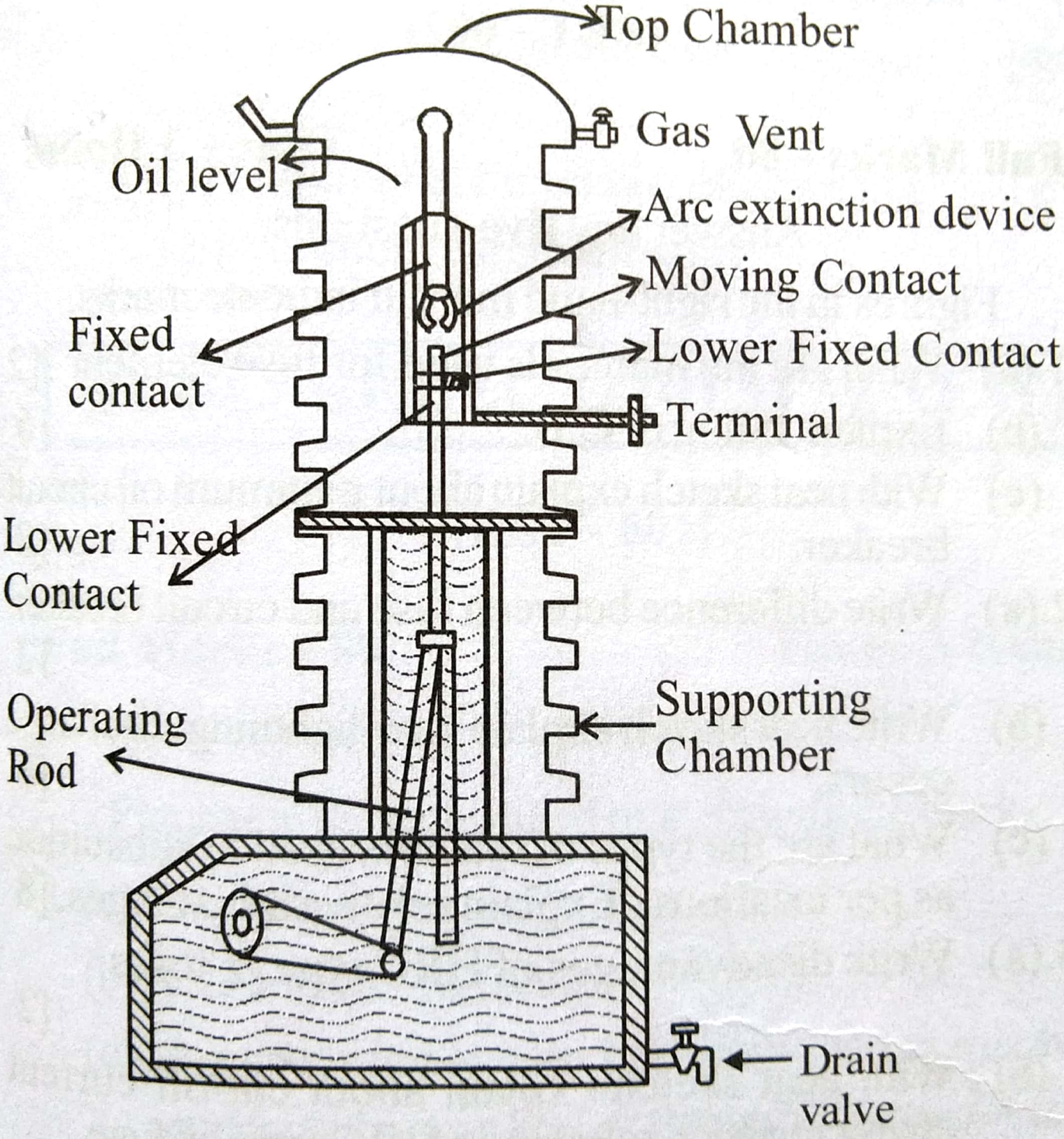
= 2.55 times rated s.c. breaking current.

Making capacity = $2.55 \times$ symmetrical breaking capacity.

Short time Current rating : It is the rms value of current that a C.B. can carry in a fully closed position without damage for a specified time interval under prescribed conditions. It is normally expressed in kA for a period of 1 sec or 4 sec. (L.V) C.B have no short time current rating.

(iii) Low oil circuit-breaker.

Ans.



The C.B. is of single break type in which the moving contact tube moves in a vertical line to make or break contact the upper half fixed contacts mounted within the arc control device. A lower ring of fixed contacts are in permanent contact with the moving arm to provide the other terminal of the phase unit. Within the moving contact tube is a fixed piston which as the tube moves down ward on opening, forces the column of oil inside the tube into the arc control device. This has two effects, firstly a partial pressure balance is ensured so that the pressure generated inside the arc - control device has little effect on the acceleration of the moving contact and secondly the amount of cavitation caused. caused by the removal of the moving contact is controlled and efficiency of arc extinction si increased.

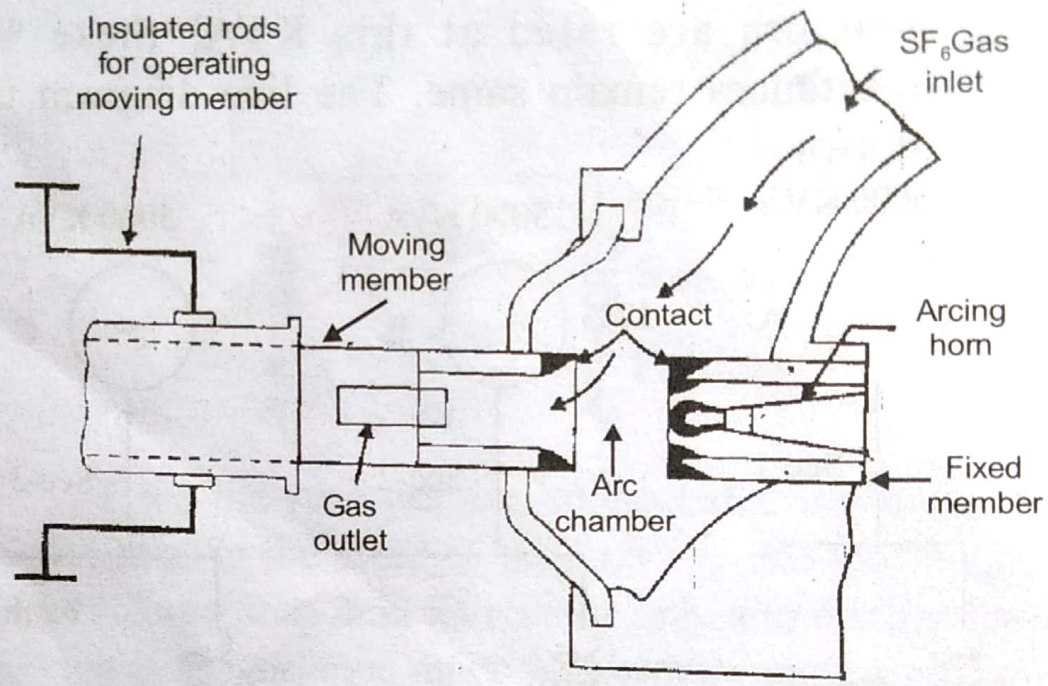
The CB arc controlled device which is built up of oil impregnated vulcanised fibre plates held under compression by tension members, the plates being arranged to form a series of vents on one side of the arc, and a series of oil pockets on the other. The fixed arcing tip is so arranged that when the CB opens, the arc is drawn in front of vents where it can be most easily exitinguished. To ensure that oil vapourised by the arc-control device. To minimise the pre-arcing in the moving contact there is turbulator plates.

The upper arcing chamber contains a separator which eliminates by centrifugal action, loss of oil when the breaker operates under fault conditions.

Low oil CB are now available for all voltages and has highest breaking capacities.

(i) SF_6 circuit-breaker.

Ans. This type of CB is prefered for EHV substantions and they have very high breaking capcity, the dielectric strength is very high & arc quenching is also effective than other dielectric material construction & working.



The CB consists of two units i.e.

(1) Interrupter unit. (2) gas unit.

Interrrupter Unit : In the interrupter Unit which has both moving contact & fixed contact and they have connected with set of current transformer fingers. The function of the current transformer finger is that when moving contacts is with drawn from the finger constraint an arc is struck between the moving nuzzel & arcing probe.

Now increase of separation between the two contacts are extended and finally SF_6 gas with high rpessure will move through the nuzzle with high pressure which will extinguish the arc.

