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CHAPTER-1

INTRODUCTION TO SWITCHGEAR

→ In our model civilisation there is a great demand for electrical energy.

→ Most of these energy is needed for lighting, heating, domestic appliances, Industrial electrical mechinary etc.

→ The importance of electric supply has reached such a stage that it is desirable to protect the total power system from harm during fault condition. And ensure maximum continuity of supply.

SWITCHGEAR

→ A switchgear essentially consist of switching and protecting devices such as switches, Fuses, circuit breakers, relay etc.

→ The apparatus ~~required~~ used for switching, controlling and protecting the electrical ckt and equipment is known as switchgear.

→ During normal operation switchgear permits to switch ON or OFF generation, transmission lines, Distribution lines and other electrical equipment

→ on the other hand when a failure or fault (short ckt) occures on any part of power system a heavy current flowing through the equipment. and interruption of service to the customer.

→ However switchgear detect the faults and disconnect the unhealthy section from the system hence switchgear protect the system from damage and ensure continuity of supply.

NOTE:- A switchgear can't be used on high voltage system for two reason.

(i) When a fuse blows out it take some time to replace it and consiquiently there is interruption of service.

(ii) The fuse can't successfully interrupt large fault current that results from faults on high voltage system.

→ In order to interrupt such heavy fault current automatic ckt breakers are used.

ESSENTIAL FEATURES OF SWITCHGEAR

The essential features of switchgear are as follows:-

i. COMPLETE RELIABILITY

With the contined to trend of interconnection and the increasing capacity of generating stations. The need for a reliable switchgear is most important so that switchgear is added to the power system to improve the reliability.

(ii) QUICK OPERATION

When fault occures on any part of power system, the switch gear must operate quick so that no damage is done to any equipment by short ckt current.

(iii) PROVISION FOR MANUAL CONTROL

A switchgear must have provision for manual control incase the electrical control fails, the necessary operation can be carried out through manual control.

(iv) ABSOLUTELY CERTAIN DISCRIMINATION

When fault occure on any section of power system the switchgear must be able to discriminate between the faulty section and the healthy section. It should be isolate the faulty section from the system without affecting the healthy section.

(v) PROVISION FOR INSTRUMENTS

→ There must be provision for instruments which may be required these may be in the form of Ammeter and voltmeter on the unit it self or the necessary current and voltage T/F for connecting to main switch board.

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SWITCHGEAR EQUIPMENT

switchgear covers a wide range of equipment concerned with switching and interrupting current under both normal and abnormal condition.

→ It includes switches, fuse, circuit breaker, relays and other equipments.

(1) SWITCHES

→ A switch is a device which is used to open or close an electrical circuit in a convenient way. it can be used under full load and no load condition but it can't interrupt the fault current.

→ when the contact of switch are open and arc is produce in the air between the contacts

→ The switches may be clasified into two types

(1) Air switch
(2) oil switch

→ Air switch are again devided in to two types

(a) Air break switch
(b) Isolators/Disconnecting switch

(a) AIR BREAK SWITCH

→ It is an air switch and it designed to open a ckt under load condition

→ In order to quench (minimise) the arc that occurs on opening such a switch special arcing horns are providing.

→ Arcing horns of pices of metal between which arc is fault during opening operation. As the switch opens, these horns are spreed farther and farther apart. Hence the arc lengthed, cooled and interrupted.

→ Air break switch are generally used outdoor for ckts of midium capacity such as line suppling and industrial load from main transmission line.

(b) ISOLATORS / DISCONNECTING SWITCH

→ It is essentially knife switch and is designed to open a circuit under no load.

→ It's main purpose is to isolate one portion of the ckt from other and is not intended to be opened while current will flowing in the line.

generally
→ such switches are used to both side of circuit breaker in order that repair and replacement of circuit breaker can ~~not~~ be made without any danger.

→ They should never be open until the CB has been opened and should always be closed before the C.B is closed.

2. OIL SWITCHES

→ As the name implies, the contacts of such switches are opened under oil usually T/F oil.

→ The effect of oil is to cool and quinch the arc that tends to form when the ckt is open.

→ These switches are used for ckts of high voltages and large current carrying capacity.

2. FUSES

→ A fuse is a short piece of wire or thin strip which melts when excessive current flow through it for sufficient time.

→ It is inserted in series with the ckt to be protected.

→ under normal operating conditions, the fuse element it at a temp. below its melting point. therefore it carries the normal load current without overheating.

→ However when a short ckt or over load occure the current through the fuse element increase ~~bet~~ beyond its rated capacity.

→ This raises the temp. and the fuse element melts, disconnecting the ckt protected by it. In this way fuse protect the equipment.

→ Hence it is noted that fuse performs both directions and interruption function.

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3. CIRCUIT BREAKER

→ A C.B is an equipment which can open or close a ckt under all condition.

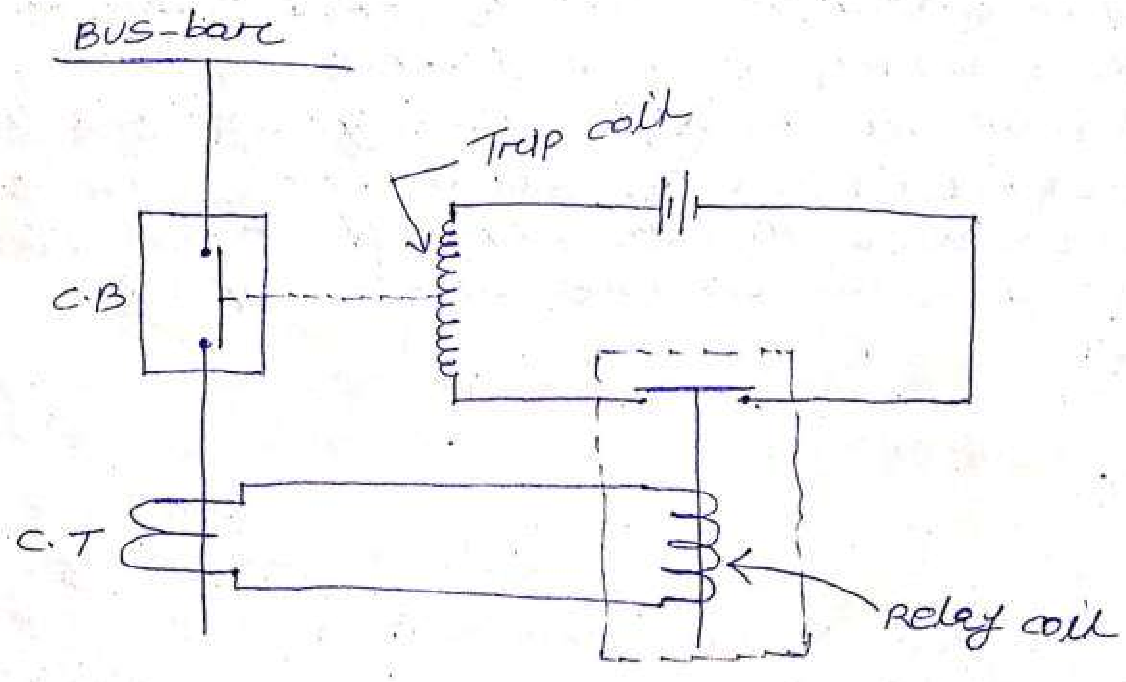
→ It is so design that it can operate manually (or by remot control) under normal conditions and automaticaly under fault condition.

→ For later operation a relay ckt is used with CB.

→ under normal operating condition the contect remain closed and the CB carries the full load current continiously. In this condition the emf in the secondary winding of C.T is insufficient to operate the trip coil of the breaker but the ~~condition~~ contacts can be opened manually.

→ But when a fault occurces the resulting overcurrent in the C.T. primary winding increases the secondary emf. hence this energizes the trip coil of the breaker and moving contects are pulled down, thus opening the contects and hence the ckt.

→ It is noted that relay performs the function of detecting a fault where as ckt breaker does the actual ckt interruption.



4. RELAY

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

→ It can be devided into three parts.

(i) The primary winding of a C.T which is connected in series with the ckt to be protected. The primary winding often consist of main conductor it self.

(ii) The second ckt is secondary winding of C.T. connected to the relay operating coil.

(iii) The third ckt is the tripping ckt which consist of a source of supply, trip coil of CB and the relay stationary contact.

→ under normal ~~condition~~ load condition the emf of the secondary winding of CT is small and the current flowing in the relay operating coil is insufficient to close the relay contacts. This keeps the trip coil of the CB on energised. Hence the contacts of CB remain close and it carries the normal load current.

→ But ~~hence~~ when a fault occures a large current flows through the primary of C.T this increases the secondary emf and hence the current through the relay. operating current. this energised the relay coil and relay contacts are closed then the trip coil of the CB is energized to open the cotects of CB.

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BUS-BAR ARRANGEMENT

→ when a no. of generator or feeders operating at a same voltage have to be directly connected electrically, bus-bar are used common electrical component.

→ Bus-bar are copper rods or thin walled tubes at constant voltage

→ some important type of bus-bar are as follows

~~(1) single busbar system~~
(1) single bus-bar system
(2) single bus-bar system with sectionalisation
(3) duplicate bus-bar system.

(1) SINGLE BUS-BAR SYSTEM

→ This system has simplest design and is used for power station. It is also used in small outdoor station having ~~view~~ few outgoing or incoming feeders and lines.

→ The ~~above~~ below fig. show the single bus-bar system for a typical power station. The generators, outgoing line and T/F are connected to the bus bar.

→ Each generator and feeders is controlled by C.B

→ The Isolators permits to Isolate generators, feeders and C.B from the bus-bar for ~~repair~~ maintenance.

ADVANTAGE

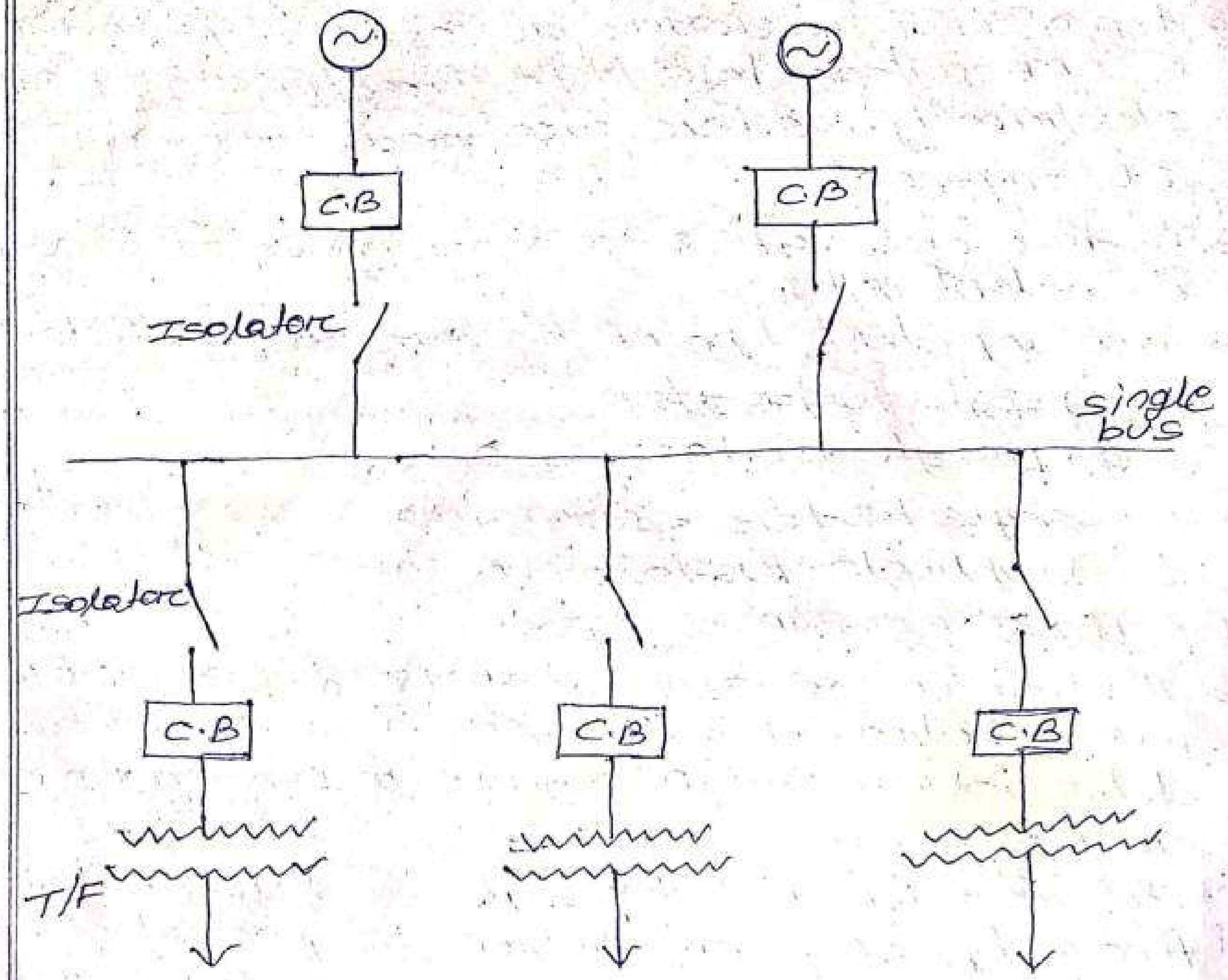
→ The main advantage of this system is low initial cost, less maintenance and simple operation.

DISADVANTAGE

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

→ If a fault occure on the bus-bar it self there is complete interruption of supply.

→ Any fault on the system is fed by all the generating capacity, resulting in very large fault.



(2) SINGLE BUS-BAR SYSTEM WITH SECTIONALISATION

→ In large generating station where several unit are installed, it is a common practice to sectionlize the bus so that fault on any section of the bus-bar will not cause complete shut down.

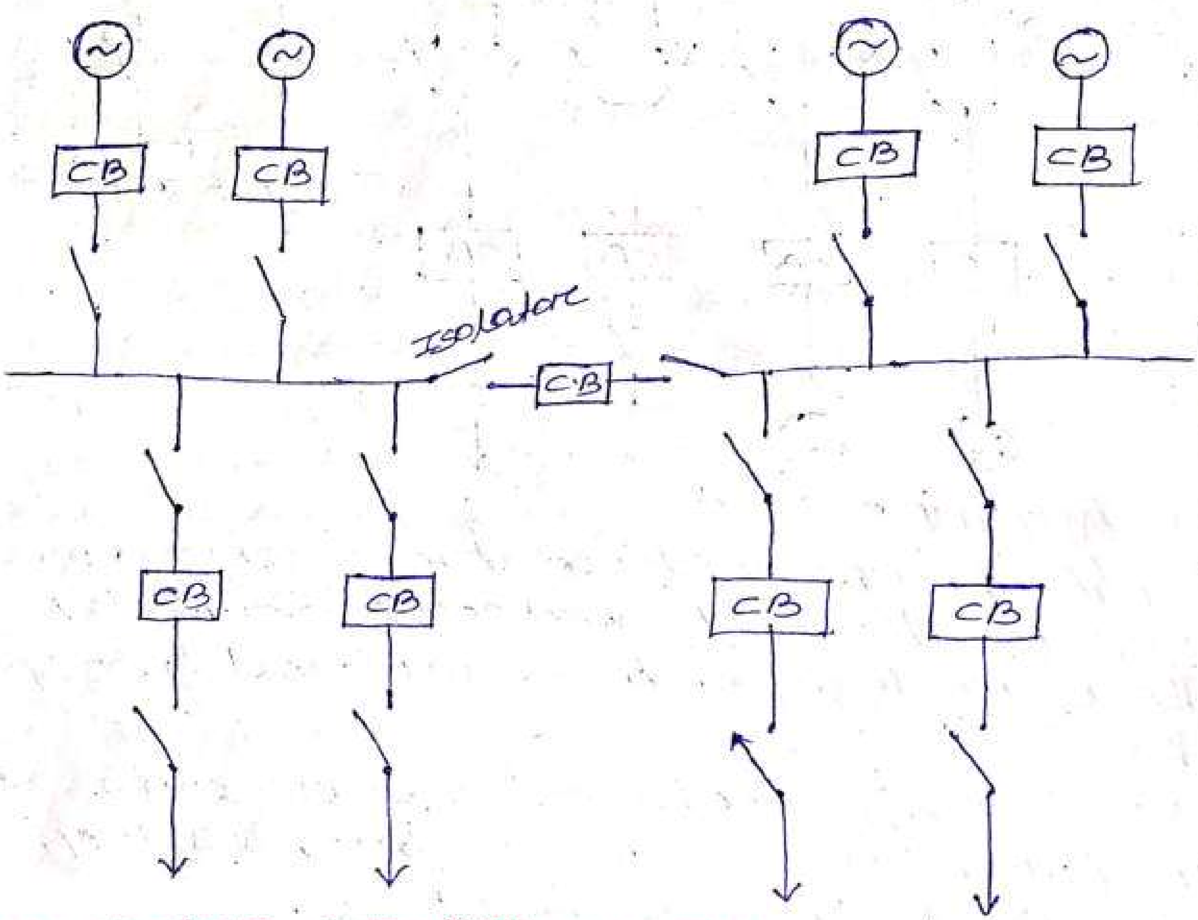
→ The below fig. shows the bus-bar devided into two section connected by a CB and Isolators.

ADVANTAGES

→ If a fault occure of any section of bus-bar that section can be Isolated without affecting the supply to other section.

→ If a fault occure on any ~~section~~ feeders the fault current is much lower than with an sectionalised bus-bar. This permits the use of CB of lower capacity in the feeder.

→ Repairs and maintance of any section of the bus-bare can not be carried out by de-energising that section only, eliminating the possibility of complete shut down.



(2) DUPLICATE BUS-BAR SYSTEM

→ In large stations, it is important that breakdown and maintance should interference as possible with continuity of supply.

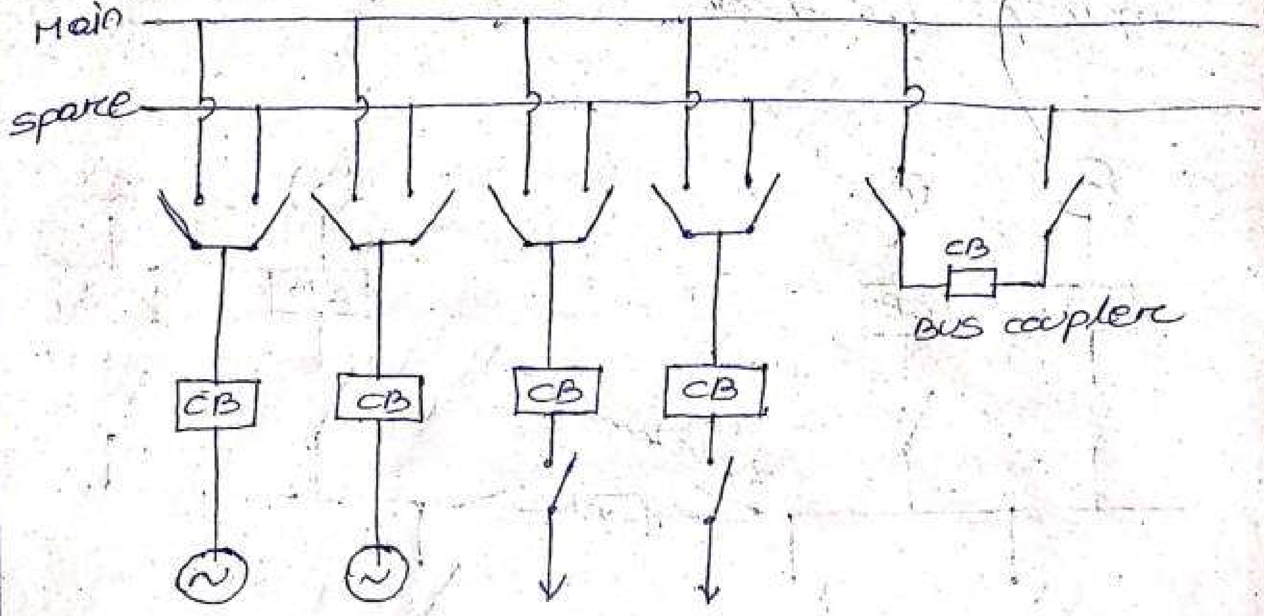
→ In order to achive this objective, duplicate bus-bare system is used in important stations. suche system consist of two bus-bares i.e main bus-bare and a spare bus-bare.

→ Each generatore and feeder may be connected to either bus-bare with the help of bus coupler. which consist of a circuit breaker and isolators.

→ The below fig show the duplicate bus-bare system here service is interrupted during switchovere from one bus to another bus.

→ However, if it were desired to switch a circuit from one to anothere without interrupt of service there would have to be two ckt breake per ckt.

such an arrangement will be too expensive.



ADVANTAGES

→ If repair and maintance is to be carried on the main Bus, the supply need not be interrupted as the entire load can be transferred to the spare bus.

→ The testing of feeder ckt breaker can be done by putting them on spare bus-bar, thus keeping the main bus-bar undisturbed.

→ If a fault occure on the bus-bar the continuity of supply to the ckt can be maintained by transferring it to the other bus-bar.

Dt- 18.12.20

SWITCH GEAR ACCOMODATION

→ The main components of a switch gear are C.BS, switches, bus-bars, instrument and transformers.

→ It is necessary to connect the to connect the switchgear in power stations and sub-station in such a way so as to safeguard personnel during operation and maintenance and to ensure that the effects of fault on any section of the gear are confined to a limited region.

→ Depending upon the voltage to be handled, switchgeare may be broadly clasified in to two types.

(i) outdoore type

(ii) Indoore type.

(i.) OUTDOOR TYPE

→ Fore voltage beyond 66kv, switchgeare equipment is installed outdoore. It is because fore such voltage, the clearances between conductores and the space required fore switches, circuit breaker, transformeres and others equipment become so great that it is not economical to install all such equipment indoore.

→ The C.B, isolatores, transformeres and bus-bars occupy considereable space on account of large electrical clearance associated with high voltage.

(ii) INDOOR TYPE

→ Fore voltage below 66kv, switchgeare is generally installed indoore because of economic consideration.

→ The indoore switchgeare is generally of metal clad type. In this type of construction all live parts are completely enclosed in an earthed metal casing.

→ The primary object of this practice is the definite localization and restriction of any fault to its place of origin.

SHORT CIRCUIT

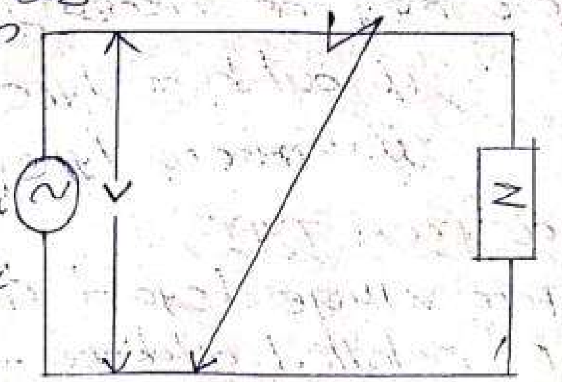
Whenever a fault occures on a network such that a large current flows in one or more phases a short ckt is said to have occurred.

→ When a short ckt occures, a heavy current called short ckt current flows through the circuit. It can be explain by refferring below fig.

→ Here a single phase generatore of voltage 'V' and internal impedance Z_i is supplying to a load Z.

→ Under normal conditions the current is the ckt is limited by load impedance Z.

→ However if the load terminals get shorted due to any reason the circuit impedance is ~~redeceued~~ reduced to a very ~~small~~ low value, z_i being z_i in this case. As z_i is very small nearly negligible, therefore a large current flow through the circuit. This is called short ckt current.



DIFFERENCE BETWEEN SHORT CIRCUIT AND OVERLOAD CONDITION

→ When a short ckt occurs the voltage at fault point is reduced to zero and current of abnormally high magnitude flow through the network to the point of fault.

→ On the other hand, an overload means that load greater than the designed values have been imposed on the system.

→ Under such conditions, the voltage at the overload point may be low, but not zero.

→ The current in the overload equipment are high but are substantially lower than that in the case of a short circuit.

CAUSES OF SHORT CIRCUIT

Dt - 19.02.19

→ A short ckt in the power system is the result of some kind of abnormal conditions in the system. It may be caused due to internal and external effect.

i. INTERNAL EFFECTS

These are caused by breakdown of equipment or transmission lines, from deteroration of insulation in a generator, transformer etc. such problem may be due to ~~ageing the~~ ageing of insulations, inadequate design or improper installation.

iii) EXTERNAL EFFCTS

→ There effect cause short ckt include insulation failure due to lightning surges, over loading of equipment causing excessive heating, mechanical damage by public etc.

EFFECTS OF SHORT-CIRCUIT

→ When a short circuit occurs the current in the system increases to an abnormally high value while the system voltage decreases to a low value i.e nearly equal to zero.

i. The heavy current due to short ckt causes excessive heating which may be result in fire or explosion sometimes short-circuit takes the form of an arc and causes damage to the system.

(ii) The low voltage created by the fault as a very harmful effect on the service given by the power system. If the voltage remains low for a few second the consumers motors may be shut down and generators on the power system may become unstable.

SHORT CIRCUIT CURRENT (SCC)

Most of the failure on the power system lead to short ckt fault and cause heavy current flow through the system.

i. A short ckt on the power system is cleared by C.B or a fuse. It is necessary therefore to know the maximum value of short ckt current so that switchgear of suitable rating may be installed to interrupt them.

ii The magnitude of short ckt current determines the setting and sometimes the types and location of protective system.

iii The magnitude of SCC determines the size of protective reactors which must be inserted in the system so that the ~~the~~ C.B is able to withstand of fault current.

iv. The calculation of SCC enables us to make proper selection of associated apparatus (Bus-Bare, C.T, etc)

FAULT IN POWER SYSTEM

→ A fault occurs in 3-φ system can be classified in to two types.

(1) symmetrical fault
(2) unsymmetrical fault

(1) SYMMETRICAL FAULT

The fault which gives rise to symmetrical fault current (i.e equal fault currents with 120° displacement) is called as symmetrical fault.

→ The most common example of symmetrical fault is when all the three conductors of a 3φ line are brought together simultaneously in to a short ckt condition (L-L-L).

(2) UNSYMMETRICAL FAULT

Those fault which gives rise to unsymmetrical current (i.e unequal line current with unequal displacement) are called as an symmetrical fault.

→ Example of unsymmetrical fault ~~the~~ are single line to ground fault (L-G), line to line fault (L-L), double line to ~~ground~~ ground fault (L-L-G) the great majority of fault of the power system are of unsymmetrically nature and the most common type of short ckt fault is L.G. fault.

CHAPTER-3

20.12.19

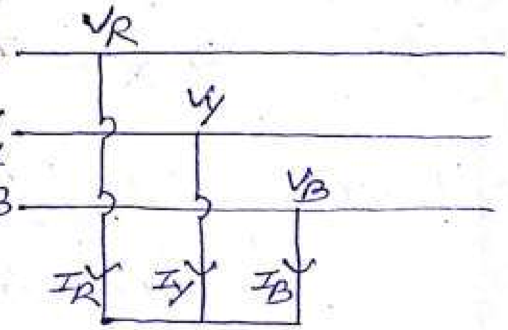
SYMMETRICAL FAULT CALCULATION

SYMMETRICAL FAULTS ON 3-PHASE SYSTEM

The fault on the power system which gives rise to symmetrical fault currents (i.e equal fault currents in the lines with 120° displacement) is called a symmetrical fault.

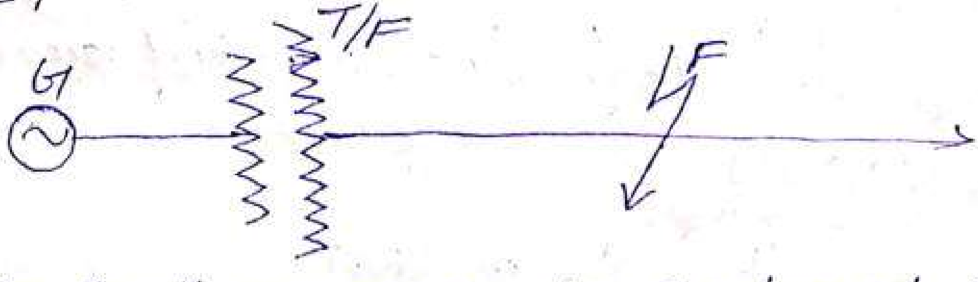
→ The symmetrical fault occures when all the three conductor of a 3-φ line are brought together simultaneously into a short ckt condition.

→ In this fig fault current I_R, I_Y and I_B will be equal in magnitude with 120° displacement among them. Because of balanced nature of fault only one phase need to be consider in calculation since condition in the other two phase will also be similar.



LIMITATIONS OF FAULT CURRENT

→ When a short ckt ~~current~~ occures at any point in a system, short ckt current is limited by the impedance of the system up to ~~also be~~ the point of fault.



→ If a fault occure on the feeder at point 'F', then the short ckt current from the generating sation will have a value limitted by the impedance of generator and transformer and the ~~~~ impedance of line between the generator and the point of fault

→ The imedance of various equipment of ckt in the line of the system is very important for the determination of s.c.c

PERCENTAGE REACTANCE

The reactance of generator, T/F, reactors etc is usually expressed in % reactance to permit rapid short ckt calculation.

→ It is the % of a total phase voltage dropped in the ckt when full load current is ~~flowing~~ following i.e.

$$\%X = \frac{IX}{V} \times 100 \quad \text{——— (1)}$$

→ where I = Full load current
V = phase voltage
X = Reactance in OHM per phase

→ Alternatively % reactance can also be expressed interms of kVA and kV

$$\%X = \frac{(kVA)X}{10(kV)^2} \quad \text{——— (2)}$$

$$\%X = \frac{IX}{V} \times 100 \quad \text{——— (1)}$$

$$X = \frac{\%X\,V}{I \times 100}$$

→ Multiplying 'V' in both neumerator and denomenator

$$X = \frac{\%X \cdot V \cdot V}{V \cdot I \times 100}$$

$$X = \frac{\%X \frac{V}{1000} \cdot \frac{V}{1000} \cdot 1000}{\frac{V}{1000} \cdot I \cdot 100}$$

$$X = \frac{\%X\,kV \cdot kV \cdot 1000}{kVA \cdot I}$$

$$X = \frac{\%X (kV)^2 \times 10}{kVA}$$

$$\%X = \frac{(kVA)X}{10 \times (kV)^2} \quad \text{------- (2)}$$

→ If X is the only reactance elements in the ckt then short ckt current is given by

$$I_{sc} = \frac{V}{X}$$

$$X = \frac{IX}{V} \times 100$$

$$X = \frac{\%X V}{I \times 100}$$

$$I_{sc} = \frac{V}{\frac{\%X V}{I \times 100}}$$

$$I_{sc} = \frac{I \times 100}{\%X}$$

$$\boxed{I_{sc} = I\left(\frac{100}{\%X}\right)} \quad \text{------- (3)}$$

→ i.e SCC is obtain by multiplying the full load current with $\frac{100}{\%X}$

PROBLEM-1

If the % reactance of the elements is 20% and full load current is 50A calculate shortckt current.

