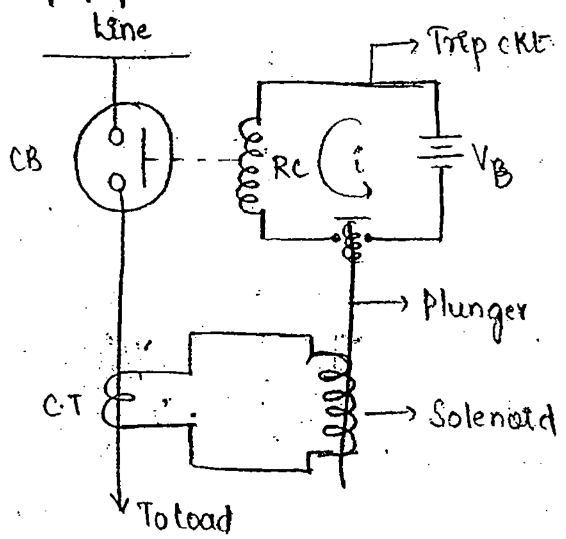
15-5-11
Sunday

POWER SYSTEM PROTECTION

Protection is a fine tuning or tracking mechanism which traces the abnormalities which are developed in the operation of power system. The main aim of a protection scheme is to safe guard or isolate the equipment from a faulty section. The following figure shows basic scheme of protection.



Under normal conditions, the moving contact is held with fixed contacts then energy flows from line to the load. If any abnormality is developed, this protection scheme operates.

Initially the system is designed in such a way that the magnetic characteristics of solenoid and mechanical characteristics of plunger are in such a way that the spring tension is more than the magnetic pull produced by the solenoid for normal operating currents.

Under the disturbance, if the current exceeds the prespecified value, the magnetic pull produced by the solenoid is more than the spring tension and the plunger is pulled down. Thereby trip circuit is closed and the relay coil energises

This relay coil attracts the moving contact of the breaker and is pulled away from fixed contacts thereby necessary isolation between line and load.

This is the basic idea of any protection scheme for any device. For designing and drafting a specific scheme of protection, relay plays very important role.

CIRCUIT BREAKERS

Circuit breaker is a device which makes or breaks the circuit.

The functionality of the breaker is similar to the function of switch but in the operation of breaker certain unwanted phenomenon called arc is developing. This made us to have a detailed study regarding breakers.

Phenomenon of Arc:

Under faulty conditions, by the action of relay, the moving contact gets seperated from fixed contact. By this contact resistance b/w the two contacts decreases and current density increases. Thereby contacts are associated with more electromagnetic energy.

$EME = \frac{1}{2} L I^2$

$ESE = \frac{1}{2} C V^2$

When the moving contact is seperated from the fixed contact by the last tip of touch, a sudden open ckt is established thereby all the electromagnetic energy is converted into electrostatic energy and voltage rises. This voltage will setup sufficient potential gradient to breakdown the insulation b/w the contacts. Then the space between the contacts gets ionised and the discharge starts from fixed contact. When this discharge touches the moving contact, a short ckt path is established. Through this shrt ckted path; heavy inrush of currents takes place. This is called arc.

This arc carries very high currents with high temperature. This may damage the load.

To safeguard the load, this arc should be extinguished as early as possible.

ARC EXTINCTION METHODS:

Arc can be extinguished by two methods.

(i) High Resistance Method.
(ii) Current zero method

(i) High Resistance Method:

In this method, the resistance of the arc is increased so that arc current decreases. The arc resistance should be increased to such an extent that the resulting current could not be able to sustain b/w the two contacts. Then arc is said to be extinguished. This can be achieved in two ways.

i) Lengthening of arc
ii) Deionisation

i) Lengthening of arc & Deionisation

This method can be applicable for AC breaking and DC breaking. But is limited to low values of voltages for the following considerations.

1) For the design of breaker size
2) For the operating time of breaker.

ii) Current Zero Method:

In this method, arc is interrupted at current zero. This method can be applicable for high voltage interruptions. In AC systems, current or voltage crosses zero for every half cycle.

into electrostatic energy and voltage rises to a high value this high voltage setup sufficient potential gradient thereby arc will restruck b/w the contacts. This high voltage is helpful in restricking of arc is called as restriking voltage.

As a means of arc extinction, large volume of dielectric is ingressed over the contacts thereby the medium becomes dielectric. In the medium of dielectric, the rise of voltage may not reach to the level of restriking and arc is said to be extinguished.

16/5/11 Monday The disadvantage with this method is that this method by default can be applicable for A.C system only. However by making use of auxiliary thyristorised, commutation choppers we can get, artificial current zero thereby high voltage DC breaking can be achieved.