Working :

The arc extinction process in SF_6 gas is glown on axially along the arc and the heat is removed from the arc by axial connection and radial dissipation.

Therefore the diameter of the arc is reduced and the dielectric strength of the medium will regain, the rate of rise of dielectric strength is more than that of heat generated.

So the arc will be extinguished with very faster way and after the current zero in each half cycle the restriking effect will be negligible and due to turbulent flow, SF_6 the arc will be deionised & the arc extinction takes place in a sudden way.

(iv) Air-Blast circuit breaker.

Ans. These breakers employ a high pressure air-blast as an arc quenching medium. The contacts are opened in a flow of air-blast established by the opening of blast valve. The air-blast cools are the arc and sweeps away the arcing products to the atmosphere. This rapidly increases the dielectric strength of the medium between contacts and prevents from re-establishing the arc. Consequently, the arc is extinguished and flow of current is interruped.

Advantages :

An air-blast circuit breaker has the following advantages over an oil circuit breaker :

(i) The risk of fire is eliminated.

(ii) The arcing products are completely removed by the blast whereas the oil deteriorates with successive operations; the expense of regular oil replacement is avoided.

(iii) The growth of dielectric strength is so rapid that final contact gap needed for arc extinction is very small. This reduces the size of the device.

(iv) The arcing time is very small due to the rapid build up of dielectric strength between contacts. Therefore, the arc energy is only a fraction of that in oil circuit breakers, thus resulting in less burning of contacts.

(v) Due to lesser arc energy, air-blast circuit breakers are very suitable for conditions where frequent operation is required.

(vi) The energy supplied for arc extinction is obtained from high pressure air and is independent of the current to be interrupted.

Dis-advantages :

The use of air as the arc quenching medium offers the following dis-advantages :

(i) The air has relatively inferior arc extinguishing properties.

(ii) The air-blast circuit breakers are very sensitive to the variations in the rate of rise of restriking voltage.

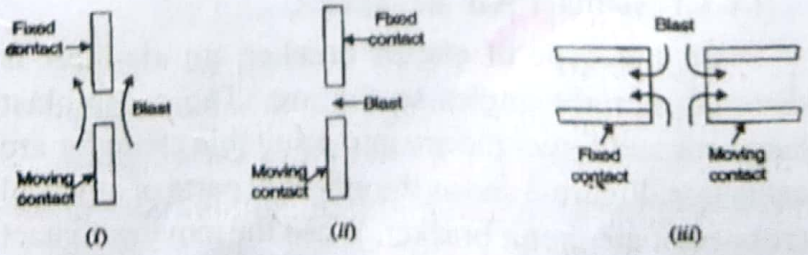
(iii) Considerable maintenance is required for the compressor plant which supplies the air-blas.

The air-blast circuit breakers are finding wide applications in high voltage installations. Majority of the circuit-breakers for voltages beyond 110 kV are of this type.

Types of Air-Blast Circuit Breakers :

Depending upon the direction of air-blast in relation to the arc, air-blast circuit-breakers are classified into :

(i) Axial-blast type in which the air-blast is directed along the arc path as shown in figure-1(i).

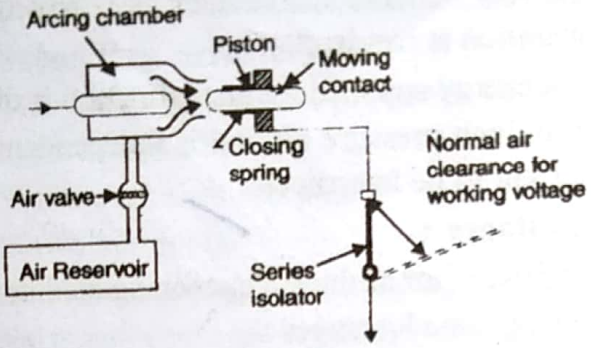


(ii) Cross-blast type in which the air-blast is directed at right angles to the arc path as shown in figure-1(ii).

(iii) Radial-blast type in which the air-blast is directed radially as shown in figure-1(iii).

(a) Axial-blast Air Circuit Breaker :

Figure-2 shows the essential components of a typical axial-blast air circuit breaker. The fixed and moving contacts are held in the closed position by spring pressure under normal conditions. The air reservoir is connected to the arcing chamber through an air valve. This valve remains closed under normal conditions but opens automatically by the tripping impulse when a fault occurs on the system.



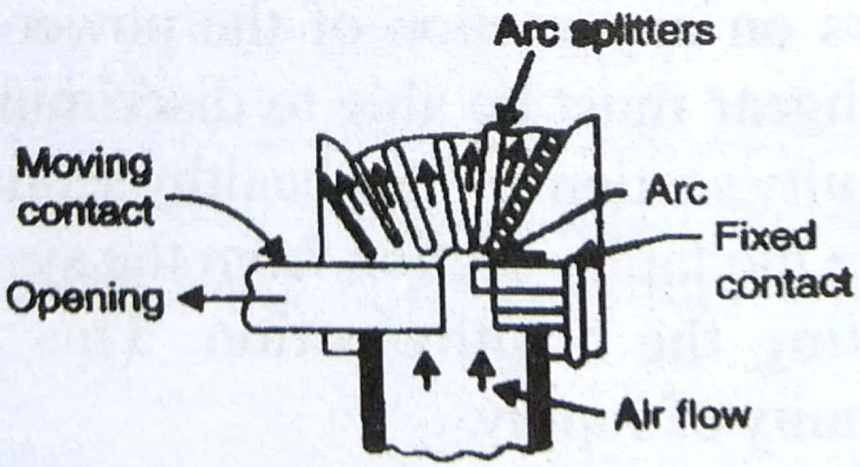
When a fault occurs, the tripping impulse causes opening of the air valve which connects the circuit breaker reservoir to the arcing chamber. The high pressure air entering the arcing chamber pushes away the moving contact against spring pressure. The moving contact is separated and an arc is struck. At the same time, high pressure air blast flows along the arc and takes away the ionised gases along with it. Consequently, the arc is extinguished and current flow is interruped.

It may be noted that in such circuit breakers, the contact separation required for interruption is generally small (1.75 cm or so). Such a small gap may constitute inadequate clearance for the normal service voltage. Therefore, an isolating switch is incorporated as a part of this type of circuit breaker. This switch opens immediately after fault interruption to provide the necessary clearance for insulation.

(b) Cross-blast Air Breaker :

In this type of circuit breaker, an air-blast is directed at right angles to the arc. The cross-blast lengthens and forces the arc into a suitable chute for arc extinction. Figure-3 shows the essential parts of a typical cross-blast air circuit breaker. When the moving contact is withdrawn, an arc is struck between the fixed and moving contacts. The high pressure cross-blast forces the arc into a chute consisting of arc splitters and baffles. The spiltters serve to increase the length of the arc and baffles give improved cooling. The result is that arc is extinguished and flow of current is interrupted. Since

blast pressure is same for all currents, the inefficiency at low currents is eliminated. The final gap for interruption is great enough to give normal insulation clearance so that a series isolating switch is not necessary.

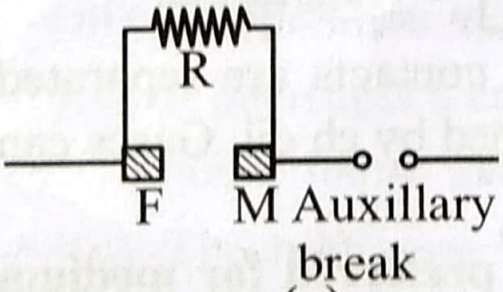


(b) Explain the resistance switching process in a CB.

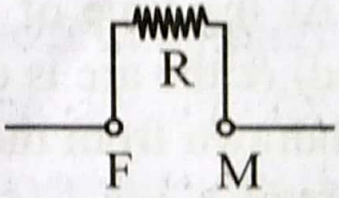
Ans. It is a delibrate connection of resistance in parallel with the contact space (or arc) is called the resistance switching. It is employed in CB having high post zero resistance of contact space (i.e. air blast CB).

Severe voltage oscillations occur due to (i) Breaking of low inductive currents (i.e. current chopping) (ii) Breaking of capacitive currents, this will endanger the operation of the system.