ANS

$$I_{sc} = I\left(\frac{100}{\%X}\right)$$

$$= 50\left(\frac{100}{20}\right) = 250A.$$

% REACTANCE AND BASE KVA

$$\%X = \frac{(kVA)X}{10(kV)^2} \quad \text{------- (2)}$$

→ It is clear from eq(2) that %X of an equipment depends upon its kVA rating.

→ Generally the various equipment used in power system have different kVA ratings. Therefore it is necessary to find the % reactance of all the elements on a common kVA rating. This common kVA rating is known as Base kVA.

→ The value of this kVA rating may be
(a) equal to that of largest plant
(b) Equal to the total plant capacity
(c) Any arbitary value.

$$\% \text{ Reactance at Base kVA} = \frac{\text{Base kVA}}{\text{Rated kVA}} \times \% \text{ Reactance at rated kVA}$$

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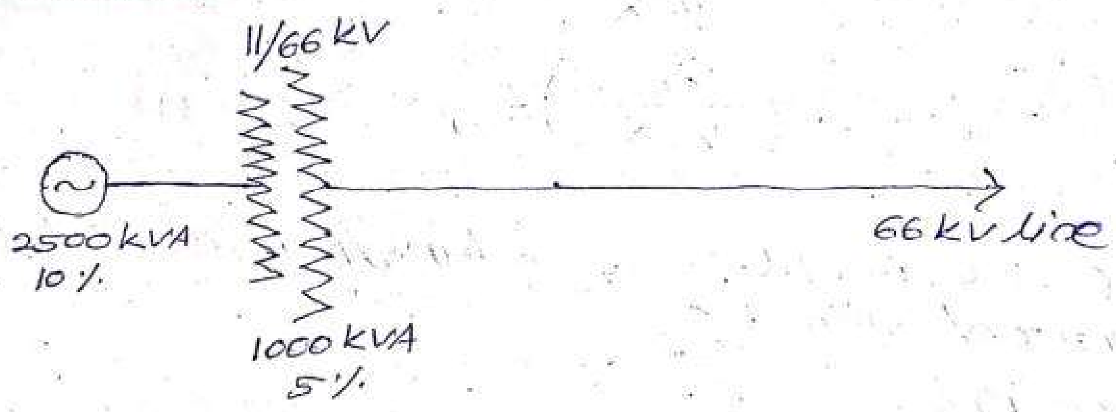
PROBLEM-2



→ consider a 3φ transmission line operating at 66kV and connected through 1000kVA T/F with 5% reactance to a generating station Bus-Bar. The generator is of 2500kVA with 10% reactance. The single line diagram of this system is shown in the above fig.

ANS

suppose a short ckt fault between 3φ occures the high voltage fault of T/F. It will be shown that whatever value of Base kVA we may chose, the value of SCC will same

CASE-1 (Equal to Large plant)

→ suppose we choose 2500kVA as the common Base kVA then the reactance of the various elements will be as follows.

→ Reactance of Generator at 2500 kVA Base

% Reactance at Base kVA

$$= \frac{\text{Base kVA}}{\text{Rated kVA}} \times \%\text{ reactance at rated kVA}$$

$$= \frac{2500}{2500} \times 10\%$$

$$\%X_G = 10\%$$

% reactance of T/F at 2500 kVA Base

% Reactance at Base kVA

$$= \frac{2500}{1000} \times 5\%$$

$$\%X_{T/F} = 12.5\%$$

$$X_{total} = \%X_G + \%X_{T/F}$$

$$= 10\% + 12.5\%$$

$$= 22.5\%$$

→ ~~The fault~~ The full load current corresponding 2500 kVA Base at 66 kV is given

$$P = \sqrt{3}\, V I \cos\phi$$

$$I = \frac{P}{\sqrt{3}\, V \cos\phi} = \frac{2500 \times 10^3}{\sqrt{3} \times 66 \times 10^3 \times 1}$$

$$= 21.86 A$$

$$I_{sc} = I\left(\frac{100}{\%X}\right) = 21.86\left(\frac{100}{22.5}\right)$$

$$= 97.15 = 97.2 A$$

CASE-2 (Equal to the plant capacity)

→ Reactance of Generator at 3500 kVA Base

% Reactance at Base kVA

$$= \frac{3500}{2500} \times 10\%$$

$$\%X_G = 14\%$$

% Reactance of T/F at 3500kVA Base

% Reactance at Base kVA

$$= \frac{3500}{1000} \times 5\%$$

$$= 17.5\%$$

$X_{Total} = \%X_G + \%X_{T/F}$

$= 14 + 17.5$

$= 31.5\%$

The full load current corresponding 3500kVA Base at 66kV is given

$P = \sqrt{3}VI\cos\phi$

$$I = \frac{P}{\sqrt{3}V\cos\phi} = \frac{3500 \times 10^3}{\sqrt{3} \times 66 \times 10^3 \times 1}$$

$$= 30.61$$

$$I_{SC} = I\left(\frac{100}{\%X}\right) = 30.61\left(\frac{100}{31.5\%}\right)$$

$$= 97.17 = 97.2A$$

CASE-3

Reactance of generator at 1500 kVA Base

% Reactance at Base kVA

$$= \frac{1500}{2500} \times 10\%$$

$\%X_G = 6\%$

Reactance of T/F at 3500kVA Base

% Reactance at Base kVA

$$\%X_{T/F} = \frac{1500}{1000} \times 5\% = 7\%$$

$X_{Total} = 6\% + 7.5\%$

$= 13.5\%$

The full load current corresponding 1500kVA Base at 66kV is given

$$P = \sqrt{3}\, V I \cos\phi$$

$$I = \frac{P}{\sqrt{3}\, V \cos\phi} = \frac{1500\times10^3}{\sqrt{3}\times66\times10^3\times1}$$

$$= 13.12$$

$$I_{sc} = I\left(\frac{100}{\%X}\right) = 13.12\left(\frac{100}{13.5\%}\right)$$

$$= 97.18 = 97.2\,A$$

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SHORT CIRCUIT KVA

→ Although the potential at the point of fault is zero, it is a normal practice to express the short-circuit current in terms of short circuit kVA based on the normal system voltage at the point of fault.

→ The product of normal system voltage and short-circuit current at the point of fault expressed in kVA is known as short-ckt kVA.

Let,

V = Normal phase voltage in volt

I = Full load current in amperes at base kVA

$\%X$ = percentage reactance of the system on base kVA upto the fault point.

→ short ckt current $I_{sc} = I\left(\frac{100}{\%X}\right)$

→ short ckt kVA for 3-φ ckt

$$= \frac{3VI_{sc}}{1000}$$

$$= \frac{3V}{1000}\times I\times\frac{100}{\%X}$$

$$= \frac{3VI}{1000}\times\frac{100}{\%X}$$

$$= \text{Base kVA}\times\frac{100}{\%X}$$

→ i.e short ckt KVA is obtained by ~~multiplyi~~ multiplying the base KVA by 100 % X.

REACTOR CONTROL OF SHORT CKT CURRENT

→ In order to limit the s.c.c to a value which the C.B can handle additional reactances known as reactors ~~and~~ are connected in series with the system at suitable point.

→ The Reactor is a coil of no. of turns designed to have a larger inductance as compare to its resistance.

→ The forces on the turns of these reactors under short ckt condition are considerable and therefore the windings must be solidly braced.

ADVANTAGES

→ Reactors limit the flow of short ckt and this protect the equipment from overheating as well as from failure due to destructive mechanical forces.

→ Troubles are localized or isolated at the point where they originate without communicating there ~~distributi~~ disturbing effects to other parts of the power system this increases the chances of continuity of supply.

→ They permit the installation of circuit breaker of lower rating.

LOCATION OF REACTORS

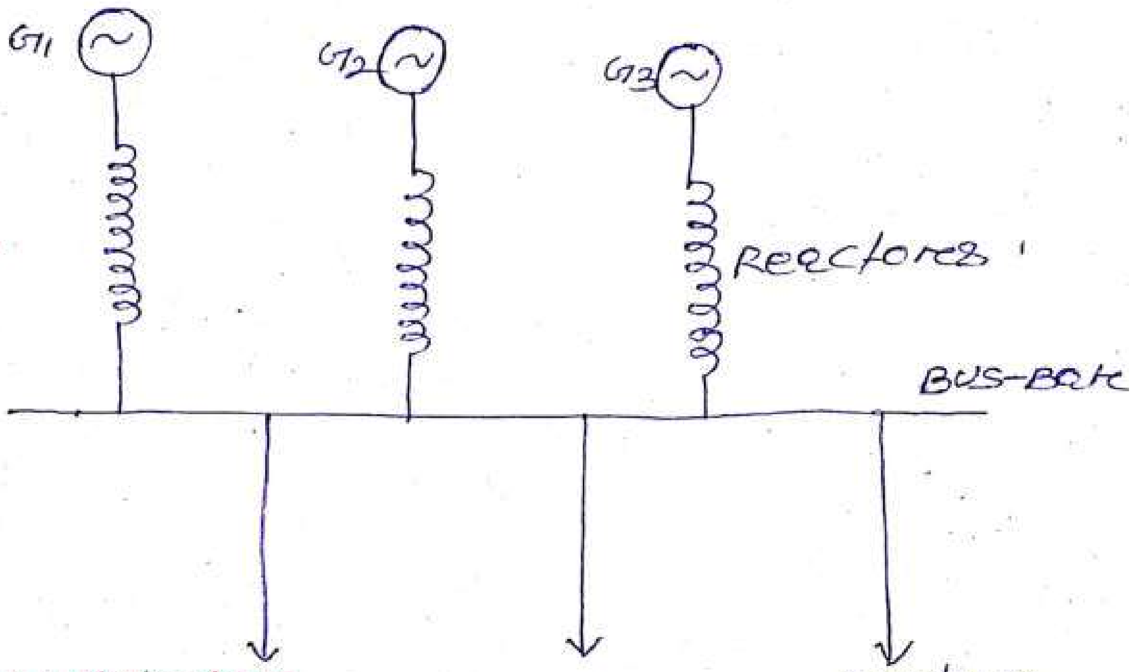
→ Short circuit current limiting the reactor may be connected

(1) In series with each generator
(2) In series with each feeder
(3) In BUS-bar.

1. GENERATOR REACTORS

When the reactors are connected in series with each generatore there known as Generatore reactores.

→ In this case the reactor may be considered as a part of lickage reactance of the generatore hence its effect it two pro-ject the generatore in the case of any short ckt behond the reactores.



DISADVANTAGE

→ There is a constant voltage drop and powere loss in the reactores even during normal opera-tion.

→ If a bus-bare or feedere fault occures close to the Bus-bare the voltage at the Bus-Bare will be reduced to a low value there by causing generatore to ~~fault~~ fall out of step,

→ If a fault occure of any feedere, the continuity of supply to othere is likely to be affected.

02.01.2020

2. FEEDER REACTOR

When the reactors are connected in series with each feeder they are known as feeder reactor.

→ since most of the short ckt occures on feeder, a large no. of reactors are used for short ckt.

ADVANTAGES

There are two main advantages feeder reactor

→ If fault occures on any feeder the voltage drop in its reactor will not affected the bus-bar voltage so that there is a little tendency for the generator to loss synchronism.

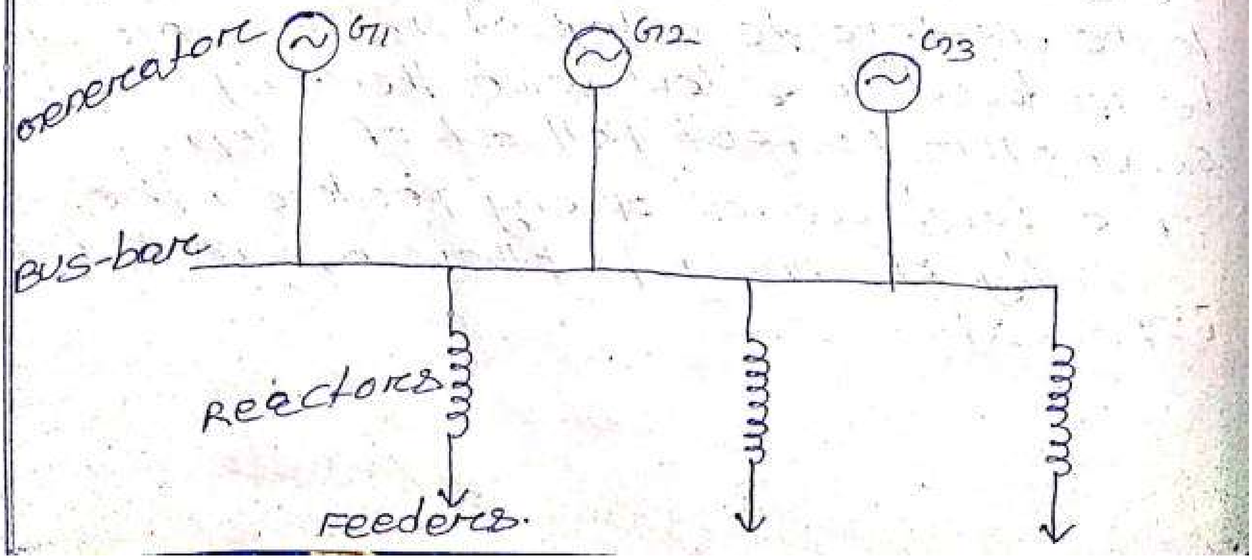
→ The fault on a feeder will no affected other feeders and consiquently the effect of the fault are localised.

DISADVANTAGE

→ There is a constant power loss and voltage drop in the reactors even during normal operation.

→ If a short ckt occures on the bus-bar no protection is provide to the generator.

→ If the no. of generators is increased the size of feeder reactor will have to be increased to keep the short ckt current within the rating of feeders and ckt breaker.



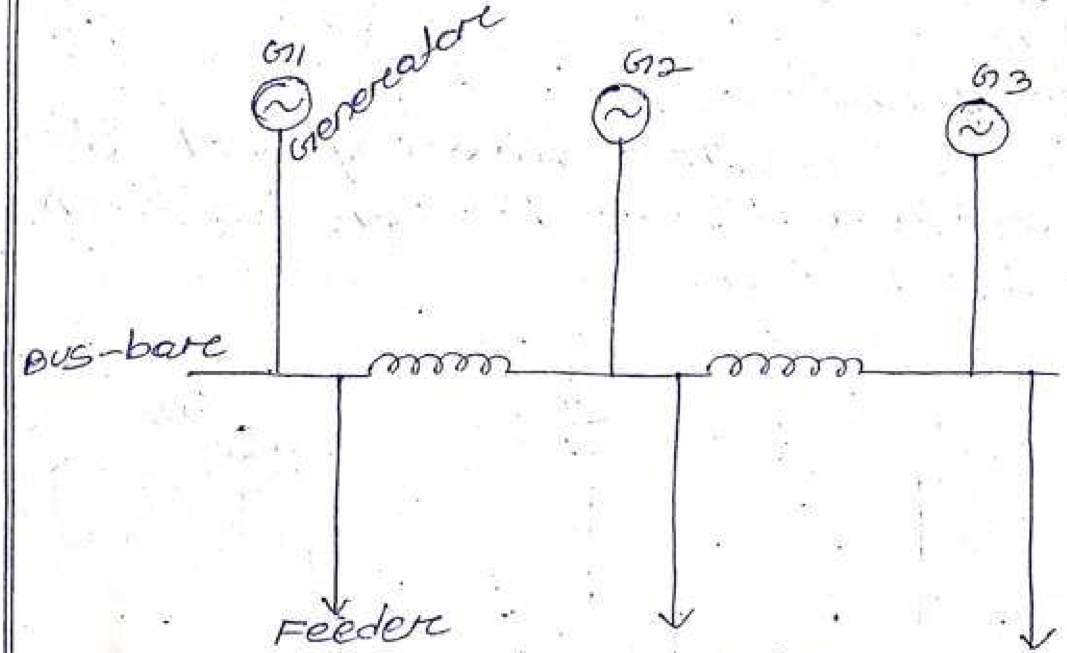
3. BUS-BAR REACTOR

→ The above 2 methods of locating reactors suffer from the disadvantage that there is considerable voltage drop and power loss in the reactor even during normal operation. so this disadvantage can be over come by locating the reactors in the busbar. There are two methods of this purpose i.e.

i. Ring system
ii. Tie-bar system

i. RING SYSTEM

→ In this system bus-bar is devided into two section and this sections are connected through reactors as shown in the below fig.



→ Generally one feeder is fed from one Generator only under normal operating condition, each generator will supply only its own section of the load and very little power will be fed by other generators. this results in low power loss and low voltage drop in the ~~sect~~ reactors

→ The main advantage of this system is that if a fault occures of any feeder only one generator mainly feeds the fault current while the current fed from other generators is small due to the presents of reactors. Therefore only that section of the bus-bar is affected to which the feeder is connected and the other section being able to continue in normal operation.

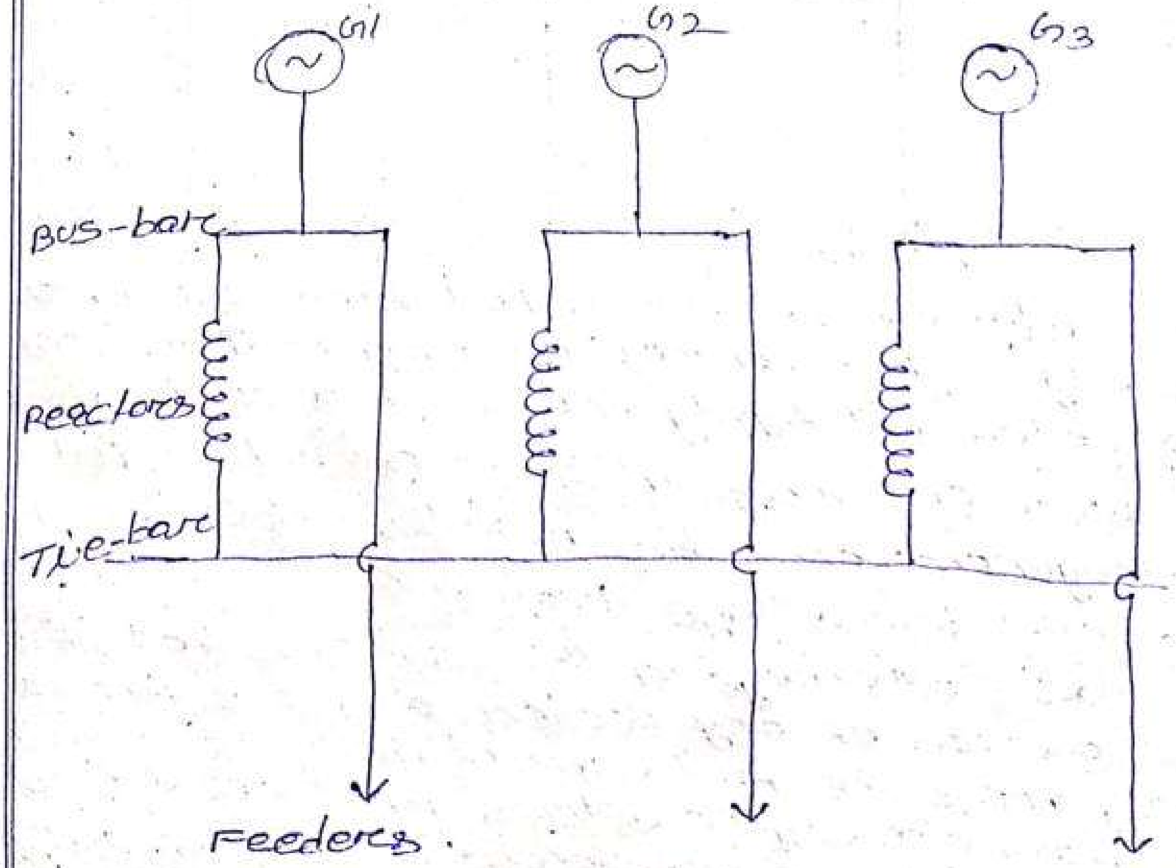
ii. TIE-BAR SYSTEM

→ The below fig. shows the tie-bar system compairing the ring system with tie-bar system it is clear that in tie-bar system there are effectively two reactors in series between section. so that reactors must have approximately half the ~~reactance~~ reactance of those used in a compairable ring system.

→ Another advantage of tie-bar system it that additional generators may be connected to the ~~changes in the existing reactors.~~ system without requiring the changes in the existing reactors.

DISADVANTAGES

This system has the disadvantage that it requires the additional bus-bar i.e known as ~~tie-bus~~ tie-bar.



03.01.20

STEPS FOR SYMMETRICAL ~~FAUL~~ FAULT CALCULATION

→ The procedure for solution of ~~such fault~~ symmetrical fault calculations has the following step

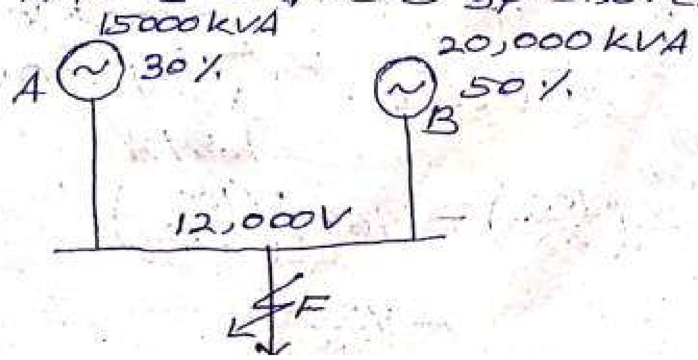
1. Draw a single line diagram of complete network indicating the rating, voltage and % reactance of each element of the network.
2. Choose a numerically convenient value of base kVA and convert all percentage reactance to this base value.
3. Corresponding to single line diagram of the network draw the reactance diagram showing 1φ of the system and the neutral. Indicate the % reactance of base kVA in the reactance diagram. The transformer in the system should be represent by reactance in series.
4. Find the total % reactance of the network upto the point of fault. Let it be %X.
5. Find the full load current corresponding to the selected base kVA and the normal system voltage at the fault point (Let it be I)
6. This various short ckt calculation are:

short ckt current, $I_{SC} = I \left(\frac{100}{\%X}\right)$

short ckt kVA $= \text{Base kVA} \left(\frac{100}{\%X}\right)$

PROBLEM-1

The single line diagram of 3φ system is shown in the fig. The %X of each alternator is based on its own capacity find the short ckt current that will flow in to a complete 3φ short ckt at point 'F'.



Ans

Let the Base kVA = 35000 kVA

% reactance of alternator A at the Base kVA is 35000 kVA

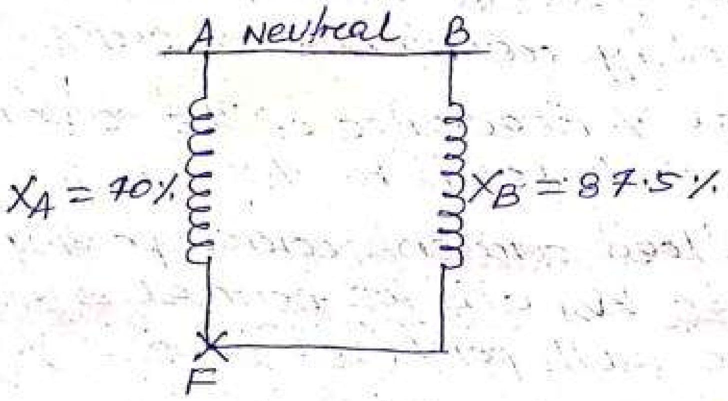
$$\% X_A = \frac{\text{Base kVA}}{\text{Rated kVA}} \times \% X \text{ at rated kVA}$$

$$= \frac{35000}{15000} \times 30$$

$$= 70\%$$

% reactance of alternator B at the Base kVA is 35000 kVA

$$\% X_B = \frac{35000}{20000} \times 50 = 87.5\%$$



→ Total % reactance from generator neutral up to fault point is

$$\% X = X_A \,||\, X_B$$

$$= \frac{X_A X_B}{X_A + X_B} = \frac{70 \times 87.5}{70 + 87.5} = 38.89\%$$

→ Line current corresponding to 35000 kVA at 12000V.

$$P = \sqrt{3} V I \cos\phi$$

$$I = \frac{P}{\sqrt{3} V \cos\phi} = \frac{35000 \times 10^3}{\sqrt{3} \times 12000 \times 1} = 1683.93$$

$$= 1684 A$$

$$I_{SC} = I\left(\frac{100}{\% X}\right) = 1684\left(\frac{100}{38.89}\right)$$

$$= 4330 A$$

Scanned by CamScanner

PROBLEM-2

A 3-φ, 20MVA, 10kV alternator has internal reactance of 5% and negligible resistance. Find the external reactance per phase to be connected in series with the alternator so that steady current on ckt does not exceed 8 times the full load current.

GIVEN

$P = 20MVA$

$V_L = 10kV$

$\%X_A = 5\%$

$I_{SC} = 8I$

$$P = \sqrt{3} V I \cos\phi$$

$$I = \frac{P}{\sqrt{3}.V} = \frac{20\times10^6}{\sqrt{3}\times10\times10^3} = 1154.7A$$

voltage per phase $V = \frac{10\times10^3}{\sqrt{3}} = 5773.5V$

$$I_{SC} = I \times \frac{100}{\%X}$$

short ckt current $= \frac{F.C\times100}{\%X}$

$$\Rightarrow \%X = \frac{F.C}{SCC}\times100$$

$$= \frac{I}{8I}\times100 = 12.5\%$$

External percentage required

$$\%X = \%X_A + \%X_E$$

$$\%X_E = \%X - \%X_A$$

$$= 12.5 - 5 = 7.5\%$$

→ Let $X\Omega$ be the per phase external reactance required

Now $\%X_E = \frac{IX}{V}\times100$

$$X = \frac{\%I_E V}{I\times100} = \frac{7.5\times5773.5}{1154.7\times100} = 0.375\Omega$$

04.02.20

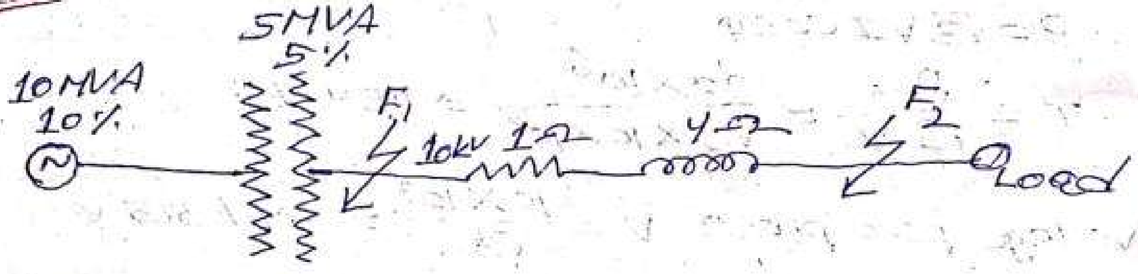
PROBLEM-3

A 3φ transmission line operating at 10kV and having a resistance of 1Ω and reactance of 4Ω is connected to generating station bus-bar through 5MVA step-up transformer having a reactance of 5%. The bus-bars are supplied by a 10MVA alternator having 10% reactance. calculate a short-ckt kVA fed to symmetrical fault between phase if it occurs

(i) At load end of transmission line

(ii) At the high voltage terminals of the transformer

Ans



Let 10000 kVA be the Base kVA.

% reactance of alternator at base kVA is 10000

$$\% X_A = \frac{\text{Base kVA}}{\text{Rated kVA}} \times \% X \text{ at rated kVA}$$

$$= \frac{10000 \times 10^3}{10 \times 10^6} \times 10\%$$

$$= 10\%$$

% reactance of Transformer at Base kVA is 10000

$$\% X_T = \frac{10000 \times 10^3}{5 \times 10^6} \times 5\%$$

$$= 10\%$$

% reactance of the transmission line

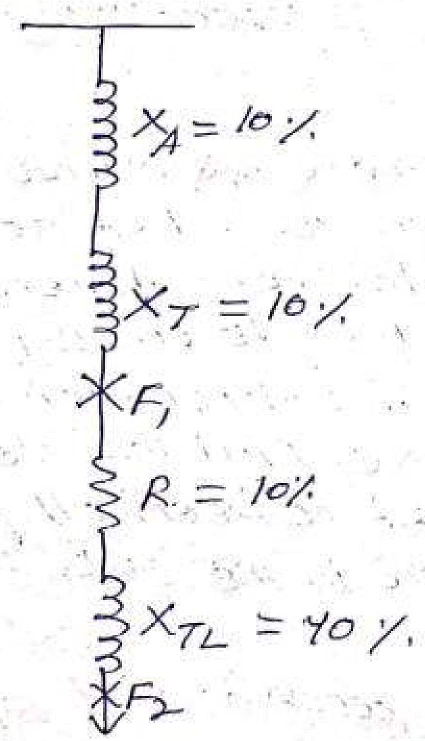
$$\% X_{TL} = \frac{\text{kVA} \times \text{reactance of transmission line}}{10 \times (\text{kV})^2}$$

$$= \frac{10000 \times 4}{10 \times (10)^2} = 40\%$$

% reactance of transmission line

$$\% R = \frac{10000 \times 1}{10 \times 10^2} = 10\%$$

The reactance diagram of network on the selected Base kVA is shown in the below fig



For a fault at the end of the transmission line (i.e point F_2)

$$\% X = X_A + X_T + X_{TL}$$
$$= 10 + 10 + 40 = 60\%$$

$$\% R = 10$$

% impedance from generator neutral to fault point F_2

$$\% Z = \sqrt{R^2 + X^2} = \sqrt{10^2 + 60^2} = 60.82\%$$

$$\text{short ckt kVA} = \text{Base kVA} \left(\frac{100}{\% Z} \right)$$
$$= 10000 \left(\frac{100}{60.82} \right)$$
$$= 16441 \text{ kVA}$$

For fault at high voltage terminals of the T/F i.e F,

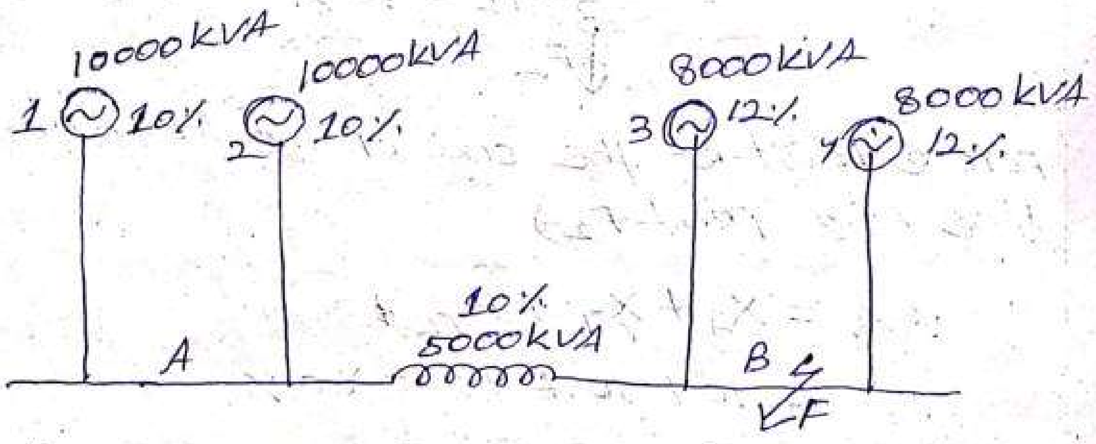
$$\%X = X_A + X_T$$
$$= 10 + 10 = 20\%$$

$$\text{short ckt kVA} = 10000\left(\frac{100}{20\%}\right)$$
$$= 50000 \text{ kVA}$$

PROBLEM-4

The section bus-bar A & B are linked by a bus-bar reactor rated at 5000 kVA with 10% reactance. on bus-bar A, there are two generators each of 10,000 kVA with 10% reactance and on B two generators each of 8000 kVA with 12% reactance. Find the steady MVA fed into a dead short ckt between all phases on B with bus-bar reactor in the ckt.

