LECTURE NOTE ON
SWITCH GEAR & PROTECTIVE DEVICE
6TH SEM ELECTRICAL ENGINEERING

Prepared By
Er. Sachin Kumar Satpathy
(Lect. In Electrical Engg.)
B.I.T ,SAMBALPUR

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CH-01.

* Introduction to Switch Gear :-

→ Now a days there is a great requirement of electric energy in Lighting, Heating, Domestic appliances, Industrial electrical machinery and electric traction.

→ The importance of electric supply in every day life has reached in such a stage that it is desirable to protect the power system from harm during fault condition and maintain continuity of supply.

→ For this purpose means Switch (ON) or (OFF) generators, transmission line, distributor and other equipments under both normal and abnormal condition, the Switch gear components are highly necessary; So a Switch gear essentially consist of switching and protecting devices such as (Switch, Fuses, Circuit Breaker, Relays, etc.).

→ During normal operation Switch gear permits to Switch-ON or Off generator, transmission lines, distributor and other electrical equipments.

→ On the other hand when failure occurs in part of the power system a heavy current flow through the equipments causing interruption of service to the consumer.

→ However the Switch gear detect the fault & disconnects the unhealthy portion or section from the system and maintain continuity of supply to other part of the system.

→ Normally the Switch gear apparatus are used for Switching controlling and protecting the electrical circuit and equipments.

IMP

* Essential features of Switch Gear :-

① COMPLETE RELIABILITY →

→ When fault occurs on any section or part of the power system

the Switch gear must operate to isolate the faulty section from healthy section, so with continued trend of interconnection and increasing capacity of generating station there is need of reliable of Switch gear has very important.

② ABSOLUTE CERTAIN DISCRIMINATION →
→ When fault occur on any section of the power system the Switch gear must be able to discriminate between the faulty section & healthy section. It should isolate the faulty section from the system without affecting healthy section which ensure continuity of a supply.

③ QUICK OPERATION (as fast as possible) →
→ When fault occurs on any part of the power system the Switch gear must operate quickly so that no damage is done to generator, transformer and other power equipments due to short circuit currents. If fault is not clear by Switch gear quickly it tightly to spread into healthy parts and cause complete shut down of system.

④ PROVISION FOR MANUAL CONTROL →
→ A Switch gear must have provision for manual control incase of automatic control fails then the necessary operation can be carried out by manually.

⑤ PROVISION FOR INSTRUMENTS →
→ There must be provision for instruments which may be required. The instruments may be ammeter, voltmeter, frequency meter, etc. for indicate proper line parameters.

* Switch Gear Equipments :-
→ Switch gears are the equipments used for switching and interrupting current under normal & abnormal condition.
→ It includes Switches, Fuses, Circuit Breaker, Relays & other equipments.

* Switches → There are the device which are used for open or close an electrical circuit in a conventional way but can't interrupt the circuit during fault condition.
→ There are different types of Switches like air Switches, oil Switches, Isolators.

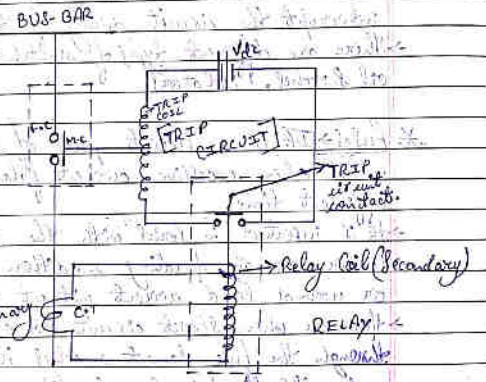
* Fuse → It is a short piece of wire or thin strip which melts when excessive current flow through it for a sufficient time.
→ It is inserted in series with the circuit to be protected.
→ Under normal operating condition it takes normal current or normal load current without over heating.
→ However when short circuit or overload occurs the current through the fuse element reaches it beyond its capacity and melts the fuse element disconnecting the circuit from the main current after clearing of fault the fuse again re-useable.

* Circuit Breaker :-
→ A CB is an equipment which can open or close a circuit under all conditions i.e. no-load, full-load & fault condition.
→ It can be designed operated manually or automatically under fault condition.

→ A CB essentially consists of fixed & moving contacts enclosed inside a metal tank and energised with Oil, Air, Gas (SF6).

*. Relay:- A relay is a device which detect the fault and supplies information to the breaker for ckt interruption.

→ The typical diagram shows the relay protection scheme of a BUS-BAR.



→ Under normal load condition the emf of the secondary winding of C.T is small and current flowing through the relay operating coil (C.T Secondary) is insufficient to close the relay contacts; so TRIP circuit remains un energised. when fault occurs a large current flow through the primary of the C.T, this induced the secondary emf and current through the relay operating coil is high.

→ The relay coil get energised enough to pull the trip circuit contact. Now, trip ckt get energised and tripping coil pull the circuit breaker (C.B) moving contact (M.C).

→ Hence, the ~~BUS-BAR~~ causing disconnected of BUS-BAR from the main circuit.

IMP

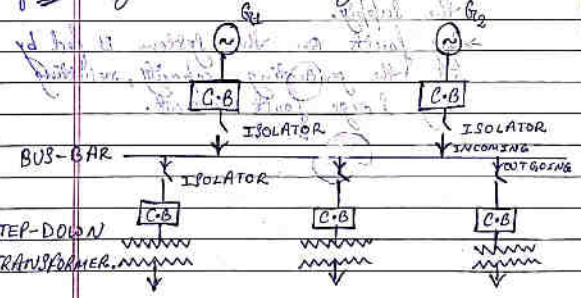
*. BUS-BAR arrangement:- When a no. of generators or feeders operating at the same voltage and directly connected electrically, ~~BUS~~ BUS-BAR's are used as the common electrical component.

→ The BUS-BAR's are copper-rods or thin walled tubes & operated at constant voltage.

→ There are different BUS-BAR arrangement systems as follows;
- (a). Single BUS-BAR arrangement.
- (b). Single BUS-BAR arrangement with Sectionalisation
- (c). Duplicate BUS-BAR System.

→ All the diagram's of BUS-BAR arrangement are 3-phase but are shown in single-line for Simplicity.

(a). Single BUS-BAR arrangement:-



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→ The Single BUS-BAR System has the simplest design and is used for small outdoor Sub-Station where few outgoing and incoming feeders are found.

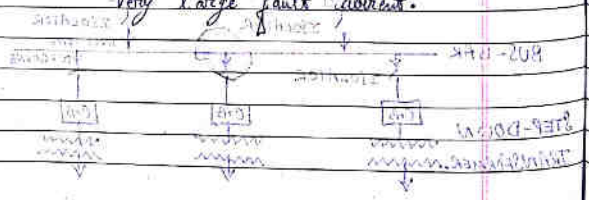
→ The generators, outgoing feeders, and transformers are connected to the BUS-BAR.

→ Each of components is controlled by a circuit breaker (C.B).

→ The Isolator permit to isolate generators, feeders & transformers manually during maintainance.

Advantages → Simple in construction.
→ Less initial cost & less maintainance.
→ Simple in operation.

Disadvantages → The BUS-BAR cannot be cleaned, repaired and tested without de-energising the whole System.
→ If a fault occurs in the BUS-BAR itself there is a complete interruption of the supply.
→ Any faults on the System is fed by all the generating capacity, resulting very large fault current.



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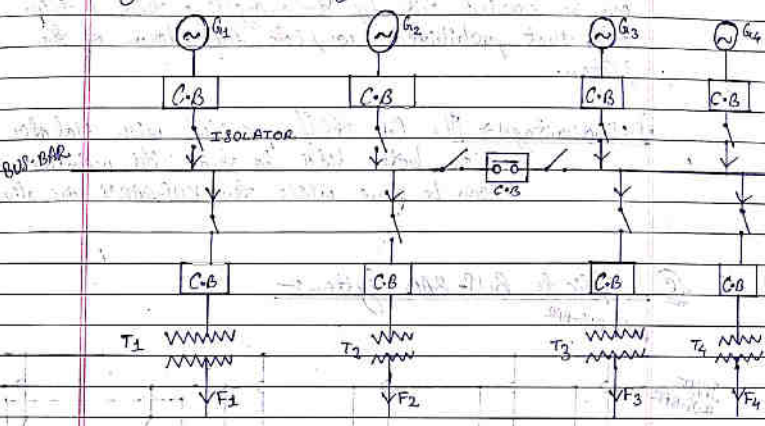
(b) Single BUS-BAR arrangement with Sectionalisation :-



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

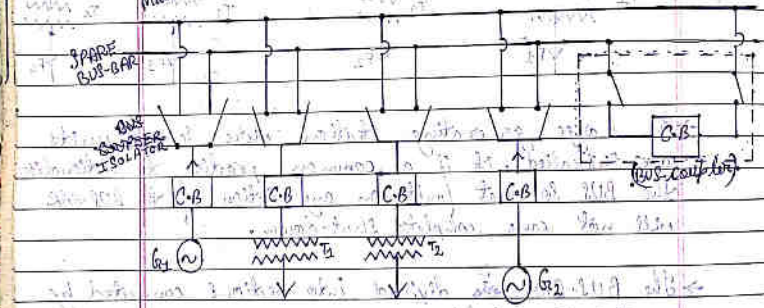
→ The BUS-BAR is divided into sections connected by a C.B & isolator.

Advantages → If a fault occurs in any section of the BUS-BAR that section can be isolated without affecting the other section.
→ Feeder (F) → If fault occur in any feeder, the fault current is much lower than unsectionalised BUS-BAR system which permits use of lower ratings C.B.

→ Repair & maintainance of any section of the BUS-BAR can be carried out by de-energising that section only, that prohibited complete shut-down of the system.

Disadvantage → The C.B itself provided with isolator on both side so that its maintainance can be done while the BUS-BAR's are alive.

(c) Duplicate BUS-BAR System :-



→ In large station where their is importance of continuity of supply & not interfare by break-down & and maintainance of bus-bar, in order to achieve this we used Duplicate BUS-BAR System.

→ In this system we found 2 BUS-BAR named as Main BUS-BAR & Spare BUS-BAR.

→ Each generator and feeder may be connected on either BUS-BAR by the help of BUS-Coupler which consists of C.B and Isolators.

→ In this scheme of BUS-BAR arrangement circuit interrupted during switch-over from one BUS to another.

Advantage → Repair & maintainance carried out in main bus-bar need not be interrupted entire load and transfer to spare-bus.

→ Testing of feeder C.B can be done by putting them on spare-bus, calling main-bus undisturbed.

→ If fault occur on the bus-bar the continuity of the supply can be maintain by transferring all load to spare-bus.

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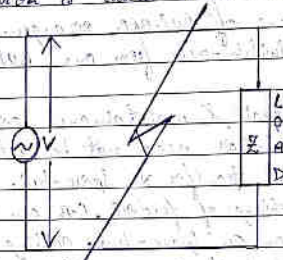
* Short Circuit :-

→ Whenever a fault occur on a network such that a large current flow in one or more lines [or phases] then the condition is called Short ckt condition.



Let,

→ A ckt consists of a generation of voltage (V) volt having internal impedance (Z_i) & load of (Z).

→ Under normal operating condition the current in the circuit is limited by internal impedance (Z_i) & load impedance (Z). i.e. $I = \frac{V}{Z+Z_i}$.

→ If any fault occurs across the load terminals and get Shorted at that time the load impedance $Z = 0$ and (Z_i) value is very small.

→ Hence, a large Short ckt current starts flowing in the circuit that is also called as ~~Over loading~~ Short Circuited.

→ On the other hand in an over load case if load greather than design value of the system, the voltage near over load point is zero. Hence, the current in the overload equipment are substantly high.

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Causes :- Internal effect →

→ The internal effects are cause by breakdown of equipments or transmission lines, deterioration of insulation of generator, x^o.

→ Such troubles may be due to edging of insulation, inadequate design or improper insulation.

:- External effect →

→ The external effect caring due to insulation failure cause due to lightining surges, overloading of equipments caring heating excessive, mechanical damage by public, etc.

Effect of SC :- When Short Circuit occurs the current in the system increases to an abnormal high value and the system voltage also reduce to a low value.

→ Due to this heavy current excessive heat is produced in the system & may result fire explotion.

→ Sometimes the short circuit takes of an "Arc" causes considerable damage of system.

→ The low voltage created due to short circuit and remain for a few second's, the consumer loads may shut down and a unstable condⁿ created across the power system.

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* Fault in a Power System :-

→ A fault occurs when two or more conductors that normally operated if potential difference come contact with each other.

→ This may be due to sudden failure of a piece of equipment, accidently damage, insulation failure, ageing effect, lightning surges, etc.

→ So the fault of in a 3ϕ system is divided into 2 types;

① Symmetrical fault.

② Unsymmetrical fault.

① Un-Symmetrical fault → Those fault which rise to unsymmetrical fault current i.e. unequal line current and unequal phase displacement.

Ex → Singe line to ground, line to line fault, double line to ground.

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* Symmetrical fault :- Those fault on the power system which rise symmetrical fault current i.e. equal fault current, equal displacement in each line. (120° displacement).

Ex → Line to line to line fault (LLL).

LLL & G fault (Line to Line to Line to ground fault).

→ The symmetrical fault occur when all the 3 conductors of a 3-ϕ line brought together simultaneously into a short circuit condition.

→ This type of fault give rise to symmetrical fault current which is 120° apart from each other.

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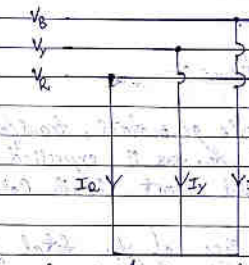

→ The symmetrical fault rarely occur in practice, the majority of the faults are unsymmetrical.

→ The symmetrical fault is most severe one severe & imposes more heavy duty on circuit breaker.

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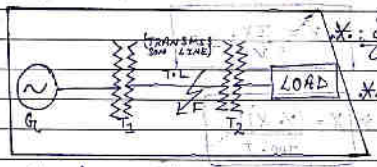

* Symmetrical fault Calculation :-

* Limitation of fault Currents :-

→ When short circuit occurs at any point of the system the short circuit current is limited by the impedance of the system upto point of fault.

→ In the above diagram if fault occur at F (fault) then the short circuit current of the G1 (generating station) will have value limited by impedance of generator, transformer & transmission line upto point of fault.

→ So we have proper knowledge about impedance of various equipments & circuit, for determination of SC current.

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✳ Different terms:-

✳ Percentage of Reactance:-

→ The reactance of the generators, transformers, transmission line and, reactors, etc. are is expressed in percentage of reactance. for rapid short circuit calculation.

→ So it is define as %ge of the total phase voltage drop in the circuit when full-load current is flowing through it.

Let X = Reactance of the system in ohm per phase.
I = Full-load current.
V = Phase voltage of the system.

So; $\%X = \frac{IX}{V} \times 100$

$\Rightarrow X = \frac{(\%X) \cdot V}{100 \cdot I}$

$\Rightarrow X = \frac{(\%X) \cdot V \cdot V}{100 \cdot V \cdot I}$

$\Rightarrow X = \frac{(\%X) \times \frac{V}{1000} \times \frac{V}{1000} \times 1000}{\frac{100 \times V \times I}{1000}}$

$\Rightarrow X = \frac{(\%X)(KV)^2 \times 10}{KVA}$

$\Rightarrow X = \frac{(\%X)(KV)^2 \times 10}{KVA}$

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So, $\frac{X\,(KVA)}{10 \times (KV^2)} = \%X$

→ So; Short Circuit Current (I_{sc}) = $\frac{V}{X}$

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

where; I = Normal full-load current.

✳ %ge of reactance and base KVA:-

→ So from the above, it is seen that the %ge of reactance (X) depends upon [KVA] rating.

→ Generally, the various equipment used in the power system have different [KVA] rating. Therefore, it is necessary to find out %ge of reactance (X) of all the elements on a common [KVA] rating, known as base KVA.

→ The base KVA of the power system may be;
(a). Equal to the largest plant capacity.
(b). Equal to the total plant capacity.
(c). Any arbitary value.

→ So, now all the %ge of (X) of rated (KVA) is to be convert %ge of (X) at base KVA.

→ So; $\%X_{(\text{Base KVA})} = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X_{(\text{Rated KVA})}$

X. Short Circuit KVA :-

→ The product of normal system voltage (V) & short circuit current (I_{sc}) at the point of fault is expressed in KVA known as Short Circuit KVA.

We know that; $I_{sc} = \frac{I}{\%X} \times 100$

So; Short Circuit KVA $= \frac{3V \times I_{sc}}{1000}$

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

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

→ Short Ckt KVA = Base KVA $\times \frac{100}{\%X}$

where; $\%X$ = % of reactance upto point of fault.

X. Steps for Symmetrical fault Calculations :-

- Step-I ⇒ Draw the single line diagram of the complete network indicating the rating, voltage & % of reactance of each element of the network.
- Step-II ⇒ Choose a numerically convinient value of base KVA, and convert all %X to that base value.
- Step-III ⇒ Corresponding to the single line diagram of the network draw the reactance diagram, showing 1φ of the system & neutral.
  Indicate the %X on the base KVA in the reactance diagram.
  The X^s in the system should be represented by a reactance in Series.
- Step-IV ⇒ Find total %X of the network upto point of fault & total $\%X_T$.
- Step-V ⇒ Then we have to find out full-load current corresponding to base KVA, and normal system voltage at the point of fault.
- Step-VI ⇒ So Short circuit current (I_{sc}) = $\frac{I}{\%X} \times 100$.

  and; Short Ckt KVA = Base KVA $\times \frac{100}{\%X}$.

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Problem-01: In the Single line diagram of a 3ϕ system, the %X of each alternator is based on it's capacity. Find the Short Ckt Current that will flow into a complete 3ϕ Short Ckt at 'F'.

15,000 KVA A ~ 30%

20,000 KVA B ~ 50%

12,000 V

F

Sol^n:- S-1 →

S-2 → Let the base KVA = 15,000 + 20,000

= 35,000 KVA

$\%X_A = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X_{(\text{rated KVA})}$

$= \frac{35,000}{15,000} \times 30$

$= 70\%$

and; $\%X_B = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X_{(\text{rated KVA})}$

$= \frac{35,000}{20,000} \times 50$

$= 87.5\%$

S-3 →

70% 87.5%

S-4 → $\%X_{T_{(\text{upto point of fault})}} = \%X_A // \%X_B$

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$\Rightarrow \%X_{T_{(\text{upto point 'F'})}} = \frac{X_A \cdot X_B}{X_A + X_B}$

$= \frac{70 \times 87.5}{70 + 87.5}$

$= 38.89\%$

S-5 → $I_{\text{Base KVA}} = \frac{35,000 \text{ KVA}}{\sqrt{3} \times 12 \times 10^3 \text{ V}}$

$= \frac{35,000 \times 1000}{\sqrt{3} \times 12 \times 10^3}$

$= 1684 \text{ Amp.}$

S-6 → $I_{SC} = \frac{I}{\%X_T} \times 100$

$= \frac{1684}{38.89} \times 100$

$= 4330 \text{ Amp.}$

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Problem-02: A power system consists of 2 generator having installed capacity of 20,000 KVA capacity each. At connected to a bus-bar having voltage 20,000 volts. 2 X^r of capacity 15000 KVA & 10,000 KVA are taking tapping from the above bus-bar and obtained a voltage of 11,000 volts. If the fault occur on both HT & LT side of the X^r, what should be the rating of the ckt breaker installed on both side to protect under Short Ckt. Condition & also find out max^m Short ckt current on both side; having generating %age of 30% each & X^r %ge of 15% & 10%.

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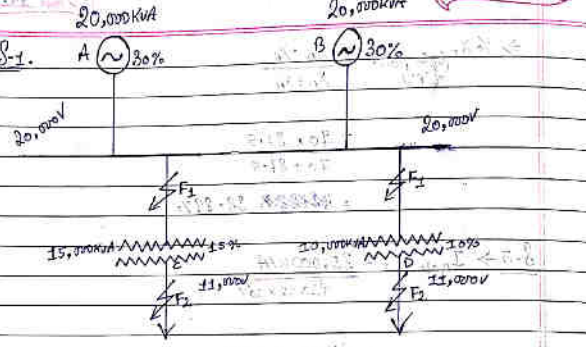
Sol^{n}:-

S-1.