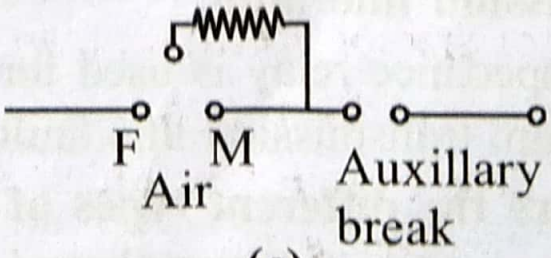
On occurence of fault, the contacts of the CB open and an arc is struck between the contacts. with the arc shunted by the resistance 'R' a part of arc current is diverted through this resistance. This result in the decrease of arc current and an increase in the rate deionization of the arc path. Thus the arc resistance is increased leading to and further increase in current through the shunt resistance 'R'. This. build up process continues until the current becomes so small that it fails to maintain. Now the arc is extinguished and the current current gets interrupted.



(a)



(b)



(c)

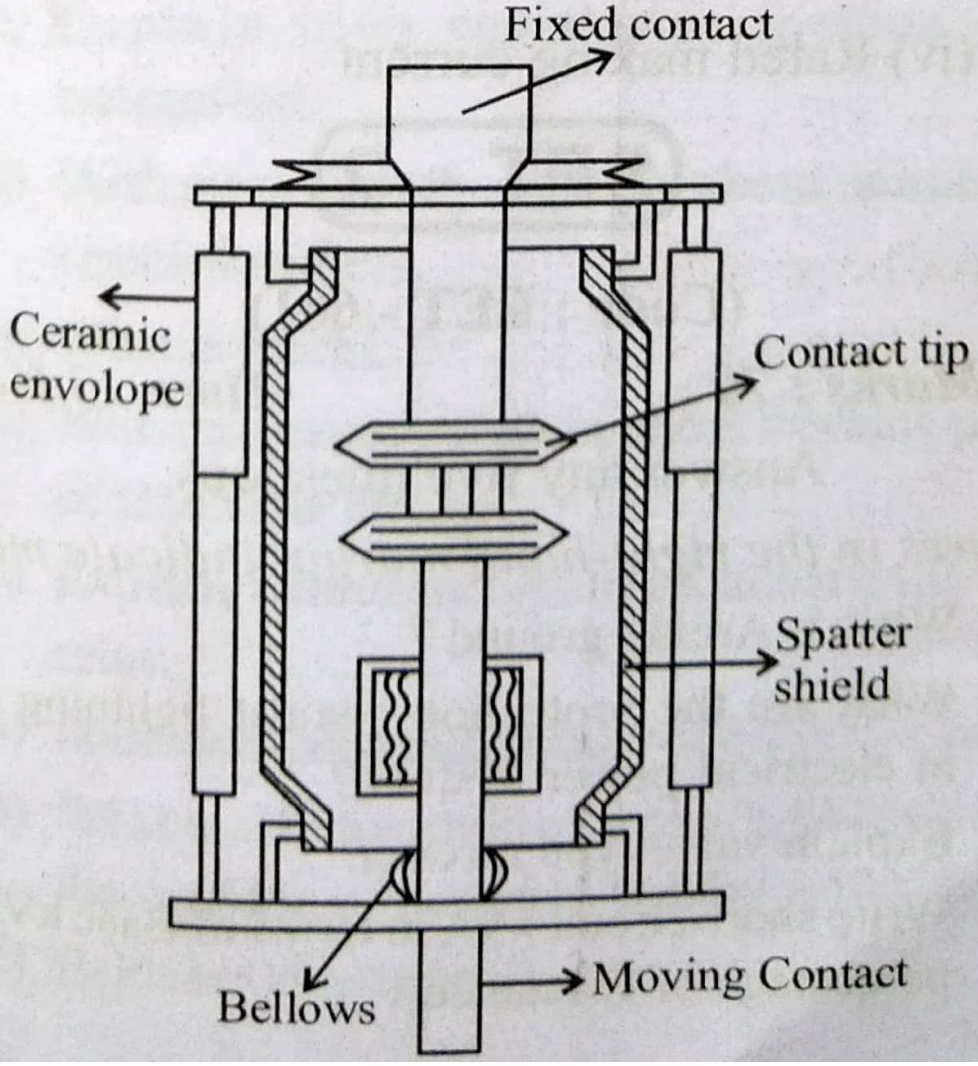
Typical resistor connection are shown in Fig. (1) a, b, c.

(b) Write briefly about vacuum circuit breaker ?

Ans. Vacuum CB :

Vacuum CB has two outstanding properties (i) Highest insulating strength (ii) interruption occurs at the first current is zero.

The lower end of the breaker is fixed to a spring operated or solenoid operated mechanism so that the metallic belows inside the chamber are moved upward and down ward during closing and opening operations respectively. The contact movement should be such as to avoid bounce. It is with nothing that the operating mechanism should provide sufficient pr. for a good connection between the contacts.



The pr. in a vacuum interrupter at the time of sealing of is kept about 10^{-6} torr. The interrupting rating is between 250 and 1000 MVA. the normal current carrying capacity for a single interrupter is 800 – 3000 A, 4.2 kV – 7.6 kV.

Advantage of V.C.B :

(i) It is a self Contained & doesnot require filling of oil or gas. They do not need auxillary air system, oil handling system etc.

(ii) Repid recovery of very high dielect. Strength on current interruption. So that only half cycle or less arcing occurs after proper contact separation.

(iii) Current interruption occurs at the first current *zero* after contact separation with no restriking.

(iv) No emission of gases : Pollution free.

(v) Non-explosive and silent operation.

(vi) Breaker unit is compact & self contained.

(vii) Larger no. of operations on load or S.C. suitable for repeated operating duty.

(viii) Usable on any voltage upto 230 kV & higher and long life, maintenance free.

(ix) No Gas deposition.

(x) High total current switched.

(xi) Constant contact resitance.

Applications :

(i) It is used for very high speed making switches in many industrial applications.

(ii) It is used for Capacitor switching where O.C.B is not sufficient.

(iii) In country like India it is suitable for 11 to 33kV. network extending into vast rural compled.

(iv) For low fault interrupting capacities the cost is low to other interrupting devices.

(c) Explain the working ...

Fuses

Definition of Fuse :→ A fuse is a short piece of metal, inserted in the ckt, which melts when excessive current flows through it and thus breaks the ckt.

Advantages :→

→ It is the cheapest form of protection available.
→ It requires no maintainance.
→ It can break heavy short-ckt currents without noise or smoke.

Disadvantages :→

→ Considerable time is lost in recovering or replacing a fuse after operation.

Desirable characteristics of fuse element :→

→ The function of a fuse is to carry the normal current without overheating but when the current exceeds its normal value it rapidly heats up to melting point and disconnects the ckt protected by it.

→ The desirable characteristics are:
(1) low melting point e.g. tin, lead.
(2) high conductivity e.g. silver, copper.
(3) free from deterioration due to oxidation e.g. silver.
(4) low cost e.g. lead, tin, copper.

Melting point :→ The constant Temp. at which the solid and liquid phase of a substance are in equilibrium at a given pressure.

Fuse element Materials :→

→ The most commonly used materials for fuse element are lead, tin, copper, zinc & silver.
→ For small currents upto 10A, tin or an alloy of tin and lead (lead 37% and tin 63%) is used for making the fuse element.
→ For larger currents copper or silver is employed.
→ Zinc is the one which does not melt very quickly with a small overload.

Important terms of Fuse :→

① **Minimum fusing current :→** It is the worth of current flowing through the fuse wire can soften.

② **Fuse Rating :→** The fuse rating is given in Ampere. It is generally that value of current at which the fuse is expected to operate safely without melting.

→ This value of current will definitely be less than the Minimum fusing current.

③ **Fusing factore :→**

$$\text{Fusing Factore} = \frac{\text{Minimum Fusing current}}{\text{Fuse Rating}}$$

→ The value of fusing factore is always greater than 1.

④ **prospective current :→** It is the expected current of Fuse is the value of current which will flow through it just before the melting of the fuse wire under short ckt Rule.

(5) Melting Time / Pree-arcing Time:-

→ This is the time taken by a fuse wiree to be broken by melting.

→ It is counted from the instant, the overe ccurrent starets to flow through the fuse, to the instant when fuse wiree is just broken by melting.

(6) Arcing Time:- After breaking of fuse wiree there will be an arcing between both melted point of the wiree which will be mitigated at the ccurrent zero.

The time from the instant arc initiated to the instant of the arc being extinguished is known as Arcing time of the feese.

(7) Total operating Time:- Total operating time of fuse is the addition of prearcing and arcing time.

Types of Fuses :→

→ In general, types of fuses may be classified into 2 types.

① Low voltage fuse
② High voltage fuse.