Ans



Let the Base kVA is 10000 kVA

% reactance of Alternator 1 at Base kVA

$$\%X_1 = \frac{\text{Base kVA}}{\text{Rated kVA}} \times \%\text{ reactance at rated kVA}$$

$$= \frac{10000}{10000} \times 10\%$$

$$= 10\%$$

$\% X_2 = 10\%$

% reactance of an alternator 3 and 4 at base kVA

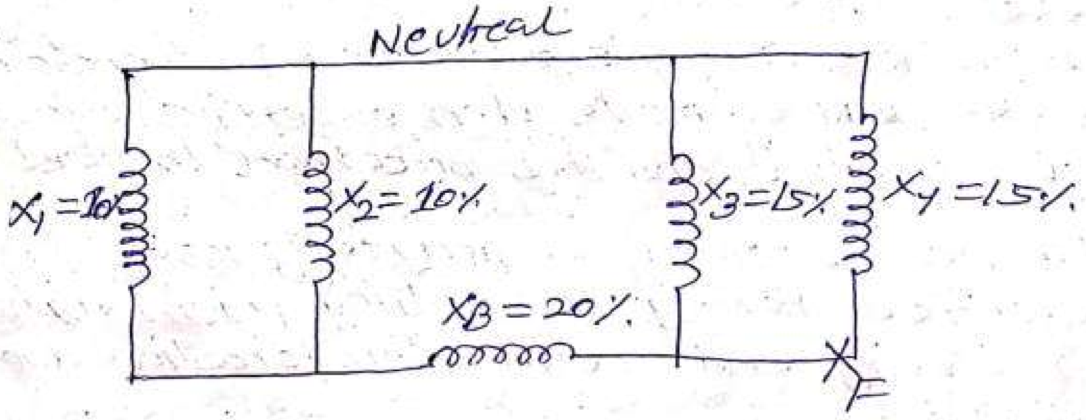
$$\% X_3 = \frac{10000}{8000} \times 12 = 15\%$$

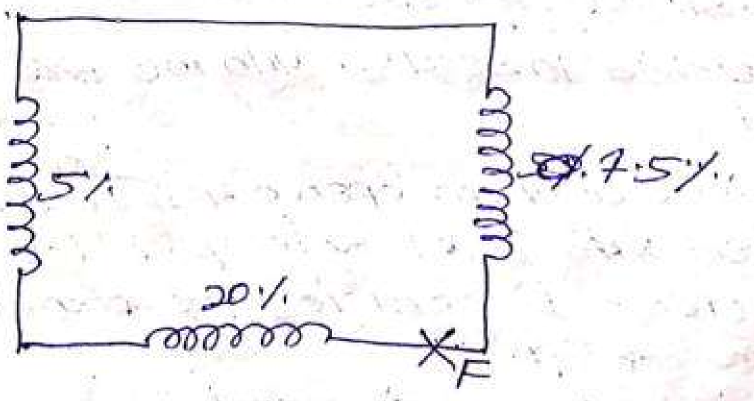
$$\% X_4 = \frac{10000}{8000} \times 12 = 15\%$$

% reactance of bus-bar reactor at base kVA

$$\% X_B = \frac{10000}{5000} \times 10\% = 20\%$$

The reactance diagram of the network selected base kVA is shown in the below fig





$\% X = (20+5) \parallel 7.5$

$$= \frac{25 \times 7.5}{25 + 7.5} = 5.76\%$$

$$\text{short ckt kVA} = \text{Base kVA}\left(\frac{100}{\%X}\right)$$

$$= 10000\left(\frac{100}{5.76}\right)$$

$$= 173611$$

$$\text{short ckt MVA} = \frac{173611 \times 10^3}{10^6} =$$

$$= 173.611 \text{ MVA}$$

06.02.20

CHAPTER-3

FUSES

FUSES

Fuse is a short piece of metal inserted in the ckt, which melts when excessive current flow through it and thus breaks the ckt.

→ The fuse element is generally made up materials having low melting point, high conductivity and least deterioration due to oxidation.

→ Ex → cu, silver, tin etc

→ It is inserted in series with the ckt to be protected

→ under normal condition operating condition the fuse element is at a temp. below its melting point therefore it carries the normal current without over heating.

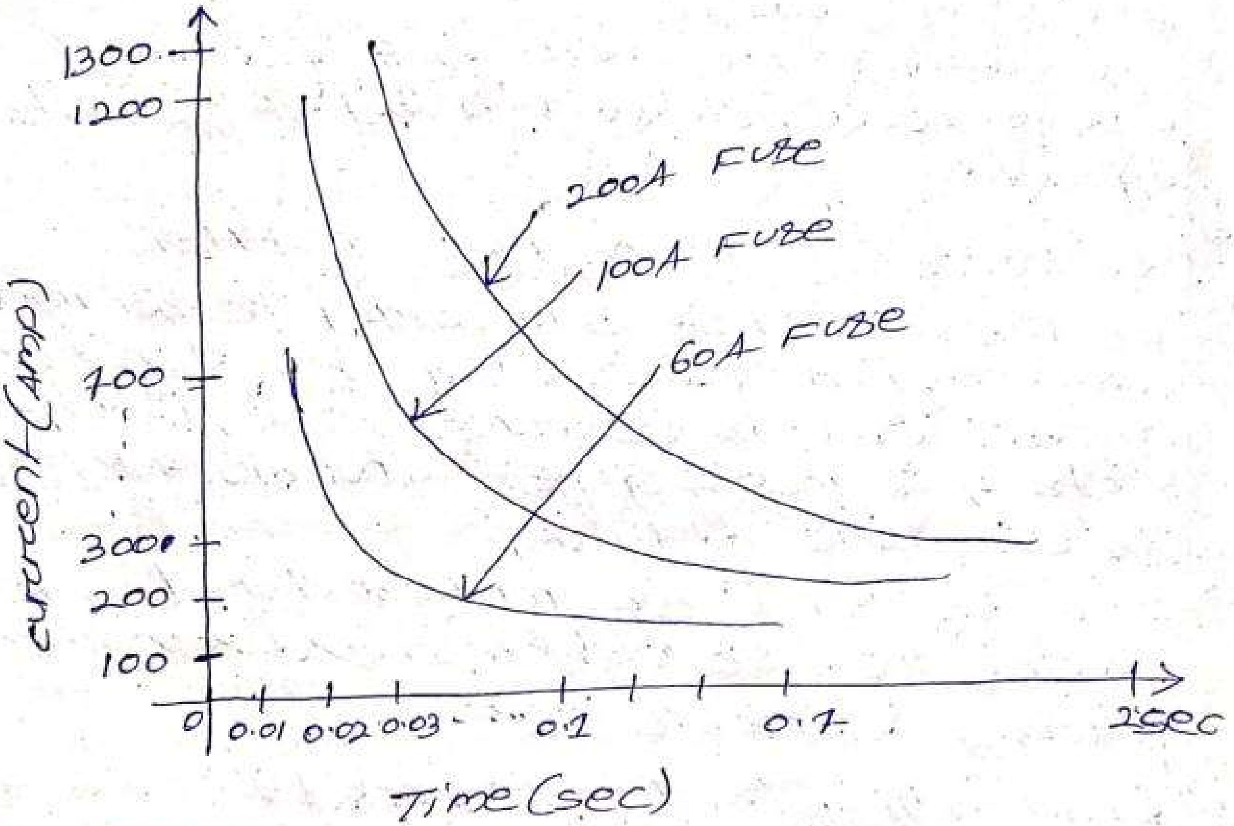
→ when a short ckt or over load occurs the current through the fuse element melts (or blowout) disconnecting the ckt protected by it. in this way a fuse protects the machine and equipments from damage due to excessive current.

RELATION BETWEEN MAGNITUDE OF FAULT CURRENT AND OPERATING TIME OF FUSE

→ The time required to blow out the fuse depends upon the magnitude of excessive current.

→ Greater the current smaller is the time taken by the fuse to blowout.

→ In otherwords a fuses has inverse time current charc.



ADVANTAGES

→ It is cheapest form of protection available.

→ Its operation is completely automatic unlike a ckt breaker which requires external equipment for automatic action.

→ It can break heavy short ckt currents without noise or smoke.

→ The smaller sizes of fues element impose a current limiting effect under short ckt conditions.

→ The inverse time current charc. of a fuse makes its suitable for over current protection.

→ The minimum time of operation can be made much shorter than the ckt breaker.

DISADVANTAGE

→ considerable time is lossed in rewiring or replacing a fuse after operation.

→ ON heavy short ckts discremination between fuses in series can't be obtain unless their is sufficient different in the sizes of the fuse concerned.

→ The current time char. of a fuse can't always be co-related with that of the protected apprates.

DESIRABLE CHAR. OF FUSE ELEMENT

→ The function of fuse is to carry the normal current without overheating but when in the current exceeds its normal value, it reapidly heats up to mealting point and disconnected the ckt protected by it.

→ In order that it may perform this function smoothly the fuse element should have the following desireable char.

i. a Low melting point:- Tin, Lead

ii. High conductivity: eg - silver, copper

iii. Free from deterioration due to oxidation: e.g - silver

iv. Low cost:- Lead, tin, copper.

08.01.20

FUSE ELEMENT MATERIALS

→ The most commonly used material for fuse element are lead, tin, copper, zinc and silver

→ For small current up to 10A Tin or Alloy of lead and tin (lead = 37%, Tin = 63%) is used for making the fuse element.

→ For larger current copper or silver is used. It is a usually practice to tin the copper to protect its from oxidation.

→ zinc (only in strip) is good if a fuse with considerable time-lag is required i.e one which does not melt very quickly with a small overload.

→ Now a days the present trend is to use to silver despite its cost due to the following regions.

a. It is comaratively free from oxidation

b. It does not deteriorate when used in dry air.

c. The coefficient of expansion of silver is so small that no critical fatigue occure. Therefore the fuse element can carry the rated current continiously for a long time

d. The conductivity of silver is very high. therefore for a given rating of fuse element. The mass of silver element required is smaller than that of other materials.

e. Due to compairatively low specific heat, silver fuseable element can be raised from normal temp. to vapourisation quicker than other ~~fuseable~~ fusible element.

IMPORTANT TERMS

1. CURRENT RATING OF FUSE ELEMENT

→ It is the current which the fuse element can normaly carry without over heating or melting

→ It depends upon the temp rise of the contacts of the fuse holder, fuse material and the surrounding of fuse.

2. FUSING CURRENT (IMP)

It is the minimum current at means the fuse element melts and thus disconnects the ckt protected by it. Its value will be more than the current rating of fuse element.

→ For a round wire, the approximate relationship between the fusing current 'I' and diameter (d) of the wire is

$$I = k(d)^{3/2}$$

where,

k = is the fuse constant, and its value depends upon the fuse element by which it is made.

SL. No.	Material	value of k	
		d in cm.	d in mm
1	copper	2530	80
2.	Aluminium	1873	59
3.	Tin	~~340.6~~ 405.5	12.8
4.	Lead	340.6	10.8

09.07.20

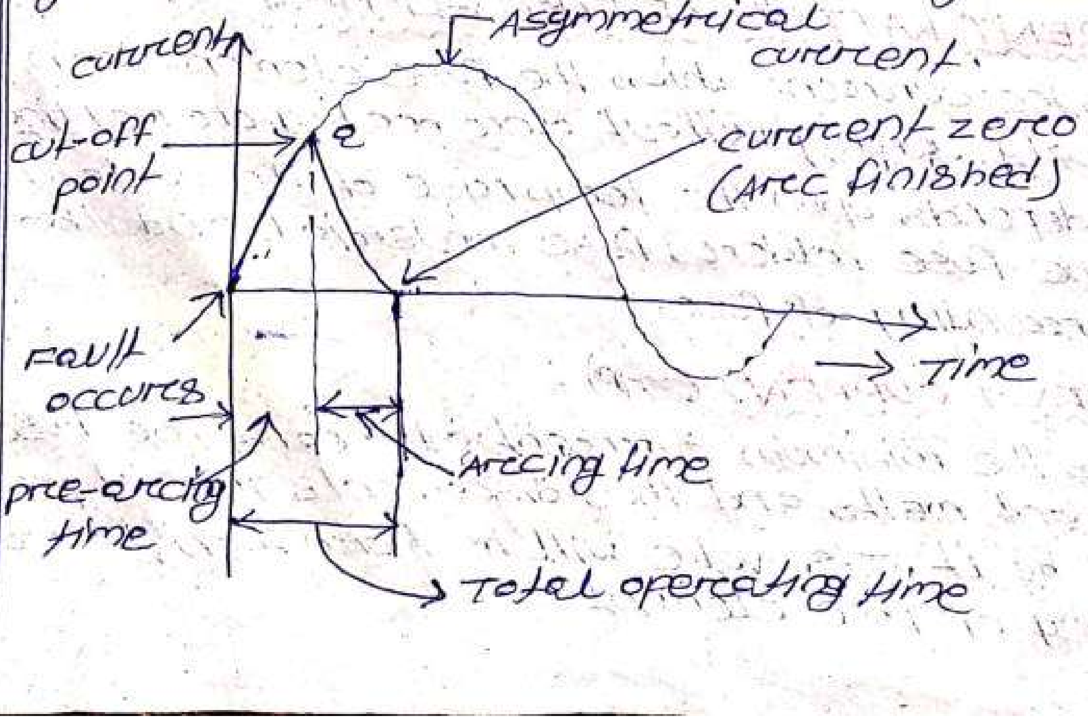
3 FUSING FACTOR (IMP)

It is the ratio of minimum fusing current to the current rating of fuse element.

$$\text{Fusing factor} = \frac{\text{Minimum Fusing current}}{\text{current rating of fuse element}}$$

→ Its value is always more than 1.

→ The smaller the fusing factor, greater is the dificulty in avoiding deteroration due to overheating and oxidation at rated carrying current.



4. PROSPECTIVE CURRENT

→ The fault current should be normally have a very large first loop; but it actually generates sufficient energy to melt the fuse element before peak of this first loop is reached. The RMS value of the first loop of fault current is known as prospective current.

$$\text{RMS value} = \frac{\text{Maximum value}}{\sqrt{2}}$$

5. CUT-OFF CURRENT

It is the maximum value of fault current actually reached before the fuse melts

→ The current corresponding point 'a' is the cut-off current.

→ The cut-off value depends upon

(a) current rating of fuse.
(b) value of prospective current
(c) Asymmetry of short ckt current.

(6) PRE-ARCING TIME

→ It is the time between the commencement of fault and the instant when cut-off occurs.

→ When a fault occurs the current rises rapidly and generates heat in the fuse element. As the fault current reaches cut-off value, the fuse element start melting and arc is initiated. The time from the start of the fault to the instant arc is initiated is known as pre-arcing time.

→ The pre arcing time is smaller i.e 0.001sec.

7. ARCING TIME

This is the time between the end of pre-arcing time and instant when arc is extinguished.

8. TOTAL OPERATING TIME

→ It is the sum of pre-arcing and arcing time.

→ It may be noted that operating time of fuse is point low (0.002sec) as compaire to ckt breaker (0.2sec)

9. BREAKING CAPACITY

It is the RMS value of AC component of maximum prospective current that a fuse can deal with at rated voltage.

TYPES OF FUSES

Fuses is may be classified in to two types.

11.01.20

1. Low voltage fuses
2. High voltage fuses.

1. LOW VOLTAGE FUSES

Low voltage fuses can be devided in to 2 types.

~~i. semi-closed~~

i. semi-enclosed rewireable fuse
ii. High-rupturing capacity (H.R.C) ~~cartridge~~ cartridge fuse.

i. SEMI-ENCLOSED REWIREABLE FUSE

semi-enclosed rewireable fuse is also known as kit-kat ~~type~~ fuse. It is used where low value of fault current are to be interrupted.

→ It is consist of a base and a fuse carrier.

→ The base is of porcelain material and carries the fix contacts to which the incoming and outgoing phase wires are connected.

→ The fuse carrier is also of porcelain and holds the fuse element (tinned cu wire) between its terminals. The fuse carrier can be inserted in or taken out of the base when desired.

→ when a fault occures the fuse element is blown out and the circuit it interrupted then the fuse carrier is taken out the blown out the fuse element is replaced by new one. The fuse carrier is then reinserted in the base to restore the supply.

ADVANTAGES

This type of fuse has two main advantages.

→ The detachable fuse carrier permits the replacement of fuse element without any danger of comming in contact with live parts.
→ The cost of the replacement is negligible.

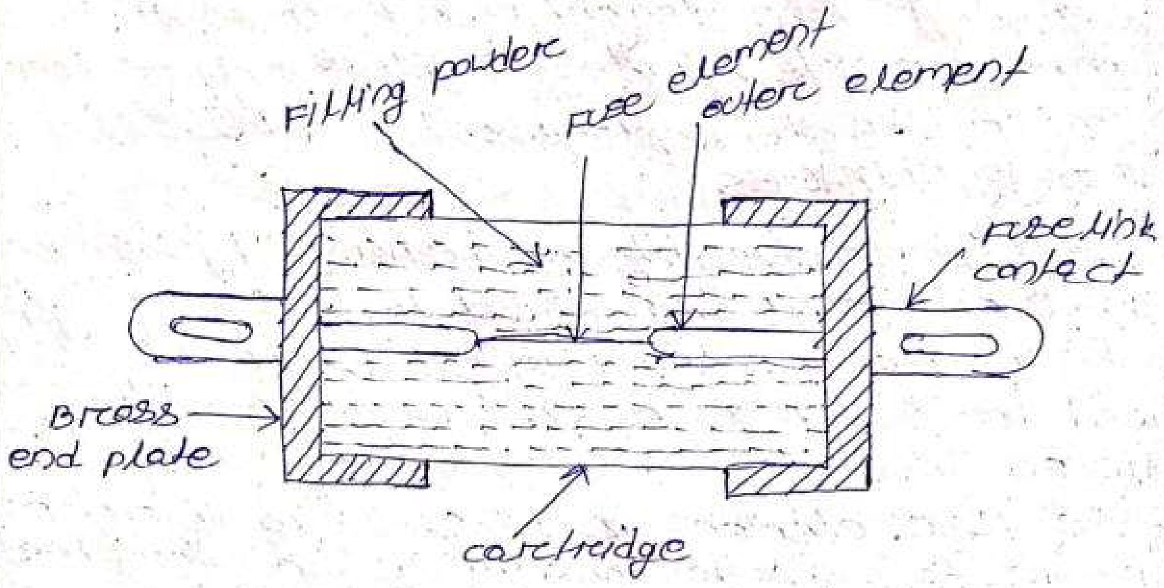
DISADVANTAGES

→ There is a possibility of renewal by the fuse wire of wrong size or by improper material.
→ This type of fuse has a low-breaking capacity and hence can not be used in ckt of high fault level.
→ The fuse element is subjected to deterioration due to oxidation through the continious heating of the element.
→ The protective capacity of such fuse is uncertain as it is affected by the ambient conditions.
→ Accurate calibration of the fuse wire is not possible because fusing currents very much depends upon the length of fuse element.

(ii) HIGH-RUPTURING CAPACITY (H.R.C) CARTRIDGE FUSE

The disadvantages of rewireable fuse is over come in H.R.C Fuse.
→ It consist of a heat resisting ceramic body having metal end-kept to which is welded silver current carrying element.
→ The space within the body surrounding the element is completely packed with a filling powder.
→ The filling material may be chalk, plaster of paris, quartz or marble dust and acts as an arc quenching and cooling therefore it carries the normal current without overheating.
→ whenever a fault occures the current increases and the fuse element melt before the fault ~~occures~~ current reaches its first peak value.
→ The heat produced in the process vaporizes the melted silver element
→ The chemical reaction between the silver vapour and the filling powder results in the formation of high resistance substance which

helps in quenching the arc.



ADVANTAGES

→ They are capable of clearing high as well as low fault current.

→ They do not deteriorate with age.

→ They have high speed of operation

→ They provide reliable discrimination.

→ They require low maintenance.

→ They cheaper than other ckt interrupting devices of equal breaking capacity.

→ They permit consistent performance.

DISADVANTAGE

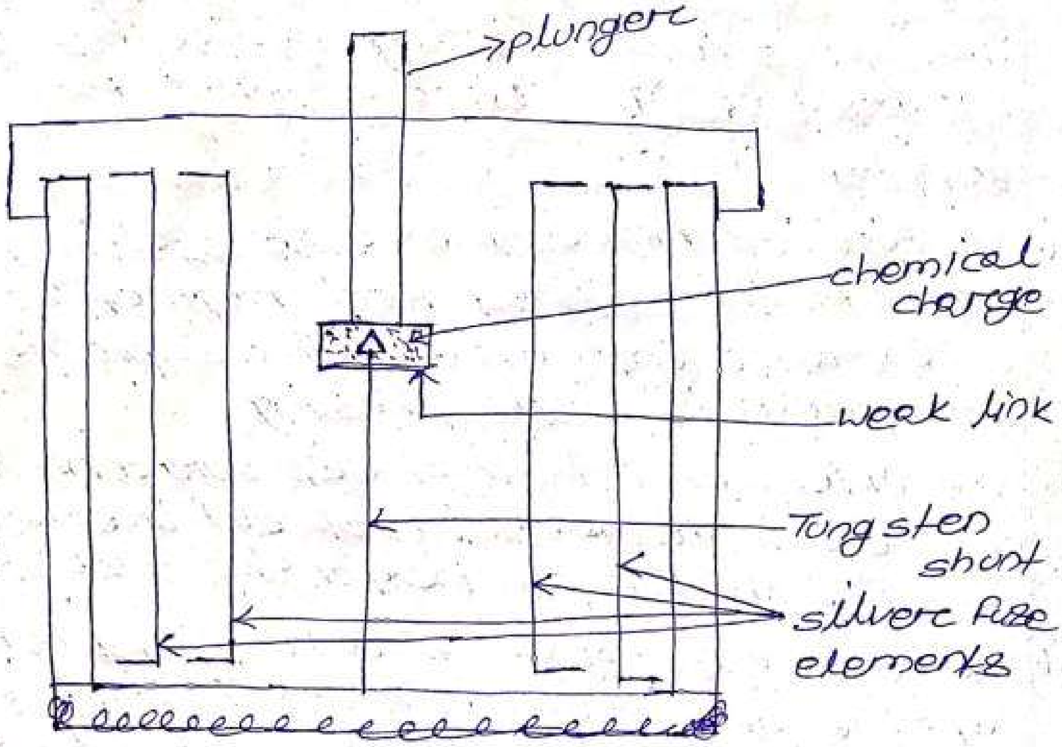
→ They have to be replaced after each operation.

→ Heat produced by the arc may affect the associated switches.

HRC FUSE WITH TRIPPING DEVICE (IMP)

→ sometime H.R.C fuse is provided with a tripping device when the fuse blows out under fault condition the tripping device causes the ckt breaker to operate.

→ The below fig shows the essentially parts of H.R.C fuse with tripping device.



→ The body of the fuse is of ceramic material with a metalic rigidly fixed at each end.

→ These are connected by the no. of silver fuse element.

→ At one end of the plunger is connected with under fault conditions hits the tripping mechanism of the C.B and causes it to operate.

→ The plunger is electrically connected through the fusible link, chemical charge and a tungsten wire to the other end of kept as shown in the fig.

→ When a fault occurs the silver fuse element are the first to be blown out and then current is transferred to the tungsten wire.

→ The weak link is series with the tungsten wire gets fused and causes the chemical charged to be detonated.

→ This forces the plunger outward to operate the C.B. and the movement of the plunger is so set that it is not ejected from the fuse body under fault condition.

ADVANTAGES

H.R.C fuse with tripping device has the following disadvantages over a H.R.C fuse without tripping device.

i. In case of 1φ fault on a 3φ system the plunger operates the tripping mechanism of the ckt breaker to open all the three phases and thus prevents single phasing.

ii. (The effect of full short ckt current need not be consider in the choice of ckt breaker) this permits the use of inexpensive ckt breaker.

iii. (The fuse tripping ckt breaker is generally capable of dealing with small fault current itself.) and this avoids the necessity for replacing the fuses except after highest current for which it is intended.

2. HIGH VOLTAGE FUSES

The low voltage fuses discussed so far have low normal current rating and breaking capacity. Therefore they can not be successfully used on high voltage system.

→ some high voltage fuses are

i. cartridge type
ii. Liquid type
iii. Metal clad fuses.

i. CARTRIDGE TYPE

This is similar in construction to low voltage cartridge type except that special design features are incorporated.

→ some designs employ fuse elements wound in the form of a helix so as to avoid corona effects at high voltage.

→ on some designs there are two fuse elements in parallel i.e one of low resistance (silver wire) and the other of hight resistance (tungsten)

→ under normal load condition the low resistance element carries the normal current but when a fault occures, the low resistance element is blown out and the high resistance element reduces the short ckt current and finaly breaks the ckt.

→ High voltage cartridge fuses are used upto 33kV with breaking capacity of about 8700A at that voltage.

(ii) LIQUID TYPE

These fuses are filled with carbon tetrachloride and have the weight range of application to H.V system.

→ They may be used for ckt up to about 100A rated current on system up to 132kV and may have breaking capacity of the order 6100A.

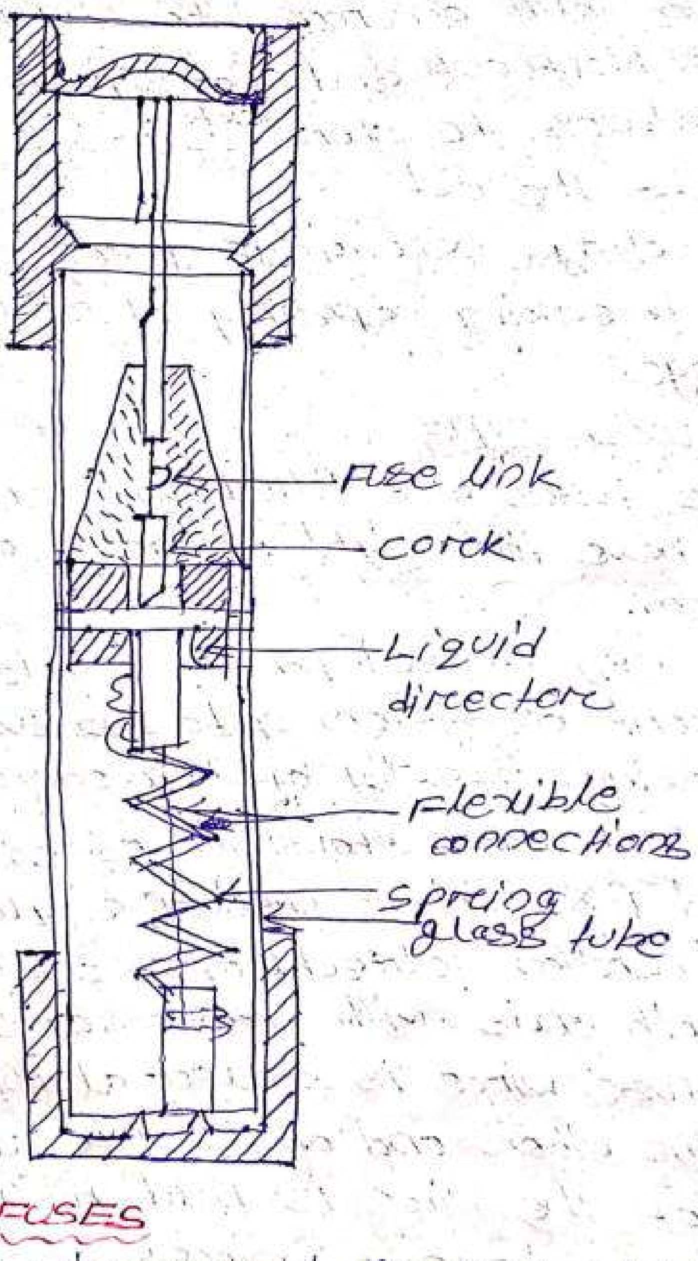
→ The below fig. shows the essential parts of liquid fuse. It consist of a glass tube filled with carbon tetrachloride solution and sealed at both ends with brass caps.

→ The fuse wire is sealed at one end of the tube and the other end of the tube and the other end of the wire is held by is strong phosphore bronze spiral spring fixed at other end of the glasstube.

→ when the current exceeds its rated value the fuse wire is blown out.

→ As the fuse melts the spring retreacts part of it through liquid director and draws it well into the liquid

→ The small quantity of gas generated at the point of fusion forces some part of liquid into the passage through ~~to~~ liquid director and it effectively extinguishes the arc.



iii) METAL CLAD FUSES

Metal clad oil-immersed fuses have been developed with the object of providing a substitute for the oil circuit breaker.

→ such fuses can be used for very high voltage ckt. and operate ~~less~~ effectivly under short ckt condition approaching there rated capacity.

CURRENT CARRING CAPACITY OF FUSE ELEMENT

→ The current carring capacity of fuse element mainly depends on the metal used and the cross sectional area but is affected by the length, the state of surface and the surrounding of the fuse.