S-2. Taking base KVA = 20,000 + 20,000 + 15,000 + 10,000

= 65,000 KVA

$$\text{So, } \%X_A = \frac{\text{Base KVA}}{\text{Rated KVA}} \times \%X_{(\text{Rated KVA})}$$

$$= \frac{65,000}{20,000} \times 30$$

$$= 97.5\%$$

$$\Rightarrow \%X_B = \frac{65,000}{20,000} \times 30$$

$$= 97.5\%$$

$$\Rightarrow \%X_C = \frac{65,000}{15,000} \times 15$$

$$\Rightarrow 65\%$$

$$\Rightarrow \%X_D = \frac{65,000}{10,000} \times 10$$

$$\Rightarrow 65\%$$

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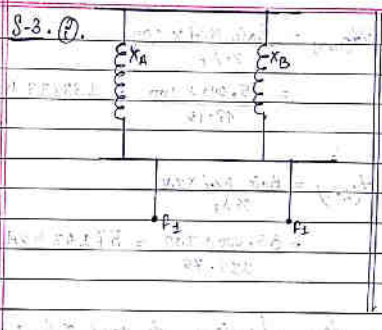
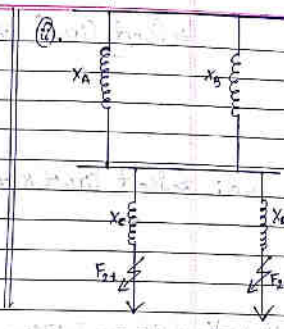
S-3. (i).



(ii).



S-4. (i). $\%X_{T_1} = \dfrac{X_A \cdot X_B}{X_A + X_B} \quad (X_A // X_B)$

$= 97.5 \times 97.5$

$97.5 + 97.5$

$= 48.75\%$

(ii). $\%XT_2 = (X_A // X_B) + X_C$

$= \dfrac{97.5 \times 97.5}{97.5 + 97.5} + 65$

$= 113.75\%$

$\Rightarrow \%XT_3 = (X_A // X_B) + X_D$

$= \dfrac{97.5 \times 97.5}{97.5 + 97.5} + 65$

$= 113.75\%$

Hence; $XT_2 = XT_3$

S-5. $I_{HT(\text{Base KVA})} = \dfrac{\text{Base KVA}}{\sqrt{3} \times 20,000\text{ V}} = \dfrac{65,000\text{ KVA}}{\sqrt{3} \times 20,000} = \dfrac{65,000 \times 10^3}{\sqrt{3} \times 20 \times 10^3}$

$= 1877\text{ A}.$

$\Rightarrow I_{LT(\text{Base KVA})} = \dfrac{65,000\text{ KVA}}{\sqrt{3} \times 11,000} = \dfrac{65,000 \times 10^3}{\sqrt{3} \times 11 \times 10^3} = 3412\text{ Amp.}$

S-6. $I_{SC(HT)} = \dfrac{I_{HT}}{\%X_{T_2}} \times 100$

$= \dfrac{1877}{48.75} \times 100 = 3851\text{ Amp.}$

$I_{SC(LT)} = \dfrac{I_{LT}}{\%X_{T_2}} \times 100$

$= \dfrac{3412}{113.75} \times 100 = 2999.56\text{ Amp.}$

$\Rightarrow$ Short Circuit $KVA_{(H.T)} = \frac{\text{Base KVA} \times 100}{\%X_T}$

$= \frac{65,000 \times 100}{48.75} = 133333$ KVA

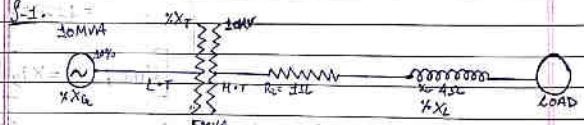
and; $\Rightarrow$ Short Circuit $KVA_{(L.T)} = \frac{\text{Base KVA} \times 100}{\%X_T}$

$= \frac{65,000 \times 100}{113.75} = 57143$ KVA

Problem-03. A 3ϕ transmission line operating at 10KV & having a resistance of 1Ω & reactance of 4Ω is connected to generating station bus-bar through 5MVA step up ΔY having reactance of 5%. The bus-bar are supplied by a ~~generator~~ 10MVA alternator having 10% reactance. Calculate the SC KVA fed to symmetrical fault between phases if it occurs:
(i). At the load end of transmission line.
(ii). At the high voltage terminal of the ΔY.

Soln:-

3-1.



3-2. Taking base KVA = 10MVA = 10×10^3 KVA

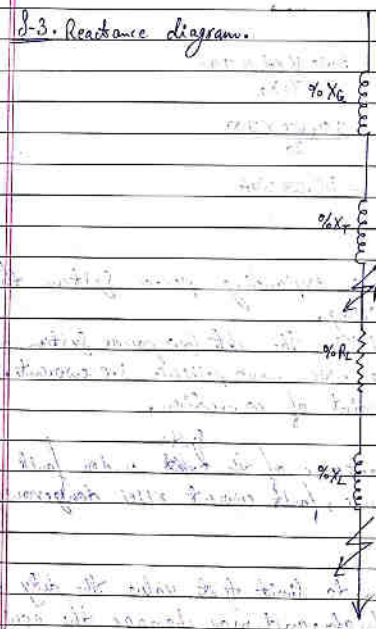
$\Rightarrow \%X_G = 10\% \left[\frac{10 \times 10^3}{10 \times 10^3} \times 10\right]$

$\Rightarrow \%X_T = \frac{10,000}{5,000} \times 5 = 10\% \left[\frac{10 \times 10^3 \text{KVA}}{5 \times 10^3 \text{KVA}} \times 5\right]$

$\Rightarrow \%X_L = \frac{\text{Base KVA} \times X_L}{10 \times KV^2} = \frac{10,000 \text{ KVA} \times 4}{10 \times 10^2} = 40\%$

$\Rightarrow \%R_L = \frac{\text{Base KVA} \times R_L}{10 \times KV^2} = \frac{10,000 \times 1}{10 \times 10^2} = 10\%$

3-3. Reactance diagram.



3-4 (i). $\%X_1 = \%X_G + \%X_T + \%X_L$

$= 10\% + 10\% + 40\%$

$= 60\%$

$\Rightarrow \%Z_1 = \sqrt{(\%R_L)^2 + (\%X_1)^2} = \sqrt{10^2 + 60^2}$

$= 60.82\%$

So, SC $KVA_1 = \frac{\text{Base KVA} \times 100}{\%X_1}$

$= \frac{10,000 \times 100}{60.82}$

$= 16442$ KVA

(ii). $\%X_2 = \%X_G + \%X_T$
$= 10\% + 10\%$
$= 20\%$

$\%$ So, SC KVA $= \frac{\text{Base KVA} \times 100}{\%X_2}$
$= \frac{10,000 \times 100}{20}$
$= 50,000$ KVA

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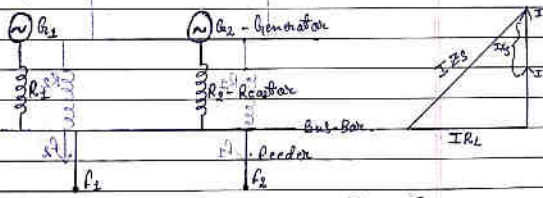
* Reactors:- In the expanding power system the fault level is also rising.
→ The C.B connected in the ckt (or) power system must have capable of dealing with max^m pollible S.C current, that can occur at their point of connection.
→ Generally, the reactance of the system under fault condition is very low. Hence, fault current rises dangerously to a high value.
→ If no step taken to limit that value the duty imposed in C.B is very high, and may damage the equipment.
→ In order to limit the short circuit current to a value which the C.B can handle additional reactance known as reactors are connected in series with the system at suitable points.
→ A reactor is a coil of number of turns designed to have a large inductance.
→ As the reactors have low resistance hence the drop will be less & may little change on efficiency.

* Advantages:-
→ Limit fault current & prevents the over-heating of equipments & from failure due to destructive mechanical forces.
→ Troubles or faults are localised or isolated at the point where they originate without communicating their disturbing effects to other parts of the power system.
→ This permits lower rating of C.B to be installed

* Locations of Reactors:-
→ The reactors are may be connected in series with each generator, in series with feeder & in series with bus-bar.

* Generator Reactors:-
→ When the reactors are connected in series with each generator, they are known as generator reactors.



→ Here the reactor may be considered as a part of leakage reactance of the generator; hence it effects to protect the generator in case of any short ckt beyond the reactors.

*. Disadvantages:-

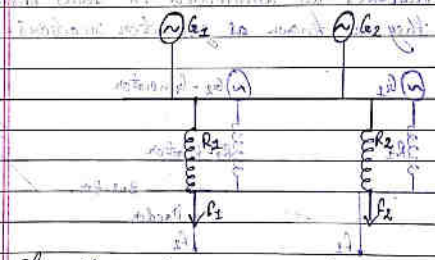
→ There is a constant voltage drop & power loss in reactors even during normal operation.

→ If fault occurs in bus-bar & feeder the voltage value of bus-bar reduced to a low value causing generator to fall-out of steps.

→ If any faults occurs at any feeder, the continuity of the supply lightly to be affected.

→ Due to that disadvantages the reactors are no longer connected in series with generator.

*. Feeder Reactors:-



→ When the reactor are connected in series with each feeder they are known as feeder reactors as most of the faults are occurs on feeders, a large number of reactors are used for such circuit.

*. Advantages:- If fault occurs on any feeder the voltage drop in the reactor will not effect the bus-bar voltage. So their is no lose of synchronism of generator.

→ The fault occurs on any feeder will not affect other feeder & consequently the faults are localised.

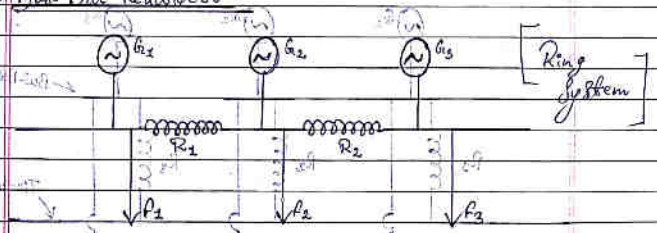
*. Dis-advantages:-

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

→ If fault occurs in bus-bar, no protection is provided to the generator, only the fault current limited by leakage reactance of the generator.

→ If the no. of generator is increased, the size of feeder reactor will have to be increased to keep the short circuit current with in the ratings of the feeder circuit breaker.

*. Bus Bar Reactors:-



→ From the above two types of reactor locations, there is a continuous voltage drop & power loss in all conditions.

→ So in order to avoid these, the reactors are to be located in the bus-bar with 2 methods of arrangement;

1. Ring System.
2. Tie bar System.

A. Ring System →

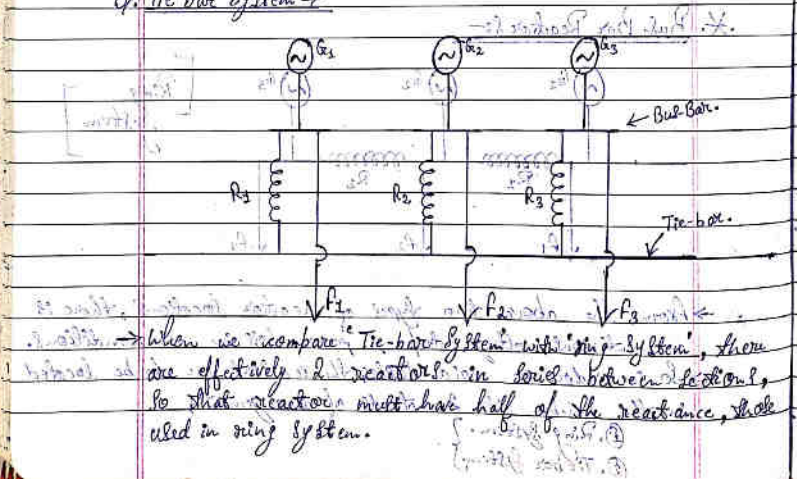
→ In this system bus-bar is divided into section and these sections are connected through reactors.

→ Under normal operating conditions, each generator will supply its own section of the load & little power fed from other generator; this results low power loss & voltage drop in reactors.

→ The advantage is that if fault occurs on any feeder only the generator mainly feeds the fault current while the current from other generator is small due to presence of reactor.

→ So only that portion of the bus-bar is get affected.

B. Tie bar System →



→ When we compare Tie-bar System with ring System, there are effectively 2 reactors in series between sections, so that reactor must have half of the reactance, that are used in ring System.

→ Tie-bar System (advantage) if a additional generator may be connected to the System without requiring changes in the existing generator.

→ However, there is a disadvantage that is, it requires a additional bus-bar.

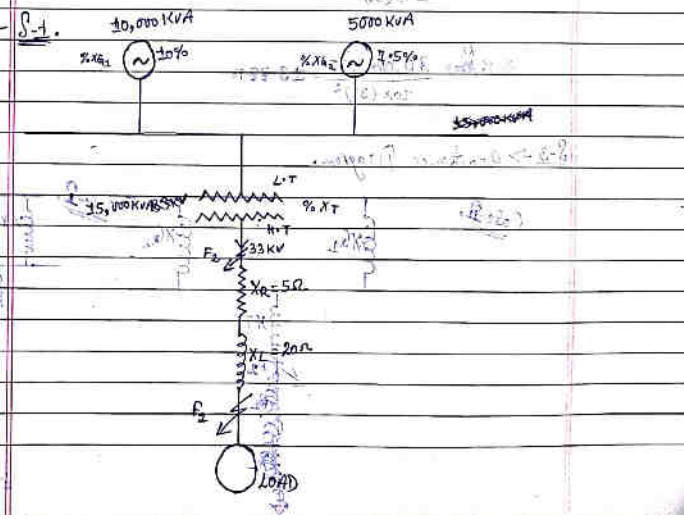
Date 17/02/2019

*. Problem → A 3ϕ transmission line operating at 33KV & having resistance of 5Ω & reactance 20Ω is connected to the generating station through 15000KVA step-up X'mer connected to the bus-bar with 2 alternators of one 10,000 KVA with 10% reactance and 5000 KVA with 7.5% reactance. Calculate the S.C KVA fed to the symmetrical fault between phases if it occurs;

(i). At the end of the transmission line.

(ii). At the high voltage terminal of the X'mer.

Solution - S-1.



Date Page 30.

S-2 ⇒ Taking base KVA = 10,000 + 5,000 + 15,000
= 30,000 KVA

$\Rightarrow \%X_{G_1} = \frac{30,000}{10,000} \times 10\%$

$= 30\%$

$\Rightarrow \%X_{G_2} = \frac{30,000}{5,000} \times 7.5\%$

$= 45\%$

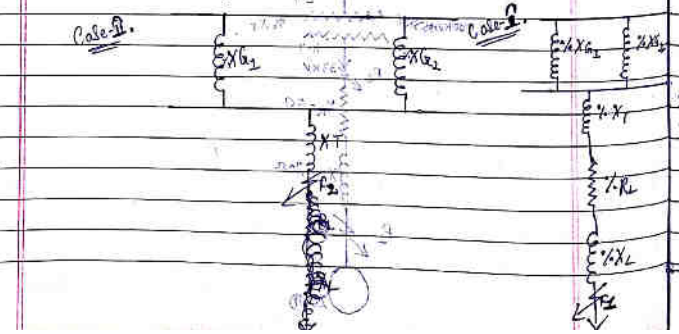
$\Rightarrow \%X_T = \frac{30,000}{15,000} \times 10\%$

$= 20\%$ 21%

$\Rightarrow \%X_L = \frac{30,000 \times 20}{10 \times (33)^2} = 55\%$

$\Rightarrow \%R = \frac{30,000 \times 5}{10 \times (33)^2} = 13.77\%$

S-3 ⇒ Reactance Diagram.



Date Page 31.

S-4 ⇒ Total $\%X_1 = (\%X_{G_1} // \%X_{G_2}) + \%X_T + \%X_L$

$= \frac{30 \times 45}{30+45} + 24 + 55$

$= 97\%$

$\Rightarrow \%Z_1 = \sqrt{\%R_L^2 + \%X_1^2}$

$= \sqrt{(13.77)^2 + (97)^2}$

$= 97.97\%$ [For (Case-I)]

⇒ Total $\%X_2 = (\%X_{G_1} // \%X_{G_2}) + \%X_T$

$= \frac{30 \times 45}{30+45} + 21$

$= 42\%$ [For (Case-II)]

S-5 ⇒ Case-I ⇒ Short Ckt KVA = $\frac{\text{Base KVA} \times 100}{\%Z_1}$

$= \frac{30,000}{97.97} \times 100$

$= 30621$ KVA

Case-II ⇒ S.C. KVA = $\frac{\text{Base KVA}}{\%X_2} \times 100$

$= \frac{30,000}{42} \times 100$

$= 71.428$ KVA

CH-03.

Date Page 32.

* Circuit Breaker :-

→ A power system consists of various circuit like transmission lines, distributors, feeders, generating plants, transformer, etc.

→ Under normal & abnormal condition the power system control by different protective element like fuse, C.B, relay, C.T & P.T, etc.

→ Acc to the installation voltage and current different protective equipments are installed.

→ If the power system is low voltage, low current fuses are installed in the line which is blown out when their is fault & again it is rewirable after clearing of faults.

→ At high voltage & high current power system, the value of voltage & current is high by limitive; if it increase from rated value it cause severe fault; so for high voltage installation C.B, relay, C.T & P.T, etc. are used.

* C.B → C.B is a piece of equipment which can;
  (i) Make or break a ckt either manually or by remote control under normal condition.
  (ii) Break the circuit automatically under fault condition.
  (iii) Break the circuit either manually or remote control under fault condition.

Date 18/01/2021

Date Page 33.

* Operating Principle of C.B :-

→ A C.B is a manual or automatic operating device essentially consists of fixed & moving contact called electrodes.

→ Under normal operating condition this contacts are remain closed and will not open automatically until and unless the system is faulty.

→ Although the contacts can be open manually or by remote control whenever desired.

→ When fault occurs at the any part of the system the trip coil of the relay get energised and energised the C.B. Hence the moving contact pulled a part by some mechanism and thus opening the main circuit.

→ When the contacts of the C.B are separated under fault condⁿ an arc (Spark) is struck between fixed & moving contact. The current is thus able to continue until the discharge ceases.

→ The production of arc not only delays the current interruption process but also produce enormous amount of heat is produced, which may damage the C.B itself.

→ So the main problem is extinguishing of arc in shortest possible time.

[Current / Unit Area = Current Density]

IMP

X. Arc Phenomenon:-

→ When short ckt or fault occurs, a heavy current flow through the contacts of the C.B. before they are opened by protective system.

→ At the instant the contacts are begins to separate the contact area decreases rapidly. At that time the fault current is very large, so the current density is increased which cause rise of temperature of the contacts.

→ The heat produced in the medium both the contacts is sufficient to ionised the air or vapourised the oil.

→ The ionised air or vapour oil acts as a conductors and current starts to flow in that medium which seen as a arc both the contacts.

→ The potential difference bet the contacts is quite small and it just sufficient to maintain the arc.

→ The arc provides low resistance path for current & the ckt. ~~it~~ remain uninterrupted so long as arc persists.

→ The factors which influence the arc phenomenon depends upon the arc resistance.

→ The greater the arc resistance, smaller the current flow between the contacts. So the arc resistance depends upon following factors;

(A). Degree of Ionisation → The arc resistance increased with the decrease in the no. of ionized particles between the contacts.

(B). Length of the arc → The arc resistance increases with the length of the arc i.e. the separation bet the 2 contacts increased then the resistance of the arc also increased.

(C). Cross Sectional area of arc → The arc resistance increases with decrease in the area of cross-section of the arc.

X. Principle of Arc Extinction →

→ The factor responsible for ↑ arc bet the contact are;
(i). Potential difference bet the contact.
(ii). Ionised particle bet the contact.