① Low voltage Fuse :→ It is also divided into 2 types namely

ⓐ semienclosed or rewirable type.
ⓑ entirely enclosed cartridge type.

ⓐ Rewirable Fuses :→ These fuses are most commonly used in house wiring and little current ckts. It is also known as a kit-kat fuse.

→ It has a porcelain base which is carrying the fixed contact through which the live wires are connected. The fuse element is built of lead, tin, copper or alloy of tin and lead.

→ The rewirable fuse has the advantages of replacement of fuse element except any risk. The cost of the replacement is also very less.

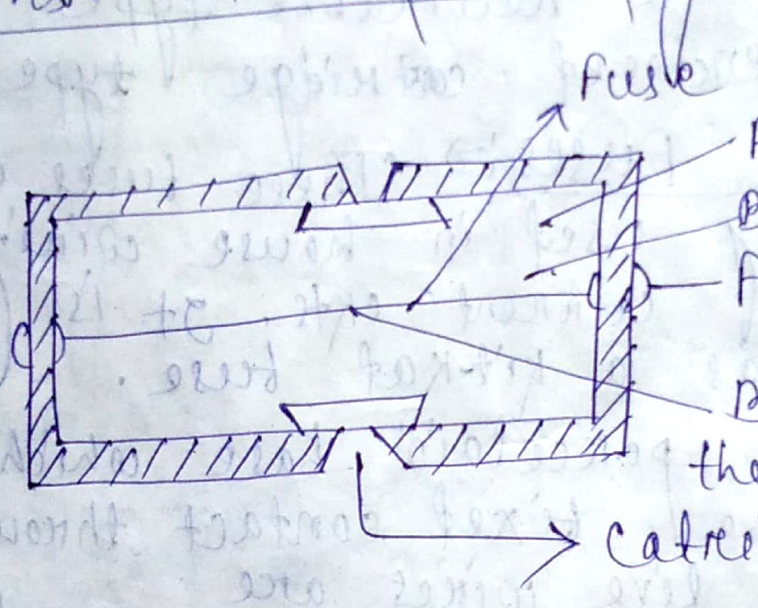
→ The following are the inconvinience of the rewirable fuse. →(मुश्किलें)

(i) unreliable operation.
(ii) slow speed of operation.
(iii) The risk of flame and fire.

(b) ~~cartridge~~ cartridge or High Rupturing Capacity (HRC) fuses :→

→ This type of fuse is required if the ckt has large concentration of power as in case of distribution system and in medium voltage installation.

Construction & Working of HRC fuse :→



→ This fuse has an outer ceramic body having good mechanical strength and temperature resistant.

→ Now a days epoxy resin is material can be used by replacing ceramic.

→ The fuse element are connected to the brass end cap and these caps are screwed by means of links at both ends.

→ The space between the fuse element & the cartridge body is filled with powered pure quartz which acts as an arc extinguishing agent. Another function of quartz is that it will avoid oxidation of silver.

→ It also absorbs heat at a very high temperature & it does not involve appreciable amount of gas.

→ The fuse element has two or more sections joining by meant of tin joint because the tin joint will limit the temperature of the fuse under small over loading condition & this bimetalic junction will help to flow the heat from high temperature to low temperature & heat dissipation will be easier.

Advantages is

1. High speed operation.
2. provides consistence performance.
3. Requires no maintainance.
4. Low temperature rise at full load.
5. capable of clearing high as well as low fault currents.

Disadvantages:-

① Needs to be replaced after each operation.
② It causes overheating of the adjacent contacts.
③ Interlocking is not possible.

② High voltage fuse:- All types of high voltage fuses are used upon the rated voltage up to 1.5 KV to 138 KV.

→ High voltage fuses are used to safe the instrument T/Fs and small T/Fs.

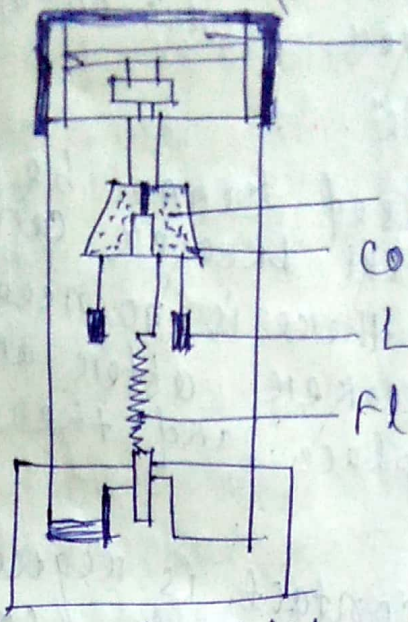
→ It is built up of silver, copper and tin. When the heat generated the arc produces which causes the boric acid to evolve high amount of gases. That's why these are used in outdoor places.

→ These are of 2 types.
① cartridge type HRC fuses.
② Liquid type HRC fuses:-

→ These are used for ckt up to 100 A rated current & systems up to 132 KV.

→ These fuses have the glass tube filled with carbon tetra chloride.

The one end of the tube is packed and another is fixed by phosphorous bronze wire. When fuse function starts, the liquid uses in the fuse extinguish the arc. This increase the short ckt capacity.



Applications of different types of fuses :-

1. power T/Fs.
2. Electrical appliances like AC, TV, Washing machines, music systems etc.
3. Electrical cabling in home.
4. Mobile phones.
5. Laptops.
6. power chargers
7. cameras, scanners, printers, and photocopiers.
8. Motor starters.
9. Automobiles, electronic devices and Gamings. etc.

(b) What are the differences between a fuse and circuit breaker ?

Ans. Difference between Fuse and Circuit breaker :

Ans. (i)Circuit breakers and fuses are both used for fault clearance and short circuits. Both posses a time element of operation, they operate practically instantaneously on S.C. but with definite time lag on over loads. C.B can be reset in less time and with less trouble that are required to replace blown fuses and spare parts are seldom required.

(ii) For l.V. say from 3.3 kV upwards, isolation is achieved by C.B. C.B may be preferred where continuity of service is an important consideration where frequent fuse replacement may be expected.

(iii) Fuse with circuit breaking arrangement is quite useful and economical.

(iv) Isolation switches are needed in case of C.B. for not accessible position of maintenance and inspection.

(v) The fuse wire will melt due to S.C. current or due to over loads automatically, but for C.B. trip coil of a relay will make the contacts to open.

(vi) Fuse has inverse time current characteristics for over loading protection.

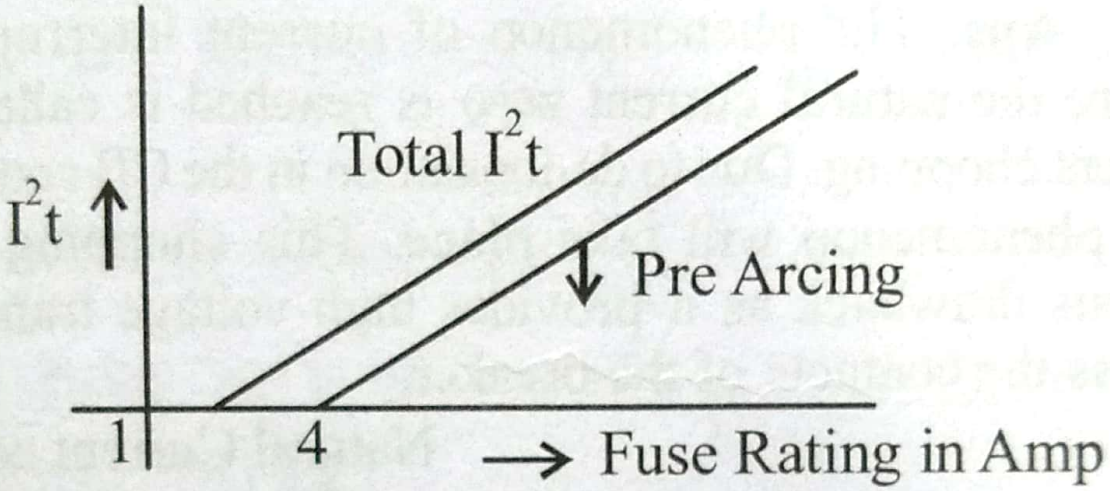
(vii) Fuses are cheap, need no maintenance, operation time is minimum, interruption has no noise, flame, gas or smoke as compared to C.B. electrical machines appliances are generally have fuse elements not any C.B.

(viii) C.B. is used both for no-load and load. i.e. it opens & closes the the circuit on no-loads, it also makes and breaks the normal operating current & it also makes & breaks under S.C. conditions.