→ Heat produce per sec = Heat lost per sec by convection, radiation & conduction.

$$I^2R = \text{constant} \times \text{effective surface area}$$

$$I^2\left(\frac{\rho l}{a}\right) = \text{constant} \times d \times l$$

where, d = diameter of fuse element
l = length of fuse element.

$$I^2\left(\frac{\rho l}{\frac{\pi d^2}{4}}\right) = \text{constant} \times d \times l$$

$$I^2 = \text{constant} \times d^3$$

$$\Rightarrow I^2 \propto d^3 \quad \text{---} (1)$$

This equation(1) is known as fuse loss.

CHAPTER-4

CIRCUIT BREAKER

INTRODUCTION

In early days during the operation of power system it is often disirable and necessary to switch ON or OFF various ~~ele~~ ckt (For EX: Transmission line, distributors, generating plants, etc) under both normal condition.

→ This function use to be performed by a switch and a fused placed in series in the ckt. but this controls have two disadvantages.

(a) when a fuse below out it takes some time to replace it.

(b) A Fuse can't successfully interrupt heavy fault current.

→ This it is necessary to employ a more dependable means of control such as a circuit breaker.

→ A circuit Breaker make and break a ckt either manually or automatically under all condition (No load, Full Load and fault ckt condition) for switching and protection of various parts of the power system.

CIRCUIT BREAKER

→ A CB is a ~~per~~ piece of equipment which can make or break a ckt either manually or by remote control under normal condition.

→ ~~It can make a ckt either~~ (break)

→ It can break a ckt automatically under fault condition.

→ It can make a ckt either manually or by ~~remorate~~ remote control under fault condition.

OPERATING PRINCIPLE OF CIRCUIT BREAKER

→ AC C.B essentially consist of fixed and moving contects called as electrodes.

→ under normal operating condition these contects remain closed and will not open automatically until and unless the system becomes faulty.

→ The contects can be opened manually or by remote control when ever desired.

→ when a fault occures of any part of the system the trip coils of circuit breaker get energized and the moving contect are pulled apart by some mechanism and thus operate in the ckt.

→ when the contect of a ckt breaker separated under fault condition and arc is strucked between them.

→ The production of arc not only delay the current interruption process but also generated huge amount of heat which may cause damage to the system or to the CB itself.

→ Therefore the main problem in the C.B is to extinguish the arc with in shortest possible time so that heat generated by it may not reach a dangreous value.

ARC PHENOMENON

→ when a short ckt occures a heavy current flow through the contact of ckt breaker before there opened by protective system.

→ At the instant when the contacts begin to separate the contect area decreases rapidly and a large fault current causes increases in current density and hence rise in temp.

→ The heat produced in the midium between contects (usually midium is oil or air) is sufficient to ionised the air or vapourized and ionise the oil.

→ The ionized air or vapour acts as a conductor and an arc is struck between the contacts.

→ The potential difference between the contact is quite smaller and is just sufficient to maintain the arc.

→ During arcing period the current flowing between the contacts depends upon the arc resistance. The greater the arc resistance then smaller the current close between the contacts.

THE ARC RESISTANCE DEPENDS UPON THE FOLLOWING FACTORS

1. DEGREE OF IONISATION

The arc resistance increases with the decrease in the no. of ionized particle between the contacts.

2. LENGTH OF THE ARC

The arc resistance increases with the length of the arc i.e separating of contacts.

3. CROSS SECTION OF ARC

The arc resistance increases with decreases in the area of cross-section of the arc.

PRINCIPLE OF ARC EXTINCTION

→ It is necessary to examine the factors responsible for the maintance of the arc between the contacts. These arc.

→ 1 - potential difference between the contacts
2 - Ionised particles between the contacts.

→ When the contacts have a small sepation the potential difference between them is sufficient to maintain the arc one way to extinguish the arc is to separate the contacts to such a distance that potential difference becomes inadequate to maintain the arc.

However this method is impracticable in high voltage system where a separation of many meters may be required.

→ The ionised particles between the contacts tends to maintain the arc. If the arc path is deionized, the arc extinction will be ~~facilitated~~ occure this may be achived by cooling the arc or by completely removing the ionised particle from the space between the contacts.

Imp

METHODS OF EXTINCTION

There are two method of extinguishing the arc in circuit breaker i.e.

(1) High resistance method

(2) Low resistance or current zero method.

1. HIGH RESISTANCE METHOD

→ In this method arc resistance is made to increase with time so the current is reduce to a value insufficient to maintain the arc.

→ Hence the current is interrupted or the arc is extinguished.

→ The main disadvantage of this method is that huge amount of energy is dissipated in the arc.

→ therefore it is employed only DC circuit breaker and low capacity AC circuit breaker.

→ The resistance of the arc may be increased by

i. Lengthening the Arc

→ The resistance of the arc is directly propositional to its length.

→ The length of the arc can increased by increasing the gap between the contact.

ii. Cooling the ARC

→ cooling helps in the deionisation of the midium between the contacts this increases the arc resistance. Efficient cooling may be obtained by a gas blast directed along the arc

iii) Reducing cross-section of the ARC

→ If the area of cross-section of the arc is reduced, the voltage necessary to maintain the arc is increased in other words the resistance of the arc path is increase with the decrease in area of cross-section.

iv) Splitting the Arc

→ The resistance of the arc can be increased by splitting the arc in to a no. of smaller arcs in series.

→ Each one of these arc experiences the effect of lengthening and cooling.

→ The arc may be split by introducing some conducting plates between the contacts.

2. LOW RESISTANCE/CURRENT ZERO METHOD

→ This method is employ for arc extinction in AC ckts only.

→ In this method arc resistance is kept low until current is zero.

→ Where the arc extinguishes naturally and is prevented ~~from~~ from restriking inspite of the rising voltage across the contacts.

→ All modern high power a.c circuit breakers employ this method for arc extinction.

→ In an AC ~~current~~ system current drops to zero after every half cycle at every current zero the arc extinguishes for a brief moment.

→ Now the midium between the contacts contains ions and electrodes so that it has small dielectric strength and can be easyly broken down by the rising contact voltage known as restriking voltage.

→ If such a breakdown occure the arc will persits for another half cycle.

→ If immediately after current zero, the dielectric strength of the midium between contacts is built up more rapidly than the voltage across the ~~voltage~~ contacts the arc fails to restrike and the current will be interrupted.

→ The rapid increase of dielectric strength of the medium near current zero can be echived by:-

a. causing the ionized particles in the space between contacts to recombine in to neutral molecules.

b. sweeping the ionized particles away and replacing them by un-ionized particles.

→ Therefore the real problem in AC arc interruption is to rapidly deionize the midium between the contacts as soon as the current become zero so that the restriking voltage can not breakdown the space between contacts.

→ The deionization of the midium ~~is~~ can be echived by

i. Lengthening of the gap

→ The dielectric strength of the midium is propositional to length of the gap between contacts.

ii. High pressure

→ If the pressure in the vicinity (surrounding) of the arc is increase the density of the particles constituting the discharge also increases.

→ The increased density of particles causes higher rate of de-ionization and consiquently the dielectric strength increases.

iii. COOLING

→ Natural combination of ionized parcatcles takes place more rapidly if they are allowed to cool.

→ Therefore dielectric strength of the midium increases by cooling the arc.

iv. BLAST EFFECT

If the ionised particles between the contact area swept away and replaced by ionised particles, the dielectric strength increases this may be achive by a gas directed along the discharge arc by forcing oil in to the contact space.

IMPORTANT TERMS

1. ARC VOLTAGE

It is the voltage appear across the contacts on the CB during arcing period.

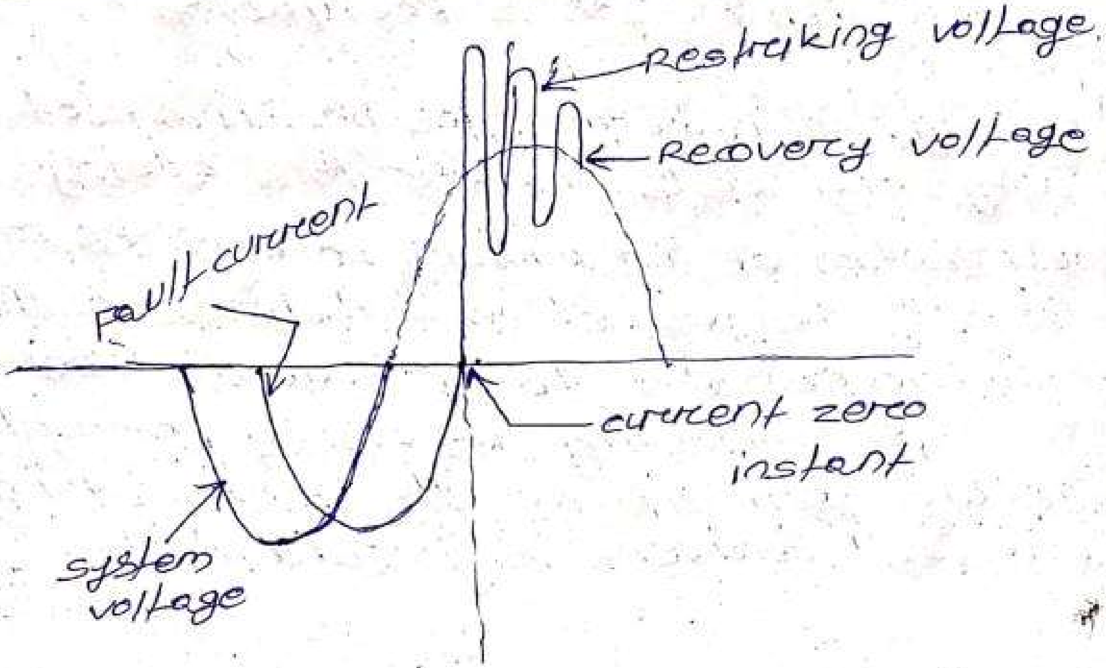
→ As soon as the contact of the ckt breaker separate and arc is formed.
→ The voltage that appears across the contacts during arcing period is called arc voltage.

2. RESTRIKING VOLTAGE (Imp)

→ It is transient voltage that appears across the contacts at or near current zero during arcing period.
→ At current zero a high frequency transient voltage appears across the contacts and is caused by the rapid distribution of energy between the magnetic and electric field associated with the plant and transmission line of the system this transient voltage is known as restriking voltage.

3. RECOVERY VOLTAGE (Imp)

→ It is the normal frequency (50Hz) R.M.S ~~value~~ voltage that appears across the contacts of the C.B. after final arc extinction it is approximately equal to the system voltage.



CLASIFICATION OF CIRCUIT BREAKER

circuit breaker may be clasified into following types.

1. oil ckt breaker (O.C.B)
2. Air blast ckt breaker
3. sulphur hexafluroide ckt breaker (SF_6 C.B) IMP
4. vacuum ckt breakers.

1. OIL CIRCUIT BREAKER

In such C.B some insulating oil (i.e T/F oil) is used as an ~~act~~ arc quenching midium.

→ The contacts are open under oil and an arc is struck between them.

→ The heat of the arc evaporates the surrounding oil and dissociates it into a substantial volume of gaseous hydrogen at high pressure.

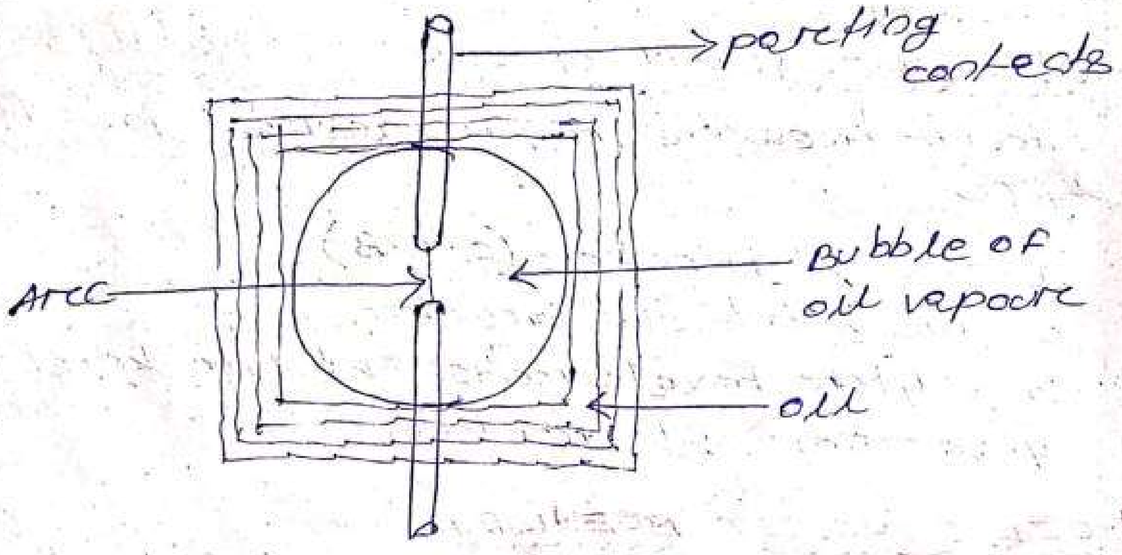
→ The hydrogen gas occupies a volume about 1000 time that of the oil decomposed.

→ The oil is therefore pushed away from the arc and an expanding hydrogen gas bubble. surround the arc region and adjacent persons of the contacts shown in the below fig.

→ The arc extinction is facilitated by two process.

a. Firstly the hydrogen gas has high heat conductivity and cools the arc thus adding the deionisation of the midium between the contacts.

b. secondly the gas set up turbulence in the oil and forces it in to the space between contacts thus eliminating the arcing products from the arc path this results in arc extinguished and fault current is interrupted.



ADVANTAGES

The advantages of oil as an arc quenching medium are:-

→ It absorbs the arc energy to decompose the oil in to gases which have excellent cooling properties.

→ It acts as an insulator and permits smaller clearance between live conductors and earthed components.

→ The surrounding oil presents cooling surface in close proximity to the arc.

DISADVANTAGES

The disadvantages of oil as an arc quenching medium are:

i. It is ~~maintain~~ inflammable and there is a risk of a fire.

ii. It may form an explosive mixture with arc.

iii. The arcing products (e.g. carbon) remain in the oil and its quality deteriorates with successive operations. This necessitates periodic checking and replacement of oil.

TYPES OF OIL CIRCUIT BREAKER

(1) Bulk OCB → plain break OCB
→ Arc control OCB

(2) Low OCB.

1. BULK OCB

→ It used in large quantity of oil. The oil has to serve two properties.

a. It extinguishes the arc during opening of contacts.

b. It insulates the current conducting part from one another and from the earthed tank.

→ This C.B may be classified into two types

(i) plain break OCB
(ii) Arc control OCB

2. LOW OIL C.B

→ Which used minimum amount of oil in such C.B oil is used only for arc extinction and the current conducting parts are insulated by the air or porcelain or organic insulating material

i. PLANE BREAK OCB

→ This CB involves the simple process of separating the contacts under the oil in the tank.

→ There is no special system for arc control other than the increase in length caused by separation of contacts.

→ The arc extinction occurs when a certain critical gap between the contacts ~~critical~~ in reached.

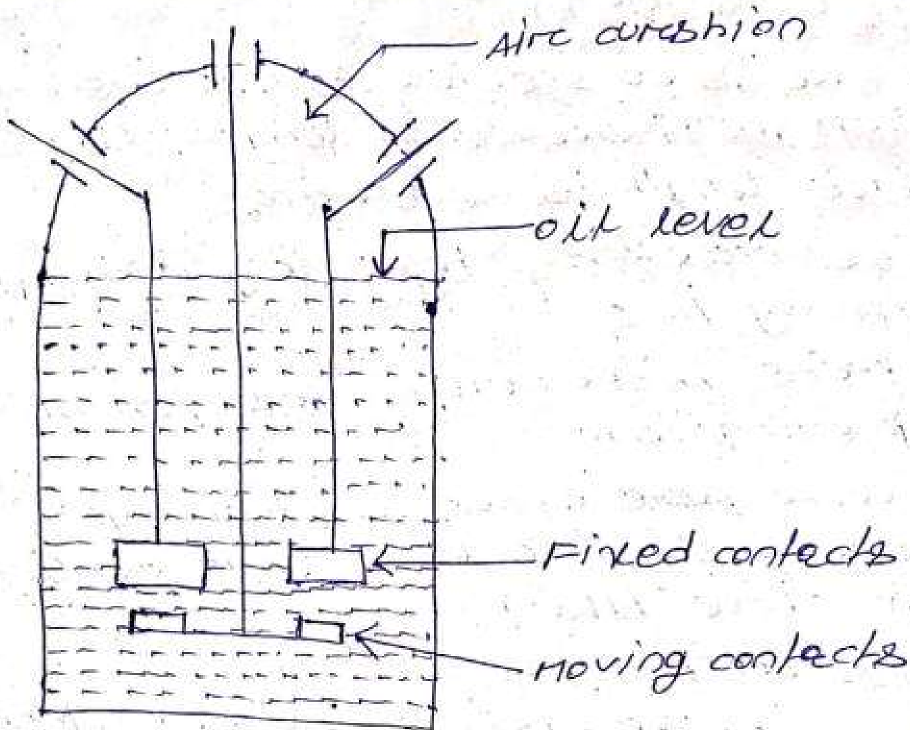
CONSTRUCTION

→ The plain OCB is the earliest type from which all other CB have develops. It has very small construction.

→ It consist of a fixed and moving contacts and closed in a strong weather-tight earthed tank containing oil up to a certain level and an air cushion above the oil level.

→ The air cushion provides sufficient space to allow for the reception of the arc gases without the generation of unsafe pressure in the dome of the CB. It also absorbs of the mechanical shock of the upward oil movement.

→ The below fig. shows a double break plane OCB it is called so because it provides two breaks in series.



OPERATION

→ under normal operating condition the fixed and moving contacts remain closed and the breaker carries the normal current.

→ when a fault occurs the moving contacts are pulled down by protective system then an arc is struck which vapourises the oil mainly into hydrogen gas.

→ The arc extinction occure by following process.

a. The hydrogen gas bubbles generated around the arc cool the arc column and add deionisation of the medium between the contacts

b. The gas set up turbulence in the oil and helps in eliminating the arcing product from the arc path.

c. As the arc lengthens due to the ~~spe~~ separating contacts and dielectric strength of the medium is increased.

→ Hence this ~~method~~ results is that at some critical gap length the arc is extinguished and fault current is interrupted.

DISADVANTAGES

→ There is no special control over the arc other than the increase in length due to which long arc length is necessary.

→ The breakers have long and inconsistent arcing time

→ These breaker do not permit high speed interruption.

* Due to ~~have~~ above disadvantages these CB are used for low voltage application (i.e not above 11kV)

iii) ARC CONTROL OCB

→ In case of plain break OCB, there is very little artificial control over the arc. Therefore long arc length is essential in order that turbulence in the oil caused by the gas may quench the arc.

→ However it is necessary and desirable that final arc extinction should occure while the contact gap is still short.

→ For this purpose some arc control method is incorporated and then the breakers are called as arc control C.B.

→ There are two type of such breakers.

1. self blast OCB
2. Forced blast OCB.

1. SELF BLAST OCB

→ In this type of OCB the gases produced during arcing period are confined to a small volume by the use of an insulating rigid pressure chamber or pot surrounding the contacts.

→ since the space for the arc gases is restricted by the chamber a very high pressure is developed to forced the oil and gas around the arc to extinguished it.

→ The magnitude of pressure developed depends upon the value of fault current to be interrupted.

→ As the pressure generated by the arc itself therefore such breakers as also called self generated pressure OCB.

→ The pressure chamber is relatively cheap to make and gives reduce final arc extinguish gap length and arcing time as against the plain break OCB.

→ several designs of pressure chamber has been develop there as below.

(a) plain explosion pot
(b) cross jet explosion pot
(c) self-compensated explosion pot

2. FORCED BLAST OCB

→ In the self-blast OCB, the arc itself generates the necessary pressure to force the oil across the arc path.

→ The maibre limitation of such breakers is that arcing times tend to be long and inconsistent when operating against currents considerably less than the rated current.

→ It is because the gas generated is much reduce at low values of fault current.

→ This difficulty is overcome in forced-blast OCB in which the necessary pressure is generated by external mechanical means independent of the fault current to be broken

→ In a forced-blast OCB, oil pressure is created by the piston-cylinder arrangement.

→ The moment of the piston is mechanically coupled to the movement contact.

→ when a fault occure, the contact get seperated by the potecting system and arc is struck between the contact.

→ The piston forces ~~got~~ a jet of oil towards the contact gap to extinguish the arc.

→ it may be noted that necessary oil pressure produced does not in any way depend upon the fault current to be breaken.

ADVANTAGES

a. since oil pressure developed in independent of fault current to be interrupted, the performance at low currents is more consistent than with self-blast OCB.

b. The quantity of oil required considerably.

2. LOW OIL CIRCUIT BREAKER (IMP)

CONSTRUCTION

The cross-section of low OCB as shown in the below fig. There are two compartment separate from each other but both filled with oil.

→ The upper chamber is the ckt breaking chamber while the ~~low one~~ lower one is the supporting chamber.

→ The two chamber is separated by ~~the~~ a partition and oil from one chamber is prevented from ~~the cham~~ mixing with the other chamber.

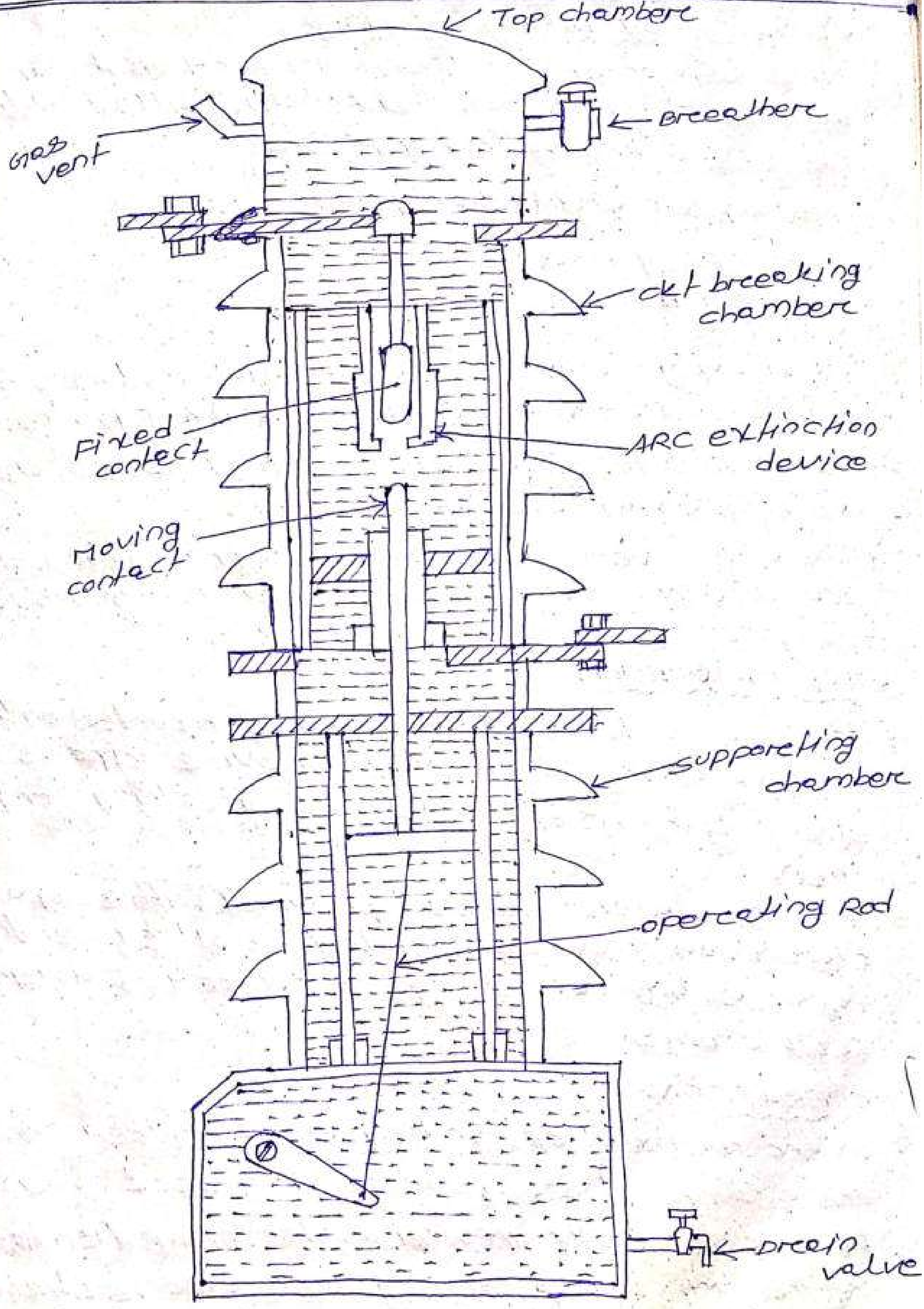
→ This arrangement has two advantages.

a. The ckt breaking chamber required a small volume of oil which enough for arc extinction.

b. The amount of oil to be replaced is reduced as the oil in the supporting chamber does not contaminated by the arc.

SUPPORTING CHAMBER

→ It is porcelain chamber mounted on a metal chamber. It is filled with oil which is separated from ckt breaker chamber.



→ The oil inside the supporeting chamber and the annulare space formed between the porcelain insulation and Bakelite papere is employed fore insulation purpose only.

CIRCUIT-BREAKING CHAMBER

It is a porclain enclosure mounted on the top of the supporting compartment. It is filled with oil and it has following parts.

a. upper and lower fixed contact
b. Moving contact
c. Turbulator.

→ The moving contact is hollow and includes a cylinder which moves down over a fixed piston.

→ The turbulator is an arc control device and has both axial and radial vents.

→ The axial vents ensure the interruption of low current where as radial venting helps in the interruption of heavy currents.

TOP CHAMBER

→ It is a metal chamber and is mounted on the ckt breaking chamber. it provide expansion space for the oil in the ckt. breaking compartment.

→ The top chamber is also provided with a separator which prevents any loss of oil by centrifugal action caused by C.B operation during fault occurs.

OPERATION

under normal operating condition the moving contact is closed with fixed contact. when a fault occurs the moving contact is pulled down by the tripping ~~pr~~ spring. then arc is stracked

→ The arc energy vapourise the oil and produces gases under high pressure.

→ These action creats terbulance in the oil to pass through a central hole. in moving contact and results in forcing series of oil through the passage of terbulance.

→ The process of turbulation is orderly one, in which the sections of the arc ~~arc space~~ is quenched by the effect of steams of oil moving across each section in term and bearing away its gases.

ADVANTAGES

→ It requireds lesser quantity of oil
→ It requires smaller space.
→ There is reduced risk of fire
→ Maintenance problem are reduced.

DISADVANTAGES

→ Due to small quanity of oil degree of carbonisation is increased.
→ There is difficulty of removing the gases from the contact space in time.
→ The dielectric strength of the oil decreases rapidly due to high degree of carbonization.

MAINTENANCE OF OCB

→ After a C.B has interrupted of fault current several times, it contacts may lose some of its dielectric strength due to some of its dielectric strength due to carbonisation.
→ This results in reduced repturing capacity of the breaker. Hence it is necessary to inspect or maintain the CB at regular interval of 3 or 6 month.

→ During inspection of the breaker, following point should be kept in view.

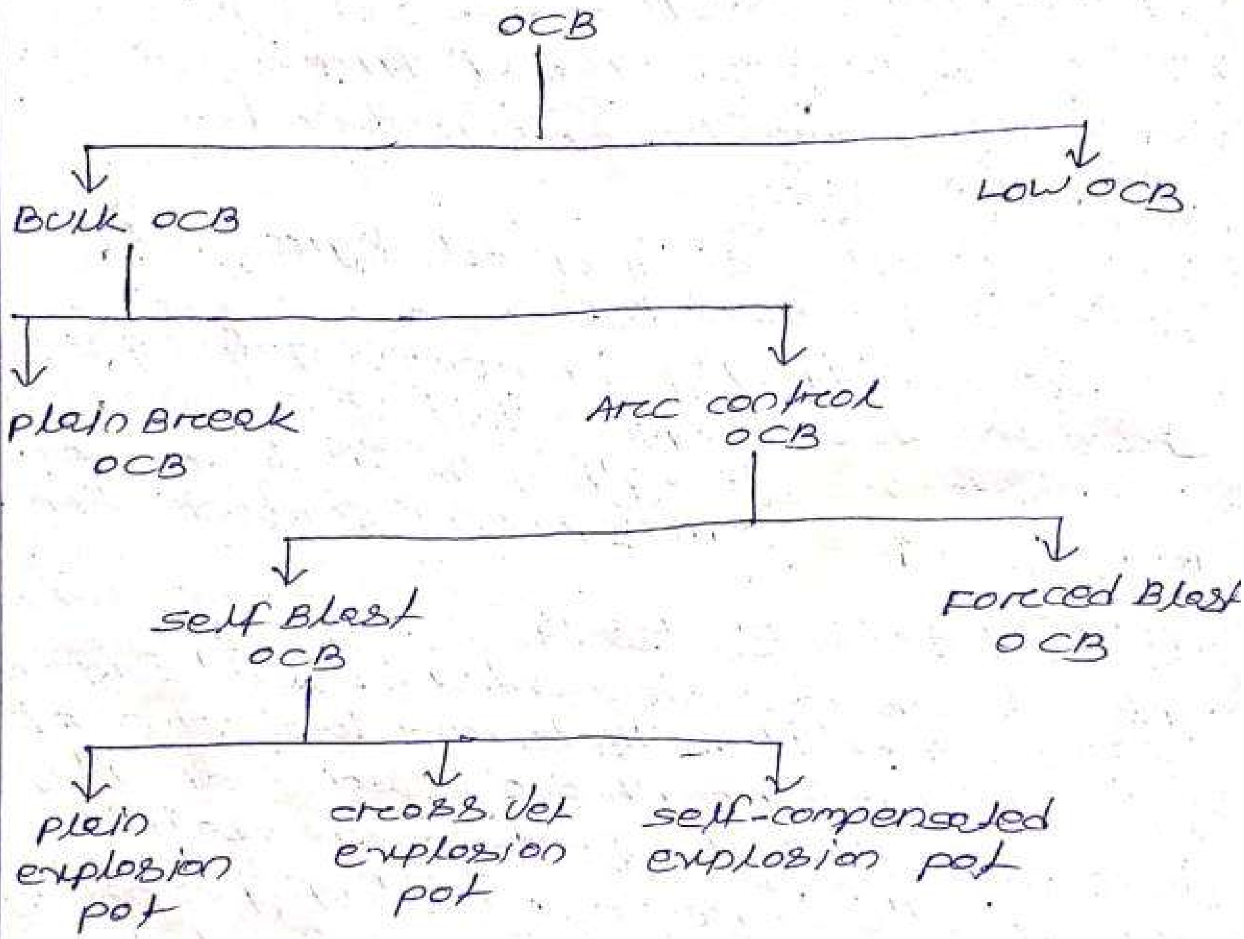
i. check the current carrying paths and arcing contacts. If the burning is severe, the contact should be replaced.

ii. check the dielectric strength of oil if the oil is badly discoloured, it should be changed of replaced.