→ When the contacts (F.C & M.C) have a small separation, the potential difference bet them is sufficient to maintain the arc. One way to extinguish of arc is to separate the contacts to such a distance that potential difference become inadequate to maintain the arc.
However, this method is impracticable in high voltage system where the separation of many metre may be required.

(ii). → The ionised particles between the contacts tends to maintain the arc. If the arc path is de-ionised the arc extinction will be facilated. So, this may be achieved by cooling the arc or by bodily removing the ionised particals from the space between the contacts.

Imp * Methods of arc Extinction :—

→ There are two methods used for extinction of arc i.e.
(i). High resistance method.
(ii). Low resistance method (or) Current Zero method.

(i). High resistance method → In this method the arc resistance is made to increase with time so that current is reduced to a value which is insufficient to maintain the arc consiquently the arc is extinguilh.

→ The principal & disadvantages of this method is that enormous amount of heat is dispated in the arc. Therefore, it is employed only in dc C.B or low capacity ac C.B.

→ The resistance of the arc may be increased by four ways;

(i). Lengthening the arc :— The resistance of the arc is directly proportional to the length of the arc. So the length of the arc can be increased by increasing the gap betn the contact.

(ii). Cooling the arc → Cooling helps de-ionised the medium betn the contacts which increase arc resistance. So, this can be achieved by a gas blast directed along the arc.

(iii). Reducing (a) 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 word, the resistance of the arc path is increased by decreasing the cross-section of the arc by letting the arc pass through a small narrow opening or by smaller area of contacts.

(iv). Splitting the arc :— The resistance of the arc can be increased by splitting the arc into a no. of smaller arcs in series. Each one of this arc experienced the effect of lengthening & cooling.

→ The arc may be split by introducing some conducting plates or horns betn the contacts known as arcing horn.

Imp (ii). Low resistance method → This method is employed for arc extinction in ac ckt's only. In this method arc resistance is kept low until current is zero where the arc extinguilhes naturally and it prevents from restriking inspite of the rising voltage across the contacts.

→ All modern high voltage C.B are employed this method of arc extinction.

→ In a ac system the current reduced to zero in every half cycle. At every current zero the arc extinguilhes for a brief moment. Now the medium contains ions & electrons so that it has small di-electric strength and can be easily broken down by rising contact voltage known as re-striking voltage. If such a breakdown occur the arc restrikes for next half cycle. If immediately current zero, the di-electric strength betn the contact built-up more rapidly than the voltage across the contact (rate of increasing of di-electric strength > rate of voltage developed across the contact).

→ Hence, the arc fail to re-stricke & current will be interrupted.

→ The rapid increase of di-electric strength of the medium near current zero can be achieved by causing the ionize particle in the space between the contact to re-combine into neutral molecules or sweeping away ionized particle and replacing them by un-ionize particles.

→ The di-electric strength both the contact can be achieved by;

$C = \varepsilon_0 \frac{A}{d}$

$\varepsilon_0 = \frac{ed}{A}$

(i) Lengthening of the gap → The di-electric strength of the medium is proportional to the length of gap between the contacts therefore, by opening the contact rapidly higher di-electric strength of the medium can be achieved.

(ii) High Pressure → If the preture of the arc increase then the density of the ionize particle decreases. Hence, di-electric strength of the medium increased.

(iii) Cooling → Natural combination of ionize particles take place more rapidly if they are allow to cool. Hence di-electric strength of the medium increase.

(iv) Blast Effect → If the ionized particle of both the contacts are swept away and replace by neutral molecules then di-electric strength of the medium increase.

* Important terms:-

(1) Arcing Voltage → It is the voltage that appears across the contacts of the CB during the arcing period. As soon as the contact of the CB separate an arc is formed; the voltage that appears across the contact during arcing period is called as arcing voltage.

→ It's value is low except for the period near current zero.

→ So at that time (near current zero) the arc voltage rises rapidly to a peak value and this peak voltage tends to maintain the current flows, in the form of arc.

(2) Re-Stricking Voltage → It is the transient voltage (unwanted frequency voltage) that appears across the contact at or near current zero during arcing period.

→ At current zero a high frequency transient voltage appears across the contact and is caused by rapid distribution of energy between the magnetic & electric field associated with plant & transmission line of the system. This transient voltage is known as re-stricking voltage.

→ The current interruption will be depend upon this voltage.

→ If the rate of rise of re-stricking voltage is higher than rate of build-up of di-electric strength then arc persist for another half cycle.

→ On the other hand of di-electric strength of the medium build-up more rapidly than re-stricking voltage, the arc fail to re-stricking.

(5). Recovery Voltage → It is the normal frequency rms voltage that appears across the contacts of the C.B. after final arc extinction, which is equal to the normal system voltage.

→ When contacts of C.B. are opened current drops to zero after some half-cycle & contacts are separated sufficiently apart from each other, the di-electric strength of the medium so high that it removes the ionised particles. Hence, the re-striking voltage is breakdown to further re-strike of the arc. and arc extinction takes place finally.

→ when arc interruption take place the voltage that appear across the contacts has no transient part and this normal system voltage is called recovery voltage.

Date 2/2/2019

*. Classification of Circuit Breaker :—

→ According to the basis of medium use for arc extinction, there are several types of C.B.

(i). Oil Circuit Breaker (use x^s oil for extinction medium).
(ii). Air Blast Circuit Breaker (here in which high pressure air use for extinction).
(iii). SF6 Sulphur hexa fluoride (SF6 gas used as extinction).
(iv). Vacuum Circuit Breaker (Vacuum used as arc extinction).

1). Oil Circuit Breaker → In this type of C.B., x^s oil (insulating oil) used as arc quenching medium.

→ The contacts are opened under oil & arc is struck between them.

→ The heat of the arc dissociated or evaporated the surrounding oil into hydrogen gas.

→ The hydrogen gas occupied the volume about 1000 times that of oil decomposed. So the oil is therefore pushed away from the arc & expanding hydrogen gas bubble surrounds the arc.

→ The nature of hydrogen gas is that, it is high heat conductivity & pushed the arc and their after hand it setup a turbulance in the oil & forced it into the space between the contacts, which eleminates arcing products from arc path.

Advantages → It absorbs the arc energy to decompose the oil into gas have excellent cooling properties.

→ It acts as an insulator which permits smaller clearance between live conductor & earthed conductor/components.

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

Disadvantages → The oil is inflammable & there is a risk of fire.

→ It may be formed an explosive mixture with air.

→ The arcing products remain in the oil. Hence quality deteriorated with successive operation.

Type of Oil C.B. :—

(i). Bulk Oil C.B → (i) Plain break Oil C.B
(ii). Low oil C.B. (ii) Arc control Oil C.B

Self blast Oil C.B — Forced blast Oil C.B

Plain explosion pot. — Cross jet explosion pot. — Self-compensated explosion pot.

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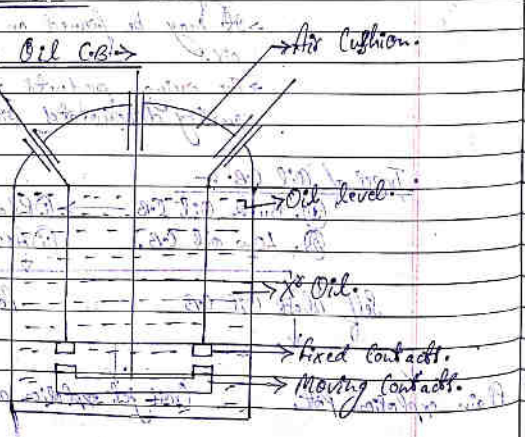
Classification of C.B:-

- C.B.
  - Oil C.B
    - Bulk Oil C.B
      - Plain break Oil C.B.
      - Arc Control oil C.B.
    - Low Oil C.B
      - Self blast Oil C.B.
      - Forced blast Oil C.B.
  - Air-blast C.B.
    - Plain Explosion Pot.
    - Cross-jet explosion pot.
    - Self-compensated explosion pot.
  - SF6 C.B.
  - Vacuum C.B.

* Bulk Oil C.B:-

(1) Plain Break Oil C.B:-



Date Page 43

→ This C.B involves simple process of separating the contacts under whole of the oil in the tank.

→ There is no special system of arc control, other than increase in length caused by separation of the contacts i.e. the arc extinction takes place in the oil medium with a critical gap b/w the contacts.

→ This type of Oil C.B is a earliest type which has very simple construction.

→ It consists of fixed & moving contacts enclosed inside a weather/air tight earthed tank containing oil upto a certain level.

→ The tank provided with a air cushion above the oil level which allow sufficient space arc gases without generating unsafe pressure.

→ It is also a double break oil C.B because it provides two breaks simultaneously.

→ Under normal operating condition, the F.C & M.C remains closed to each other and breaker carries normal current.

→ When fault occurs the M.C are pushed down by protective system & an arc is struck b/w F.C & M.C which vaporises the oil into hydrogen gas.

→ The hydrogen gas bubbles generated around the arc which cools the arc column & deionization the medium b/w the contacts.

→ The gas set-up turbulance in the oils & helps to eliminating arcing products.

→ As the arc length increases due to separating contacts the dielectric strength b/w the medium is increased, so arc extinction takes place.

Date Page 44

Disadvantages:
- There is no special control over the arc other than increase in length.
- These breakers have long arcing time.
- It doesn't permit high speed of interruption.

Used:
- Upto 11 KV.
- Used for low voltage installation.

Date 25/07/2019

(iii). Arc Control Oil C.B:—

- In case of plain break oil C.B there is a little control over the arc; so there if a long arc length is essential in order to produced turbulance in the oil; so in order to achieve short contact length some arc control is incorporated. Such breakers are known as of Arc control Oil C.B.

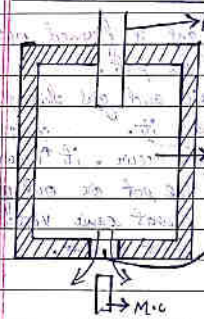
- Arc control Oil C.B is are of 2 types;
  - (A). Self blast oil C.B.
  - (B). Forced blast oil C.B:

Self-blast Oil C.B: In this type of C.B the gase produced during arcing are confined to a small volume by the use of insulating rigid pressure chamber or pot surrounded the contacts. So the space available for arc gase is restricted by the chamber and high pressure is developed inside the oil which forces the oil around the arc & extinguish it.

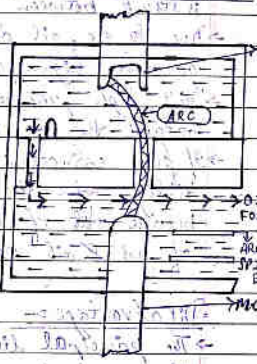
Date Page 45.

- So according to the construction of the chamber for produced self pressure it is of upto 3 types;
  - (A). Plain explosion pot.
  - (B). Cross-jet explosion pot.
  - (C). Self compensated explosion pot.

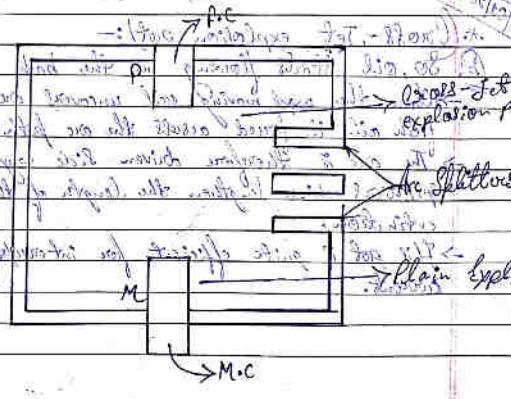
(A). Plain explosion pot:—



(B). Cross jet explosion pot:—



(C). Self-compensated explosion pot:—



*(Plain explosion pot):-

(a) It is a rigid cylinder of insulating material (bakelite) and enclosed the fixed & moving contacts.
→ The moving contact is a cylindrical rod which is passing through a restricted opening (throat).
→ When fault occur the contacts are get separated and arc is struck between F.C & M.C.
→ Due to arc, oil decomposes and gas is formed which generate high pressure inside the pot.
→ This high pressure forced the oil and gas through and around the arc which extinguish it. (extinction)
→ If final extinction of arc doesn't occur, it occurs immediately after the M.C leaves the pot or out of throat, because out of M.C from the throat cause violent rushes of gas & oil occurs through that throat.

Disadvantage:-
→ The principal limitation of this type of pot is that it cannot be used for very low & very high current.

Date 29/04/2019

*(Cross-Jet explosion pot):-

(b) So, oil starts flowing in the back spaces.
→ When the moving coil uncovers arc splitter ducts, fresh oil is forced across the arc path.
→ The arc is therefore driven side ways & touched the arc splitters which lengthen the length of the arc causing arc extinction.
→ This pot is quite efficient for interrupting the heavy fault current.

*(Self-Compensated explosion pot):-

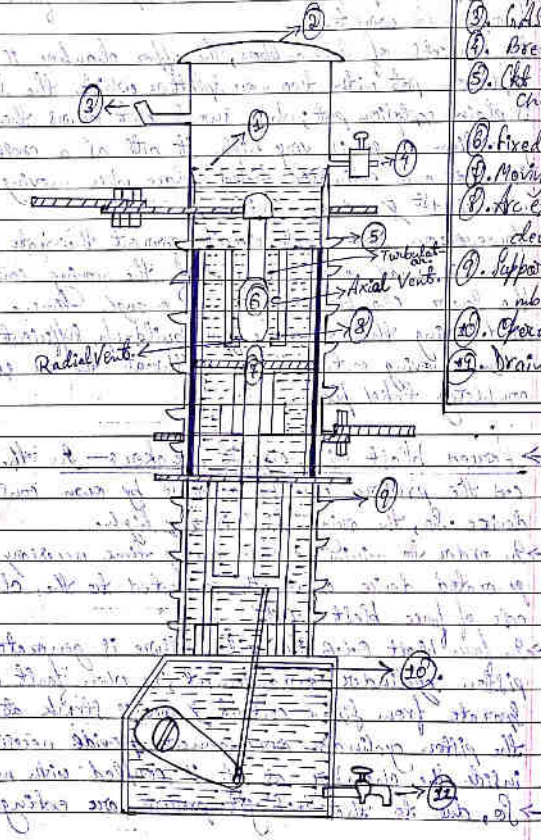
(c) It is a plain combination of plain explosion pot & cross-jet explosion pot; so it can interrupt low fault current & heavy fault current.
→ It consists of 2 chamber, the upper chamber is Cross-jet explosion pot with two - arc splitter while the lower chamber is plain explosion pot; when short ckt occurs the rate of generation of gas is very high it acts as a cross-jet explosion pot and extinction take place when moving contact uncovers 1st & 2nd arc splitter.
→ However; on low short circuit current the rate of gas generation is small and the trip of the moving contact reaches the lower chamber as it has enough time.
→ And during this time the gas build-up sufficient pressure and when moving contacts is out of throat the arc extinction completely take place.

B. → Forced blast oil circuit breakers:- In the self-blast C.B the pressure will be generate by own construction device. So, the arcing time is very high.
→ In order to minimize the arcing time necessary pressure generated device externally connected to the chamber in case of force blast O.C.B.
→ In force blast O.C.B the oil pressure is generated by the piston cylinder arrangement, so when fault occur the M.C. Separate from fixed contact & arc is struck at that time the piston cylinder arrangement provide necessary pressure inside the chamber as it is coupled with moving contact.
→ So, due to that oil jet pressure are extinguish.

Date 30/01/2019

Imp

X. Low Oil Circuit Breaker:-



1. Oil level.
2. Top Chamber.
3. Gas Vent.
4. Breather.
5. Ckt Breaking Chamber.
6. Fixed Contact.
7. Moving Contact.
8. Arc extinction device.
9. Supporting Chamber.
10. Operating Rod.
11. Drain Valve.

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→ The oil use in the circuit breaker perform 2 functions i.e. firstly it acts as an arc quenching medium & secondly it separate the 2 live parts.

→ It is seen that only small type of oil actually used for arc extinction whereas the major part portion used as insulation.

→ So, for this reason if voltage rating increased the quantity of oil required also increases in case of Buck oil C.B which not only increased the expensed, tank size & weight of the breaker but also increase the risk of fire as well as maintainance problems.

→ So, in order to minimise the problem low oil C.B developed.

→ In case of low oil C.B, solid material is used for insulation purpose whereas it uses small quantity of oil sufficient for arc extinction.

Construction:-

→ It consists of 2 chambers; the upper chamber is the circuit breaking chamber whereas the lower chamber is known as supporting chamber.

→ The 2 chambers are separated by a partition i.e. it prevent mixing of oil of 2 chamber.

Supporting Chamber → It is a porcelin chamber mounted on a metal chamber. It is filled with oil which is physically separated from circuit breaking chamber.

→ The inner side of the supporting chamber & the annular space between the porcelin insulation & bakelized paper is reinforced for insulation purpose.

Date 31/01/2019

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* Circuit Breaking Chamber → In the circuit breaking chamber we founds 3 elements:
  (i). Fixed Contact.
  (ii). Moving Contact.
  (iii). Turbulator.

→ The moving contact is a hollow cyclinder which moves down by a piston.
→ There are 2 types of vent found in the turbulator i.e.
  (A). Radial Vent.
  (B). Axial Vent.
→ If the fault current is low the axial vent helps in the interruption whereas when fault current is high, radial vent is used.

* Top Chamber → It is a metal chamber mounted above the circuit breaking chamber.
→ It provides space for expansion of oil during circuit breaking.
→ It also provide with gas-vents & breather for safety of the circuit breaker.

* Operation :-
→ Under normal operating condition the moving contact remain engaged with fixed contact & normal current flow through it.
→ When fault occurs the moving contact is pulled down by tripping spring and arc is struck.
→ Due to arc the oil get vaporised and gases is produced under pressure.
→ Now, these gases forces the oil to pass through central hole of the moving contacts and gases to be outlet causing turbulance. So due to that turbulance inside the chamber

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Separation of arcing products from arc path and arc get quenched and circuit interruption caused.

* Advantages :-
→ It requires low oil.
→ It also requires smaller space.
→ It reduced risk of fire.
→ Maintaince problem low.

* Disadvantages :-
→ Due to smaller amount of oil the degree of carbonisation is high.
→ The di-electric strength of the oil deteriorates rapidly due to high carbonisation.

* Air-Blast Circuit Breaker :-
→ In this type of C.B. high pressure air blast acts as a arc quenching medium. As soon as the contacts are separate during fault, an air-blast established by opening the valve which results sweep away of arcing products to the atmosphere and also pulls the arc & contacts.
→ This causing rapidly increase of di-electric strength between the contacts, and arc is extinguish, current get interrupted.

* Advantages → The risk of fire is eliminated.
→ As arcing products are completely remove by the blast from the chamber, the degree of di-electric strength build-up is higher than that of O.C.B.

→ Their is no need of replacement of air as that of O.C.B
→ Here the Arcing time is low as the rate of di-electric strength build-up is high.
→ This C.B is used where their is frequent faults occurs due to less arc energy loss.

* Disadvantages:- The air has relatively inferior arc extinguishing properties.
→ Continous maintainance required to compressor plant (air-blast equipment).

* Uses:- Upto voltage beyond 110KV.

* Types:- Their are 3 type of air blast C.B.
1. Axial Blast type.
2. Cross Blast type.
3. Radial Blast type.

1. * Axial Blast:- In this type of air blast C.B, the air flow along the arc path.

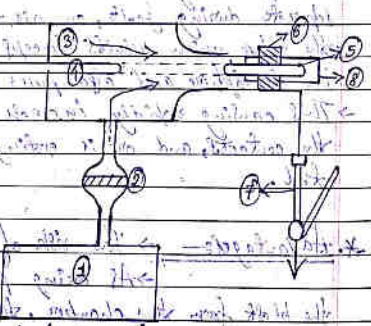

Fig-1.

1. Air Reservoir.
2. Air Valve.
3. Arcing Chamber.
4. Fixed Contact.
5. Moving Contact.
6. Spring.
7. Series Isolator.
8. Piston.