(b) What are the characteristics of the fuses, explain in brief.

Ans. The Ch. of HRC fuses are (i) I^2t Ch. (ii) Cut off current Ch. (iv) time current Ch. (v) Non-deteriorating Ch.

The I^2t Ch. is shown below



The cut off current Ch. shows that a heavy fault current will be interrupted and the ability is known as cut-off. Due to this Ch. S.C. current dues n't attain the prospective current. Due to this Ch. the arc is quenched on blowing out of the fuse.

The HRC fuses interrupts the. S.C. current very quickly & both thermal and magnetic stresse are minimised.

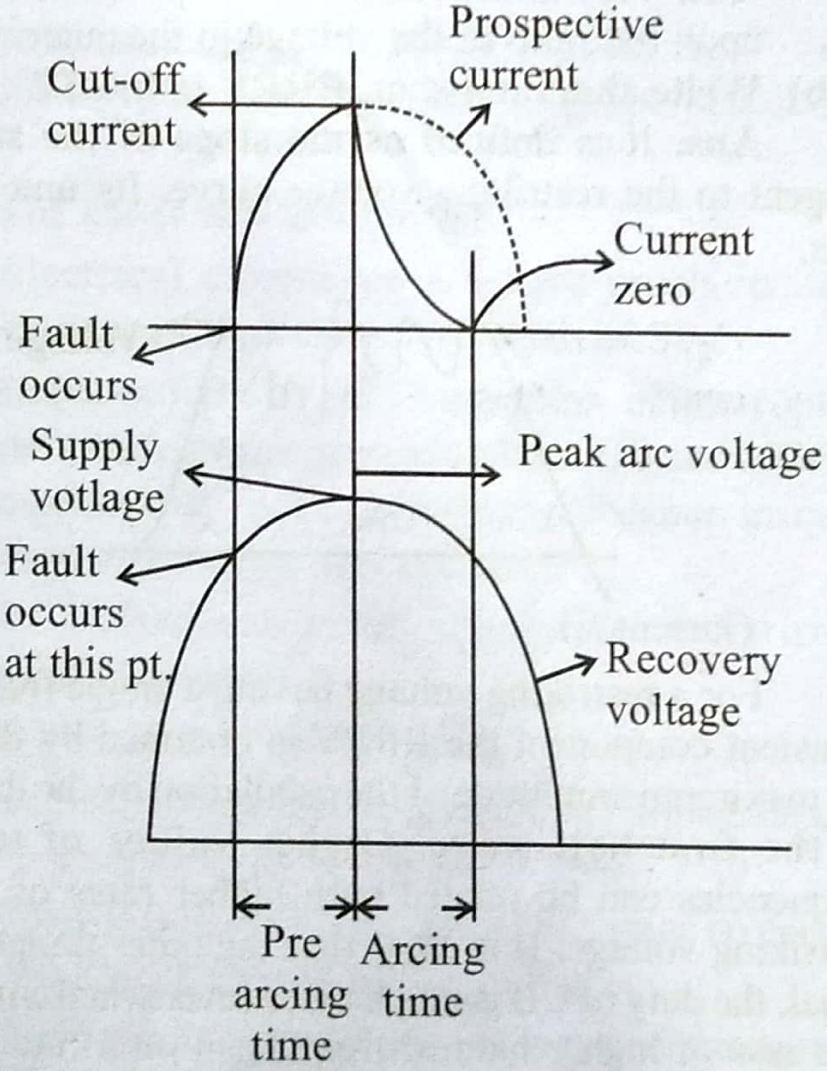
For over load protection inverse time-current Ch. is needed & the HRC fuse exhibits this property.

HRC fuses do not deteriorate their functions even after fault interruption.

Cut-off current characteristics of a HRC fuse is described below:

When a HRC fuse interrupts a heavy fault current at that time it is able to limit the S.C. current. Cut off is in fact one of the main reasons why HRC fuse is so successful as a protective device & it is many times preferred over C.B.

Cut-off occurs when the heavy fault current starts flowing through the fuse element & silver fuse element & silver fuse element starts melting at one or more points. On blowing out of fuse an arc is formed between two ends & a transient current is super imposed on the prospective current. When both these two current sum = 0, arc is quenched. The cut-off characteristics is drawn below :



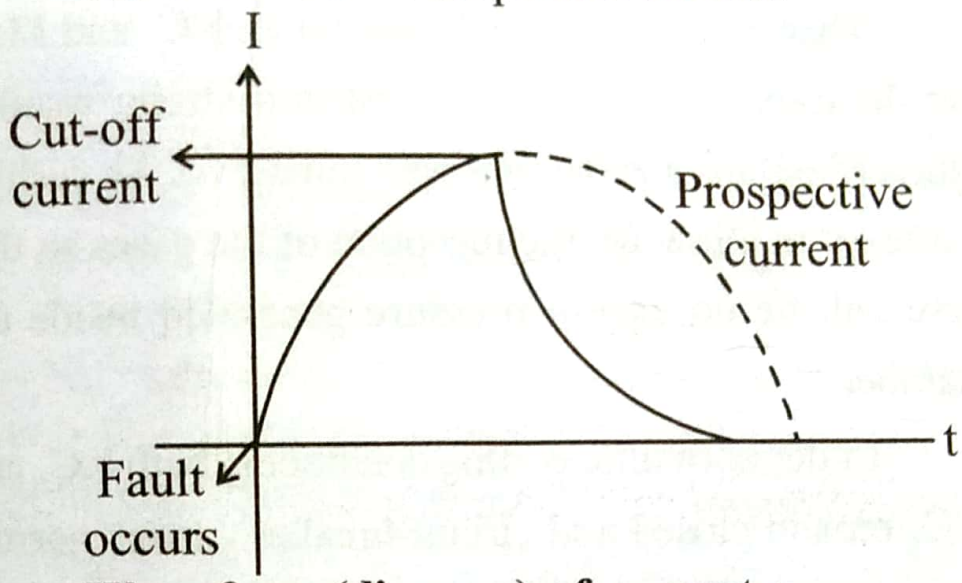
In this characteristics, the arc voltage is several times than the supply voltage depending upon the length & C.S. of the fuse. The Cut-off current is the max current to which the fault current reaches before the fuse melts.

(b) Define prospective current and cut-off current.

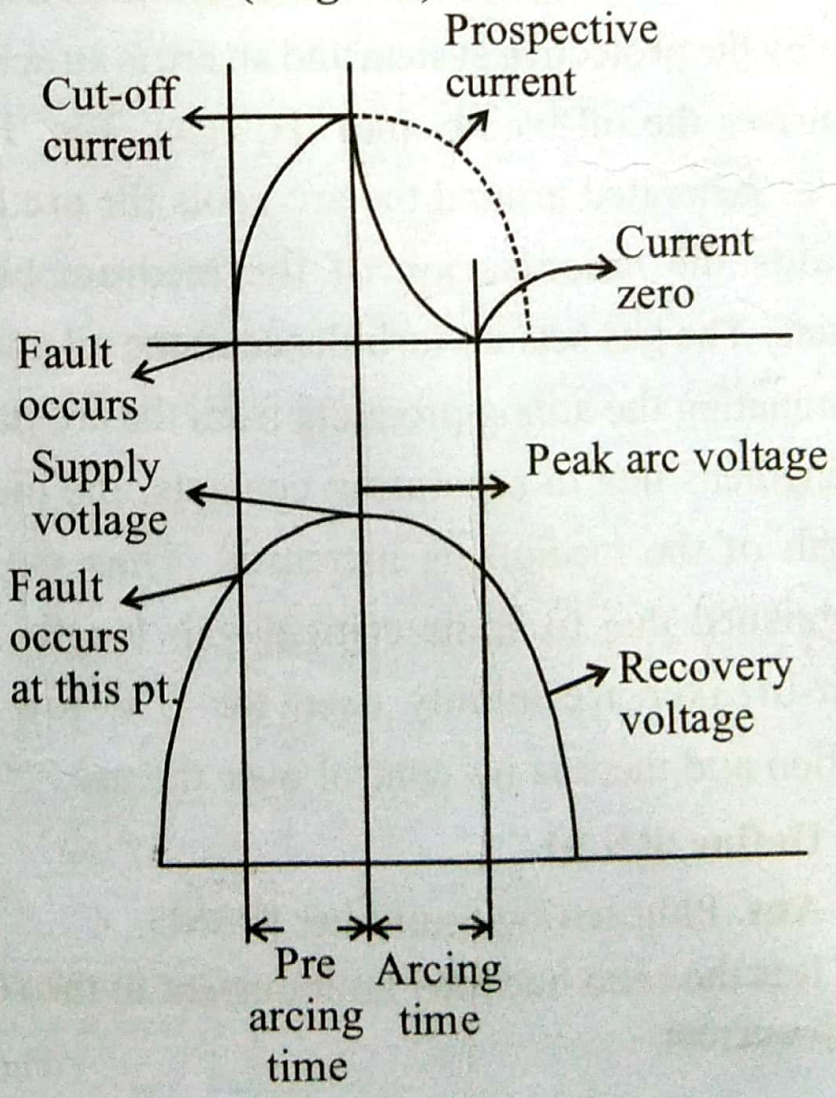
Ans. prospective Current : It is the rms value of the firt loop of the fault current.