→ check the insulations for possible damage. clean the surface and remove carbon deposits with a strong and dry fabric.

→ check the oil level

→ check clossing the tripping mechanism.



2. AIR-BLAST OCB

→ These breakers employ a high pressure air blast as an arc quenching midium.

→ The contacts are open in a flow of air blast established by opening of blast valve.

→ The air blast cools the arc and sweep away the arcing product to the atmosphere.

→ This rapidly increases the dielectric strength of the midium between the open contact and prevents from reestablising the arc hence the arc is extinguish and flow of current is interoupted.

TYPES OF AIR-BLAST CKT BREAKER

1. Axial Blast Aire C.B
2. cross Blast Aire C.B
3. Radial Blast Aire C.B

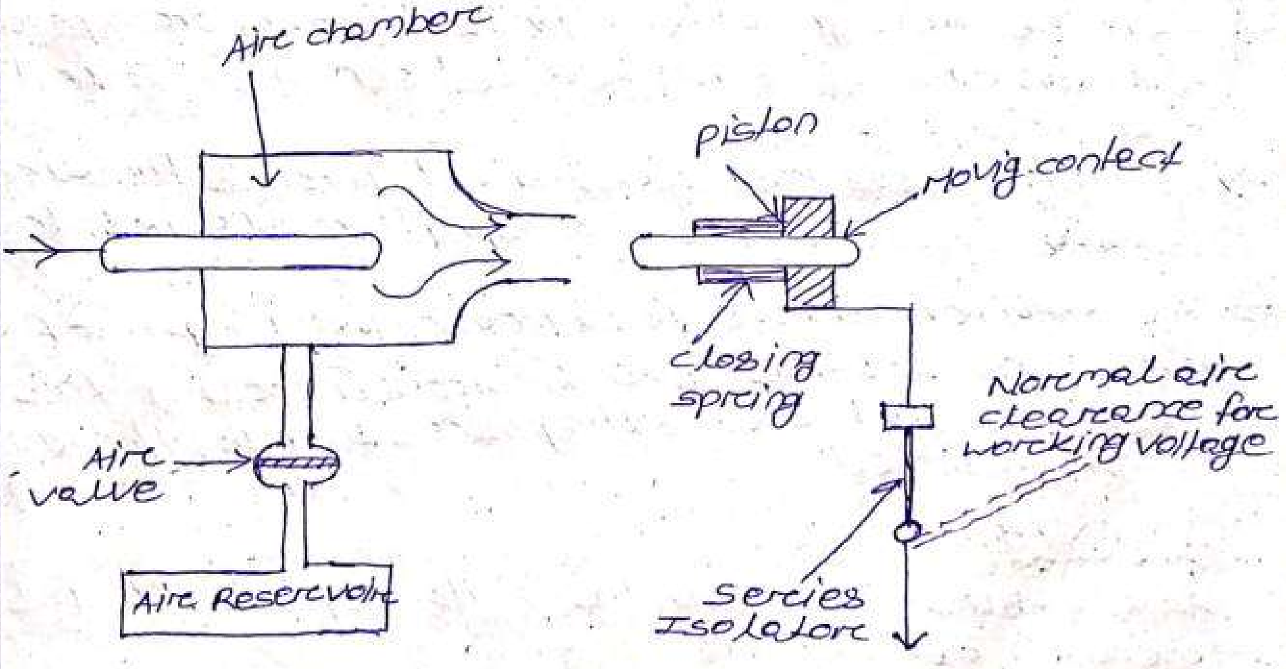
1. AXIAL BLAST AIR C.B

The below fig shows the essential parts of axial blast aire C.B.

→ The fixed and moving contacts are held in the closed position by spring pressure under normal condition.

→ The aire reservoire is connected to the arcing chamber through an aire valve. these valve remain closed under normal condition. But opens automatically by the tripping impulse when a fault occures on the system.

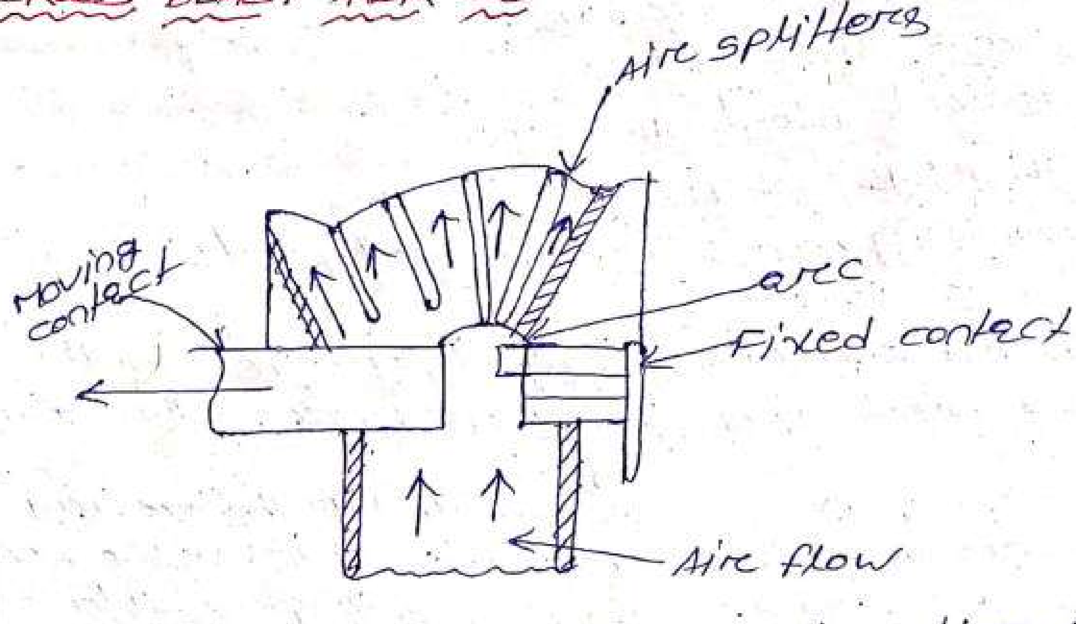
→ when a fault occures the tripping ~~mechanist~~ impulse cause opening of aire valve which connects the C.B reserviour to arcing chamber.



→ The high pressure entering the arcing chamber pushes away the moving contact against spring pressure the moving contact is separated and the arc is struck.

→ At the same time high pressure aire blast flows along the arc and takes away the ionised gases along with it. Hence the arc is extinguished when fault current interrupted.

2. CROSS BLAST AIR C.B



→ In this type of CB an air blast is directed at right angle to the arc.

→ The cross blast lengthens the arc and forces the arc in to a suitable slope for arc extinction.

→ When the moving contact is withdrawn or separated an arc is strucked between the fixed and moving contact

→ The high pressure cross-blast forces the arc ~~in to a~~ consisting a arc splitter and baffles.

→ The splitter serve to increase the length of arc and baffles give improved cooling this results in that arc extinguishes and fault current is interrupted

ADVANTAGES

An air-blast C.B has the following advantages over an oil ckt breaker.

i. The risk of fire is eliminated.

ii. The arcing products are completely removed by the blast where as the oil detoriorates 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 rapid build up of dielectric strength between contacts. Therefore, the arcing energy in only a fraction of that in OCB, thus resulting is less burning of contacts.

v. Due to less arc energy, air blast C.B are very suitable for conditions where frequency operation is required.

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

DISADVANTAGES

The use of air as the arc quenching midium offers the following disadvantages:

i. The air has relatively inferior arc extinguishing properties.

ii. The air blast ckt breaker are very sensitive to the variation in the rate of rise of restriking voltage.

iii. considerable maintenance required for the compressor plant which supplies the air-blast.

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

SULPHUR HEXAFLOURIDE (SF_6) CIRCUIT BREAKER

CONSTRUCTION IMP

The below fig shows the parts of SF_6 C.B.

→ It consist of fixed and moving contacts enclosed in a chamber containing SF_6 gas. This chamber is connected to SF_6 gas reservoir.

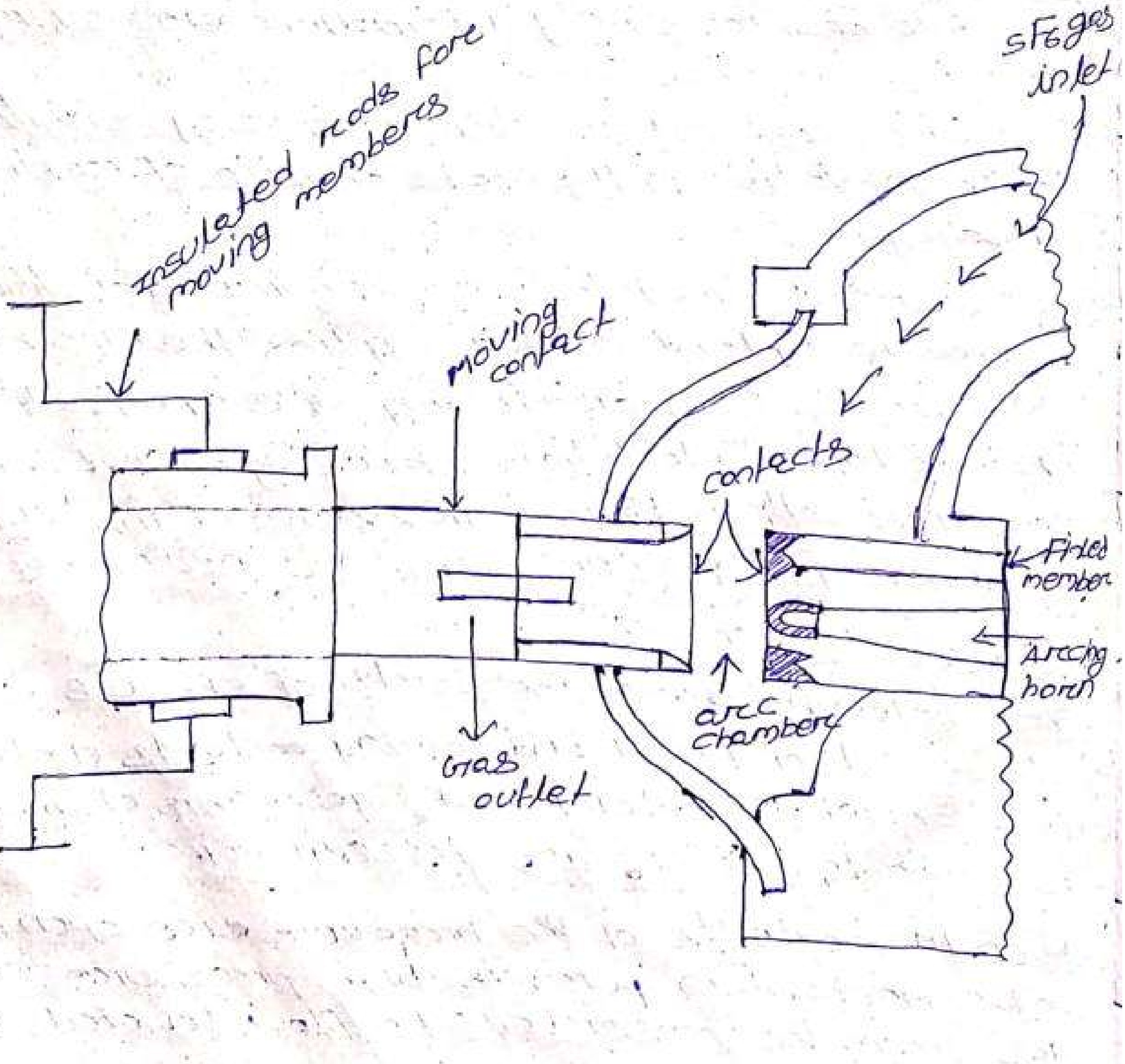
→ when the contacts of the breaker are open the valve mechanism permits high pressure SF_6 gas from the reservoir to flow towards arc interruption chamber.

→ The fixed contact is the hollow cylindrical current carrying contacts fitted with an arc horn.

→ The moving contact is also hollow cylinder with the rectangular holes in the sides to permit the SF_6 gas to let out through ~~sie~~ these holes after flowing along and across the arc.

→ The tip of fixed contact, moving contact and arcing horn are coated with copper-tungsten ~~are~~ arc resistant material.

→ Since SF_6 gas is costly it is recondition and retained by suitable auxillary system after each operation of the breaker.



WORKING

- In a closed position of the breaker the contact remain surrounded by SF_6 at a pressure of about 2.8 kg/cm²
- When the breaker operates the moving contact is pulled apart and the arc is struck between the contacts.
- The movement of moving contact is synchronized with the opening of a valve which permits the SF_6 gas at 14 kg/cm² pressure from the reservoir to the arc interruption chamber.
- The high pressure flow of SF_6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective. The result is that the medium between the contacts quickly build of high dielectric strength and causes arc extinction.
- After the CB operation or after arc extinction the valve is closed by the action of a set of spring.

ADVANTAGES

- Due to the superior arc quenching properties of SF_6, these breakers have very short arcing time.
- Since the dielectric strength of SF_6 gas is 2 to 3 times that of air such breaker can interrupt larger current.
- The SF_6 C.B gives a noise less operation due to its ~~closing~~ closed gas ckt.
- The closed gas enclosure keeps the interior dry so that there is no moisture problem.
- There is no risk of fire because SF_6 gas is not inflammable.
- There are no carbon deposits so that insulation problem are eliminated.

→ The SF_6 breaker have no maintenance cost, light foundation requirements and minimum ~~ox~~ auxiliary equipment.

DISADVANTAGES

→ SF_6 breaker are costly because of cost ~~for~~ of SF_6 gas.

→ since SF_6 gas has to be recombined or re-condition after every operation of breaker additional equipment is required.

APPLICATION

→ SF_6 C.B is consist of interrupter units each capable of dealing with current up to ~~60k~~ ~~and~~ 60 kA and voltage in the ranges of 50 to 80kV

~~VACCU~~

VACUUM CIRCUIT BREAKER

PRINCIPLE

since vacuum offers highest insulating strength it has superior ~~arc~~ arc quenching properties then any other midium.

→ when the contacts of the breaker are open in vacuum are arc will produce between the contacts by the ionisation of metal vapoure of contacts.

→ However the arc is queckly extinguished because the metalic vapoures electrons and ions produced during arc rapidly condences on the surfece of C.B contacts, resulting in quick recovery of dielectric strength it reduces the arc.

CONSTRUCTION

The ~~b~~ below fig. shows the parts of vaccum C.B. It consist of fixed contect, moving contect and arc shield mounted inside a vaccume chamber

→ The moveable membere is connected to the controol mechanism by stainless steel bellows this enable the peremenet sealing of vacuum chambere so at to eliminate the possibility of leak.

→ A gas vessel or ceramic vessel is used as the outere insulating body the arc ~~his~~ shield pervents the deterciation of the internal dielectreic streangth by preventing metalic vapoures falling on the inside surface of the outtere insulating cover.

WORKING

→ when the breakere operate the moving contact separeate for fixed contact and an arc is ~~t~~ struck between the contact.

→ The production of arc is due to the ionisation of metal ions and depends very much ~~of~~ upon the metal of contact.

→ The arc is quickly extinguished because the metalic vapoures the ions produced dureing arc are defused in a shoretime and seized by the surface of moving and fixed members and arc shields. since vacuum helps very first rate of recovery of dielectric streength the arc ~~is~~ extingction in a vacuum C.B occurs with a short contact separation

ADVANTAGES

Vacuum C.B. has following advantages

→ They are compact, reliable have longere life

→ There are no fire hazards.

→ There is no generation of gas dureing and aftere operation

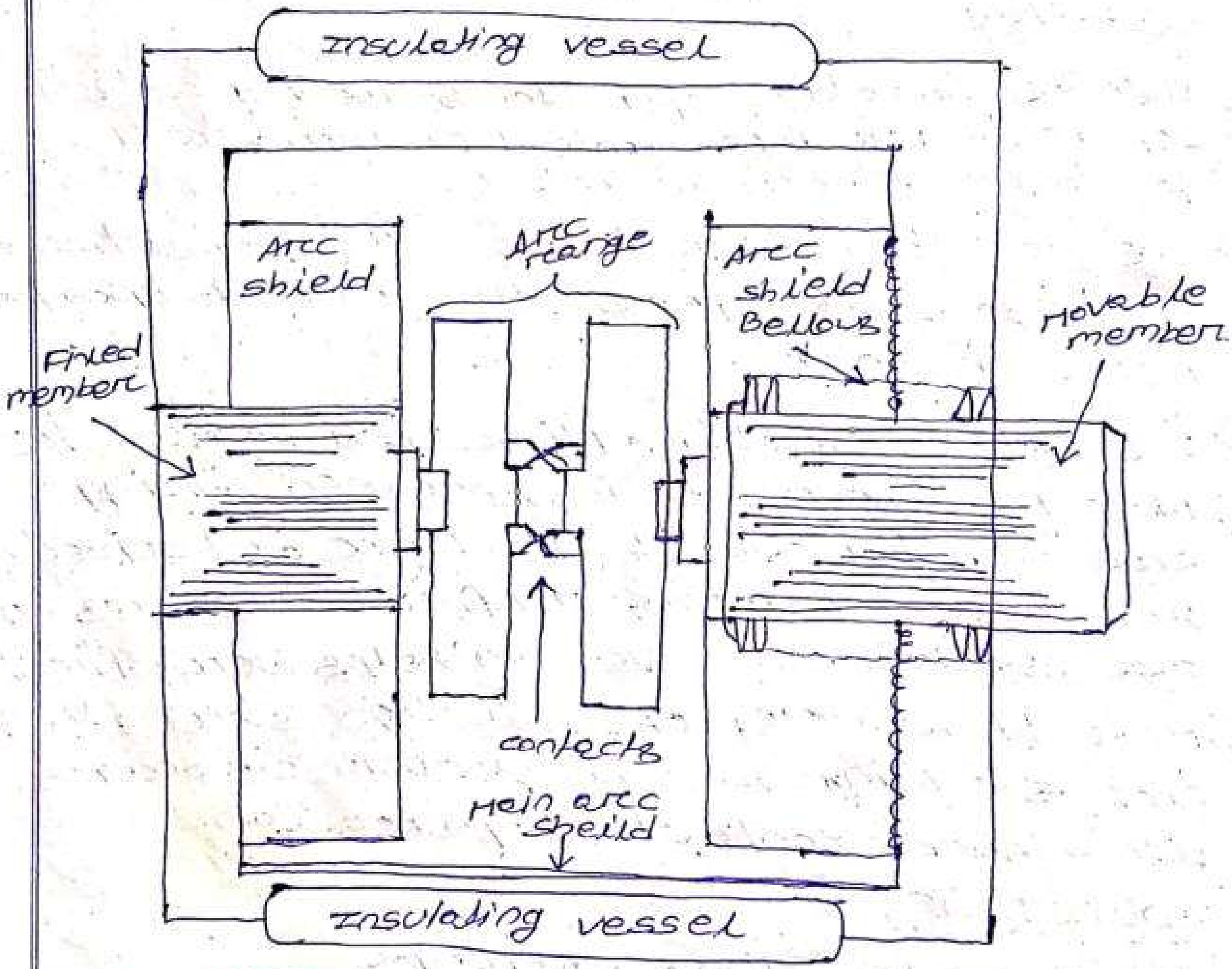
→ They can interrupt any fault current. The outstanding feature of a VCB is that it can be break any heavy fault curerent ~~pefe~~ perfectly just before the contacts reach the definite open position.

→ They required little maintenance and are quiet in operation.

→ They can successfully withstand lighting surges

→ They have low arc energy.

→ They have low ~~initial~~ interetia and hence required smaller power for control mecanism.



APPLICATION

→ vacuum C.B are being employed for outdoor applications ranging from 22kV to 66kV. Even with limited rating of say 60 to 100MVA, they are suitable for a majority of applications in rural areas.

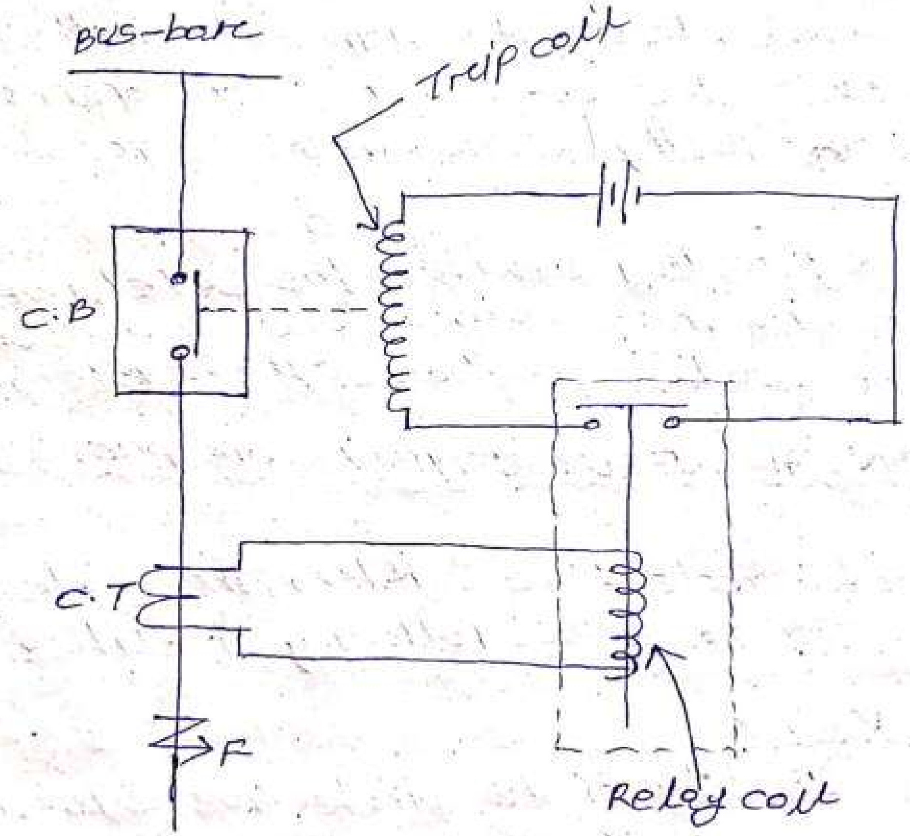
CHAPTER-5

PROTECTIVE RELAY

→ A protective relay is a device that detect the fault and initiates the operation of the C.B to isolate the defective element from the rest of the system.

→ The relay detect the abnormal condition in the electrical ckt by constantly measuring the electrical quantities which are different under normal & fault condition.

→ The electrical quantity which may change under fault conditions are voltage, current, frequency and phase angle.



→ A typical relay ckt is shown in the above fig. This diagram shows one phase of 3φ system for simplicity.

→ The relay ckt connections can be divided into three parts

(i) First part is the primary winding of a current transformer (C.T) which is connected in series with the line to be protected.

(ii) second part consists of secondary winding of C.T. and the relay operating coil.

(iii) Third part is tripping ckt which may be either a.c. or d.c. It consist of a source of supply, the trip coil of the ckt breaker and the relay stationary contacts.

→ When a short ckt occurs at point F on the transmission line, the current flowing in the line increases to an ~~enormous~~ higher value.

→ This result in a heavy current flow through relay coil, causing the relay to operate by closing its contacts.

→ This in turn closes the trip ckt of the breaker, making the circuit breaker open and isolating the faulty section from the rest of the system.

→ In this way relay ensures the safety of the ckt equipment from damage and normal working of the healthy portion of the system.

FUNDAMENTAL REQUIREMENT OF PROTECTIVE RELAY

→ In order to protect the system, the protective relay should have the following qualities.

1. SELECTIVITY

It is the ability of the protective system to select correctly that ~~path~~ part of the system which is in trouble (fault) and disconnect the faulty part without disturbing the rest of the system.

2. SPEED

The relay system should disconnect the faulty section as fast as possible. ~~for the~~

3. SENSITIVITY

It is the ability of the relay system to opperate with low value of actuating quantity.

4. RELABILITY

It is the ability of the relay system to operate under the pre-determined conditions. without reliability, the protection would be ~~rendered~~ largly ineffective.

5. SIMPLYCITY

The relaying system should be simple so that it can be easyly maintained.

6. ECONOMY

The most important factore in the coice of perticulare protection system is the economic aspect. The protective system should not more than ~~[illegible]~~ of the total cost.

DIFFERENCE BETWEEN C.B AND FUSES (privious chapter)

Sl.No.	perticulare	FUSE	CIRCUIT BREAKER
01	Function	→ It performs both detection and interruption function	→ It performs interruption function only the detection of fault is made by relay.
02.	operation	→ completely automat ~~ically~~ ic.	→ It requires extra equipment (i.e relay) fore automatic action.
03.	Breaking capacity	→ small	→ very large.
04.	operating time	→ very small (i.e 0.002 sec)	→ compairatively large (0.1 to 0.2 sec)
05.	Replacement	→ Requires replacement after every operation	→ No replacement after operation.

BASIC RELAY

Most of the relay in service one electrical power system are of electro mechanical type they work on the following two main operating principles.

1. Electomagnetic attraction relay
2. Electromagnetic induction relay.

1. ELECTROMAGNETIC ATTRACTION RELAY

Electromagnetic attraction relay operate by vertue of an armature being attracted to the poles of an electromagnet or a plunger being drawn in to solenoid.

→ such relay may be actuated by DC or AC ~~quantit~~ quantities.

→ The important types of electomagnetic attraction relay are-:

(a) Attracted armature type relay
(b) solenoid type relay
(c) Balanced beam type relay

a. ATTRACTED ARMATURE TYPE RELAY

The below fig. shows the arrangement of attracted armature type relay.

→ It consist of laminated electromagnet M carrying a coil 'c' and a pivoted laminated armature.

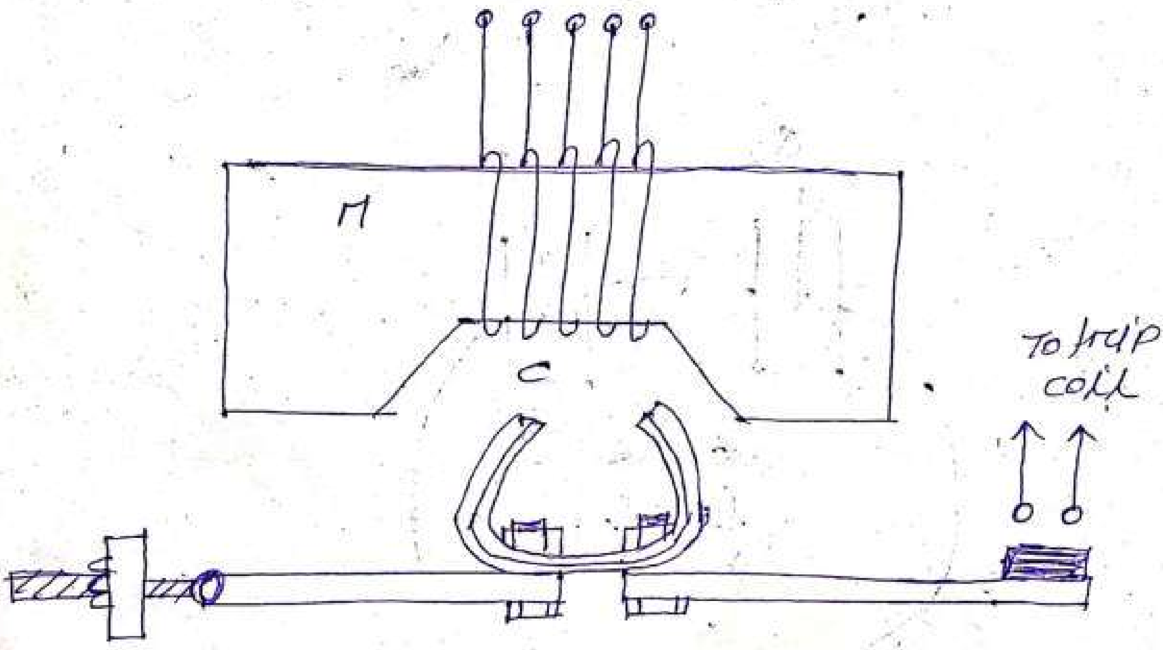
→ The armature is balanced by a counter weight carries a pair of spring, contact fingers at its free end.

→ under normal operating condition the current through the relay coil 'c' is such that counter way holds the armature ~~is attracted~~ in the position as shown in the fig.

→ However when a short ckt occures the current through the relay coil increases sufficiently and the relay armature is attracted upwords.

→ The contact on the relay armature bridge a pair of stationary contact ~~at tree~~ attached to the relay frame.

→ This complete the trip ckt which results in the opening of C.B and therefore it disconnect the faulty section



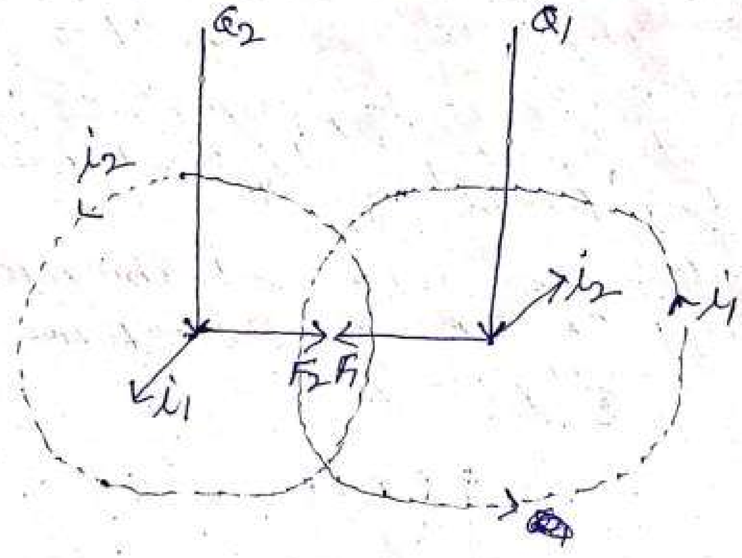
2. ELECTRO MAGNETIC INDUCTION RELAY

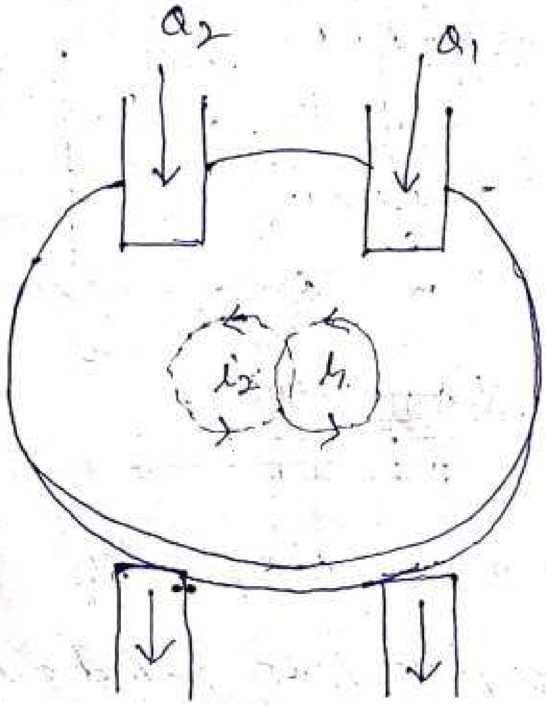
→ It operate on the principle of induction motor are widely used for protective relaying purpose involving AC quantities.