* Cross-Blast:-

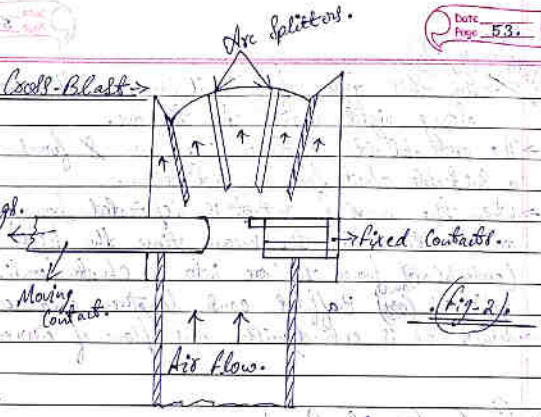

Fig-2.

Axial Blast:-
→ In this type of C.B the F.C & M.C are held together by spring pressure under normal condition. (Fig-1).
→ The 2 contacts are enclosed inside a arcing chamber which is connected to a air reservoir through air valve, and this valve closed under normal condition. when fault occurs the tripping impulse open the air valve and air rushed inside the arcing chamber from air reservoir.
→ Due to high pressure of air, the arc starts separated from F.C and arc is struck.
→ At the same time high pressure air-blast flows along the arc & take away the ionized particles from the path.
→ Due to this effect the di-electric strength rapidly build-up and arc get extinguished and current get interrupted.
→ In this type of air blast C.B the separation length is generally small (1.75 cm).

Date 05/02/2024

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2.

• Cross blast :- (Fig-2.)

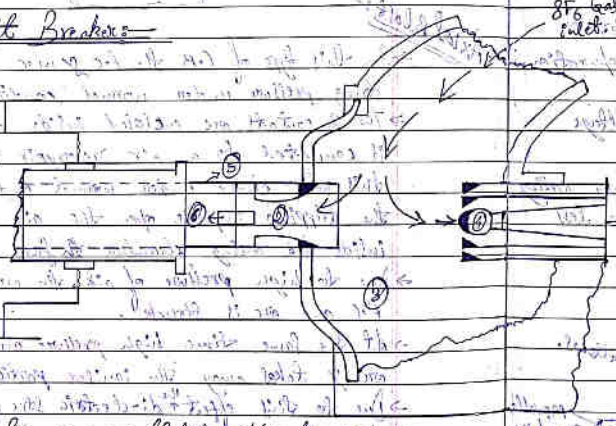
→ In this type of Circuit breaker, the air is directed along right angled to the arc.

→ The cross-blast lengthen the arc & forced the arc into a suitable chute for arc extinction.

→ When the moving contact is separated from fixed contact arc is struck at the mean time the high pressure air (cross-blast) forced the arc into a chute consisting of arc splitters and Baffles cause lengthen and cooling of arc.

→ Result arc is extinguish and flow of current interrupted.

X. SF-6 Circuit Breakers



1. Fixed Contact.
2. Moving Contact.
3. Arc Chamber.
4. Spring Frame.
5. Moving Member.
6. Gas Outlet.

→ In SF-6 C.B. SF_6 is used (Sulphur Hexafluoride) as arc quenching medium.

→ SF_6 is a highly electron negative gas i.e. it has strong tendency to absorb free electrons.

→ All the free electrons are rapidly capture by gas to form immobile negative ions, which build-up high di-electric strength both the contacts.

Date

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• Construction → It consist of fixed contact & moving contact enclosed in a chamber which is connected to a SF_6 gas reservior.

→ When contacts are separated the valve open and SF_6 gas with high pressure inlet to the chamber.

→ The fixed contact is a hollow cylinder carrying arc horns.

→ Moving contact is also a hollow cylinder having rectangular hole at the centre.

→ The tips of the fixed contact & moving contact are coated with copper-tungsten arc resistant material.

→ As SF_6 gas is highly costly, so after each operation it is reconditioned and reclaimed by suitable oscillatory system and store in reservior.

• Working → When both the contacts are closed at normal operation the SF_6 gas surrounded the contacts at a pressure of 2.8 Kg/cm².

→ As soon as fault occur moving contact pulled apart from fixed contact and the valve synchronised permit SF_6 gas at 14 Kg/cm² pressure from reservior to the arc chamber.

→ This high pressure SF_6 gas absorb free electrons of the arc path & increase the di-electric strength of the medium, which cause extinction of arc.

→ After extinction of arc the valve is closed by a set of spring.

• Advantages → Due to superior arc quenching property of SF_6 gas the arcing time is very short.

→ Di-electric strength build-up by SF_6 gas is more than 2-3 times of that of air.

→ It give smokeless & noiseless operation due to ~~ex~~ ill closed gas circuit and no exhaust to atmosphere.
→ All the chamber is closed no moisture found inside it.
→ No risk of fire in such breakers.
→ Their is no carbon deposition.
→ It has low maintainance cost.
→ It is suitable for where their is explosion hazards exist such as Coal mine.

• Disadvantages → It is highly costly of gas.
→ Extra reconditioned & reclaimed ckt is needed for necessary after each operation.

• Application →
→ It is able to dealing 66 KV in voltage range 50 - 80 KV.
→ It also used for 115 KV - 230 KV at power rating 10 mva to 20 mva; which is interrupting time left than 3 cycle.

Date 06/04/2019

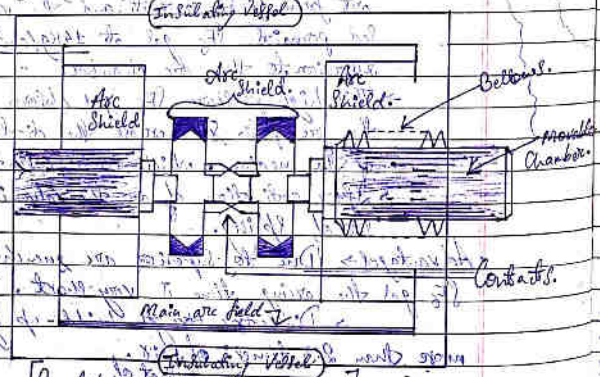


Fig. (Vacuum Circuit Breaker).

* Vacuum Circuit Breaker :- In such breakers vacuum (Degree of vacuum in the range of 10^{-7} to 10^{-5} torr, is used for arc quenching medium.
→ Since vacuum offer high insulating strength, so it has fast superior quenching properties than other medium.

→ Principle :- When the contacts of the breakers are opened in vacuum of range 10^{-7} to 10^{-5} torr an arc is produced between the contact due to ionisation of metal vapour of the contact.
→ However, the arc quickly extinguish because the metal vapour, electrons & ions produced during arcing condensed rapidly due to vacuum.

→ Construction :- In the diagram, it consists of f.c & m.c and arc shield (coating) mounted inside the vacuum chamber.
→ The moving member is connected to control mechanism by stainless steel bellows.
→ This allows permanent sealing of the vacuum chamber & eliminate possibility of leak.
→ A glass vessel or ceramic vessel is used of outer insulating body.
→ The arc shield prevents deterioration of the internal di-electric strength by preventing metallic vapours falling on the inside surface of outer insulating cover.

→ Working :- When breaker operates the m.c separate from f.c and arc is struck.
→ The production of arc is due to ionisations of metal ions and depends upon material of contact.
→ Contact quickly extinguish because the metallic vapours & electron are diffused in a short time as the chamber is sized by moving & fixed member and arc shield.

→ Since Vaccum has very fast rate of recovery of dielectric strength. So are can extinguish in small separation (0.6 to 5 cm).

→ Advantages :- They are compact, reliable & longer life.
→ There are no fire hazards.
→ There is no gas generation.
→ They can interrupt any fault current.
→ It require less maintainance.
→ It can withstand in lightning surge.
→ They has low arc energy.

→ Application :- It is used for protection of long distance transmission where the installation is outside.
→ It is used for outdoor application ranging from 22 KV to 66 KV having power rating 60 to 100 mVA.

Date 07/08/2019

* Switch-Gear Components :-

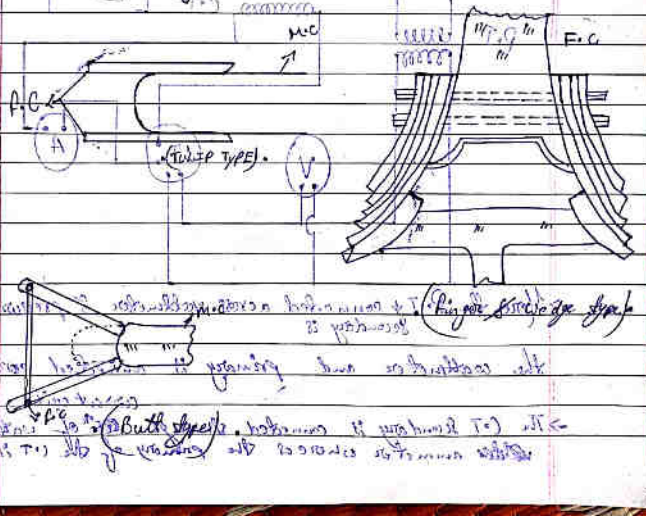
1. Bushing.
2. Circuit Breaker Contacts.
3. Instrument transformer.
4. Bus-Bar and Conductors.

1. Bushing :- When higher voltage conductor passes through metal sheet or frame which is at earth potential then necessary insulation is provided in the form of bushing. So bushing helps to prevent electrical break-down between enclosed conductor and surrounded earthed metal body.

→ It is mainly used in oil circuit breaker.
→ The failure of bushing occurs due to di-electric failure both insulating material and conductor and secondly break-down may occur in the form of flash over [sparking] before bushing get punctured.

2. Circuit-Breaker Contacts :- The C.B contacts are required to carry both normal current as well as short ckt current. So they are design in such a way that the temp. should not rise specified limit and the voltage drop also low. So the C.B contacts are Tulip type contact, finger & Wedge Contact & Butt Contact.

Date 13/08/2019



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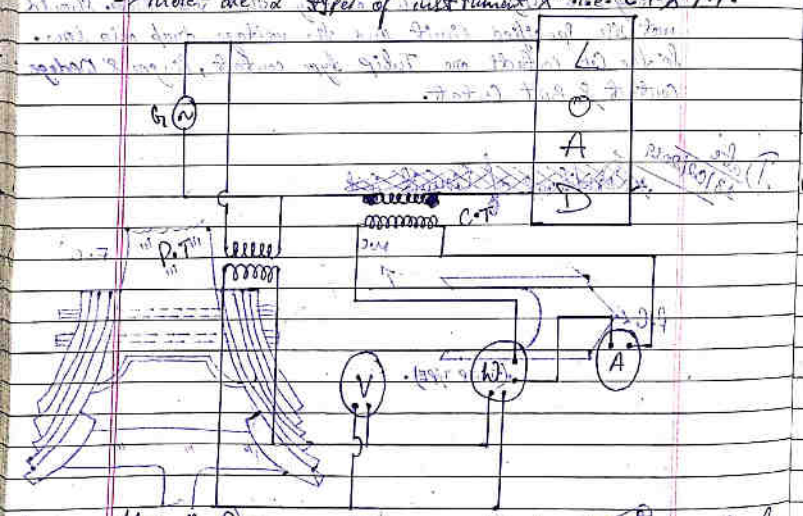
(3) Instrument transformer:— In a modern power system the circuits are operate at high voltage & high current in which the protective system & measuring system not work satisfactorily.

→ This difficulty is overcome by using instrument x'. The function of instrument x' is to transform voltage or currents in the power lines to a value which is convinient for the operation of measuring instrument as well as relays.

→ There are 2 types of instrument x' i.e. C.T. & P.T.



→ Here the P.T is connected across voltmeter & pressure coil of secondary is the wattmeter and primary is connected across the supply

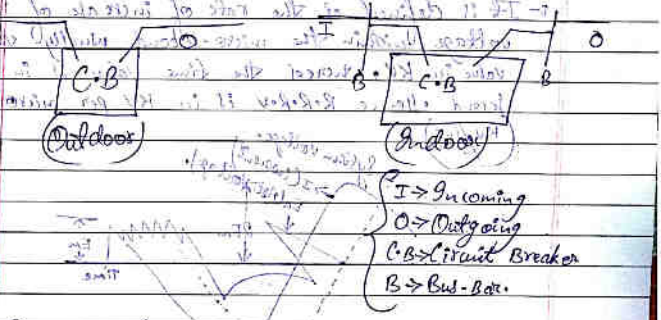
→ The C.T secondary is connected through current coil of wattmeter & ammeter whereas the primary of the C.T is connected

Date Page 61.

series with the main circuit.

(4) Bus-Bar & conductors:— The current carrying members of the circuit breakers are f.c & m.c are connected external point of the breakers.

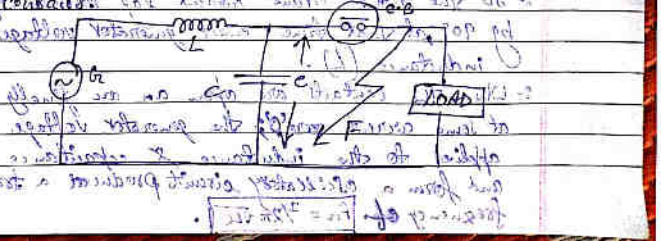
→ If the switch gear is outdoor type then the 2 points are directly connected to supply lines whereas if the switch gear is indoor type the incoming conductors for the C.B connected through a bus-bar.



* Problems of Circuit interruption:—

→ The power system contains an appreciate amount of inductance & some capacitance. So when a fault occurs the energy store in the system can be considerable.

→ This energy is dissipated, within the C.B contacts.

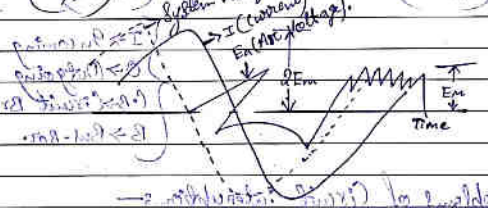


→ So it is (C.B) design such that it can easily dissipate the store energy.

→ In the diagram (L) is the inductance per phase upto point of fault & (C) is the capacitance per phase of the system where as the resistance of the system is neglected as the value is so small value.

(i). R.R.R.V → Rate of rise of restriking voltage :-

→ It is defined as the rate of increase of restriking voltage within the micro-second wudlly the voltage value in KV, whereas the time values is in micro second. Hence R.R.R.V is in KV per micro second (KV/μs).



∴ Consider opening of the C.B during fault condition.

∴ Before the instant of interruption the capacitance (C) is short circuited by fault and only inductance (L) is present in the circuit.

∴ So the short circuit current lag behind the voltage by 90° at that time entire generator voltage appears across inductance (L).

∴ When the contacts are open an arc finally extinguish at some current zero '0' the generator voltage suddenly applied to the inductance & capacitance in series and form a oscillatory circuit produced a transient frequency of $f_n = \frac{1}{2\pi\sqrt{LC}}$.

→ This frequency appears across capacitance (C) & CB breaker contact.

→ This transient voltage is known as re-striking voltage & may be reach instantaneously 2 times of phase to neutral voltage i.e. 2Em and cause possibility of re-striking of arc between the contacts.

→ The rate of rise of re-striking voltage which decides whether arc restrik or not.

→ If R.R.R.V > Rate of Rise of di-electric Strength between the contacts than the arc will re-strik otherwise arc fails to re-strik. So R.R.R.V depends upon 2 factors i.e. Recovery voltage & Natural frequency of oscillation.

(Recovery voltage) :-

→ It is the normal system voltage which is seen after final extinction of arc between the 2 contacts.

(Natural frequency of oscillation) :-

→ It is the normal frequency of the system.

→ If short occur near the power station then (C) is being small & natural frequency will be high & R.R.R.V also high.

(ii). Current Chopping :-

→ It is the phenomenon of current interruption before the natural current reached to zero.

→ This is occurs mainly in air-blast circuit breaker, because they retain the same extinguishing power irrespective of any magnitude of current to be interrupted.

→ When it breaking low current the powerful deionising effect of air-blast causes the current to fall ~~naturally~~ zero before natural current zero. This phenomenon is called current Chopping and it caused production of high voltage transient across the contact of C.B.

→ Considered arc current (i) which had to be chopped down, as current chopped down therefore the energy store in the inductance i.e. $\frac{1}{2}Li^2$.

→ After current chopping the energy store by the inductor will be transfer to the line capacitance (C), and charging it to a voltage (e) [prospective voltage].

$$\Rightarrow \frac{1}{2}Li^2 = \frac{1}{2}Ce^2$$

$$\Rightarrow e = i\sqrt{L/C}$$

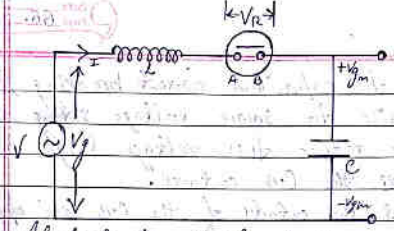
→ The prospective voltage is very high as compare to the dielectric strength gain by the gap. So the breaker again re-strike.

→ As the de-ionising effect still in action therefore chop occurs again but the arc current is smaller in compare the previous case. This induce a lower prospective voltage to re-ignite the arc. So before current interruption several chops may be occur until a low current is to be interrupted which produce an insufficient prospective voltage and arc fails to re-strike.

Date 14/02/2020

(iii) Capacitive Current Breaking's—

→ Another case of excessive voltage surge in the C.B interruption of capacitive current. Such type of example is that circuit on load or long transmission line disconnecting with capacitor bank for power factor improvement.



→ At that circuit actually carry capacitive current i.e. (I) leads the voltage (V) by 90° at that time the C.B is open and the current reduces to zero.

→ At this instant the generating voltage (Vg) will be max^m ($V_{g_{max}}$) and lagging behind the current by a 90°.

→ So the opening of the C.B leaved standing charge and charge up the capacitor (C).

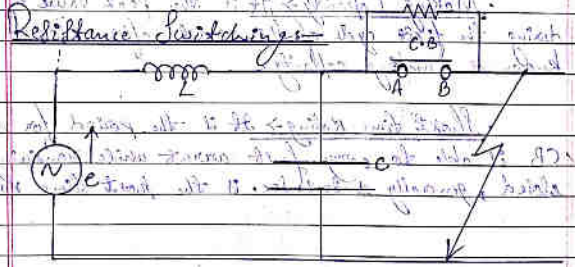
→ Here (V_R) is the rec voltage across C.B contacts which is initially zero and increased slowly in the beginning but after a half-cycle the plates of capacitor having (+ve) max^m voltage other plate (-ve) max^m and it becomes [$2V_m$].

→ This voltage is sufficient to re-strike the arc. So the separated parts of the C.B joint by arc having low resistance.

→ This voltage increases further & further and attain voltage of value $4V_m$, $8V_m$ and so on and arc further re-strike.

→ But due to leakage & corona loss this voltage max^m upto $5V_m$.

✳ Resistance Switching's—



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→ We know that; the capacitive current breaking & current chopping give rise to severe voltage oscillation so in order to reduce this voltage surge a resistance (R) shunted across the C.B contacts.
→ When fault occurs the contacts of the C.B are opened and arc is struck.
→ All the contacts are shunted by resistance (R) part of the arc current diverted towards shunt resistance (R) consequently arc current reduces.
→ & di-electric strength build-up is also continue to arc path resistance also increased and this process continue until extinction of arc.
→ The shunt resistance also helps to limit oscillatory growth of re-striking voltage i.e. $f_n = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{1}{4R^2C^2}}$

Date 18/02/2019

*. Circuit Breaker Ratings:-

• Breaking Capacity → It is defined as the RMS value of current that a CB is capable of breaking at a given recovery voltage under specified condition (Rated PF & Rated rise of Restriking voltage).

• Making Capacity → It is the peak value of current during the first cycle of the current after closure of CB it known as making capacity.

• Short time Rating → It is the period for which the CB is able to carry fault current while remaining are closed, generally 1 to 2 sec. is the short time rating.

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"FUSES."