Cut-off current : The melting of a fuse element before the current reaches the prospective peak is called the cut off current

Cut of current < Prospective current.



Wave form (diagram) of current :



Cut-off Current : It is the current value at the melting of fuse element before the current reaches the prospective peak. Also it may be defined as the value of current at which the cut-off occurs. In the figure point-A shows the cut-off current. This current depends upon (i) current rating of the fuse (ii) the value of prospective current (iii) asymmetry of s.c. current.

Introduction to Switchgear

Switch gear :→ In an electric power system, switch gear is composed of electrical disconnect switches, fuses or ckt breakers used to control, protect and isolate electrical equipment.

→ Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream.

→ The apparatus used for controlling, regulating and switching on or off the electrical ckt in the electrical power system is known as switch gear.

→ The switches, fuses, ckt breakers, isolators, relays, current and potential transformers, indicating instrument, lightening arresters and control panels are the examples of the switchgear.

→ It is placed both the high and low voltage side of the power transformers.

→ high voltage are use for step-up and step-down application.

(iii) Essential Features of switchgear.

Ans. The essential features of switchgear are :

- **Complete reliability :** With the continued trend of interconnection and the increasing capacity of generating stations, the need for a reliable switchgear has become of paramount importance. This is not surprising because switchgear is added to the power system to improve the reliability.

When fault occurs on any part of the power system, the switchgear must operate to isolate the faulty section from the remainder circuit.

- **Absolutely certain discrimination :** When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section. It should isolate the faulty section from the system without affecting the healthysection. This will ensure continuity of supply.
- **Quick operation :** When fault occurs on any part of the power system, the switchgear must operate quickly so that no damage is done to generators, transformer and other equipment by the short-circuit currents. If fault is not cleared by switchgear quickly, it is likely to spread into healthy parts, thus endangering complete shut down of the system.
- **Provision for manual control :** A switchgear must have provision for manual control. In case the clectrical (or electronics) control fails, the necessary operation can be carried out through manual control.
- **Provision for instruments :** There must be provision for instruments which may be required. These may be in the form of ammeter to voltmeter on the unit itself or the necessary current and voltage transformers for connecting to the main switchboard or a separate instrument panel.

Switch gear equipments

(1) Switches :- A switch is a device which is used to open or close an electrical ckt in a convinient way. It can be used under full load or no-load conditions but it cannot interrupt the fault currents.

→ When the contacts of a switch are opened, an arc is produced in the air between the contacts.

→ The switches may be classified into
(1) air switches / air-break switches.
(2) Oil switches.

(1) air-break switch :- It is an air switch and is designed to open a ckt under load.

(2) Oil switches :- The contacts of such switches are opened under oil, usually transformer oil.

(2) Fuses :- A fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time. It is inserted in series with the ckt to be protected.

→ When a short ckt or overload occures, the current through the fuse element increases beyond its rated capacity. This raises the temp. and the fuse element melts disconnecting the ckt

protected by it.

(3) ckt breakers :→ A ckt breaker is an equipment which can open or close a ckt under all conditions i.e. no load, full load and fault conditions.

→ It is so designed that it can be operated manually or by remote control under normal conditions and automatically under fault conditions.

Low voltage ckt breakers :→
Miniature ckt breaker (MCB),
Moulded case ckt breaker (MCCB),
Residual current ckt breaker and
Ground fault ckt interrupter.

High voltage ckt breakers :→
Vaccum ckt breaker, SF_6 ckt breaker, Oil ckt breaker and Air blast ckt breaker.

(4) protective Relays :→ These are the vital parts of the switchgear equipment.

→ A relay is a device which detects the fault and supplies information to the breaker for ckt interruption.

→ The function of a protective relay is to initiate a signal to ckt breakers for disconnecting the elements of the power system when it develops a fault.

(5) Instrument Transformers :-

→ Instrument T/Fs [current T/Fs and voltage T/F] are used in switchgear installations for the measurement of electrical parameters for protection & metering purposes.

C.T :- An instrument T/F in which the secondary current is substantially proportional to the primary current & differs in phase from it by approximately zero degrees is called a C.T.

V.T :- A V.T is an instrument T/F in which the secondary voltage is substantially proportional to the primary voltage and differs in phase from it by approximately zero degrees.

(6) Surge Arresters :-

→ It is also known as surge supressors.

→ These are used to protect the substation equipment from temporary over-voltages, switching impulses and lightning impulses.

→ commonly 2 types of surge arresters are used :-

(1) Metal-oxide based (ZnO) type
(2) C-R type of surge arrestors/ suppressors.

(7) Auto Reclosures and sectionalisers:-

→ These are used in the distribution networks of medium voltage switchgear up to 33 kV class.

→ These types of equipments are basically used in the continents of America and Australia.

(8) Disconnect switch / Isolator:→

→ Disconnectors (Isolators) are the devices which are generally operated off-load to provide isolation of main plant items for maintainance, or to isolate faulted equipment from other live equipment.

→ Air insulated or open terminal disconnectors are available in several forms for different applications.

Switchgear Accomodation:→

→ It is necessary to house the switchgear in power stations and substations in such a way so as to safeguard during operation & maintenance and to ensure that the effects of faults on any section of the gear are confined to a limited region.

→ Depending upon the voltage to be handled, switchgear may be broadly classified into 2 types.

(1) Outdoor type.

(2) Indoor type.

(1) Outdoor type :- For voltages beyond 66 KV, switchgear equipment is installed outdoor.

→ It is because for such voltages the clearances between conductors and the space required for switches, ckt breakers, transformers and other equipment become so great that it is not economical.

(2) Indoor type :- For voltages below 66 KV, switchgear is generally installed indoor because of economic considerations.

→ The indoor switchgear is generally of metal-clad type.

→ In this type of construction all live parts are completely enclosed in an earthed metal casing.

Bus-Bar Arrangement :→

Definition :→ An electrical busbar is defined as a conductor or a group of conductors used for collecting electric power from the incoming feeders and distributes them to the outgoing feeders.

→ In other words, it is a type of electrical junction in which all the incoming and outgoing electrical current meets. Thus, the electrical bus bar collects the electric power at one location.