→ There not used with DC quantity for it operations.

→ An induction relay essentially consist of pivoted 'Al' disc placed in ~~to~~ two alternating magnetic field of the same frequency ~~but~~ displaced in ~~this~~ time and space.

→ The torque is produced on the disc by the intersection of one of the magnetic field in the current induced in the disc ~~by~~ the other.





$\phi_1 = \phi_{1max} \sin\omega t$

$\phi_2 = \phi_{2max} \sin(\omega t + \alpha)$

→ The two AC fluxes ϕ_2 and ϕ_1 differing in phase by an angle α then the induced emf in the disc and cause the circulation of eddy current. i_2 and i_1 respectivly there current lag behind there respective fluxes by 90°

$$\phi_1 = \phi_{1max} \sin \omega t$$

$$\phi_2 = \phi_{2max} \sin(\omega t + \alpha)$$

where ϕ_1 and ϕ_2 are the instantaneous value of fluxes and ϕ_2 leads ϕ_1 by an angle α.

$$e \propto \frac{d\phi}{dt}$$

$$i \propto \frac{d\phi}{dt}$$

$$i_1 \propto \frac{d\phi_1}{dt}$$

$$i_1 \propto \frac{d}{dt}(\phi_{1max} \sin \omega t)$$

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

$$i_2 \propto \frac{d\phi_2}{dt}$$

$$i_2 \propto \frac{d}{dt}(\phi_{2max} \sin(\omega t + \alpha))$$

$$i_2 \propto \phi_{2max} \cos(\omega t + \alpha)$$

$$F_1 \propto \phi_1 i_2$$

$$F_2 \propto \phi_2 i_1$$

Net force 'F' at the instant is

$$F \propto F_2 - F_1$$

$$F \propto \phi_2 i_1 - \phi_1 i_2$$

$$F \propto \phi_{2max} \sin(\omega t + \alpha) \cdot \phi_{1max} \cos \omega t - \phi_{1max} \sin \omega t \, \phi_{2max} \cos(\omega t + \alpha)$$

$$F \propto \phi_{1max} \phi_{2max} (\sin(\omega t + \alpha) \cdot \cos \omega t - \sin \omega t \cdot \cos(\omega t + \alpha))$$

~~$F \propto \sin(\omega t + \alpha - \omega t)$~~

~~$F \propto \sin(\alpha)$~~

$$F \propto \phi_{1max} \phi_{2max} \sin(\omega t + \alpha - \omega t)$$

$$F \propto \phi_{1max} \phi_{2max} \sin \alpha$$

$F \propto \phi_1 \phi_2 \sin\alpha$

where ϕ_1 and ϕ_2 are the r.m.s value of fluxes.

→ The following points may be noted from eq(1)

a. Grater the phase angle α between the fluxes, the greater is the net force applied to the disc. the maximum flux will produced when the two fluxes are 90° out of phase.

b. The net force is the same at every instant but this fact does not depend upon the assumptions made in arriving at eq(1)

c. The direction of the net force and hence the direction of motion of disc depends upon which flux is leading.

IMPORTANT TERMS

1. PEAK-UP VOLTAGE

It is the minimum current in the relay coil at which the relay starts to operate.

→ so long as the current in the relay coil is less than the peak-up value of the relay does not operate and the breaker controlled by it remains in closed position.

2. CURRENT SETTING

→ It is often desireable to adjust the peak-up current to any required value. this is known as current setting.

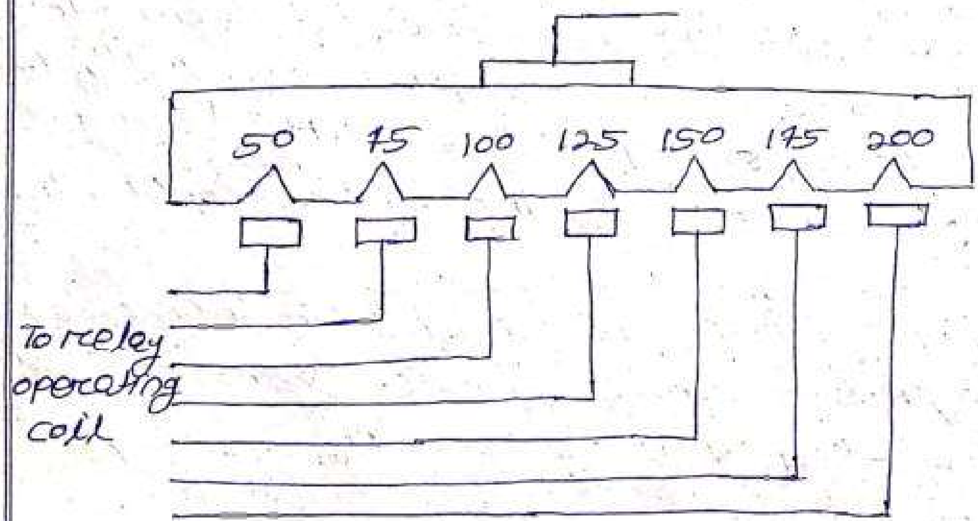
→ This is usually achived by the use of tappings on the relay operating coil. ~~The taps are brought together~~

→ The tapping are brought out to a plug bridge as shown in the below fig. The plugs bridge permits to alter the no. of turns on the relay coil

→ The changes the torque on the disc and hence the time of operation of relay.

→ The value of assigned to each tap are expressed in term of percentage full-load rating of C.T. with which relay is assosiated and represent the above value which is the disc commences to rotate and finally closes the trip circuit

pick-up current = Rated secondary current of C.T X current setting



3. PLUG SETTING MULTIPLIER (P.S.M) IMP

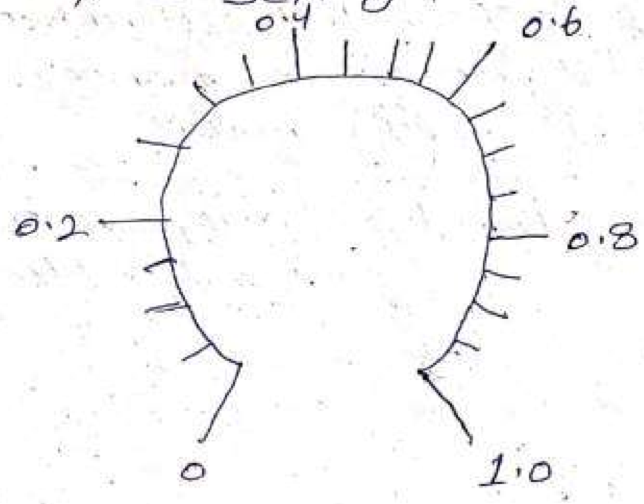
→ It is the ratio of fault current in the relay coil to the peak-up current.

$$P.S.M = \frac{\text{Fault current in the relay coil}}{\text{peak-up current}}$$

$$= \frac{\text{Fault current in the relay coil}}{\text{Rated secondary current of C.T X current setting.}}$$

4. TIME SETTING MULTIPLIER (TSM) Imp

A relay is generally provided with control to addust the time operation this adjustment is known as time setting multipliere.



→ The time setting dial is calibreated from 0 to 1 steps of 0.05 sec. These figurees are multiplier to be use to convert the time derived from time/P.S.M. curve in to the actual operating time.

→ If the time setting is 0.1 and the time obtain from Tim/P.S.M curve is 3 sec then actual relay operating time is 3×0.1 = 0.3 sec

FUNCTIONAL RELAY

→ Relay are generally clasified according to the function they perform for the protection of electric power ckt.

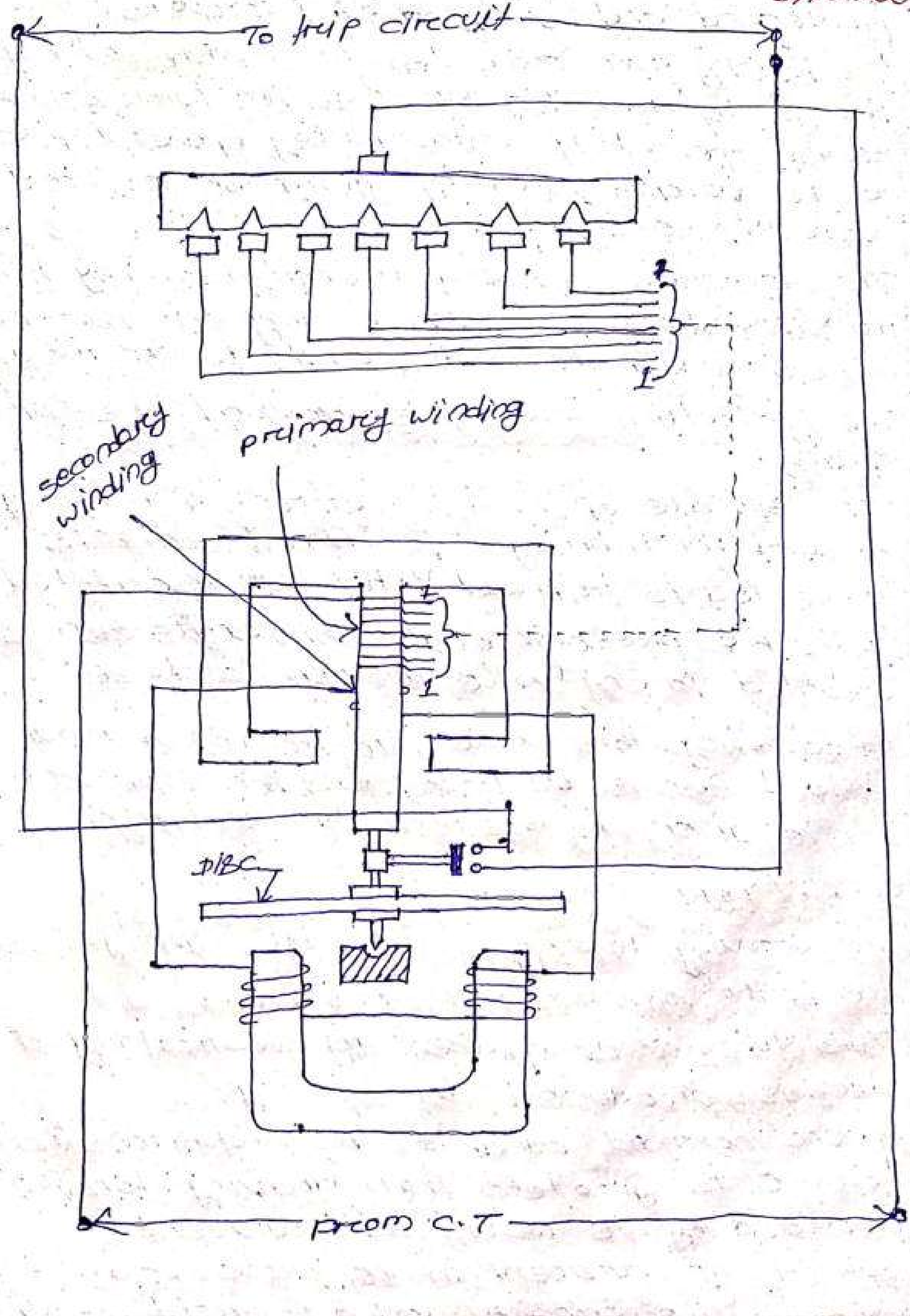
→ A relay which reconises over current in a ckt and initiates corrective measures would be termed as an overcurrent relay irrespective of the relay design.

→ similarly an over voltage relay is one which reconises overvoltage in a ckt.

→ The following important types will be discussed in this chapter

1. Induction type overcurrent relays
2. Induction type reverse power relay.
3. Distance Relay.
4. Differential relays
5. Translay scheme.

1. INDUCTION TYPE OVERCURRENT RELAY (non-directional)



CONSTRUCTION

→ The above fig. show the construction of non-directional induction type over current relay.

→ It consist of a metalic disc (AL) which free to rotate in between the pole of two electromagnet.

→ The upper electromagnet has a primary and a secondary winding. The primary is connected to the secondary of C.T in the line to be protected and is tapped at intervals.

→ The tapping are connected to a plug setting bridge by which the no. of active turn on the relay operating on the relay operating coil can be varied, thereby giving the desired current setting.

→ The secondary winding is energized by induction principle from primary winding and is connected in series with the winding on the lower magnet.

→ The controlling torque is provided by a spiral spring.

→ The spindle of the disc carries a moving contact which bridges two fixed contacts (connected to trip ckt) when the disc rotate through a present angle this angle can be adjusted to any value between '0' to 360'.

→ By adjusting this angle, the travel of moving contact can be adjusted and hence the relay can be given any desired time setting.

OPERATION

→ The driving torque on the 'AL' disc is set up due to the induction principle.

→ This torque is opposed by restraining torque which is produced by spring.

→ under normal condition ~~restriction~~ restraining torque is greater than driving torque produced by the relay coil current.

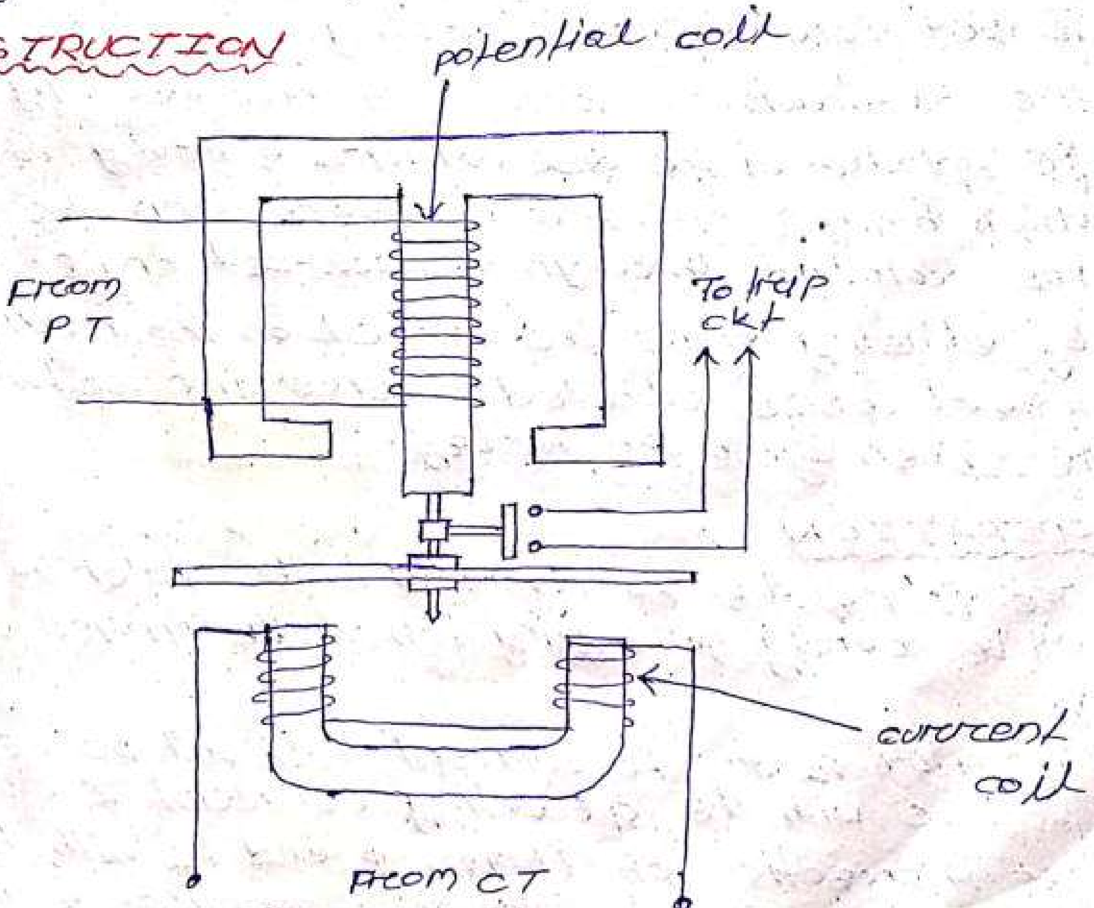
→ But, if the current in the protected ckt exceeds the pre-set value (current setting) the driving torque become greater than the restraining torque & hence the disc rotate and the moving contact bridges the fixed contact when the disc rotate through a pre-set angle.

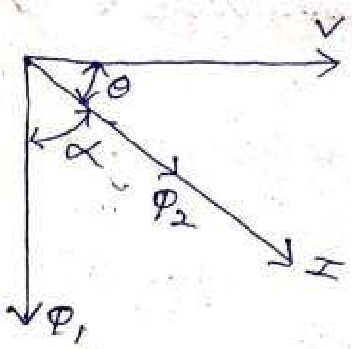
→ The trip ckt operated the C.B which disconnect the faulty section.

INDUCTION TYPE DIRECTIONAL POWER RELAY

→ This type of relay operates when power in the ckt flows in a specific direction. Thus this type of relay is essentially a wattmeter and direction of the torque set up in the relay depends upon the direction of the current relative to the voltage with which it is associated

CONSTRUCTION





CONSTRUCTION

→ The above fig. shows the typical induction typical directional power relay.

→ It consist of a 'Al' disc which is free to rotate in between the poles of two electromagnets.

→ The upper electromagnet carries a winding (called potential coil) on the central limb. Which is connected through a potential transformer (PT) to the ckt voltage source.

→ The lower electromagnet has a separated winding (called current coil) connected to the secondary of C.T in the line to be protected.

→ The current coil is provided with no. of tappings connected to the plug setting bridge which is used for current setting.

→ The restraining torque is provided by spring the spindle of the disc carries a moving contact which bridges two fixed contacts when the disc has rotated through a pre-set angle.

→ By adjusting angle the travel on the moving contact can be adjusted & hence time setting can be given by to the relay.

OPERATION

→ The flux ϕ due to current in the potential coil will be nearly 90° lagging behind the applied voltage V.

→ The flux ϕ_2 due to current coil will be nearly in phase with the operating current I.

→ The interaction of fluxes ϕ_1 and ϕ_2 with the eddy currents induced in the disc produces a driving torque given by.

$$T \propto \phi_1 \phi_2 \sin\alpha$$

since $\phi_1 \propto V$, $\phi_2 \propto I$

$$T \propto VI \sin(90-\theta)$$
$$\propto VI \cos\theta$$
$$\propto \text{power in the ckts}$$

→ It is clear that the direction of driving torque on the disc depends upon the direction of power flow in the ckt to which the relay is associated.

→ When the power in the ckt flow in the normal direction, the driving torque and the restraining torque (due to spring) help each other to turn away the moving contact from the fixed contacts.

→ Consequently, the relay remains inoperative. However, the reversal of current in the circuit reverses the direction of driving torque on the disc.

→ When the reverse driving torque is large enough, the disc rotates in the reverse direction and the moving contact closes the trip ckt.

→ This causes the operation of the ckt breaker which disconnects the faulty section.

INDUCTION TYPE DIRECTIONAL OVERCURRENT RELAY

→ The directional power relay is unsuitable for use as a directional protective relay under short ckt condition.

→ When a short ckt occurs the system voltage ~~faults~~ falls to a low value and there may be insufficient torque developed in the relay to causes its operation.

→ This difficulty is overcome in the directional overcurrent relay which is designed to be almost independent of system voltage and power factor.

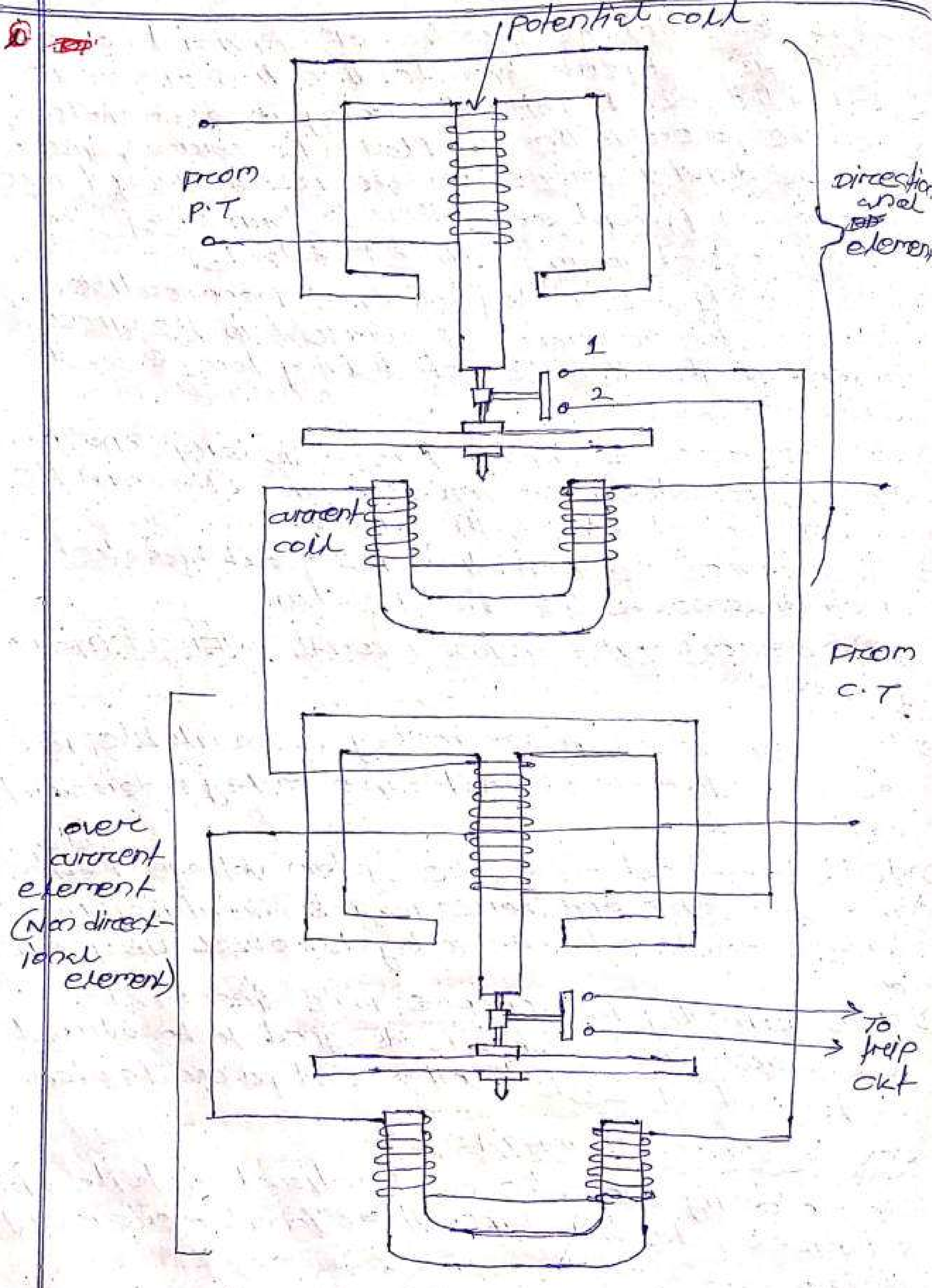
CONSTRUCTIONAL DETAILS

The below fig shows the constructional details of a typical induction type directional overcurrent relay.

→ It is consist of two relay elements mounted on a common case

i. Directional element

ii. Non-directional elements



potential coil
From P.T
directional element
1
2
current coil
From C.T
over current element (Non direct-ional element)
To trip ckt

i. Directional element

It is essentially a directional power relay which operates when power flows in a specific direction.

→ The potential coil of this element is connected through a potential transformer to the system voltage.

→ The current coil element ~~are~~ energised through a C.T. by the ckt current. This winding is carried over the upper magnet of the non-directional element.

→ The trip contact (1 & 2) of the directional element are connected in series with the secondary ckt of the overcurrent element.

→ Therefore the latter element cannot start to operate until ~~its~~ its secondary ckt is completed.

→ In other word the directional element must operate first (i.e ~~no~~ contact 1 & 2 should close) in order to operate the overcurrent element.)

ii) Non-directional element

It is an overcurrent element similar in all respects to a non-directional over current relay ~~described~~

→ The spindle of the disc of this element carries a moving contact which closes the fixed contact (trip ckt contacts) after the operation of directional element.

→ It may be noted that plug-setting bridge is also provided in the relay for current setting but ~~this~~ has been omitted in the fig. for clarity and ~~similare~~ simplicity.

→ The tappings are provided on the upper magnet of over current element and are connected to the bridge.

OPERATION

→ under normal operating condition the power flow in the normal direction in the ckt protected by relay.

→ Therefore, directional power relay (upper element) does not operate, thereby keeping the over current element (lower element) unenergized.

→ However, when a short ckt occurs, there is a tendency for the current or power to flow in the reverse direction.

→ should this happen the upper of the element rotates to bridge the fixed contact 1 and 2.

→ This completes the ckt for overcurrent element. The disc of this element rotates and the moving contact attached to it closes the trip ckt.

→ This operate the C.B which isolates the ~~CB~~ faulty section

→ It is made by the following condition is satisfied.

i. current flows in a direction such as to operate the directional element.

ii. current in reverse direction exceeds the pre-set value.

iii. excessive current persists for a period corresponding to the time setting of over current element.

DIFFERENTIAL RELAY

A differential relay is one that operates when the phasor difference of 20 or more similar electrical quantities exceeds a pre-determined value.

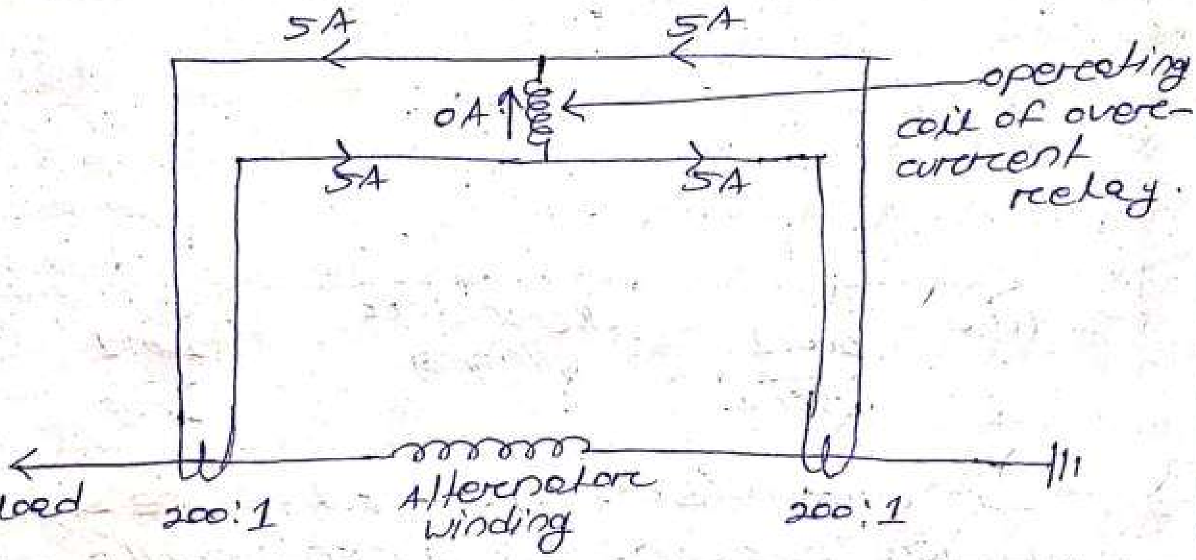
→ There are two systems of differential/balanced protection.

1. current balanced protection
2. voltage balanced protection.

1. CURRENT DIFFERENTIAL RELAY

→ The below fig. show the arrangement of over current relay comected to operate as differential relay.

→ A pair of identical C.Ts are sitted on either end of section to be protected (Alternatore winding)



→ The secondary of CTs are connected in such a way that they carry the induced current in same direction.

→ The operating coil of overcurrent relay is connected across the C.T secondary ckt.

→ These differential relay compaires the current at a two ends of the alternatore winding.

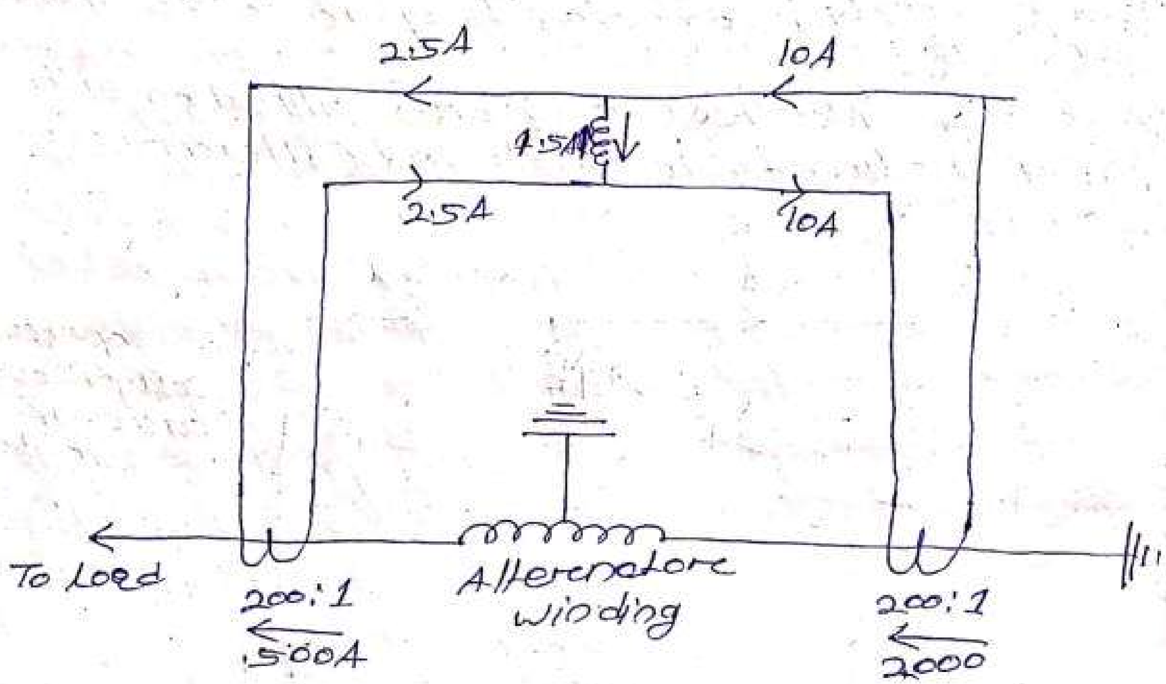
OPERATION

→ under normal operating condition suppose the alternatore winding carries a normal current of 1000A.