→ A fuse is a short piece of metal inserted in the ckt which melts when excessive current flows through it & thus breaks the circuit.
→ The fuse element is generally made up of material having low melting point & high conductivity and low deterioration due to oxidation. e.g. Silver, Copper, Gold, Platinum.
→ It is inserted serial in the circuit to be protected.
→ Under normal operating condition, the fuse element is at a temp. below its melting point. Therefore, it carries normal current without overheating.
→ However, when fault occurs (short ckt) or (over load) the current through the fuse increased beyond its rated value & increases the temp. of the fuse element and the fuse element melt (blown out).
→ The time required for blown out of the fuse depends upon the magnitude of fault current. If fault current is greater than smaller is the blown out time & vice-versa.
→ So due to this characteristics it is used for over current protection.

*. Advantages:- (1). It is the cheapest form of protection.
(2). Requires no maintainance.
(3). Its operation is inherently automatic like CB.
(4). It can break heavy short ckt current without noise & smoke.
(5). The smaller size of fuse element is imposed a current limiting effect under short ckt condition.
(6). It obeys inverse time - current characteristics, suitable for overcurrent protection.
(7). The minimum time of operation can be made much shorter than with the CB.

(Alloy of tin & lead) domestic purpose

* Disadvantages:-

1. Considerable time is lost in rewiring or replacing after each operation.
2. On heavy short-ckt discrimination both fuses in series can't be obtained unless there is sufficient difference in fuse.
3. The current time characteristics of fuse can't always be co-related with that of protected apparatus.

* Characteristics of fuse elements:-

→ Low melting Point; (Tin (Sn) & lead (Pb)).
→ High Conductivity; (Silver & Cu).
→ Free from deterioration due to oxidation; (Silver).
→ Low Cost; (lead, Cu, tin).

Date 22/10/2020

* Fuse elements materials:-

→ The most commonly used fuse materials are lead, tin, Cu, Zn, Silver.
→ For small current upto 10Amp (tin or an alloy) of (lead & tin) [lead 37% & tin 63%].
→ For larger current we use (Cu & Silver).
→ Zinc is a good fuse material which obey considerable time-lag characteristics.

* Imp. Terms:- (1) Current Rating of fuse element → It is the current which the fuse element can normally carry with out over heating, or melting.
→ It is depends upon temp. rise of the contact of fuse holder, fuse material & surrounding atmosphere.

(2) Fusing Current → It is the min^m current at which the fuse element melts and thus disconnect the circuit protected by it.
→ Fusing Current > Normal current rating of the fuse.

(3) Fusing factor → It is the ratio of min^m fusing current to the current rating of the fuse element.

→ [Fusing factor = min^m fusing current / current rating of fuse.]

→ This value is always > 1.

(4) * Prospective Current → It is the RMS value of the first loop of the fault current obtained if the fuse is replaced by an ordinary conductor of negligible resistance.

(5) Cut-off Current → It is the max^m value of fault current actually reached before the fuse melts.

* Types of fuse :- It is of 2 types i.e. low voltage & high voltage fuses.

Date 23/10/2020

(a) Low voltage fuse → (upto 100 Amp.) or (200 Amp.)
→ The low voltage fuse can be divided into 2 types i.e.
(i) Semi-enclosed re-wireable fuse.
(ii) H.R.C (High Rupturing capacity) fuse. cartridge.

(i) Semi-enclosed re-wireable fuse → construction →
→ This type of fuse is suitable where low value of fault current are to be interrupted.
→ It consist of base of porcelin and a fuse carrier also porcelain.

The fuse carrier holds the fuse element whereas the base carries in coming as well as outgoing terminal.

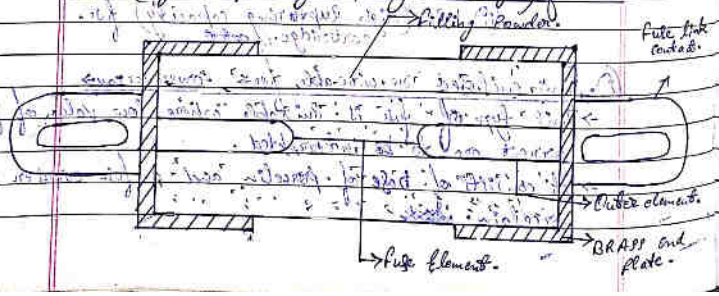
- Working:-
  - → When fault occurs the fuse element is blown out and the circuit is to be interrupted.
  - → After clearing of fault the fuse carrier taken out and fuse element replaced by a new one and it is again inserted inside the base.

Advantages:- → The fuse carrier which is a detachable one which permits replacement of fuse element without danger.
→ The cost of the fuse replacement is negligible.

Disadvantages:- → There is possible of renewal of fuse wire of wrong size and improper material.
→ This fuse has low breaking capacity.
→ The fuse element is subjected to deterioration due to oxidation.

- Uses:- This type of fuse is made from 6 Amp., 16 Amp., 32 Amp., 48 Amp., 64 Amp., 100 Amp., 200 Amp., 400 Amp., 500 Amp.

(ii) HRC (High Rupturing Capacity Cartridge) fuse:-



Construction:-
→ The low & uncertain breaking capacity of the re-wireable fuse is overcome by HRC fuse.
→ It consists of a heating resisting ceramic body with 2 end metal caps.
→ The inner side of the fuse consists of 2 outer elements which actually carry silver fuse element.
→ The space inside the HRC fuse filled with filling powder i.e. Chalk, Plaster of Paris, Quartz & marble dust.
→ The powder acts as Arc Quenching medium or Cooling medium.

Operation:-
→ When fault occur the fuse element melts before the fault current reaches first peak value.
→ The heat produced during fuse element melts vaporised the powder and a high resistance material is form which acts as Arc Quenching medium.

Advantages:- → It is capable of clearing both high & low currents.
→ They doesn't deterioxate with age.
→ They have high speed of operation.
→ They provide reliable discrimination.
→ They require no maintainance.
→ Cheaper than other interrupting device.

Disadvantage:- → They have to be replaced after each operation.
→ Heat produce by the arc may be effected associated switchgear.

Date 26/02/2019

[High Rupturing Capacity (HRC) Fuse]

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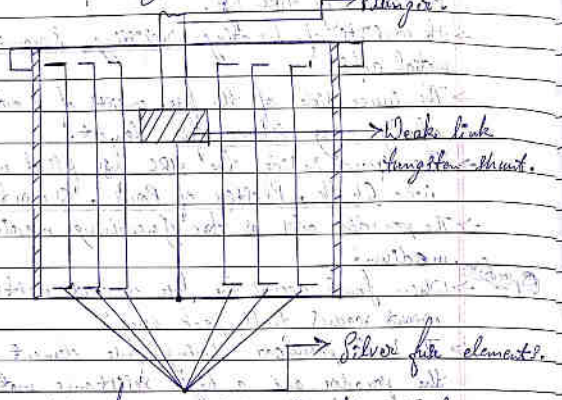
* HRC fuse with tripping device :-



→ Sometimes H.R.C. fuse providing with tripping device.
→ When the fuse blows out under fault condition, the tripping device (Plunger) cause circuit breaker to operate.
→ In the diagram, the body of the fuse is a ceramic material.
→ There is a fixed metallic cap, fixed rigidly at one end and the other side connected through a plunger.
→ The metallic caps are joined to each other by a silver fuse elements.
→ The Plunger is electrically connected to metal caps through Tungsten fuse element.

Working:-
→ When fault occurs the silver fuse elements are first blown out & flows the current to Tungsten element and the weak link fused with the tungsten wire got fused and the plunger forced outwards cause operation of C.B.

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Advantages:- In case of a 1-ϕ fault on a 3-ϕ system the plunger operates and the tripping mechanism of the C.B. open 3-ϕ C.B avoids 1-ϕing of the system.
→ By using this type of fuse full short-ckt current need not to be consider and relatively lower rating C.B. are use.
→ This type of fuse trip C.B generally capable of dealing small fault current

Use:- This type of fuses may be used for breaking capacity 16000 Amp. to 30,000 Amp. at 440 Volt.

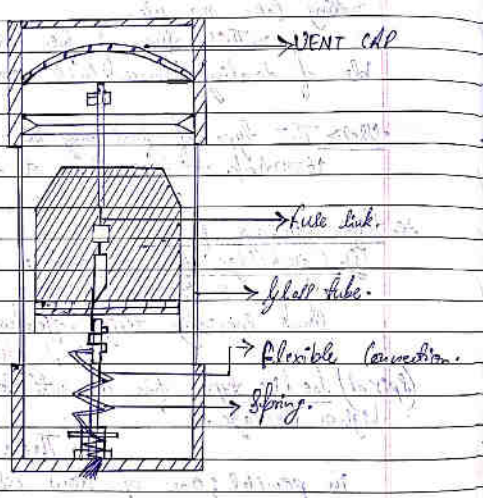
* High Voltage fuse:-
1). Cartridge type:- The construction of this type of fuse is similar to that of low-voltage type but some specially design features are employed.
→ In this type of fuse we found (Spiral) helix type fuse element to avoid Corona effect at higher voltage.
→ There are 2 fuse elements are in parallel; one of low resistance (Silver wire) & other is high resistance (Tungsten wire).
→ Under normal operating conditions the low resistance elements carries normal current. When fault occurs the low resistance elements first blown out and the high resistance element reduce the short-ckt current and finally breaks the circuit.

Use:- It is used upto 33KV with breaking capacity about 8700 Amp.

→ If operating voltage 132 KV then breaking capacity 6000 Amp.

Date 01/03/2019

* Liquid type fuse:-



→ The figure shows high voltage liquid type fuse. It consist of a glass tube filled with CCl_4 (Carbon tetrachloride) solution sealed at both ends with brass caps.

→ The fuse wire is sealed at one end of the tube and the other end of the wire is held by strong phosphor-Bronze spiral spring fixed at other end of the glass tube.

→ When the current exceeds the prescribed limits then the fuse

wire is blown out.

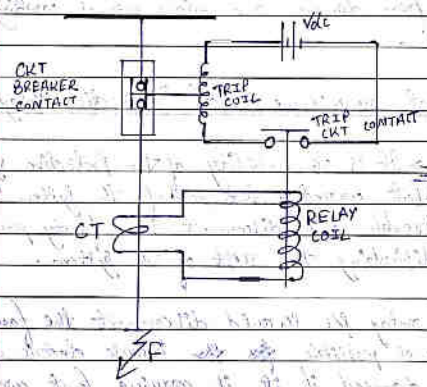
→ The spring retracts through a baffle and draws fuse link inside the liquid.

→ The small quantity of gas is generated at the point of fusion forces some parts of the liquid into the pated through baffle and arc is extinguish.

IMP

* (Protective Relays):-

→ A Protective relays is a device that detects the fault & initiates the operation of the C.B. to isolate the defective element from the rest of the system.



→ The relay detects abnormal condition in the electrical circuit by constantly measuring the electrical quantities like current voltage & frequency & phase angle which changes under fault condition.

→ The typical relay system can be divided into 3 parts i.e.

1. First part is primary winding of the CT. which is connected series with the line to be protected.

secondary winding of the

(ii). Second part consist of C.T. or relay operating coil.
(iii). Third part is the tripping circuit which may be either ac or dc source of supply and operate the trip coil & ckt breaker contacts.

→ When short ckt occurs at the point (P) on the transmission line the current flowing in the line is very high which results heavy current flow in relay coil and causing the relay to operate trip contacts.
→ This close the trip circuit and making the CB to open.
→ In this way relay ensure the safety of the circuit of equipments from damage and allow normal working of the healthy portion.

DMP

*. Fundamental requirements of Protective Relays:-

1. **Selectivity** → It is the ability of the Protective system to select correctly that part of the system if in trouble and disconnect the faulty part without disturbing the rest of the system.

2. **Speed** → The relay should disconnect the faulty section as fast as possible because electric operated may be damaged if it is carrying fault current for a long time, not affected the near healthy section and prevent possibility of severe fault.

3. **Sensitivity** → It is the ability of the relay system to operate with low value of actuating quantity

Generally
→ Relays are rated in volt-Ampere. Such that the lower rated relays is higher sensitive than high rating relays. Among 1VA & 3VA relays; 1VA is high sensitive.

4. **Reliability** → It is the ability of the relay R/s to operate under the predetermined condition; without reliability the protection would be rendered largely ineffective.

5. **Simplicity** → The relaying R/s should be simple & such that it can be easily maintained. So simplicity & reliability are co-related.

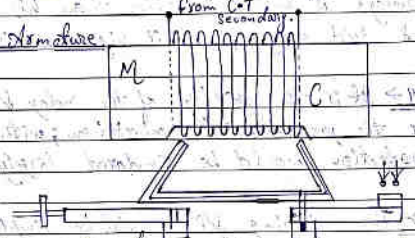
6. **Economic** → The moth imp. factor is the choice of particular protection scheme according to economic aspect.
→ As per the rule the protective R/s cost should not more than 5% of the total cost.
→ When the apparatus to be protected is almost importance like generator, x'r & main transmission line economic confederations are often sub-ordinate to reliability.

Date 02/03/2019

*. Basic Relays:-
→ The basic relays used in power system operate by current & voltage supplied by C.T or P.T.
→ So theirs is change in electrical quantity under fault condition such that the relay operates according to the variation of electrical quantity.
→ Moth of the relay operate according to two principles;
1). Electro-magnetic attraction type.
2). Electro-magnetic induction type.

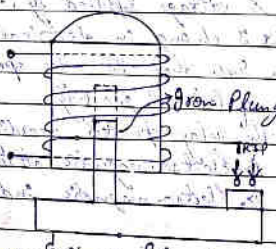
* Electro-magnetic Attraction type :-

(i). Attracted Armature type :-



→ It consists of laminated electromagnet (M) which carry coil (C).
→ Below the electromagnet a pivoted laminated armature balanced by counter weight & spring attached to one side of the chamber.
→ The other side of the iron armature holds the tripping contacts.
→ When fault occurs the current through the relay coil increased sufficiently and armature attracted towards the electromagnet by over-come the counter weight force.
→ Hence the trip circuit contact get closed & initiate the operation of C.B.

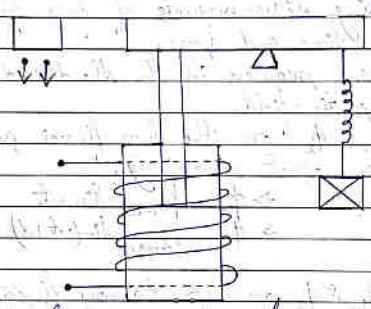
(ii). Bole noid type :-



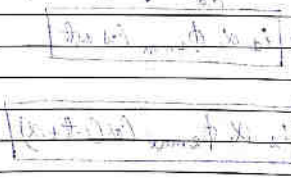
→ The above diagram shows Solenoid type relays under

fault condition the current through the relay coil more than the pick-up value causing plunger to be attracted by the Solenoid by overcome plunger gravity pull & spring ~~pressure~~ pressure and closes the trip circuit causing operating of C.B.

(iii). Balance Beam type :-



→ It consists of a iron armature fastened to a balance beam.
→ Under normal operating condition the current through the relay coil is not so high and the beam is in horizontal position.
→ On occurance of fault the current reaches relay pick-up value and the beam is attracted downward by the coil. This causing operation of C.B.



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* Electro-magnetic Induction type relay :—

→ This type of relay operate on the principle of induction motor & widely used for protective relaying purpose involving ac electrical quantities, so there is not need of dc electrical quantities in the principle of operation.

→ It consists of an Al. disc which is pivoted between 2 alternating electro-magnets of same frequency but displaced in time and space.

→ The torque produced in the Al. disc due to interaction of 2 magnetic field.

→ Let ϕ_1 & ϕ_2 are the two fluxes produced by upper & lower magnet respectively.

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

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

$\because i = I_m \sin \omega t$, $\phi \propto I$, $\phi = \phi_m \sin \omega t$

where; ϕ_1 & ϕ_2 are instantaneous fluxes and the (ϕ_2) leads (ϕ_1) by an angle (α).

$$\Rightarrow i_1 = K_1 \frac{d\phi_1}{dt}$$

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

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

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

Similarly;

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

Date

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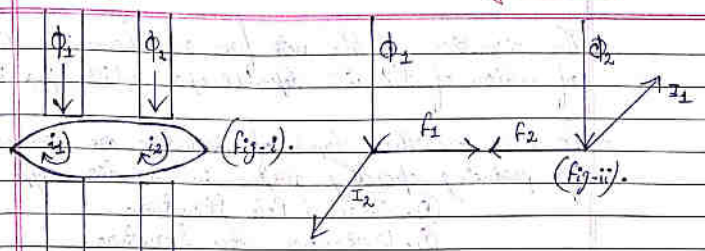


Now; $F_1 \propto \phi_1 I_2$

$F_2 \propto \phi_2 I_1$

Therefore; Net force $(F) \propto F_1 - F_2$

$$\Rightarrow F \propto (\phi_1 I_2) - (\phi_2 I_1)$$

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

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

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

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

$$\Rightarrow \boxed{F \propto \phi_1 \cdot \phi_2 \cdot \sin \alpha}$$

→ From the above expression the net force (F) produced in the Al. disc is proportional to ϕ_2, ϕ_1 and the angle bet ϕ_2 & ϕ_2 (α).

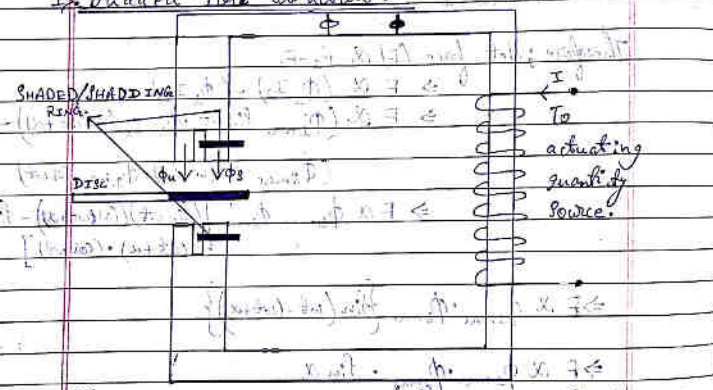
→ The force will be greater if (α) between the fluxes is greater and maximum when $(\alpha = 90°)$.

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

→ So there are three types of structure are commonly used for producing operating torque in induction type relay.

1. Shaded Pole Structure.
2. Watt-hour meter Structure.
3. Induction-Cup Structure.

1. Shaded Pole Structure:-



→ The general arrangement of shaded pole structure shown in the figure.

→ It consists of a pivoted Al. disc which is free to rotate in the air-gap of electromagnet. One-half of each pole of the magnet is surrounded by a Cu band it known as Shading-Ring.

⇒ ϕ_s = Flux produced in the Shaded portion of the pole.

⇒ ϕ_u = Flux produced in the Un-Shaded portion of the pole and (ϕ_u) leggs behind (ϕ_s) by (α).

→ Due to interaction of two magnetic field (ϕ_s & ϕ_u) torque will produced in the Al. disc. So;

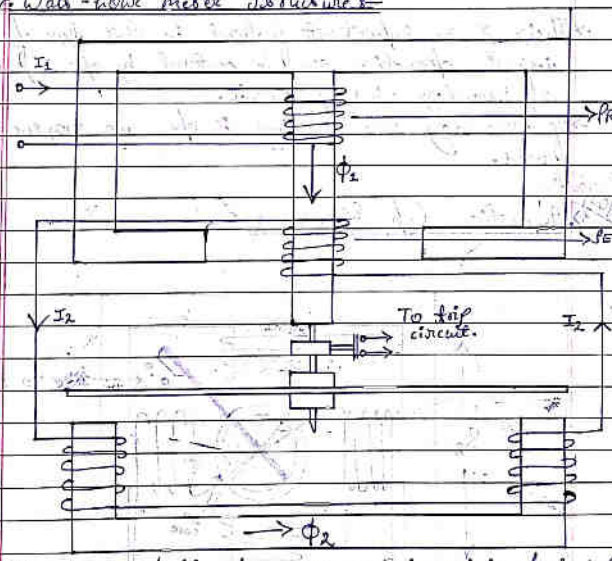
$$\Rightarrow \boxed{T \propto \phi_s \phi_u \sin\alpha}$$

→ As in the same core (ϕ_s & ϕ_u) are produced by current (I); So $\Rightarrow T \propto I \cdot I \sin\alpha$

$$\Rightarrow T \propto I^2 \sin\alpha$$

→ The torque (driving torque) produced in the Al. disc is proportional to square of the current in the relay coil.