Basic Terms and Definitions:

1. Arc Voltage:

The potential difference across the contacts during the arc is called arc voltage.

2. Restriking Voltage:

It is a transient voltage at or near current zero. It can be estimated as

$$V_R = V_M\left(1 - \cos\frac{t}{\sqrt{LC}}\right)$$

where L and C are equivalent inductance and capacitance.

3. Recovery Voltage:

It is the potential difference across the contacts when the arc is totally eliminated. It is generally 95 - 98 % of Full load value of voltage.

It can be
K = 1.0
For
5. Rate of
voltage
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1) Oil
2) Air
3) SF
4) Vac
and hence

4. Active Recovery Voltage:

It is the instantaneous form of recovery voltage. It can be estimated as $V_{ar} = K V_m \sin\phi$ where ϕ is ϕ phase an[gle]

K = 1.0 when 3-ϕ fault is grounded or isolated

$$K = 1.5$$

For V_{ar} to be max^m, power factor of system = 0.

5. Rate of Rise of Restriking Voltage (RRRV)

It is the ratio between maximum possible restriking voltage to the time taken to reach this value.

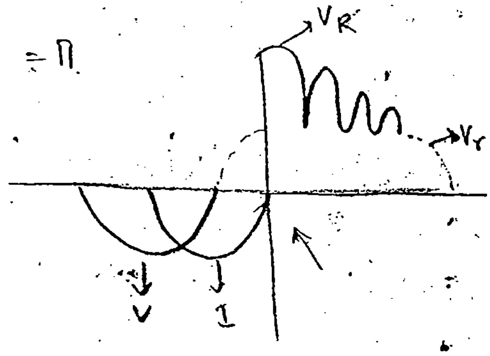
$$V_{Rmax} = 2V_m$$

for this to happen $-\cos\frac{t}{\sqrt{LC}} = 1$

$$\frac{t}{\sqrt{LC}} = \cos^{-1}(-1) = \pi$$

$$t = \pi\sqrt{LC}$$

$$\therefore \boxed{RRRV = \frac{2V_m}{\pi\sqrt{LC}}}$$



Classification of Circuit Breakers:

Breakers are classified acc. to the dielectric used. As per this, there are

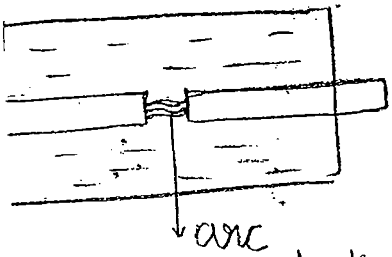
1) Oil ckt breakers
2) Air blast ckt
3) SF_6 ckt breakers
4) Vacuum ckt breakers.

In this breakers, oil is used as dielectric medium and hence the name. These are further classified into 2 types linimum Oil C·B

Bulk Oil CB

In this breaker, oil serves the additional purposes ike insulation and cooling. Synthetic oil is the oil used. (658°K)

1 part of oil → 1475 – 1625 volume of gas.



The arc current carries high temperatures. If the temperature of the arc exceeds 658° K, the oil nearby the arc gets intouch with it decomposed into gas.

one particle of liquid decomposed, that generates 1475-1625 ıts of gas. The decomposed gas consists of 70% of hydrogen, % of acetelene, 8% of ethane and 5% of methane.

The small volume of oil generates large size of gas bubbles. ıs volume imbalance setup turbulence inside the oil.

l with this turbulent force rushes into the space between the ntacts thereby space b/w the contacts is occupied with dielectric edium.

In the medium of dielectric at current zero, the rise of the tage may not reach to the level of restriking there by arc may t restrike.

hese breakers can be used upto 33 KV only.

Minimum Oil Circuit Breaker:

In bulk oil C·B, large volume of oil is used for cooling d insulation, very small amount is useful for arc extinction. sage of Bulk oil has the following disadvantages.

Oil is costlier and bulky.

It has a tendency to catch fire.

It has leakage property by which the appearance is not neat

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4. By the ingression of moisture, the viscosity of oil increases there by circulation of speed decreases. This leads to the thermal breakdown.

Keeping in view of the above stated disadvantages, a modified form of C.B is designed in such a way that how much amount of oil is required for arc extinction, that much is only used. The other purposes like insulation or cooling are served by gaseous or solid dielectrics. These breakers can be used upto max^m voltage of 132KV.

AIR BLAST C.B:

The spread velocity of air is more than the oil, so air is used as arc extinction medium for the operating voltages beyond 132KV. Air can be drawn from atm. The necessary air pressures can be developed from compressor cylinder mechanism. By cascading no of units, high voltage operations can be achieved.