→ Then the current is the two secondary are equal are shown in the above fig.

→ These current circulate between the two C.T and no current will be flow through the differential relay. Hence the relay will remain in operative.

→ If a ground fault occurres on the alternator winding as shown in the below fig., the two secondary current will not be equal and the current flows through the operating coil of the relay and the relay starts to operate.



→ If sum current (500A) flow out of one side while a larger current (2000A) enters the other sides due to ground fault as shown in the above fig. then the difference of the C.T secondary current is 10−2.5 = 7.5A will flow through the relay coil and causing the relay to operate.

DISADVANTAGES

→ The impedence of the pilot cables generally causes a slide difference between the current at two end of the section to be protected if the relay is very sensitive then the small differential current flowing through the relay may cause it to operate even under no fault condition.

→ Accurate matching of CT can not be achive due to pilot ckt impedance.

2. VOLTAGE BALANCED DIFFERENTIAL RELAY

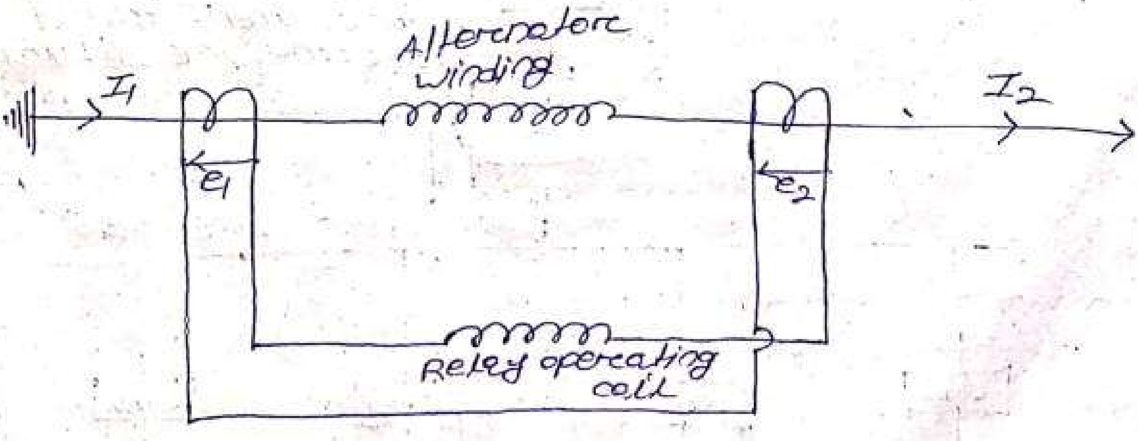
→ The below fig. show the arrangement of voltage balanced protection in this scheme of protection, two similar CTs are connected at end of the element to be protected by means of pilot wire.

→ The secondary of C.T are connected in series with a relay in such a way that there induced emf are in opposition.

→ under normal condition equal currents ($I_1 = I_2$) flows in ~~the secondary~~ both primary winding. therefore secondary voltages of the two T/Fs are balance against each other. and no current will flow through the relay operating coil.

→ when a fault occurs in a protected zone, the current in the two primary will differ from each other ($I_1 \neq I_2$) and there secondary voltage will no longer be in balanced.

→ This voltage difference will cause it current to flow through the operation coil of relay which causes the relay to operate.



TYPES OF PROTECTION

→ There are two types of protection

1. primary porotection
2. ~~seco~~ Back-up protection.

1. PRIMARY PROTECTION

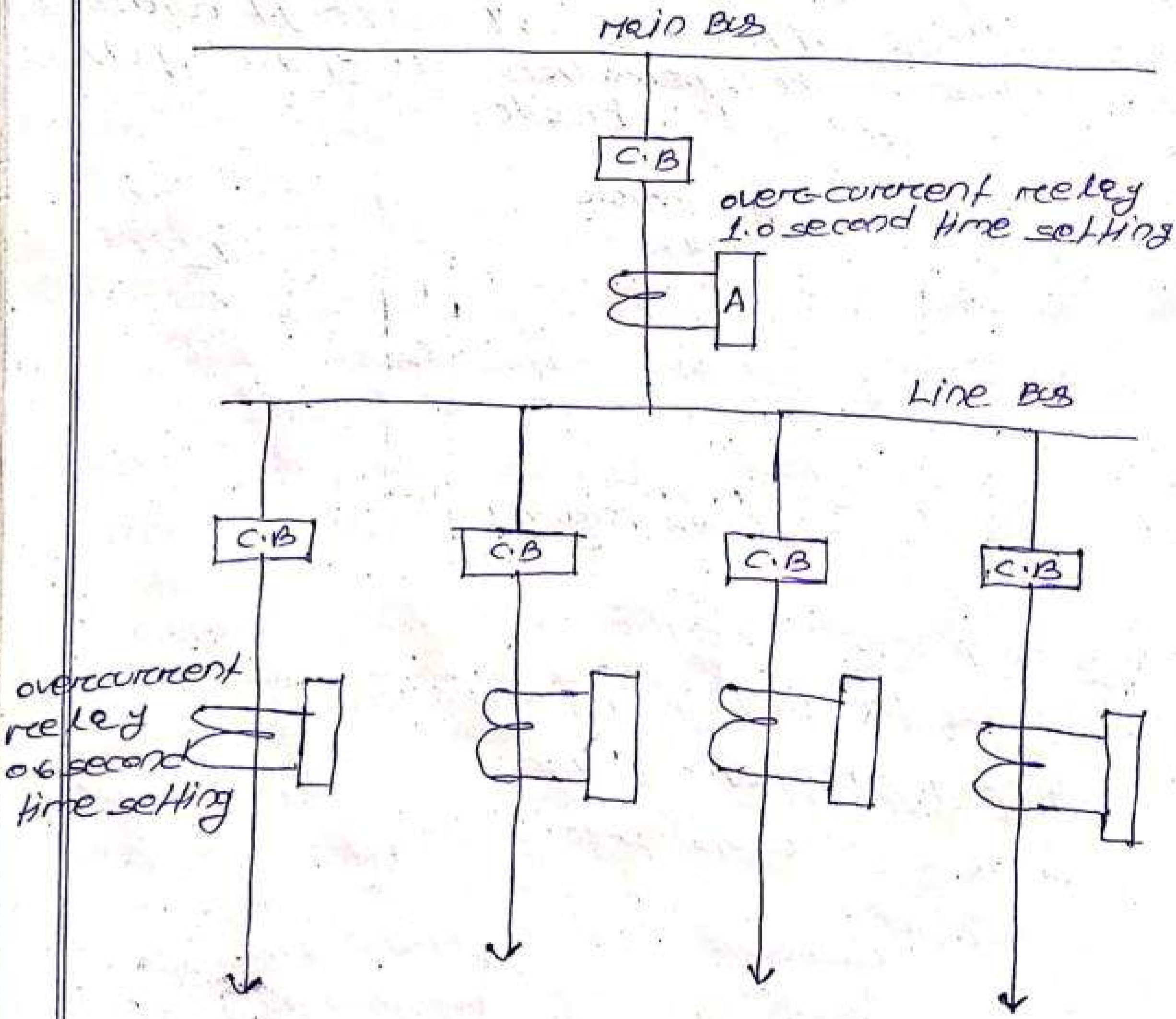
→ It is a protection scheme which design to protect the component part of the power system.

→ The below fig each line has an overcurrent relay that protects the line.

→ If a fault occure on any line, it will be clear by its relay and C.B. This forms the primary or main protection and serves as the first line of defence.

→ The service record of primary relaying is very high ~~itt~~ with well over ninety percent of all operation being correct.

→ However sometimes faults are not cleared by primary ~~tte~~ relay system because of trouble within the relay, wiring system or breaker. under such condition, back-up protections does the required job.



2. BACK-UP PROTECTION

→ It is the second line of defense incase of failure of primary protection. It is designed to operate with sufficient time delay so the primary relaying will be given enough time to function if it is able to.

→ The above fig. shows, relay 'A' provides back-up protection of each of the four lines.

→ If a line fault is not cleared by its relay and entire breaker, the relay A on the group breaker will operate after a definite time delay and clear the entire group of lines.

→ It is evident that when back-up relaying functions a larger part is disconnected that when primary relaying functions correctly. Therefore, greater emphasis should be placed on the better maintenance of primary relaying.

CHAPTER-6
PROTECTION OF ELECTRICAL POWER EQUIPMENT AND LINES

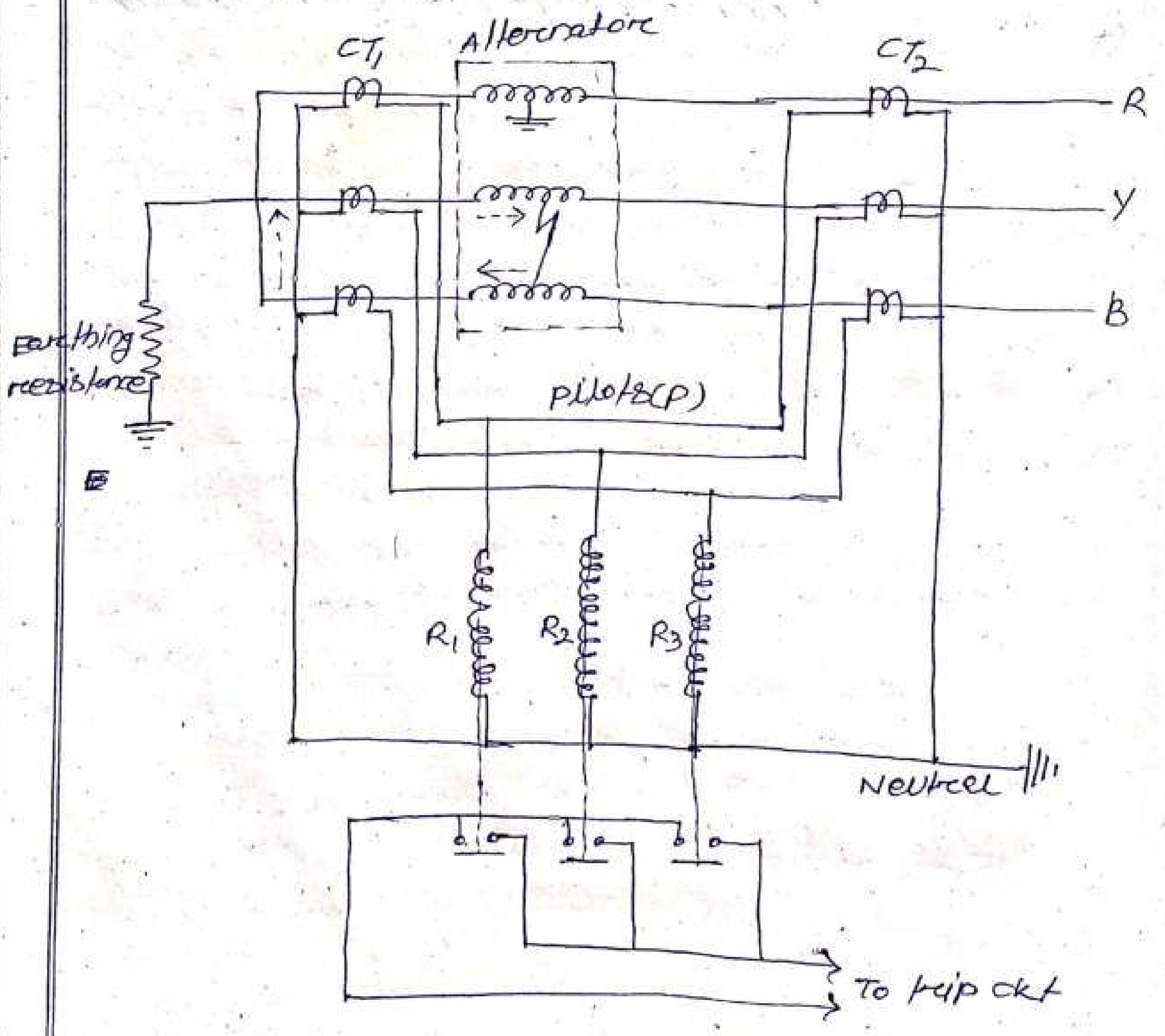
PROTECTION OF ALTERNATOR

→ some of the important faults which may occur on an alternator are:-

1. Failure of prime-mover
2. Failure of field
3. overcurrent
4. over speed
5. over voltage
6. unbalanced loading
7. stator winding faults.

DIFFERENTIAL PROTECTION OF ALTERNATORS

→ In this type of protection of alternator is known as Merz-price circulating current scheme



CONSTRUCTION

→ The below figure show the arrangement of current differential protection of a 3-φ alternator.

→ Indentical CT pairs CT_1 and CT_2 are place on either side of each phase of the stator windings.

→ The secondaries each set of CT are connected in star; the two neutral point and the corresponding terminals of two star group being connected together by means of a four-core pilot cable.

→ Thus there is an independent path for the currents circulating each pair of current T/Fs and the corresponding pilot φ.

→ The relay coils are connected in star, the neutral point being connected to the CT common neutral and outer ends one to each of the other three pilots.

OPERATION

→ under normal operating condition the current at both ends of each winding will be equal and hence the current in the secondaries of two CTs connected in any phase will also be equal.

→ Therefore, there is balanced circulating current in the pilot wires and no current flows through the operating coils (R_1, R_2 and R_3) of the relays.

→ suppose an earth fault occure on phase R due to breakdown of its insulations to earth as shown in the above fig.

→ The current in the affected phase winding will flow through the core and frame of the machine to earth, the ckt being completed through the neutral earthing resistance.

→ The current in the secondary of two CTs in phase R will become unequal and the difference of the two currents will flow through the corresponding relay coil (i.e R_1), Returning via the neutral pilot.

→ consequently, the relay operates to trip the circuit breaker.

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→ Imagine that now a short-ckt fault occures between the phases Y and B as shown in above fig.

→ The short ckt current circulates via the neutral end connection through the two windings and through the fault as shown be dotted arrows.

→ The current in the secondaries of two CTs in each affected phase will become unequal and the differential ~~in these phases~~ current will flow through the operating coils of the relays (i.e R_2 and R_3) connected in these phases. ~~The relay~~

→ The relay thereon closes its contacts to trip the ckt breaker.

BALANCED EARTH FAULT PROTECTION

→ In small size alternator the neutral ends of the 3φ windings are connected internally to a single terminal.

→ Therefore it is not possible to use Merz-price ~~the scheme~~ circulating current principle because there is no facility for connecting CT in the neutral connection of each phase winding.

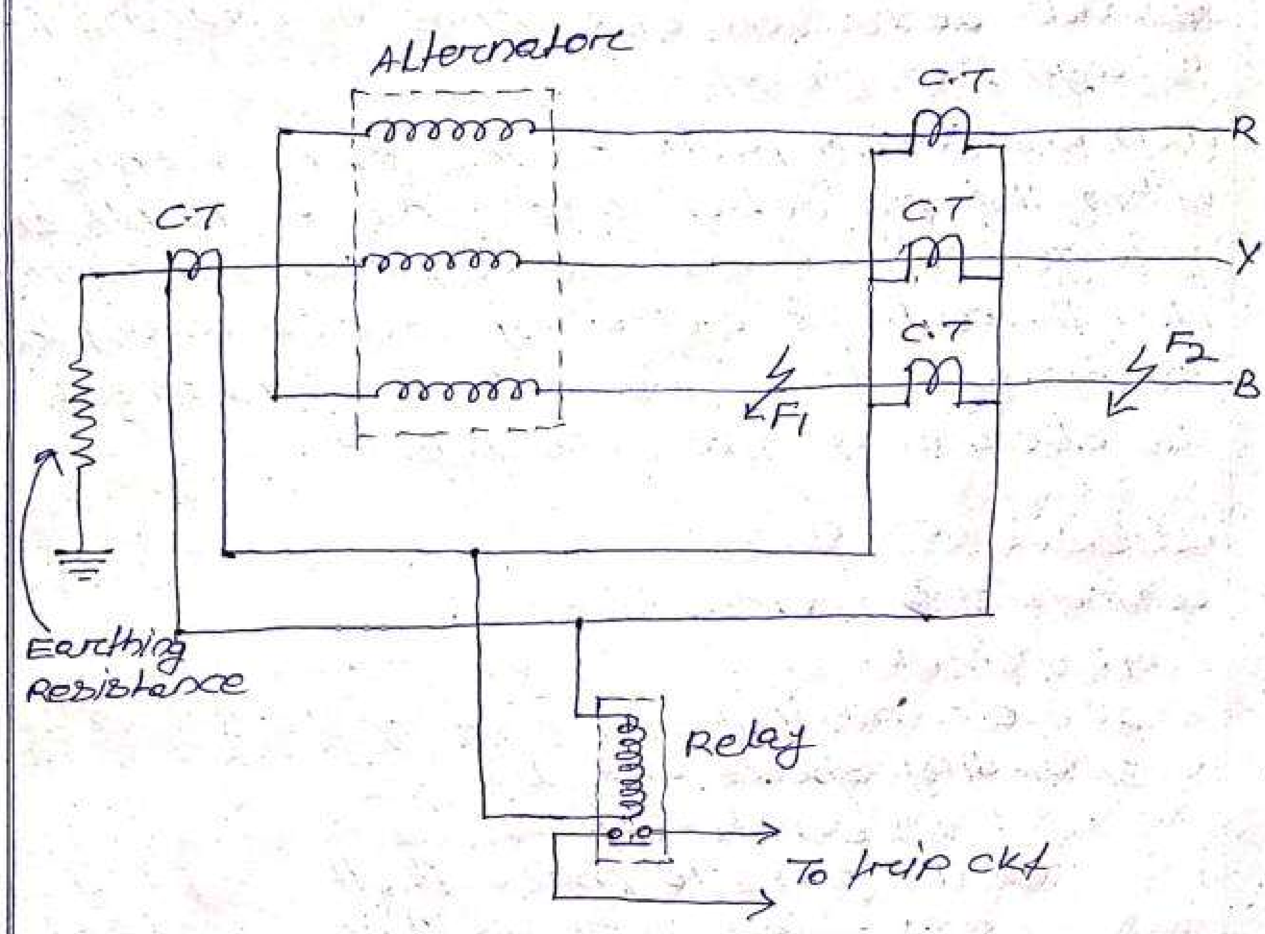
→ Therefore to privide protection against earth fault balanced earth fault protection is used.

CONSTRUCTION

The below fig shows the arrangement of balanced earth fault protection for a 3φ alternator.

→ It consist of three lines CTs one mounted in each phase, having there secondaries connected in parallel will that of single CT in the conductor joining the stare point of the alternator to earth.

→ A relay is connected across the T/F secondary. The protection against earth fault is limitted to the region between the neutral and the line CB.



OPERATION

→ under normal operating condition the current flowing in the alternator leads and hence the current flowing in the secondaries of the line CTs add to zero and no current flows through the relay.

→ Also under these conditions, the current in the neutral wire is zero and the secondary of neutral CT supplied no current to the relay.

→ ~~In an earth fault occured at F2 which is within the protected zone hence currents are no longer equal and differential current flow through the operating coil of relay then the relay closes its contact to disconnect the alternator from the system.~~

→ If an earth fault occure at F_2 which is external to the protected zone. the sum of current at the terminals of the alterenator is exactly equal to the current in the equal neutral connection and hence no current flow through the relay.

→ When an earth fault occure at F_1 which is within the protected zone hence currents are no longer equal and the differential current flow through the operating coil of relay then the relay closes its contact to disconnect the alterenatore from the system.

PROTECTION OF T/F

common T/F faults are

1. open ckt
2. over heating
3. winding short ckt i.e
   (a) earth fault
   (b) phase to phase fault
   (c) Inter-turn fault.

PROTECTION SYSTEM FOR T/F

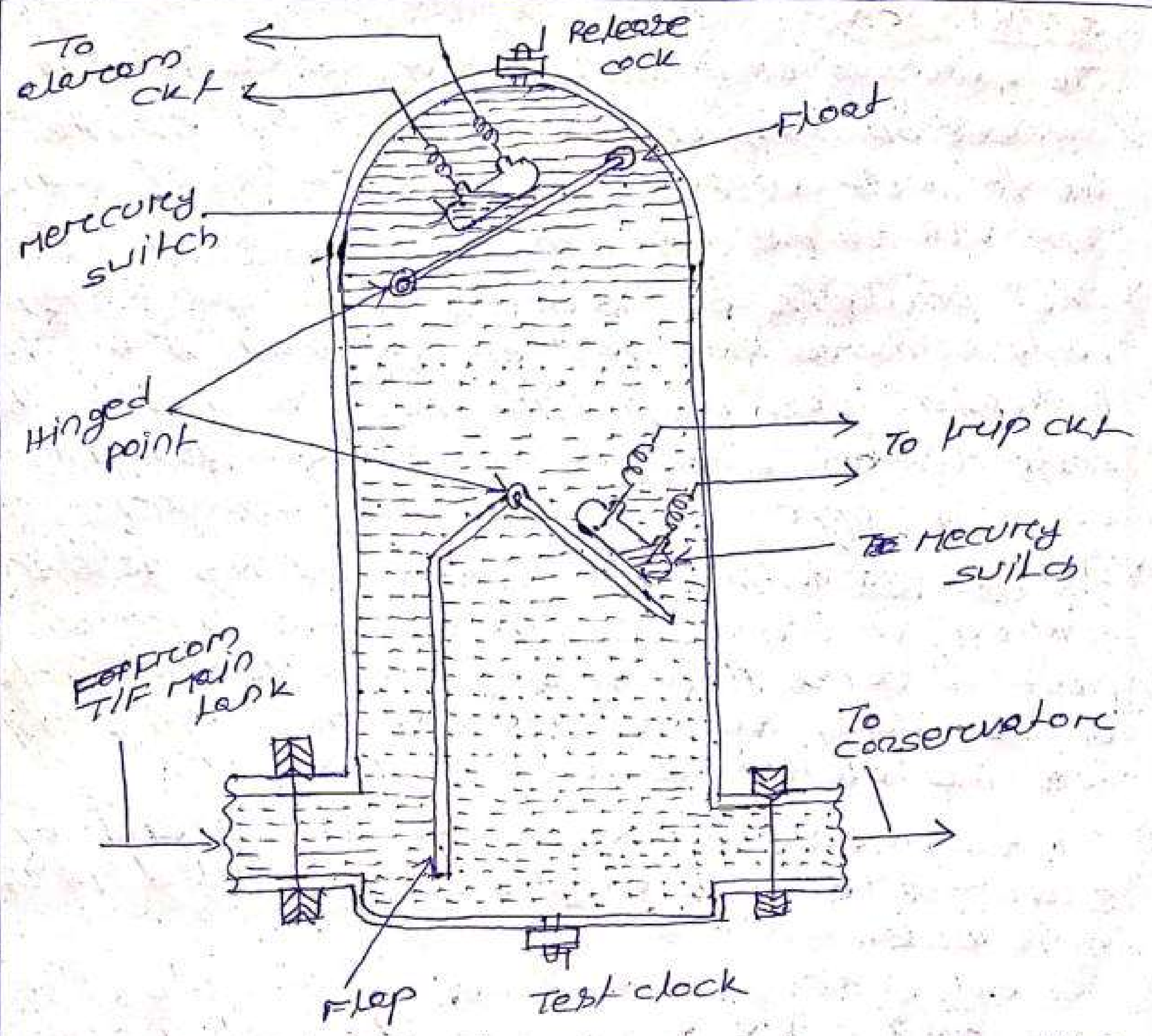
The principle relay used for T/F protection are

1. Buchholz Relay
2. Earth fault relay
3. over current Relay
4. Differential relay.

1. BUCHHOLZ RELAY

INTRODUCTION

Buchholz relay is a gas actuated relay. installed in oil immersed T/F for protection against all kinds of fault it is used to give an alarm incase of incipient fault (i.e slow



developing fault) in the T/F and disconnect it form the supply.

CONSTRUCTION

The above fig. show the constructional details of buchholz reelay.

- → It takes the form of a domed vessel placed in the connecting pipe between the main tank and conservatore.
- → This device has two element.
- → The uppere element consist of a mercurry type switch attached to a float.
- → The lower element contain a ~~mercurry~~ mercurry switch manted on a hinged type flap located in the direct path of the flow oil form the T/F to a conservatore.
- → The upper element closes an alarm ckt during incipient fault where the lower element is arranged to trip the C.B in case of several internal fault.

OPERATION

The operation of Buchholz relay is as follows

- Incase of incipient faults within the T/F, the heat due to fault causes the decomposition of some T/F oil in the main tank.
- The products of decomposition ~~of some T/F~~ contain more than 70% of hydrogen gas. The hydrogen gas being light tries to go into the conservator and in the process get entrapped in the upper part of relay chamber
- When a predetermined amount of gas gets accumulated, it exerts sufficient pressure on the float to cause it to ~~tilt~~ tilt and close the contacts of mercury switch attached to it. This completes the alarm ckt to sound an alarm.
- If a serious fault occurs in the T/F ~~and~~ an enormous amount of gas is generated in the main tank.
- The oil in the main tank rushes towards the conservator via the Buchholz relay and in doing so tilts the flap to close the contacts of mercury switch.
- This complete the trip ckt to open the CB controlling the T/F.

ADVANTAGES

- It is simplest form of T/F protection
- It detects the incipient fault at a stage much earlier than is possible with other forms of ~~poto~~ protection.

DISADVANTAGES

- It can only be used with oil immersed T/Fs equipped with conservator tanks.
- The device only detect only faults below oil level in the T/F. Therefore separate protection is needed for connecting cables.

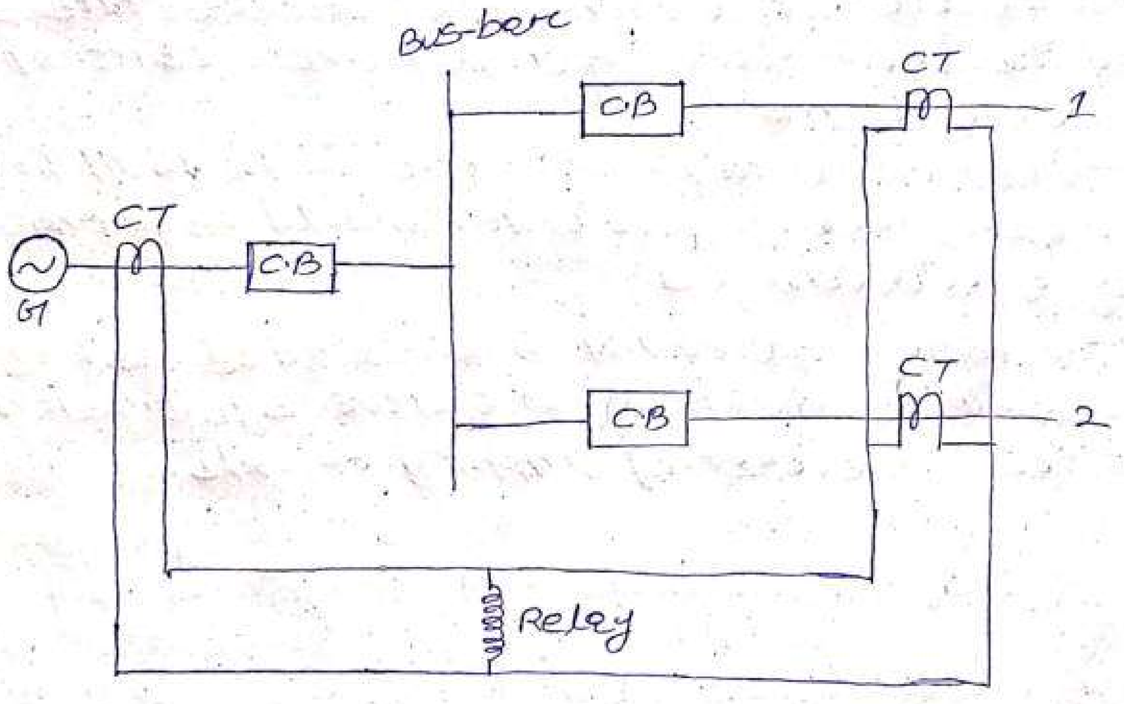
BUS-BARS PROTECTION

Busbars in the generating station and substation form important link between the incoming and outgoing ckts.

→ If a fault occures on a bus bar considerable damage and distruption of supply will occure. ~~unless~~ Therefore it is necessary to protect the bus-bar.

→ The most commonly used scheme for busbar protection is differential protection.

DIFFERENTIAL PROTECTION OF BUSBAR



→ The above fig. show the single line diagram of current differential ~~ck~~ scheme for a busbar.

→ The busbar is fed by a generator and supplies load to two lines.

→ The secondary of CT is the generator side leads, in line 1 and line 2 which are all ~~co~~ connected in parallel.

→ The protective relay is connected across this parallel connection. Here all CTs must be same ratio.

→ under normal condition or external fault condition the sum of current entering the bus is equal to those leaving it. and no differential current flow through the relay hence relay remain inoperative.

→ If a fault occure within a protected zone the current entering the bus will no longer be equal to those leaving it.

→ Then difference of these current will flow through the relay and couse the opening of the generatore CB and each of line C.B.