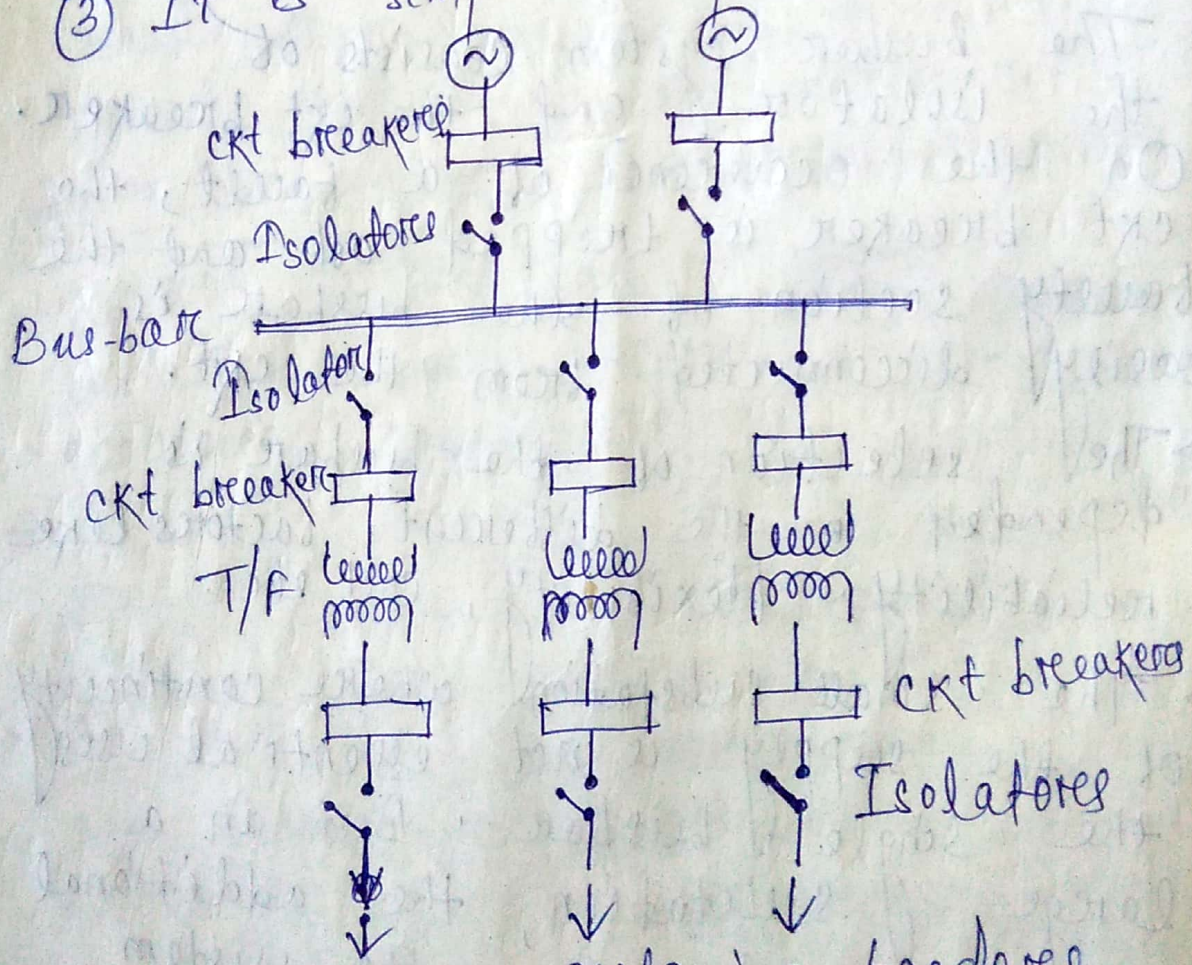
→ The busbar system consists of the isolators and the ckt breakers. On the occurrence of a fault, the ckt breakers is tripped off and the faulty section of the busbar is easily disconnected from the ckt.

→ The selection of the busbar is depended on the different factors like reliability, flexibility, cost etc.

→ The small substation where continuity of the supply is not essential uses the single busbar. But in a large substation, the additional busbar is used in the system so that the interruption does not occurs in their supply.

Single Busbar Arrangement :→

→ The arrangement of such type of system is very simple & easy.
→ The system has only one busbar along with the switch.
→ All the substation equipment like the T/F, generator and the feeder is connected to this busbar only.
→ The advantages of single bus bar arrangements are :→
1. It has low initial cost.
2. It requires less maintenance.
3. It is simple in operation.



[Single bus-bar Arrangement]

Disadvantages :→

→ The bus-bar cannot be cleaned, repaired or tested without de-energising the whole system.

→ If a fault occures on the busbar itself, there is a complete interreception of supply.
↳ disturbance

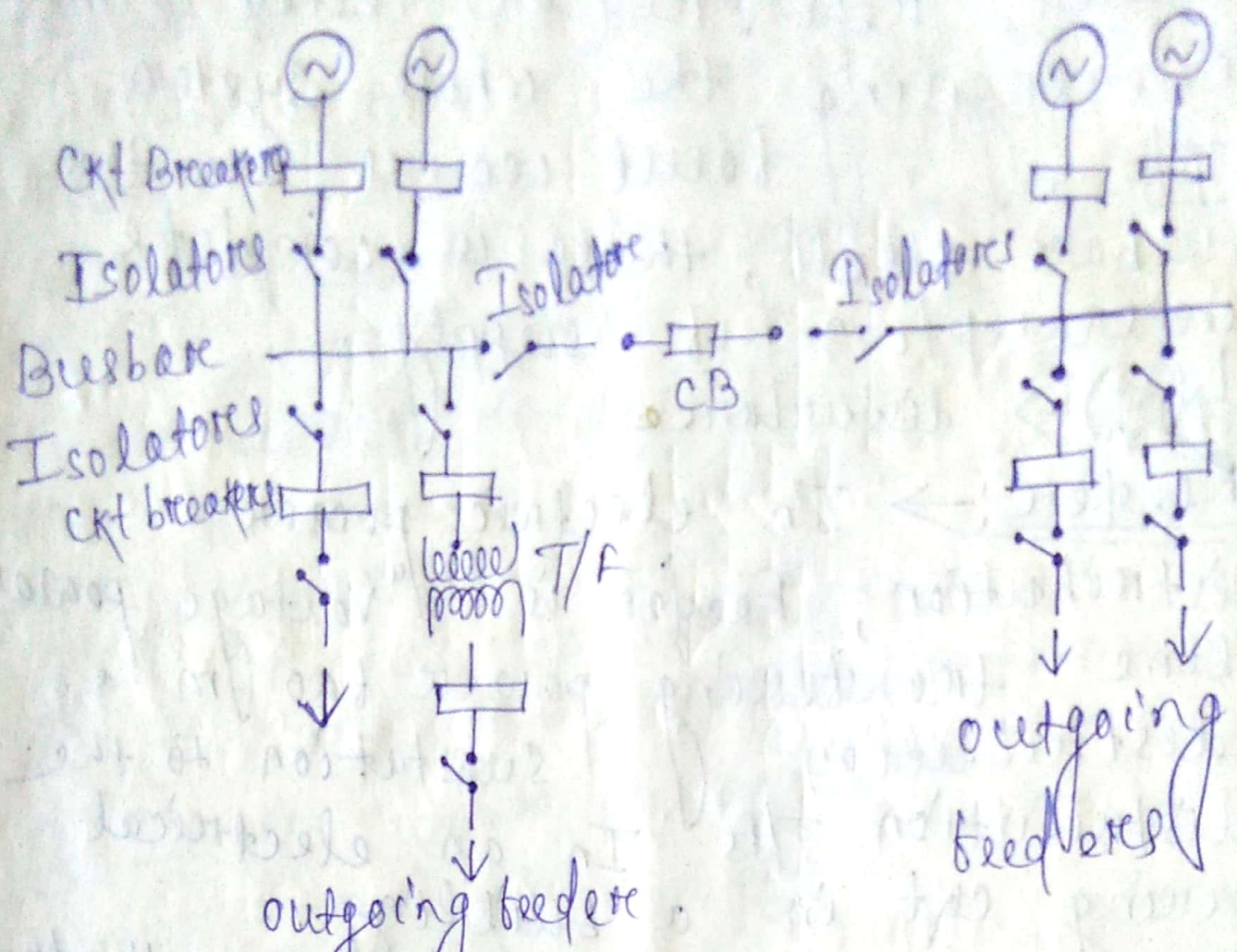
Feeder :→ In electric power distribution, Feeder is "voltage power line transfering power from a distribution substation to the distribution T/Fs In an electrical wiring ckt in a building.

→ Feeder is a wire/line that carries power from a T/F or switchgear to a distribution panel.

Single bus-bar Arrangement with Bus sectionalisation :→

→ In large generating stations where several units are installed, it is a common practice to sectionalise the bus so that fault on any section of the bus-bar will not cause complete shutdown.

→ Here, the busbar is devided into two sections connected by a ckt breaker and isolators.



sectionalised single busbar system

Advantages:→

(1) The faulty section is removed without affecting the continuity of the supply.

(2) The maintainance of the individual section can be done without disturbing the system supply.

(3) The system has a current limiting reactor which decreases the occurrence of the fault.

Disadvantages :⇒

① The system uses the additional ckt breakers and isolators which increases the cost of the system.

Main and Transfer Bus Arrangement :→

→ Such type of arrangement uses two types of busbars namely main busbars and the auxiliary busbar.

→ The busbars arrangement uses bus coupler which connects the isolating switches and ckt breakers to the busbars.