2. Watt-hour meter Structure:-



→ It consists of Al. disc arrange to rotate freely between the poles of two-electromagnets.

→ The upper-electromagnet carried 2 winding, primary and part of secondary winding whereas the lower magnet carried other part of the secondary winding.

→ The primary winding carried current (I_1) and produced flux (ϕ_1) which is linked with the secondary winding, produce current (I_2).

→ Now, (I_2) current circulates through out the secondary winding and produce flux (ϕ_2) which lagg's behind (ϕ_1) by an angle (α).

→ Hence torque produced in the Al. disc due to interaction of two fluxes (ϕ_1 & ϕ_2).

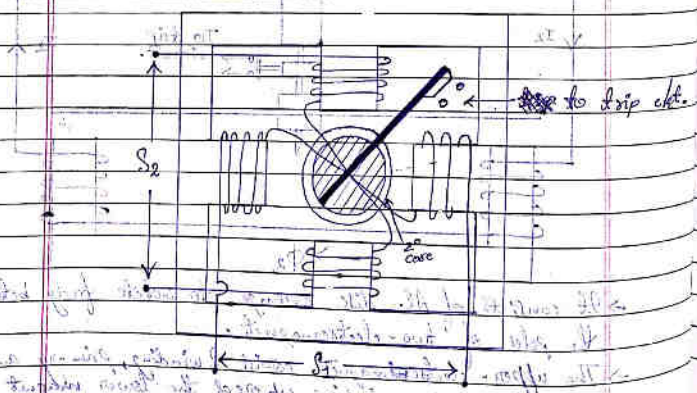
$$\Rightarrow \boxed{T \propto \phi_1 \phi_2 \sin\alpha}$$

→ There is an important features in this type of relay i.e. the operation can be control by opening or closing of secondary winding circuit.

→ If Secondary side winding is open no torque is produced.

Date 08/03/2019

3. Induction Cup Structures:-



→ It is the same as that of induction type motor except that the motor iron is stationary, only the rotor conductor portion being free to rotate. The moving element is a hollow cylinder which turns on its axis.

→ The rotating field produced by 2 pairs of coils wound on 4-poles.

→ This rotating field induced a current in the cup to provide necessary driving torque and hence the torque produced due to interaction of two flux ϕ_1 & ϕ_2 i.e.

$$\boxed{T \propto \phi_1 \phi_2 \sin\alpha}$$

where; (α) is the phase angle between flux ϕ_1 & ϕ_2.

→ A pair of spring attached to the spindle to prevent continous rotation of tripping contact.

USES:- It is very efficient torque producer so this type of relay has very high speed of operation about 0.1 sec.

*. Relay timing:- According to the time of operation i.e. the time when the actuating element is energized to the instant when the relay contacts are closed, the relays are of several types;

① Instantaneous Relay:- An IR is one in which no intentional time delay is provided.

→ In this type of relay the contacts are closed immediately after the current in the relay coil exceeds the min^m calibrated value.

→ For this is a short time interval between the instant of pick-up and closing of relay contact.

→ The operating time of this type of relay expressed in cycles i.e. 1/50 cycle = 0.02 sec.

(2). Inverse time relay :-

→ In this type of relay the operating time is inverse ly proportional to magnitude of actuating quantity.

→ In this type of relay at value of current less than peak-up value the relay don't operated, & at higher value the time operation of relay decrease steadily with increase in current.

(3). Definite time lag relay :- In this type of relay there is a definite time gap between the instant of peak-up and closing of relay contacts.

→ This particular time setting is independent of amount of current through relay coil.

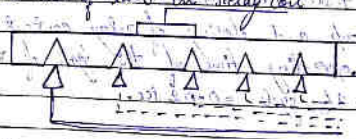
* IMP. TERMS :- Pick-up Current →

It is the min^m current in the relay coil at which the relay start to operate. At normal operating cond^n, the current in the relay coil is less than pick-up value.

Date 11/03/2019

:- Current Setting →

It is required to adjust peak-up current at any required value this it known as Current Setting. This can be achieved by using tappings on the relay operating coil. This relay operating coil provides with plug bridge which permit to alter the no. of turns on relay coil.



:- Peak-Up Current = Rated Secondary Current of the C.T x Current Setting.

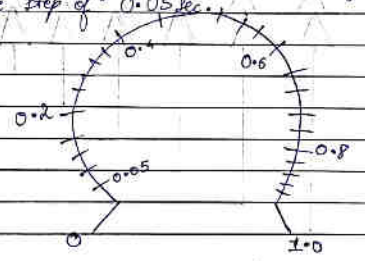
Plug Setting Multiplier (PSM) → It is defined as the ratio of fault current in relay coil to the pick-up current.

⇒ P.S.M = Fault Current in relay coil / Pick-Up Current.

or; = Fault Current in relay coil / Rated Secondary Current of the C.T x Current Setting

Time Setting Multiplier (TSM) → A relay generally provided with adjustment to the time operation, this adjustment of time is known as time setting multiplier (TSM).

The time setting dial is calibrated from 0 to 1 and each step of 0.05 sec.



* Functional Relays :- Most of the relay in the power sys are of electro-magnetic attraction type or electro-magnetic induction type but the relays are generally classified according to the function to be perform known as functional relays.

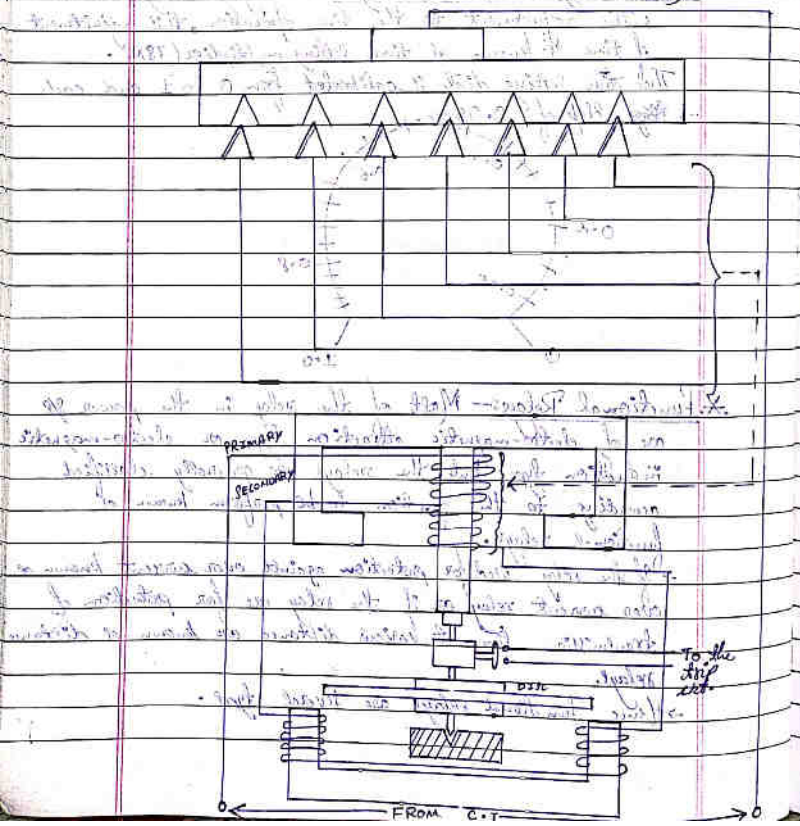
→ If the relay used for protection against over current known as over current relay or if the relay use for protection of transmission line at varied distance are known as distance relays.

→ Hence functional relays are several type.

Date Page 88.

(i). Induction type over current relays.
(ii). Induction type reverse power relays.
(iii). Distance Relays.
(iv). Differential relays.
(v). Translay Schemes.

(i). Induction type Over Current Relays — (NON-DIRECTIONAL RELAY).



Date Page 89.

→ This type of relay works on Induction principle and initiates when current exceeds pre-determined value.

• Constructions —

→ It is a typical non-directional over current relay having coil of 2 electro-magnet the upper electro-magnet had a primary & a secondary winding and the primary winding is connected to secondary of a C.T. which is mounted in the line to be protected.

→ The metallic Al. disc pivoted at the centre of the 2 magnets.

→ The tappings are connected to a plug-setting bridge which have several tapped at equal interval.

→ The secondary winding of the relay which is at lower magnet is activated by induction principle.

→ The controlling torque provided to the spring by a spiral spring.

→ The spindle carries the pair of trip contacts which rotates through a pre-set angle which can be adjusted between 0° to 360°. And this adjustment adjust the time setting.

• Operation →

→ The driving torque on Al. disc + let-up due to induction principle, the driving torque opposed by the restraining torque provided by the spring under normal operating condition. Hence under normal operating condition restraining torque is greater than driving torque and Al. disc is stationary. However, the current in the ckt to be protected exceed pre-determine value then driving torque is greater than restraining torque, and hence Al. disc is starts rotating through a pre-set angle enclose the trip contact which operate the CB.

Note :- This Relay are used on ac ckt only and can operate for fault current in either direction.

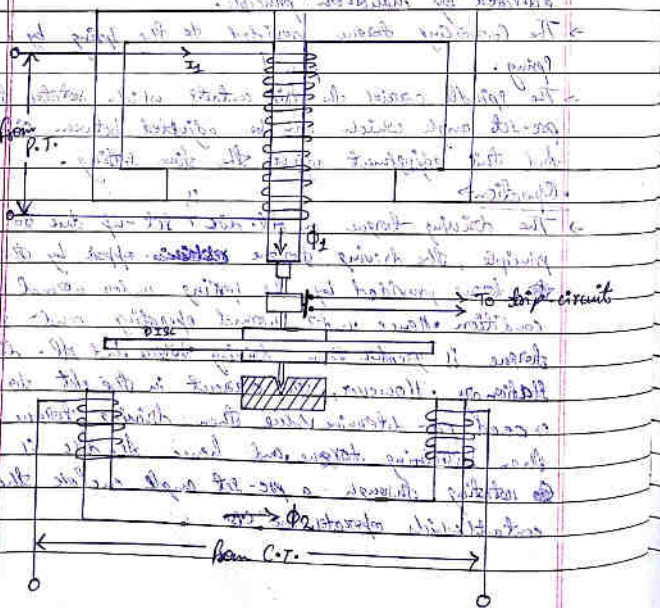
Date 12/03/2019 IMP.

(ii) Induction type directional power relay :-

→ This type of relay operate when power in the circuit flowing in a specific direction.

→ This type of relay is so design that it obtained the operating torque by interaction of magnetic field derived from both voltage & current source of the circuit to be protected.

CONSTRUCTION :-



→ The typical diagram of a induction type directional power relay consist of an Al. disc which is free to rotate in between 2 electro-magnet (laminated silicon steel).

→ The upper electro-magnet carries the winding at the central limb excited by potential i.e. (P.T).

→ The lower electro-magnet has separate winding (Current Coil) connected to the secondary of (C.T.) in the line to be protected.

→ The Current Coil provided with several tappings for peak-up current adjustment.

→ The spindle of the disc carried a moving contact which bridges the 2 contact when disc has rotated a pre-set angle.

→ By adjusting the moving angle we adjust the operating time of the relay.

$$T = \frac{\theta}{\omega}$$

OPERATION :-

→ The flux (ϕ_1) due to potential coil lagging nearly 90° behind the supply voltage (V).

→ The flux (ϕ_2) due to current coil in phase with the current / line current (I).

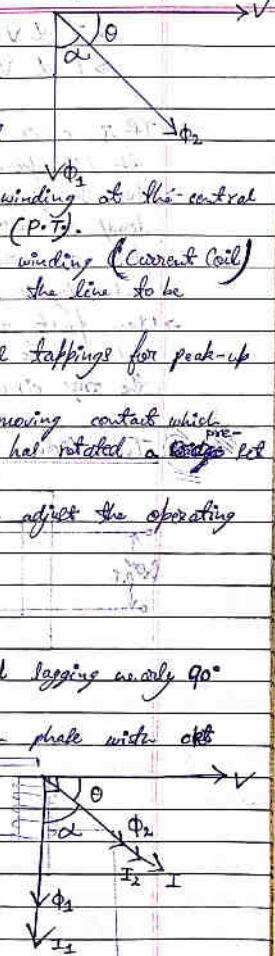
→ Due to interaction of flux (ϕ_1 & ϕ_2) driving torque produce in the Al. disc.

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

$\because \phi_1 \propto I_1 \propto V$

and, $\phi_2 \propto I_2 \propto I$

$$\Rightarrow T \propto V I \sin\alpha$$



$\Rightarrow T \propto VI \sin(90^\circ - \theta)$

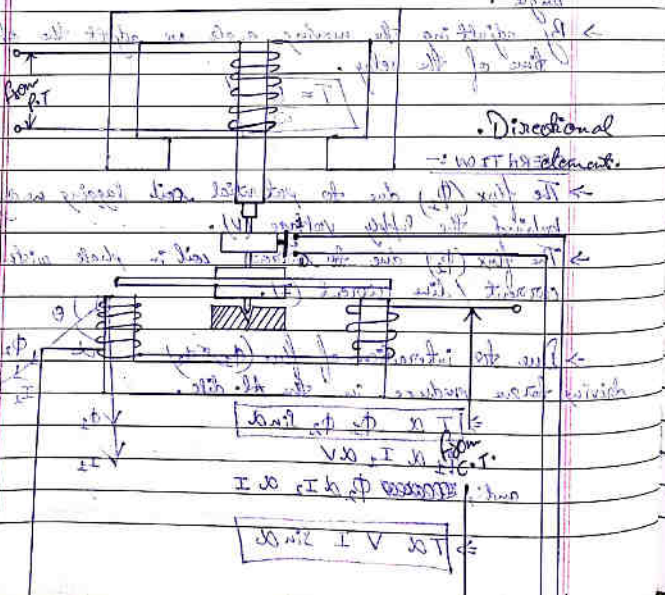
$\Rightarrow T \propto VI\cos\theta \propto$ Power in the circuit.

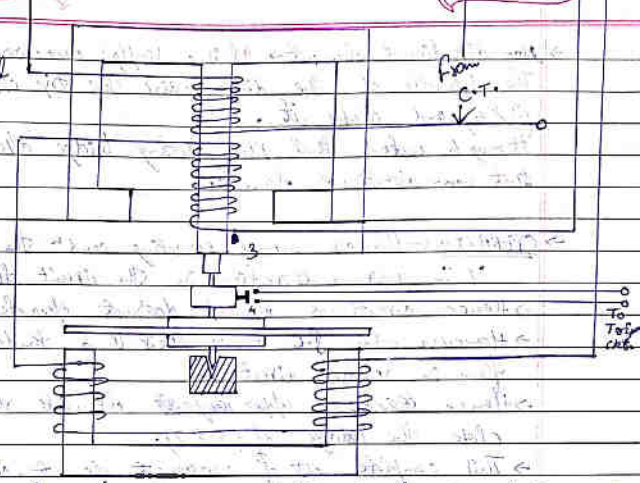
→ It is clear that driving torque produce in the disc depends upon direction of power flow in the circuit.

→ When the power flow is in the normal direction (source to load) the driving torque & straining torque help each other so they away the moving contact from fixed contact and relay is in-operative.

→ When fault occurs the driving torque is large enough and rotate the disc in the reverse direction and close the trip circuit and cause the operation of C.B.

(iii) Induction type directional overcurrent relay :-





→ This type of relay is suitable directional protective relay under S.C. condition. When S.C occurs the system voltage fall to a low value and may be insufficient torque develop in the relay to cause its operation.

→ This difficulty overcome in directional over-current relay.

• CONSTRUCTION :-

→ It consists of 2 elements directional as well as non-directional elements.

→ Directional element :- It operate when the power flows in specific direction. It consist of a potential coil excited by P.T. and current coil energized by C.T.

The trip contact (1,8,2) are connected in series with secondary of non-directional element so non-directional element cannot operate until the directional element operate.

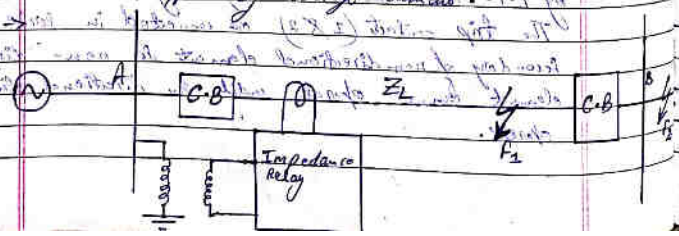
→ Non-directional element → It is a simply over current elements. The spindle of the disc carries the str ckt contact (3,8,4) and close it.
It may be noted that plug setting bridge also provided in that non-directional element.

→ OPERATION → Under normal operating cond^n the power flow is in normal direction in the circuit to be protected.
→ Hence directional element doesn't operate.
→ However when S.C occur there is a tendency of power flow in reverse direction.
→ Hence upper element rotates and close the bridge of (1,8,2).
→ This complete ckt of overcurrent element. Now the now directional electro-magnet activate and rotates the spindle such that the (3,8,4) contacts closed which activate the str ckt.

Date 13/02/2019

*. Distance or Impedance Relay :-

→ The operation of relay discussed earlier depends upon the current only flowing in the protected circuit.
→ Besides this the operation of relay is governed by ratio of applied voltage to current in the protected circuit.
→ So in impedance relay the torque produced by current element is opposed by voltage element.



→ The basic operation of impedance relay shown in the diagram. The impedance relay has 2-elements i.e. voltage elements & current elements.
→ The voltage element excited by potential $\propto$ (P.T.) whereas the current element is excited by current $\propto$ (C.T.).
→ The line (A to B) is the protected zone.
→ The relay is so design that it closes its contacts (relay contact) when protected section impedance falls below pre-determined value (Z_L).

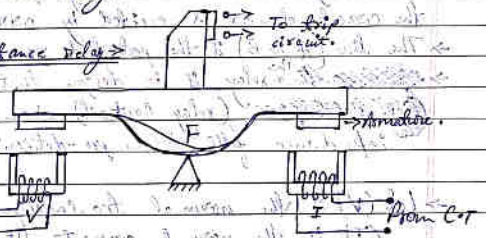
→ Let (V) is the normal transmission voltage.
(I) is the normal current flowing in the T.L.
$\Rightarrow \boxed{Z_L = \frac{V}{I}}$ where; Z_L → transmission line impedance in protected zone.

→ Now; Suppose fault occurs at point (F_1) in the protected zone, the impedance (Z_{L_1}) = $\frac{V}{I}$ between the points where relay installed is less than normal value of (Z_L). Hence relay shows operation.
$\Rightarrow \boxed{Z_{L_1} < Z_L}$ $\left(Z_{L_1} = \frac{V_1}{I_1}\right)$
and; when fault occur outside the protected zone (F_2) then impedance (Z_L) value is remain constant as ($V \& I$) value doesn't affected the C.T. & P.T. Coil of protected zone. Hence relay it in operate
$\Rightarrow \boxed{Z_{L_2} > Z_L}$ $\left(Z_{L_2} = \frac{V_2}{I_2}\right)$

* Types of distance relay :-

(i) Definite distance relay.
(ii) Time distance relay.

(i) Definite distance relay →



CONSTRUCTION → It consist of pivoted beam (F) and 2 electro-magnets energised respectively by current & voltage of the protected circuit.

→ The armature of 2 electro-magnet mechanically coupled to the beam in both sides of opposite arm.

→ This relay is so design such the torque produce by the 2 electro-magnet are in opposite direction.

• Operation :-

→ Under normal operating condition the pull due to voltage element is greater than current element therefore the relay contacts are open.

→ However, when fault occurs inside the protected zone the applied voltage to the relay decrease & current increases (S/C fault).

→ Therefore the pull of current element is greater than voltage element.

→ Therefore the beam is tilt in a direction close to trip contact.