PROTECTION OF LINES

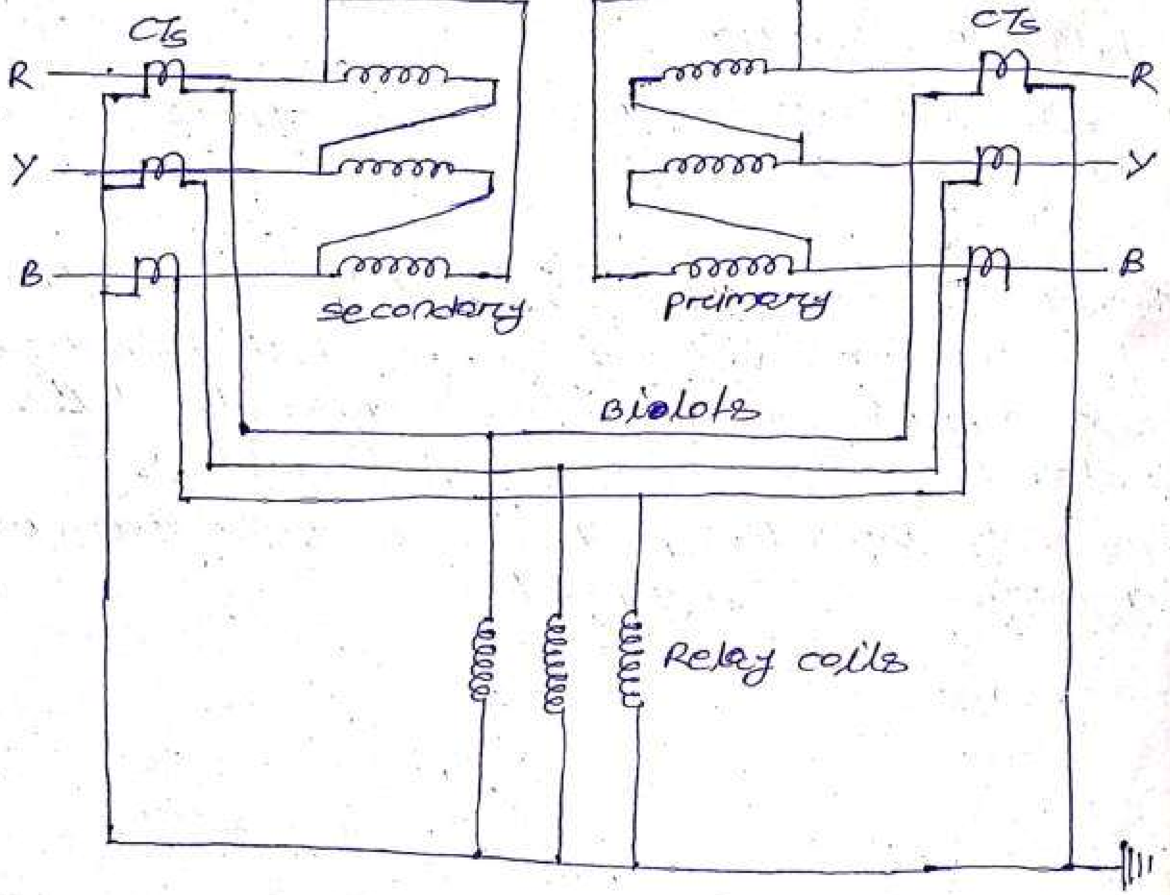
The requirements of line protection are:-

i. In the event of a short-ckt breaker closest to the fault should open, all other CB remaining in a closed position.

ii. Incase of nearest breaker to the fault fails to open, back-up protection should be provided by a adjecent CB.

iii. The relay operating time should be just as possible in order to preserve system stability without unnecessary tripping of ckts.

DIFFERENTIAL PROTECTION OF T/F



→ The above fig. shows the Merz-price circulating-current scheme for the protection of a 3Φ ~~delta~~ delta/delta power T/F against phase to ground and phase-to-phase faults.

→ This compensates for the phase difference between the power T/F primary and secondary.

→ The CTs on the two sides are connected by pilot wires and one relay is used for each pair of CTs.

→ During normal operating conditions, the secondaries of CTs carry identical currents.

→ Therefore the current entering and leaving the pilot wires at both ends are the same and no current flow through the relays.

→ If a ground or phase-to-phase fault occures, the current in secondaries of CTs will no longer be the same and the differential current flowing through the relay ckt will clear the C.B on both sides of the T/F.

→ The protected zone is limited to the region between CTs on the high-voltage side and the CTs on the low-voltage side of the power T/F.

→ It is noted that this scheme also protection for short-ckts between turns on the same phase winding.

→ when a short ckt occure between the turns, the turn-ratio of the power T/F is altered and causes unbalanced between current T/F pairs.

→ If the turn ratio of power T/F is altered sufficiently, enough differential current may flow through the relay to cause its operation.

→ However, such short-ckts are better taken ~~are~~ care of by Buchholz relays.

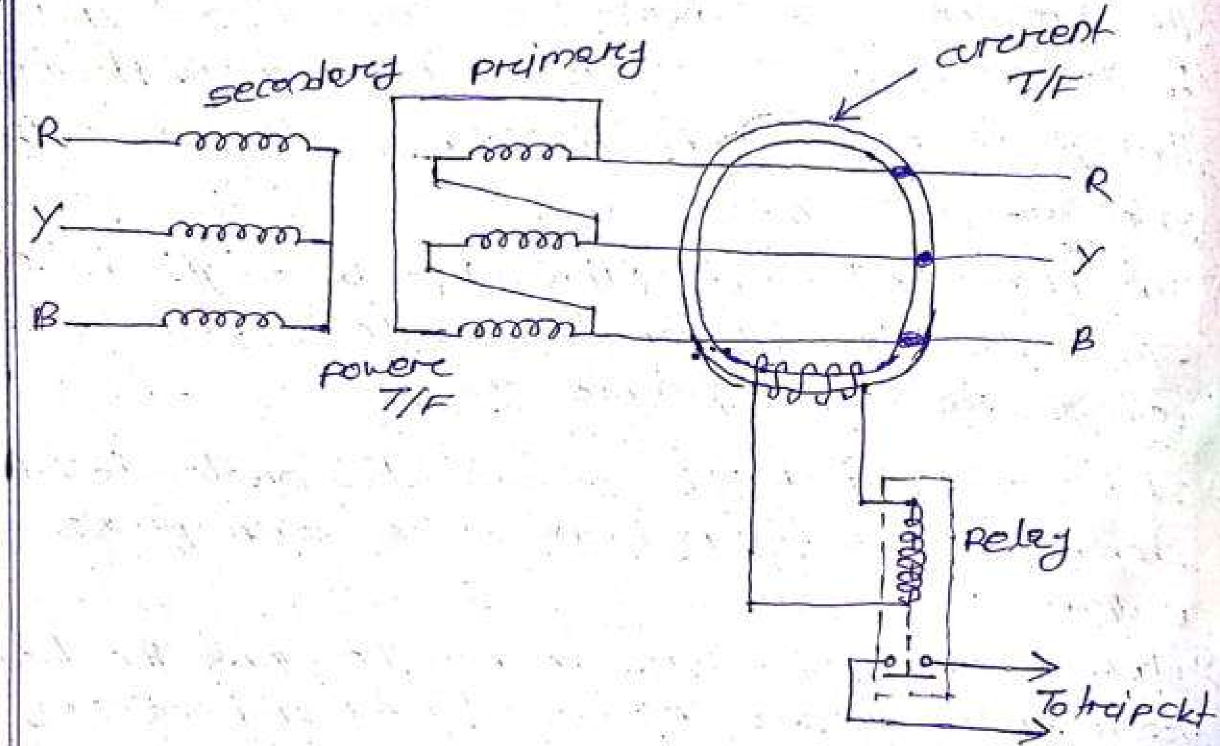
EARTH FAULT PROTECTION FOR T/F

→ The earth fault usually ~~occure~~ involves a partial breakdown of winding insulation to earth

→ The resulting leakage current is considerably less than the short ckt current

→ The earth fault may be contineous for a long time and causes considerable damage before it ultimately develops into a short ckt and removed from the system.

→ one method of protection against earth fault in a T/F is the core balance leakage protection shown in the below fig.



→ The three leads of the primary winding of power T/F are taken through the core of a CT, which carries a single secondary winding.

→ The operating coil of a relay is connected to this secondary.

→ under normal operating condition, the vector sum of three phase current is zero and there is no-resultant flux in the core of ~~bal~~ balance.

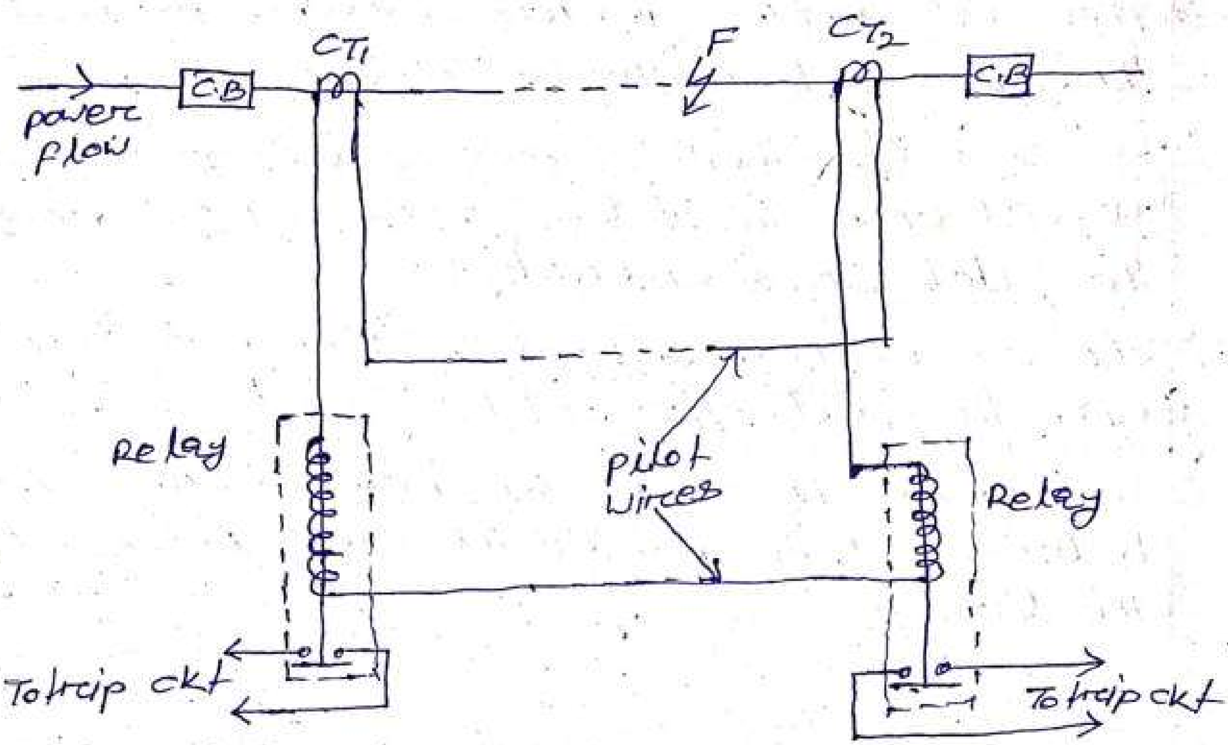
→ consequently, no current flows through the relay and it remains inoperative.

→ when the earth fault occure in the T/F, the vector sum of three phase current is no longer zero.

→ The resultant the current sets up flux in the core of the CT. which induced emf in the secondary winding.

→ This energises the relay to trip the C.B and disconnect the faulty T/F from the supply.

MERZE PRICE PROTECTION OF FEEDER



- The above fig show the single line diagram of merze-price voltage balanced system for a protection of a 3ϕ line.
- Identical CTs are connected in each phase at both ends of the line.
- The pair of CTs in each line is connected in series with a relay in such a way that under normal conditions, Their secondary voltages are equal and in opposite i.e. they balance each other.
- under normal conditions, current entering the line at one end is equal to that leaving it at the other end.
- Therefore, equal and opposite voltages are induced in the secondaries the CTs at the two ends of the line.
- The result is that no current flows through the relays

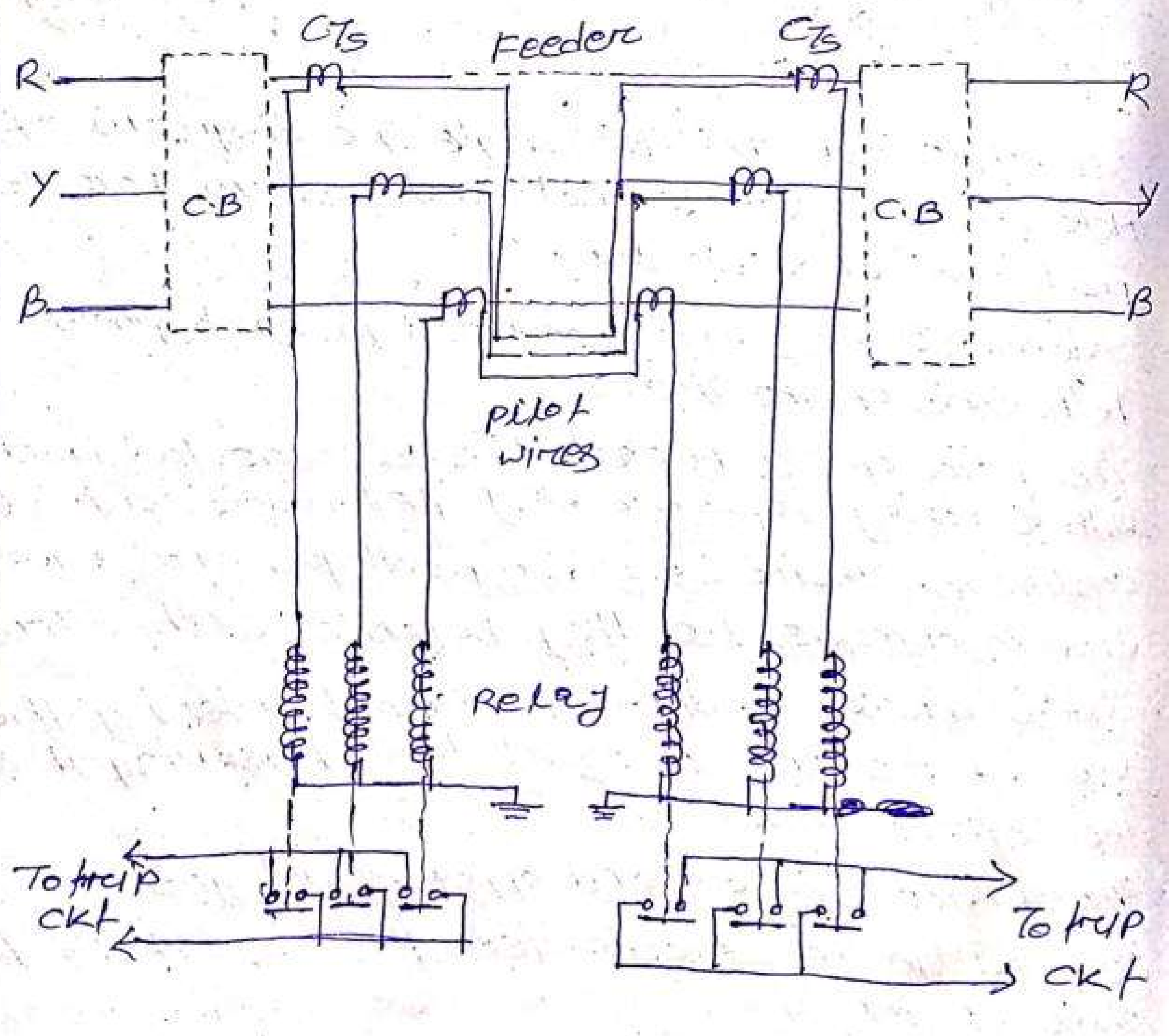
→ suppose a fault occurs at point F on the line as shown in the above fig.

→ This will causes greater current to flow through CT_1 then through CT_2.

→ consequently, their secondary voltages become unequal and circulating current flows through the pilot wires and relays.

→ The C.B at Both ends of the line will trip out and the fault line will be isolate.

→ The below fig shows the merze-price voltage balance scheme for all the three phases of the line.



CHAPTER - 7

PROTECTION AGAINST OVERVOLTAGE AND LIGHTING

VOLTAGE SURGE

A sudden rise in voltage for a very short duration on the power system is known as a voltage surge or transient voltage.

→ Transient or surge are of temporary nature & exist for a short duration but they can able to cause overvoltage on the power system

→ surge originate from switchgear & from other causes but the most imp surge are caused by lighting striking a transmission line.

CAUSES OF OVERVOLTAGE

→ The overvoltages on a power system may be divided into two types i.e

1. Internal causes
2. External causes

1. INTERNAL CAUSES

→ Internal causes do not produce surge of large magnitude. These causes occure due to oscillations ~~sets~~ set up by the sudden change in the circuit conditions.

→ The internal causes of ~~overed~~ voltages are as follows:-

i. SWITCHING SURGES

The overvoltages on the power system due to switching operation are known as switching surges.

→ Switching surges occures in case of an open line, incase of a loaded line etc.

ii. INSULATION FAILURE

→ The most common case of insulation failure in a power system is due to grounding of conductors (i.e insulation failure between line & ground) which may cause overvoltages.

iii. ARCING GROUND:

The phenomenon of arc taking place in line-to-ground fault (L-G fault) of a 3-Φ system with consequent production of transient is known as arcing ground.

→ This ~~arg~~ may cause serious damage to the equipment in power system.

2. EXTERNAL CAUSES

→ External causes of surge occures due to lighting. This causes very severe overvoltage & may incase the system voltage to several times of normal voltage

LIGHTNING

An electric discharge between cloud and earth, between clouds or between the charge centres of the same cloud is known as lightning

MECHANISM OF LIGHTNING DISCHARGE

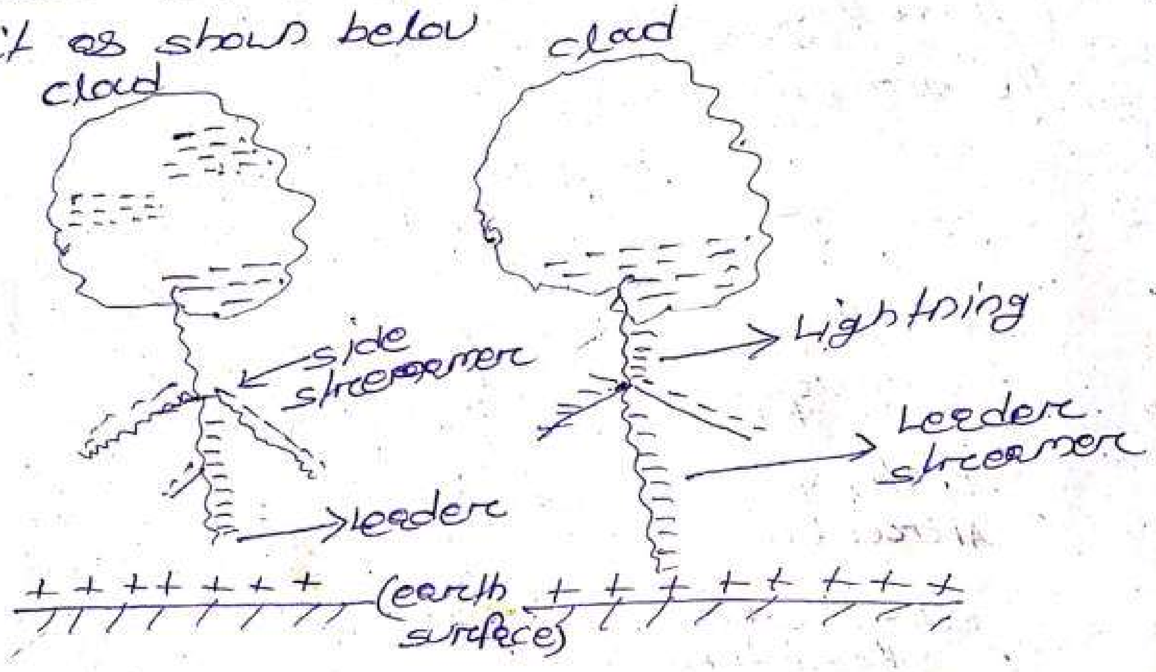
→ When a charged cloud passes over the earth it induces equal & opposite charge on the earth below the cloud.

→ As shown in the below fig a negatively charged cloud inducing a positive charge on the earth below it.

→ As the charge acquired by the cloud increases then the potential between cloud & earth increases & therefore a potential gradient in the air increases.

→ when the potential gradient is sufficient i.e (5kv/cm to 10kv/cm) to break down the surrounding air & the lighting stroke starts.

→ As soon as the air near the cloud breaks down the lighting stroke or a streamere called as leader streamere starts from the cloud towords the earth & carries charge with it as shown below



HARMFUL EFFECTS OF LIGHTNING

i. If lightning hits the winding of a T/F or generator then it may cause considerable damage.

ii. If the arc is initiated in any part of the power system by lightning stroke then this arc will set disturbing oscillations in line.

iii. During lightning due to heavy currents there will possibility of failure of insulations in electrical ckt.

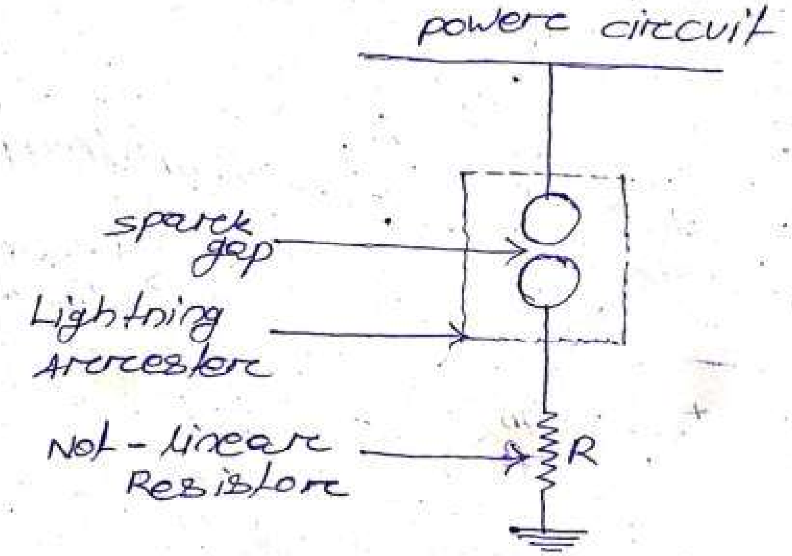
iv. Tele-communication lines are very much affected by lightning serious disturbance may take place.

PROTECTION AGAINST LIGHTNING

The most commonly used device for protection against lightning is lightning arresters

LIGHTNING ARRESTERS/SURGE ~~DRIVER~~ DIVERTER

→ A lightning arrester or a surge diverter is a protective device which conducts the high voltage surges on the power system to the ground.



CONSTRUCTION

The above fig shows the basic form of a surge deverter. It consist of a spark gap in series with a non-linear resistor.

→ one end of the diverter is connected to the terminal of the equipment to be protected & the other end is effectively grounded

OPERATION

→ under normal ~~operating condition~~ operation, the lightning arrester is off the line ie conducts no current to earth or the spark gap is non-conducting.

→ when the lightning strikes an overvoltage occurs, the air insulation across the gap breaks down & an arc is formed, providing a low resistance path for the surge to the ground. In this way the excess charge on the line due to surge is harmlessly conducted through the lightning arrester to the ground.

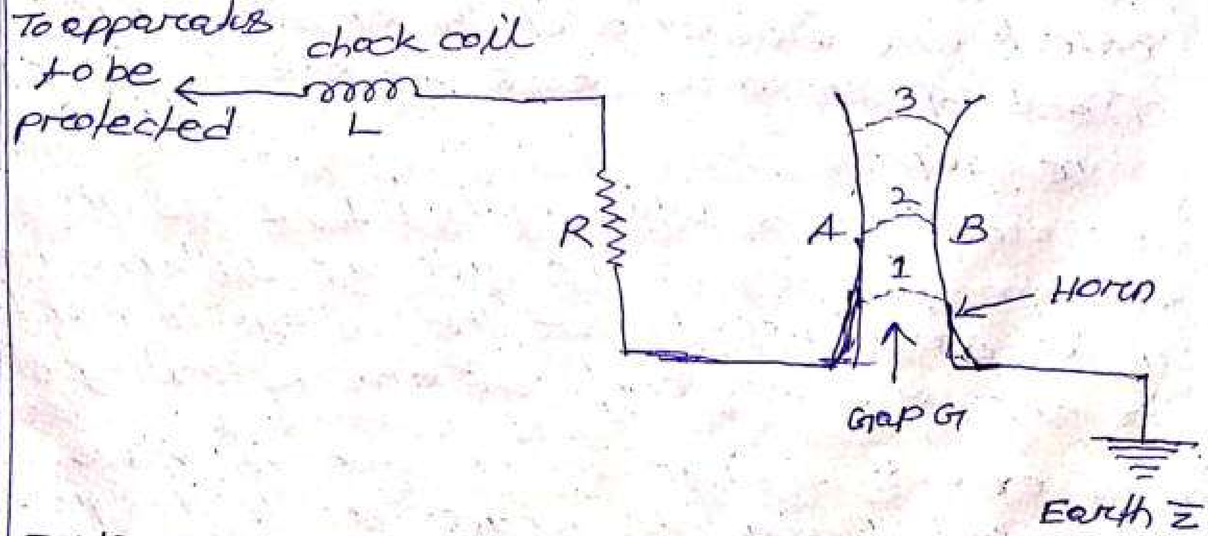
TYPES OF LIGHTNING ARRESTERS

There are several type of lightning arrester in general use. They differ on construction basic but operate on same principle i.e ~~poving~~ proving low resistance path for the surges to the ground.

→ Types of lightning arrester are as follows.

1. Horn gap arrester
2. value type arrester
3. Rod gap arrester
4. Multigap arrester
5. Expulsion type arrester

1. HORN GAP ARRESTOR



CONSTRUCTION

→ The above fig. show the horn gap arrester
→ It consist of two horn shaped metal rods A & B separated by a small air gap

→ The horns are so constructed that distance between them increases towards the top. The horns are mounted on porcelain insulators.

→ one end of the horn is connected to the line through a resistance R & chock coil while the other end is grounded.

→ R helps the limitting the current to a small value & chooke coil so designed that it offers small reactance at normal power frequency. Thus the chock does not allow the transient to enter the apparatus to be protected.

OPERATION:-

→ under normal operating condition, the gap is non-conducting i.e normal supply voltage is insufficient to ~~int~~ initiate the arc between the gap.

→ when an overvoltage occures, spark-over takes place across the ~~saw~~ small gap G. The heated air ~~arc~~ around the arc & magnetic effect of the arc caise the arc to travel up the gap.

→ The arc moves into position 1, 2 & 3. then at some position of the arc the distance may be too ~~great~~ greeat for the voltage to maintain the arc & consequently the arc is extinguish.

→ The excess charge on the line is thus conducted through the arrestere to the ground.

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ADVANTAGES

→ The arc is self-clearing therefore this type of arresters does not cause short-ckting of the system after surge is over.

→ series resistance helps in limiting the follow current to a small value.

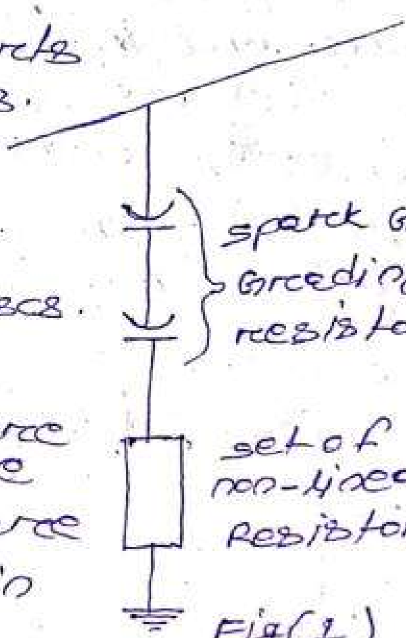
2. VALVE TYPE ARRESTER

CONSTRUCTION

→ Fig(1) shows the various parts of a valve type arresters.

→ It consist of 2 part i.e
   a. series spark gaps
   b. Non-linear Resistor discs. in series

→ The non linear element are connected in series with the spark gap. Both parts are accomodated in porcelain ~~on cotst~~ container.



Fig(1)

WORKING

→ under normal condition, the normal system voltage is insufficient to cause the breakdown of air gap assembly.

→ on the occurance of overvoltage, the breakdown of the series spark gap takes earth by the non-linear resistors.

→ since the magnitude of surge current is very large, the non-linear elements will offer a very low resistance to the passage of surge. Hence the surge will rapidly go to earth instead of line.

→ when the surge is over, the non-linear resistors assume high resistance to stop the flow of current.

ADVANTAGES

→ They provide very effective protection against surges.

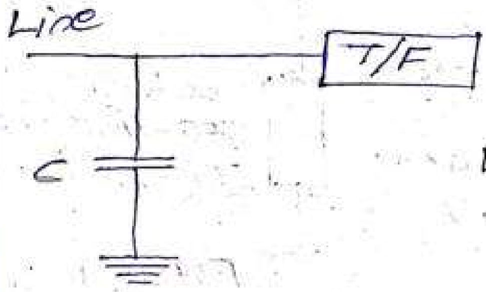
→ They operate very rapidly ~~tod~~ taking less than a second

→ The impulse ratio practically unity

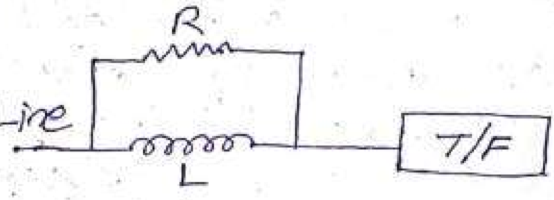
SURGE ABSORBER

→ There are the protective device which reduce the steepness of wave of a surge by absorbing surge energy

→ Diagram of the surge absorber is shown in below figs.



Fig(1)



Fig(2)

→ In fig(1) a condenser (C) is connected between lines & earth & acts as a surge absorber. Reactance of a condenser (X_C) is inversely propositional to frequency ~~& (X_C) is inversely propositional~~ & 'X_C' will be low at high frequency & vice verse. Since surges are of high frequency, capacitor act as short ckt & passeds surges directly to earth. Hence T/F winding is protected

→ In fig(2) there is a chok coil (L) & a Resistor (R) which is connected across (L). The choke offers high reactance to surge frequency ($X_L \propto F$) then surges are forced

to flow through 'R' where they are dissipat-
ed.

CHAPTER-8
STATIC RELAY

STATIC RELAY

The relay does not contain any moving part is known as static relay.

ADVANTAGES OF STATIC RELAY

→ The static relay give the quick response long life, high reliability & accuracy.

→ The reset time of the relay is very less.

→ The chance of unwanted tripping is less in this relay.

→ The static relay consumeres very less power.

→ The relay amplifiers the input signal which increases their sensitivity.

→ A static relay can perform several functions like over current, under voltage, single phasing protection.

IDMT RELAY (INVERSE DEFINITE MINIMUM TIME RELAY)

→ In this type of relay the current in the system increases, the secondary current of the CT is increased proportionaly.

→ The secondary current enteres the relay current coil. But when the CT becomes saturated, there would not be a further proporrtional increase in CT secondary current with increased system current.

→ From this phenomenon, it is clear that from trick value to certain range of faulty level an invers time relay shows specific inverse characteristic.

→ But after this level of fault, the CT becomes saturated & relay current does not ~~incre~~ increase further with increasing fault level of the system.

→ As the relay current does not increase further there would not be any further reduction in time of operation in the relay & we define this time as minimum time of operation.

→ Hence the char. is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high so that this relay is referred as inverse definite minimum time over current relay or IDMT relay