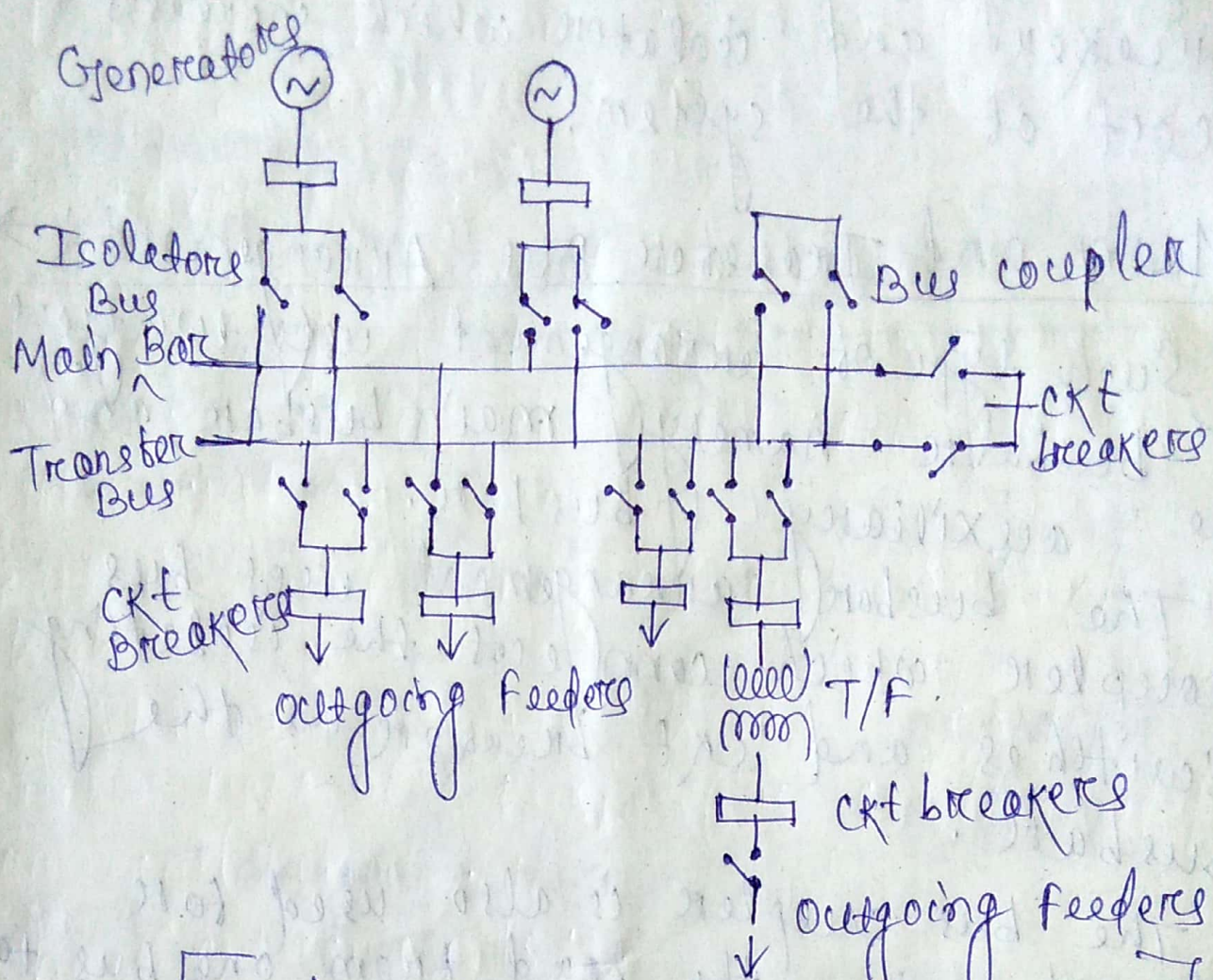
→ The bus coupler is also used for transferring the load from one bus to another in case of overloading.

→ The following are the steps of transferring the load from one bus to another.

(1) The potential of both the busbars kept same by closing the bus coupler.

(2) The busbars on which the load is transferred is kept close.

(3) open the main busbar.



Main and Transfer Bus Arrangement

Advantages :→

(1) The continuity of the supply remains same even in the fault. When the fault occures on any of the buses the entire load is shifted to the another bus.

(2) The repair and maintenance can easily be done on the busbar without disturbing their continuity.

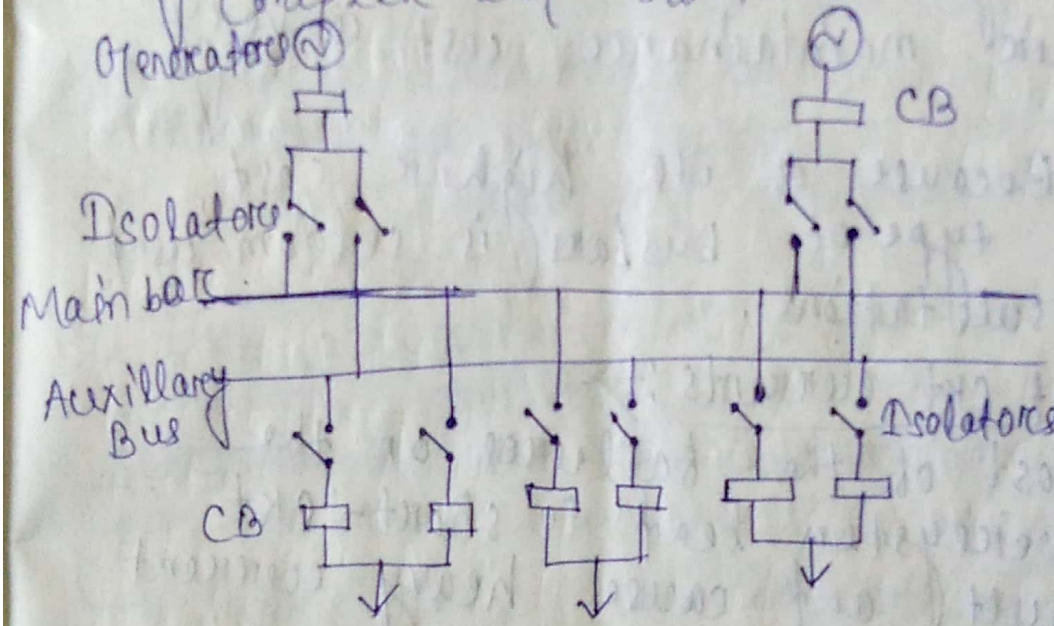
(3) The load can easily be shifted on any of the buses.

Disadvantages :-

→ The fault on any of the bus would cause the complete shutdown on that whole substation.

Double Bus Double Breaker Arrangement

→ This type of arrangement requires two bus bar and two ckt breakers. It does not require any additional equipment like bus-coupler and switch.



Double Bus Double Breaker Arrangement

Advantages :-

→ This type of arrangement provides the maximum reliability and flexibility in the supply. Because the fault and maintenance would not disturb their continuity.

→ The continuity of the supply remains same because the load is transferreable from one bus to another on the occurrence of the fault.

Disadvantages :→

→ In such type of arrangement two buses and two ckt breakers are used which increases the cost of the system.

→ There maintainance cost is very high.

Because of its higher cost, such type of busbars is seldom used in substations.

short ckt currents :→

→ Most of the failures on the powersystem lead to short-ckt fault and cause heavy currrent to flow in the system. The calculations of these short-ckt currents are important for the following reasons :→

(1) A short ckt on the power system is cleared by a ckt breaker or a fuse. It is necessary therefore, to know the maximum possible values of short-ckt current so that switchgear of

suitable rating may be installed to interrupt them.

(2) The magnitude of short-ckt current ↳([illegible]) determines the setting and sometimes the types and location of the protective system.

(3) The magnitude of the short-ckt current determines the size of the protective reactors which must be inserted in the system so that the ckt breaker is able to withstand the fault current.

(4) The calculation of short-ckt currents enables us to make proper selection of the associated apparatus [e.g. busbars, current T/Fs etc.] so that they can withstand the forces that arise due to the occurrance of short ckts.

Faults in a power system:→

→ A fault occurs when two or more conductors that normally operate with a potential difference come in contact with each other. These faults may be caused by sudden failure of a piece of equipment, accidental damage or short-ckt to

overhead lines are by insulation failure resulting from lightning surges.

→ Irrespective of the causes, the faults in a 3-ϕ system can be classified into two main categories. i.e.

(i) symmetrical fault.
(ii) unsymmetrical fault.

① symmetrical fault :→ The fault which gives rise to symmetrical fault currents [i.e. equal fault currents with 120° displacement] is called a symmetrical fault.

→ The most common example of symmetrical fault is when all the 3 conductors of a 3-ϕ line are brought together simultaneously into a short-ckt condition.

② unsymmetrical faults :→ Those faults which gives rise to unsymmetrical currents [i.e. unequal line currents with unequal displacement] are called unsymmetrical faults.

——X——