→ As we know that, at S.C condition pull of current element is greater than pull of voltage element. So we can write;

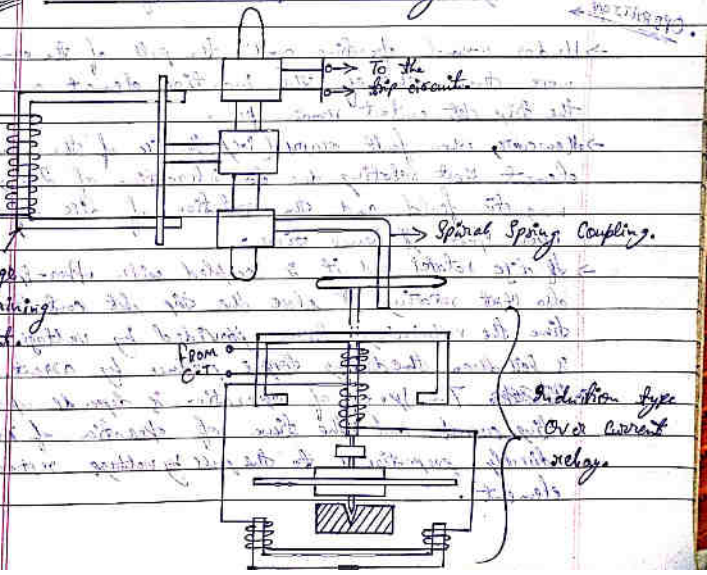
force in the $[K_1 V^2 < K_2 I^2]$ i.e. the current element is proportional to (I^2) and force produced in the voltage element is proportional to (V^2).

$$\Rightarrow \left[\frac{V}{I} < \sqrt{\frac{K_2}{K_1}}\right]$$

$$\Rightarrow \left[Z < \sqrt{\frac{K_2}{K_1}}\right]$$

where; K_1 & K_2 are two constant which are depend upon ampere turns of 2 electro-magnet.

(ii) Time distance impedance relay →



• INTRODUCTION →

→ The time distance impedance relay is one which adjust its operating time acc^n to the distance of the relay from fault point.

→ So operating time (T) directly proportional to $\left(\frac{V}{I}\right)$; $\left[T \propto \frac{V}{I}\right]$

or, $[T \propto Z]$

or, [T ∝ distance].

• CONSTRUCTION → consists

→ It consists of a current driven induction element similar to double-winding type induction over current relay.

→ The spindle carrying disc of this element which is connected by means of a spiral spring.

→ The lower spindle coupled with upper spindle which carries the trip contacts.

→ The trip ckt bridge contact normally open and by voltage restraining element of it is excited from a P.T.

• OPERATION →

→ Under normal operating cond^n the pull of the armature is more than that of the induction element and hence the trip ckt contact remain open.

→ However, when fault occurs (i.e.) the disc of the induction element start rotating due to interaction of 2 magnetic magnetic field and the rotation of disc depends upon speed & hence time.

→ If disc rotates and it is coupled with upper spindle it also start rotating & close the trip ckt contact. At that time the restraining torque provided by voltage element is less than the driving torque produce by current element.

→ The speed of operation is depends upon operating current and the time of operation of relay is directly proportional to the pull by voltage restraining element.

→ Therefore the time of operation depends upon both voltage & current. $\left[T \propto \frac{V}{I} \propto Z\right]$ Z = (impedance of certain distance upto point of fault).

Date 14/03/2019

*. Differential Relay :-

→ Most of the relay which are discussed work on excess of current.

→ This relays are less sensitive because they cannot make distinction between heavy load condition & minor-fault condition.

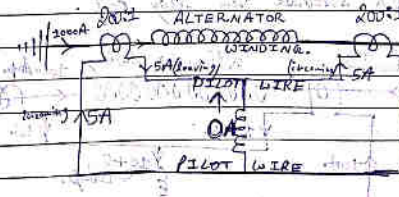
→ So a differential relay is one that operates when the phase or difference of 2 or more similar electrical quantities exceeds a pre-determined value.

→ So their are 2 types of differential relays i.e. Current differential relay & voltage differential Relay.

① Current Differential Relay →, It is one which compare the current entering a section of the s/s with the current leaving the section.

→ Under normal operating condition the 2 currents are equal but as soon as fault occur this condition is no longer stable.

→ This difference of current flow through the relay coil, which cause operating or pick-up of relay.



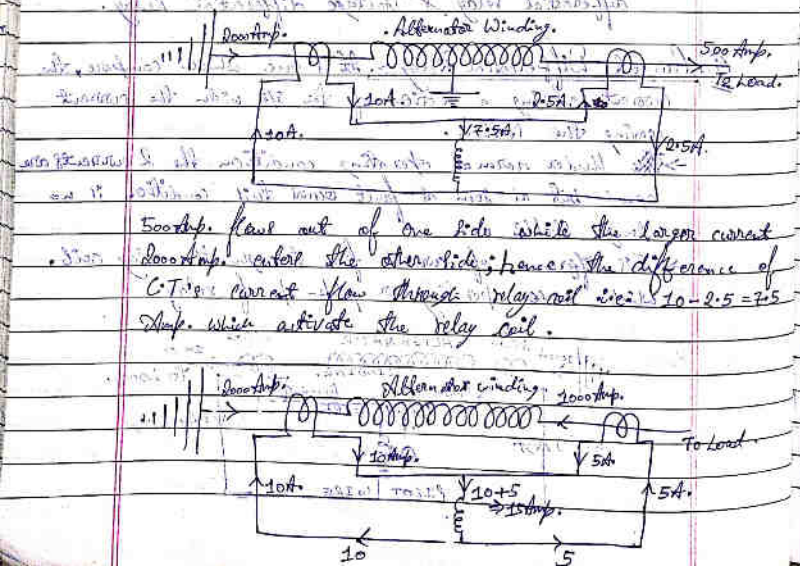
→ The above diagram shows an over current relay to operate as differential relay. A pair of identical C.T. are fitted on either side of the protected section (alternator winding).

→ The secondary side of the C.T are connected in series in such a way that they carry induced current in the same direction.

→ Hence under normal operating cond^n no current flow through relay coil.

→ Let the current 1000 Amp. exit from alternator winding, the current in the 2 secondary of C.T are equal, this current will circulate between the 2 C.T's and no current will flow through differential relay.

→ Let a fault condition of alternator winding, if some current ground



500 Amp. flow out of one side while the larger current 1000 Amp. enter the other side; hence the difference of C.T's current flow through relay coil i.e. 10 − 2.5 = 7.5 Amp. which activate the relay coil.

→ If current flow to the fault from both sides then the C.T Secondary's are drawn current 10Amp. & 5Amp. which flows through relay operating coil.

• Disadvantages:- The Pilot wire's cause slightly difference both the currents at the 2 ends of the section to be protected, if the relay is very sensitive then the small differential current flowing through the relay it to operate even under no fault condition.

→ The capacitance may be seen both pair of pilot wire cause incorrect operation of the relay when large current is flowing.

→ Accurate matching of C.T's cannot be achieved due to impedance of the pilot wire.

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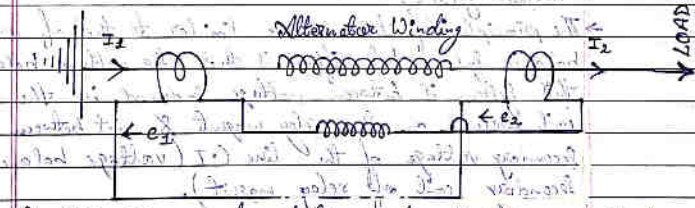
* Voltage Balance Differential Relay:-



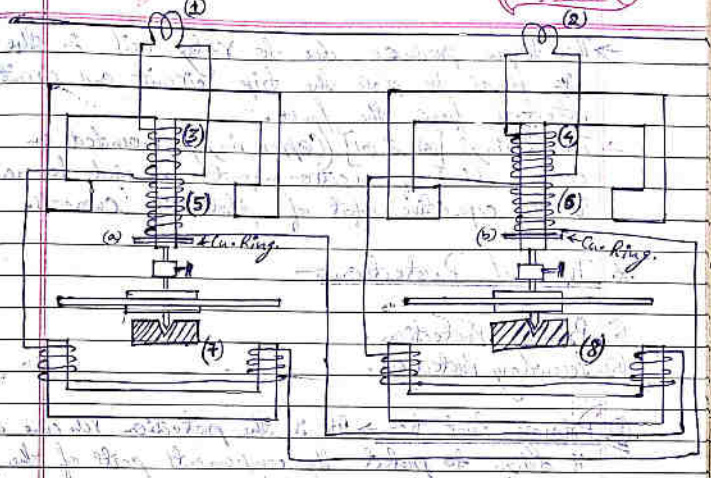
→ In this scheme of protection, two similar currents x^r are connected at either end of the elements to be protected by means of pilot wires.

→ The secondary of C.T (s) are connected in series with relay in such a way that under normal operating condition, their induced emf are in opposition hence no resultant emf.

→ Under healthy condition ($I_1 = I_2$) & ($e_1 = e_2$) hence no resultant current flow through the relay coil.
→ When fault occurs in the protected zone the current in the 2 primaries of the C.T(s) will differ from each other ($I_1 \neq I_2$).
→ Hence secondary voltages no longer balanced to each other, which cause flowing of current through relay coil & trip the circuit.

*. Disadvantages:-
→ A multigap is construction is required to achieve balance between C.T pairs.
→ The system is suitable for protection of cable of relatively short length because longer length cable shows capacitance drop across the line.

*. Translay Scheme:- It is the modified form of voltage balance system.
→ The principle of this scheme similar to that of voltage balance system but differs is that the voltage balance in this system is between voltage induced in the secondary coil wound on the relay magnet &, not between the secondary voltage of the line C.T (voltage balance bet secondary coil of relay magnet).
→ It consists of two identical double-winding induction type relay fitted in either side of the feeder to be protected.
→ The primary coil of the relays are supplied through a pair of C.T, where as the secondary winding of 2 relays connected in series by pilot wire in such a way that the voltage induced in the former opposed to one another.



*. Operation:- Under normal operating condition 2 ends of the protected feeder is same & the primary winding of the relay carry the same current and hence equal voltage induced in the relay coil (i) & (ii) (3&4).

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→ The coil 3&4 induced equal emf in the secondary winding (5,6,7&8) coil.
→ All this windings are so connected that the induced emfs are series opposition to each other. Hence no resultant emf and no resultant current in the pilot wire which cause no torque in that disc.
→ On occurrence of fault inside the protected zone, unequal voltage will be induced in the secondary winding of the relay hence current circulate in the pilot wire.

→ The torque produce due to relay coil in the Al. disc tends to close the trip circuit and circuit protected from the fault.

→ The 2 rings [(a) & (b)] (Copper rings) mounted on central limb of electro-magnets are used to neutralise the capacitive effect of pilot wire currents.

* Types of Protection :-

(a). Primary Protection.
(b). Secondary Protection.

(i) Primary Protection → It is the protection scheme which is design to protect the component parts of the power system (alternator, X^r, feeder).

→ Each line has an overcurrent relay that protect the line. If a fault occure in any line it will be cleared by Relay & C.B. This forms the primary or main protection and served as 1st line of defence.

→ The service record of primary protection 90% of all operation being correct.

(ii) Back-up (Secondary) Protection → It is the 2nd line defence in case of failure of primary protection.

→ It is design to operate with sufficient time delay so that primary relaying will be given enough time to function if it is able to.

→ It is also over-current relay having time delay of nearly about 0.6 second.

* Protection of Alternator & X^r :-

→ The Power System consists of several elements like alternator, X^r, Station Bus-Bars, transmission line and other equipments.

→ This equipments are desireable and necessary to protect from several and variety of faults.

→ The most severe fault occurs in the X^r & alternators due to S.C's. So we use several protection techniques for above equipments.

Protection of Alternator →

→ Alternators are 3ϕ ac generating equipments. So their are different imp. faults occurs on an alternator this are;

(i). Failure of Prime Mover.
(ii). Failure of fields.
(iii). Overcurrent.
(iv). Overspeed.
(v). Over Voltage.
(vi). Unbalance loading.
(vii). Stator Winding faults.

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(i) Failure of Prime Mover:- → When input to the alternator or prime-mover may fail, the alternator runs as synchronous motor and draws some current from supply system. This condition is known as inverted running.

→ In case of turbo-alternator sets failure of steam supply may cause inverted running. So steam supply is gradually restored, the alternator will pick-up load without disturbing the system.

→ If the steam failure is likely to be prolonged, the machine can be safely isolated by control room attendent.

→ In case of hydro-electric power plant protection against inverted running is achieved by providing mechanical devices on the water wheels.

→ If the water flow drops to a inefficient rate to maintain the electrical output, the alternator is disconnected from the system.

(ii) Failure of Field:- The chances of field failure in an alternator is very rare. If it does occur no immediate damage will be caused by permitting the alternator to run without a field for a short period.

→ If the fault is continue for a long time then control room attended advik to disconnect faulty alternator manually from the system bus-bar. So no alternator protection provided to this type of fault.

(iii) Over Current:- It occurs mainly due to partial break-down of windings insulation or due to overload on the supply system.

→ The alternators now a days so design that they have very high value of internal impedance (Synchronous impedance (Z_s)),

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so that they will stand against complete short ckt and three terminals for sufficient time without serious overheating.

→ If overload occurs the alternator dis connected manually.

→ So this type of alternator protection in case of a power-plant cause interfering of continuity of supply.

(iv) Over Speed:- The chief cause of over-speed is the sudden loss of all or major part of the load on the alternator.

→ So the modern alternators are usually provided with centrifugal mechanical devices mounted on the same (driving) shaft to trip the main valve of the prime mover and avoid dangerous over speed occurs.

(v) Over Voltage:- The over voltage in an alternator occurs when speed of the prime mover increases or due to sudden loss of the alternator load.

→ So the field excitation system of alternator is no design that over voltage condition at normal running speed cannot be occur.

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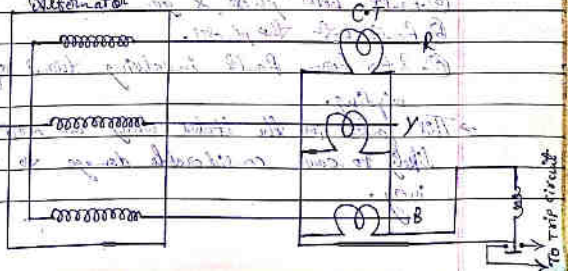
(vi) Unbalanced Loadings:- It means that there are different phase current in the alternator phases.

→ The unbalance loading arises from faults to earth or faults between phases on the circuit external to the alternator.



→ For avoid unbalance loading in an alternator this protection schemes is use. In this scheme there are 3 line C.T's are mounted on each phase and the secondary of this C.T's are connected in parallel.

→ A relay is connected across the x^r secondary in parallel.

→ Under normal operating condition, equal currents flow through the different phases of alternator.

→ Hence algebric sum of currents of each phase is equal to (ZERO) and no current flow through the neutral wire. and hence no current flow through C.T secondary and relay coil and relay is in-operated.

→ However if unbalance occurs the current induced in the secondary will be different. Hence result an current flow across the C.T secondary and relay coil, and relay starts operate and trip the C.B. and disconnected the load from alternator.

→ The above faults are (i) to (vi) are external fault to the alternator.

(vii) Stator Winding faults (Internal faults):-

→ The Stator winding faults mainly due to the insulation failure of the Stator winding.

→ The main type of Stator winding faults are:-

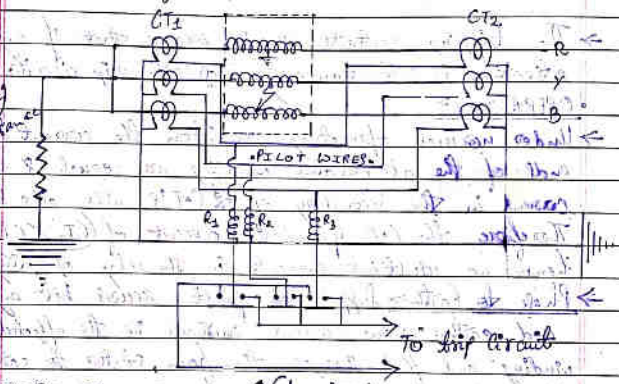
(A) Fault - both phase & ground.

(B) Fault - both the phase.

(C) Stator turns fault involving turns of the same phase winding.

→ This faults in the Stator winding are most dangerous and likely to cause considerable damage to the expensive machinery.

→ Therefore, merz-price protection scheme is absolutely necessary for protection of alternator against such faults, differential method of protection is used (merz-price scheme).



* MERZ-PRICE SCHEME → (above figure)

(Merz-Price Protection Scheme / Differential method of protection)

INTRODUCTION→

→ This is the most common s/e of protection of stator winding fault employed circulating current principle

CONSTRUCTION→

→ The arrangements shows 2 identical C.T pair (C.T-1 & C.T-2) which are placed on either side of the each phase winding (of stator).

→ The secondary of each set of C.T are connected in star, the neutral points and corresponding terminals of the 2-star groups are being connected together by means of 4-pilot wires.

→ Therefore and independent path for the current circulating for each pair of C.T corresponding to pilot wire (P).

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→ The Relay Coils are connected in star, neutral point being connected to the C.T. common neutral and the outer ends one to each of the other 3 pilot wires.

→ The tripping contacts are so arrange that if any relay coil activate, it instantaneously close the trip circuit.

• OPERATION →

→ Under normal operating condition the current at both ends of the alternator winding are equal & hence current in the secondary of the C.T's will also be equal. Therefore the C.T secondary current of (CT_1 & CT_2) and hence no resultant current in the relay operating coil.

→ Phase to Earth → Suppose a earth occurs b/t any phase and earth. Now current increases in the affected phase winding and flow through the frame, stator to earth.

→ Hence the current in the secondary of 2 CT's are unequal (entry current ≠ living current).

→ So the difference of 2 unequal current of 2 C.T's flow through affected phase relay coil cause tripping of C.B.

→ If fault occurs between any 2 phases (P-P). Hence current in the affected phase on both side of alternator are unequal, corresponding C.T secondary current also unequal cause circulating current in the pilot wire and flow through respective relay coil, close the trip contact of the C.B.

→ It may be noted that the relay circuit is so arrange that if it energised (relay coil) cause opening of the C.B connected to the alternator B-B and opening of the field circuit of the alternator.

Date 02/04/2019

(ABOARIL) (X^r oil)

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* Protection of transformers → X^r are static device which are enclosed and generally oil emerged. So chances of fault occuring are very rare.

→ If fault occurs then X^r is quickly disconnected from the s/s so automatic protection systems are design for protection of X^r.

→ For small distribution X^r are connected to the supply s/s through fuses instead of C.B. However, for power X^r probability of fault is high so automatic protection system are necessary.

→ Common X^r faults are • Open circuit faults; Over-heating fault (over-load); Winding Short circuit (Inter turns faults); phase to earth fault; phase to phase faults.

→ An open ckt in case of a 3φ X^r may cause undesirable heating so relay protection is not provided against open-ckt i.e. ~~occurrence of open ckt~~ the X^r is simply disconnected on occurrence of open-ckt fault.

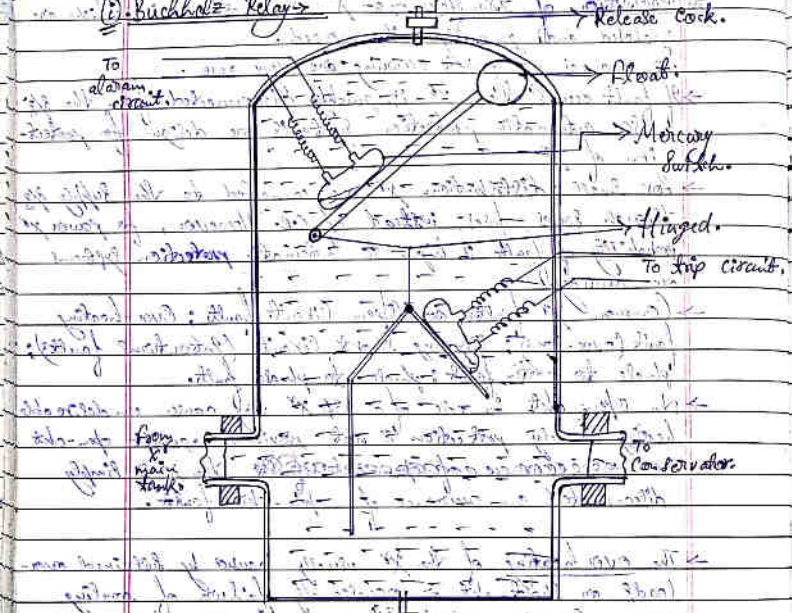
→ The over heating of the X^r usually caused by sustained overloads or short-ckt or occasionally failure of cooling system. So relay protection is provided with thermal overheating, and sound alarm & fault.

→ In case of winding short-circuit the X^r simply disconnected quickly by relaying protection s/e otherwise it may cause explosion.

* Protection s/e of X^r → For protection of power X^r merz-price circulating scheme is highly necessary, beside this scheme other protective equipments are used for X^r.

(i). Buchholz Relay.
(ii). Earth-fault Relay.
(iii). Over-current Relay.
(iv). Differential System (Merz-Price).

(i) Buchholz Relay →



→ It is a gas actuated relay installed in oil emerged XF for protection against all kinds of faults.

→ This relay use to give an alarm during incipient fault (slow developing fault) and has a capacity of disconnect the XF during severe fault.

→ It is install in the pipe between conservator & main tank.

→ The Buchholz relay are generally used for XF protection above 750 KVA.

Construction →

→ It is domed vessel type having 2 elements: upper & lower element; the upper element consist of mercury switch attach to a float.

→ The lower element consists of a hinged type flap attached to a mercury switch placed in the direct path between conservator & main tank.

Operation →

→ In case of a incipient fault heat is produced in the oil and decomposed the oil of the main tank, so 70% five to decomposition of hydrogen gas is produced which is a light gas and tried to go top of the relay chamber.

→ Now the gas surrounded the float and produced pressure which cause tilt of mercury switch and close the alarm ckt contact.

→ If a serious fault occurs (phase to phase (or) phase to earth fault) then enormous amount of heat & gas are produced and oil start rush towards main tank to conservator tank and tilt the flap as well as mercury switch which close the trip ckt contact, and C.B disconnected the XF.

Advantages & Disadvantages:-

Advantages → It is the simplest form of XF protection.
→ It able to detect smaller incipient fault.

Disadvantages → This is only used for oil emerged type XF.
→ It only detect fault below oil level in the XF. So separate protection is needed for connecting cables.

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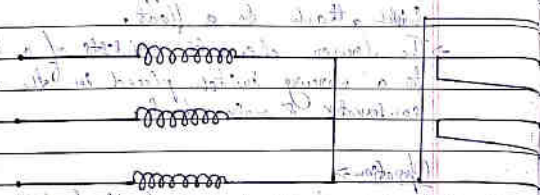
(ii) Earth fault (or) Leakage Protection:



(Figure)

INTRODUCTION →

→ The earth-fault indicates partial breakdown of winding insulation to earth.

→ The resulting leakage current is considerably less than that of S.C. current.

→ This type of fault continue for a long time and cause considerable damage before it ultimately develops S.C. and removed from the system.

→ So in this condition earth fault relay is profitable and disconnect the system when fault initiates.

→ It is a non-directional current relay having low setting (PSM).

CONSTRUCTION →

→ The 3 ϕ leads of the primary windg of power system are taken through a core of the C.T. which carry a single secondary winding.

→ The operating coil of the relay is connected to that secondary winding.

→ The relay operating coil carries pair of stripping contacts.

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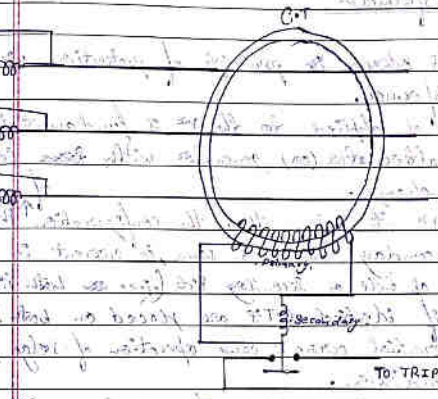

OPERATION →

→ Under normal operating condition the vector sum of 3ϕ primary windg current are equal to zero.

→ Hence no resultant current in the core & no flux produced in the core of the C.T.

$$\Rightarrow \vec{I}_p + \vec{I}_y + \vec{I}_b = 0$$

$$\Rightarrow I_m \sin(\omega t) + I_m \sin(\omega t - 120^\circ) + I_m \sin(\omega t + 120^\circ) = 0$$

→ But soon as fault occurs both earth & windg due to insulation failure the vector sum of 3ϕ current is no longer zero.

→ Hence resultant current set-up a flux in the core of the C.T. and induced emf in the secondary windg. of C.T. which energized relay operating coil and trip the C.B. to open.

Δ	Δ	Y	Y	.1
Y	Y	Δ	Δ	.2
Y	Δ	Δ	Y	.3
Δ	Y	Y	Δ	.4

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* Merz-Price Protection Scheme (or) Differential protection Scheme of a 3φ transformer:

→ Generally, this is principle of protection used for power transformer.

→ The system as applied to the 3^{ϕ} is fundamentally same as that of alternator (or) generator with certain complicating change.

→ In a power 3^{ϕ} it is seen that the configuration of windings in the primary & secondary are not same, so current in the primary side of (or) secondary side (i.e. on both sides) are not same. If identical C.T's are placed on both sides then a differential current cause operation of relay under no load condition.

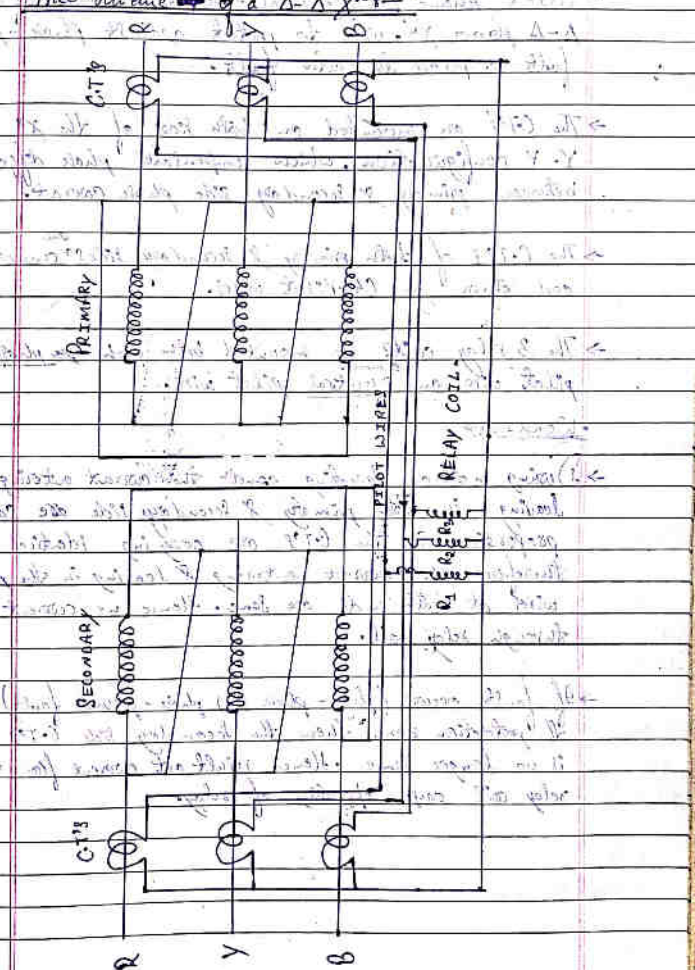
→ This can be avoid by mounting different turn ratio C.T's both on primary & secondary side of the power 3^{ϕ}.

→ There is usually phase difference between primary & secondary side currents in case of a 3^{ϕ} power transformer even if C.T's are different and proper turn ratio and cause differential current flows through relay coil during normal operating conditions. So, this phase difference of current avoided by appropriate connection of C.T's on both side of the 3^{ϕ}. Hence different connections of C.T's are employed for current match-up on both side.

Sl.No.	Power transformer		C.T's	
	Primary.	Secondary.	Primary.	Secondary.
1.	Y	Y	Δ	Δ
2.	Δ	Δ	Y	Y
3.	Y	Δ	Δ	Y
4.	Δ	Y	Y	Δ

Date Page 117.

* Circulating current scheme / Differential Scheme / Merz-Price Scheme of a Δ-Δ 3^{ϕ} transformer:



Protection

- CONSTRUCTION →

→ The diagram shows Merz-Price Scheme / Circulating-Current Scheme / Differential-Protection Scheme of a 3ϕ Δ-Δ power xmr, used to protect against phase-phase fault or phase to earth fault.

→ The C.T's are mounted on both side of the xmr are of Y-Y configuration, which compensates phase difference between primary & secondary side phase current.

→ The C.T's of both primary & secondary sides are connected to each other by 04-pilot wires.

→ The 3 relay coils are mounted betw each phase of pilot wire and common neutral pilot wire.

- WORKING →

→ During normal operating cond the current entering & leaving in both primary & secondary side are same proportion so the C.T's are carrying identical current; therefore the current entering & leaving in the pilot wired at both ends are same. Hence no current flow through relay coil.

→ If fault occurs (phase-phase (or) phase-ground fault) inside the protection zone, then the secondary side C.T's current is no longer same. Hence result an current flow through relay coil cause operating of relay.

* Protection Against Over-Voltage :- (Voltage Surge) :-

→ A sudden rise of voltage for a short period (from normal value) in the power system is known as over voltage / voltage surge, or transient voltage.

* Causes of Over Voltage :- There are 2 cause i.e.
  (1) Internal cause.
  (2) External cause.

(1) Internal Causes / reasons :- Internal reasons are as follows;
  → Switching Surges.
  → Insulation failure.
  → Arcing ground.
  → Resonance.

(2) External Causes :- The internal causes are avoided by suitable design of power system equipments.

→ Lightning :- An electric discharge between cloud & earth, between clouds or and charge centres of the same cloud is known as lightning.

→ Lightning is huge spark between clouds & earth or neighbouring clouds due to breakdown take place of di-electric strength of the air.

→ The most accepted theory for explain how cloud acquired charge is that; during upwith of warm moist air from the earth, the friction between the air & tiny particles of water causes the building-up of charges.

→ When drops of water are form the larger drop became (+vely) charged & the smaller drops became (-vely) charged.

→ When the drops of water are accumulate they form cloud and hence clouds may poses +vely or -vely charge.
→ The charge of the clouds may so large that it cause discharge between earth or other clouds seen as a lightning.

→ Due to lightning the air suddenly heats up and causing it to expand so the surrounding air pushes the expanded air back and which causing wave motion of the air recognised we as thunder.

Date 10/04/2019

* Mechanism of Lightning Discharge:-

→ When charge cloud passes through the earth it induced equal and opposite charge.
→ The charge acquired by the cloud increases the potential gradient and if it is sufficient (5KV/cm) to (30KV/cm) then the surrounding air get breakdown and lightning stroke start

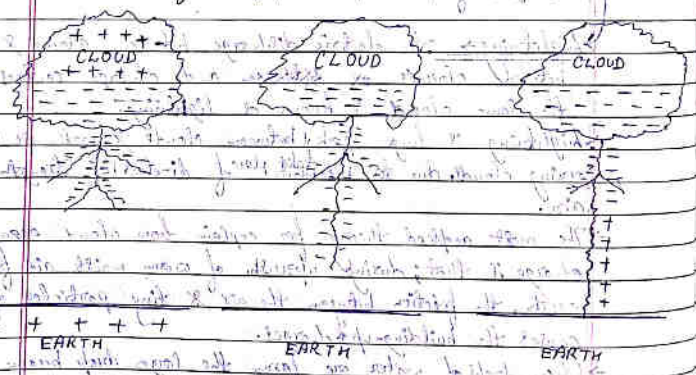


fig 1. fig 2. fig 3.

(i) As soon as the air near the cloud get breaks then charge streamer known as Pilot/Leader streamer start from cloud towards earth and if this potential gradient is maintained in the tip of the streamer then it complete the journey towards earth otherwise incomplete.

(ii) In some case the leader streamer continue its journey towards earth and comes in contact with earth or some object. Hence during the path several points of luminescence which looks like stepped leaders and each step about 50m distance from each other.

(iii) If path of the streamer leader is so ionised that complete breakdown occurs of air insulation, leader streamer reached the earth and a return streamer shoots up from the earth towards the cloud in the same path. This action can be compared with a doing of a pulse between (+ve) & (-ve) terminal which cause sudden spark and we called as high stroke lightning/heavy lightning.
Once its starts complete break-down of air occurs which follows further heavy lightning.

→ The time required for travelling the charge towards earth is about 0.0005 sec. to 0.5 sec.

→ 87% of all lightning stroke results from (-vely) charge clouds only 13% originate from (+vely) charge clouds.

→ It has been estimated that throughout the world there are 100 lightning stroke occur per second.
→ One lightning discharge may have current in the range of 10 KAmp to 90 KAmp.

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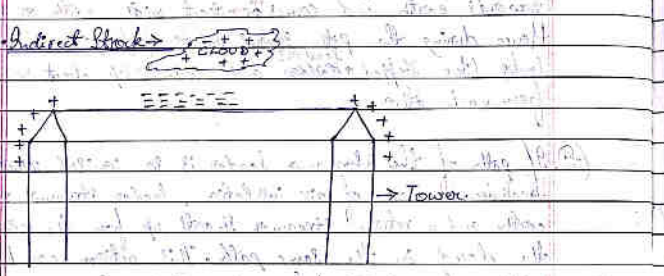
→ There are 2 types of lightning Stroke ; Direct Stroke.
Indirect Stroke.

• Direct Stroke → In this type of Stroke the lightning discharge is directly from the cloud to the subject equipment (like, overhead lines, towers) and the overvoltage occurs across insulator which cause flash over.

• Indirect Stroke →



→ This type of Stroke results electro-statically induced charge on the conductor due to presence of charge cloud.

→ If +ve charge cloud above the conductor then due to electrostatic force the (-ve) charge start gather below charge cloud & the (+ve) charge leaks through earth via insulator when this charge cloud diffused now the (-ve) charges can not flow to the earth over the insulator and travel along the line in both direction looking like travelling wave.

* Protection against Lightning → Due to lightning over voltage occurs near equipments and may damage these expensive equipments so in order to avoid lightning Stroke most commonly used device are : (A). Earthing Screen.
(B). Over-head ground wire.
(C). Lightning Arrestor.

Date

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• Earthing Screen → The power station or grid sub-station generally housing expensive equipment so in order to protect against lightning Stroke earthing screen is provided. It consist of a network of Cu-Conductor mounted all over the electrical equipment in the sub-station and this network properly connected to earth at least two points through low impedance which provides low resistance path to the lightning Stroke.

• Over-head ground wires → The most effective method of providing protection against lightning Stroke in over-head transmission line is over-head ground wires.

→ The over-head ground wire are placed above the line conductor or top of the tower at such a position that practically all lightning Stroke are intercepted by them.

→ When direct lightning Stroke occur at transmission line heavy current 10 K Amp. to 90 K Amp. flow from ground wire to ground through tower & footing resistance, such that the flash over voltage (voltage between cross-arm & conductor across insulator) is high as compare to voltage between ground wire to ground.

→ So for proper discharge the footing resistance always kept low value and current allow discharge through line conductor.

• Lightning Arrestor → Lightning Arrestor or a Surge diverter is a protective device which conducts the high voltage surge on the power system to the ground.

Principle →

$\frac{dv}{dt} < 9$

Principle

→ The lightning arrester consists of 2 conductors having a gap series with non-linear resistance. The gap is so adjusted that the normal system voltage doesn't produce any arc.

→ The property of non linear resistance is that the resistance decreases as the voltage increases and vice-versa.

→ So under normal operating condition L.A. behaves OFF-switch and no current flow to the earth.

→ On occurrence of the lightning stroke the air betⁿ the gap become ionised due to high electro-static stress and an arc seen across the gap such that the surge voltage discharge to the earth through non-linear low resistance.

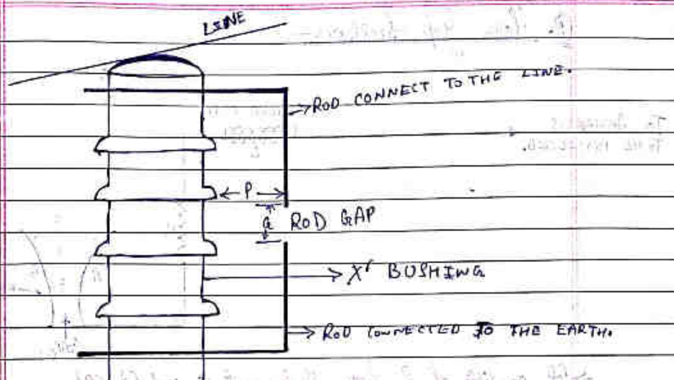
* Types of L.A :-

① Rod Gap Arrester :- The rod gap arrester is very simple construction which consists of two 1.5 cm rod which are bend right angle with a gap between them.

→ One rod is connected to the line of the ckt whereas the other is connected to the earth.

→ The distance betⁿ gap & insulator must not be less than 1/3rd of the gap length so that the arc does not reach the insulator and damage it.

$P > \frac{1}{3}G$



→ Generally the gap length is so adjusted that the breakdown should be occur at 80% of spark-over voltage in order to avoid cascading of very steep (rise) wave fronts across the insulator.

→ Generally this type of arrester found across the bushing of the X^R.

→ Under normal operating condition the gap remain non-conducting, on the occurrence of high voltage surge the gap became conducting and the surge current conducted towards earth.

Limitation →

→ After surge voltage over the arc is maintained by the normal system voltage and S.C. of system may occurs.

→ The rod may melt or get damaged due to excessive heat produced by the arc.

→ The climatic condⁿ affect the performance of the arrester.

→ The polarity of the surge also affects the performance of the arrester; due to this limitation this type of arrester is used for back-up protection.

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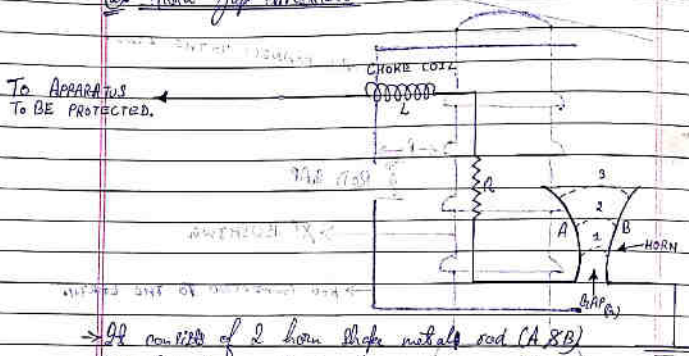
② Horn Gap Arrestors—



→ It consists of 2 horn shape metallic rod (A & B) separated by a small gap.
→ The horns are so constructed that the distance between them gradually increases towards top.
→ This 2 horns are mounted on porcelain insulator.
→ One end of the horn is connected to the line through a resistance (R) & choke coil (L) whereas the other end of the horn is effectively grounded.
→ The resistance (R) will limit the flow of current to a small value whereas the choke coil (L) help to offer small reactance at normal power frequency but high reactance at transient frequency.
→ The gap both the horns is so adjusted that the normal system voltage doesn't produce any spark or insufficient to produce arc.

Operation:—

→ Under normal operating condition the gap is non-conducting hence no arc produced across the gap.
→ On the occurrence of over voltage the air of the gap becomes ionised due to high electrostatic force and cause ionisation of arc. The arc moves progressively into position (1, 2 & 3).

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→ At some position of the arc (3-position) the gap is too long that the arc fails to maintain with that surge voltage and it become extinguish, and excess charge moved to the ground.

Advantages → The arc is self clearing, hence this type of arrestor doesn't cause short circuiting of the p/s after clearing of voltage surge or fault.
→ Series resistance help to limit flow of current to a small value and inductance (L) helps to limit transient frequency.

Disadvantages →
→ The bridging of gap by some external agency (Birds) can render the device useless.
→ The setting of gap likely to be change due to corrosion or pitting (rusting).
→ The time of operation is comparatively long about 3 seconds.