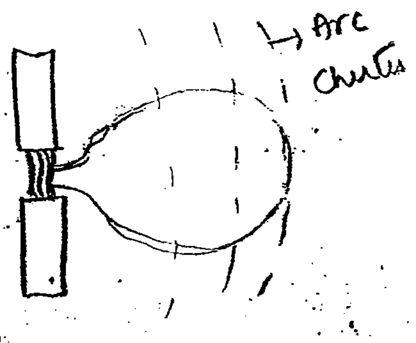
Eg: 4 units for 220 KV
8 units for 400 KV

These are of two types.

1) Cross blast
2) Axial blast.

1. Cross Blast

In this breakers, the blast of air is in ⊥ar directio to the arc as shown in figure.



Owing to the higher air pressure, the arc expands like a balloon, thereby arc resistance increases. Intern arc current decreases. This low value of arc current cannot be sustained b/w the

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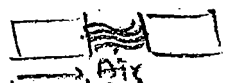
In this type sufficient value of arc resistance is developed so resistance switching is not necessary. These breakers are used for low voltage capacity. load Base load — Thermal

· Axial Blast : Peak load or base load — Hydel

In this type, the blast of air is in axial direction to the contacts.



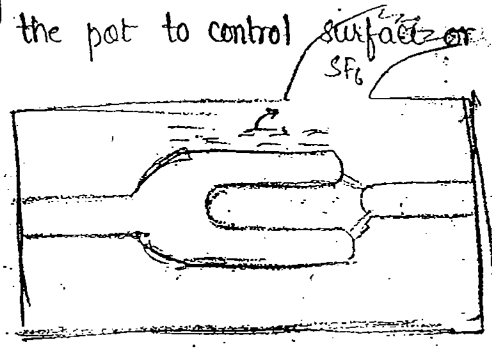
To have good interruption capacity, the air at a higher pressure should be allowed. This breaker should be kept totally in a sealed container. These breakers are used upto 400 KV. Resistance switching method is used for the interruption of arc.

SF_6 CIRCUIT BREAKER:

SF_6 is having higher dielectric constant and strength over air. So it is preferred for higher operating voltages upto 800 KV. These breakers are preferred to use beyond 132 KV. However for some special applications, SF_6 in the range of 6.6 KV and 100 KV are also available.

SF_6 is a electronegative gas having the property of absorbing ions. When the arc is struck, SF_6 with pressure of 14.8 Kg/cm² is released into the pot there by medium gets deionised. Then arc may not be able to restrike.

Under normal operating conditions also, SF_6 at a pressure of 8 Kg/cm² is allowed inside the pot to control surface or localised ionisation.



Vacuum C.B :

In vacuum C.B, metallic vapours are liberated due to the formation of hotspots. These hot spots further develop metallic fumes which are acting as path finders for arc to struck b/w

As the v... reach to the... There by arc... can be ach... With th... can be opera...

17/5/11 Tuesday RATING

The ...

1. No. of B...

Cascaded ...

2. Voltage

3. Current ... Three ...

1. Peak

2. Sym...

3. Asym...

4. Capac... C...

In two ...

1. Break...

fault ...

As the vacuum is initially present, the rise of voltage may no reach to the level of restriking after I cycle current zero. There by arc may not restruck. In this way I cycle interrup can be achieved.

With these breakers Ist swing stability is also possible. This can be operated upto 33 KV only.

17/5/11 Tuesday

RATING OF BREAKERS:

The circuit breaker is labelled with the following ratin

1. No. of poles:

It is a fn of voltage. more no. of units are cascaded for getting higher operating voltages.

2. Voltage and Frequency.

These ratings are same as line ratings.

3. Current:

Three types of currents are labelled.

1. Peak value of load current
2. Symmetrical short ckt current (I_{sy})
3. Asymmetrical short ckt current (I_{Asy})

$I_f = I_{ac} + I_{dc} \Rightarrow I_A$

$I_f - I_{ac} \Rightarrow I_{sy}$

$$I_{ASY} = 1.8\, I_{sy}.$$

4. Capacity.

Capacity is short ckt capacity which can be expressed in two forms.

1. Breaking Capacity

It is the capacity expressed with rms values of fault current and supply voltage.

$$BCc = \sqrt{3}\, V_L I_{sy} \times 10^{-6} \text{ MVA}$$

It is the capacity expressed with the peak value of supply voltage and fault current.

$$MC = \sqrt{3}\, V_m I_{sy} \times 10^{-6}\ MVA$$

$$= \sqrt{3}\,(\sqrt{2} V_L)\,(1.8\, I_{sy}) \times 10^{-6}$$

$$= (\sqrt{2} \times 1.88)\,(\sqrt{3} V_L I_{sy} \times 10^{-6})$$

$$\boxed{MC = 2.55\ B.C}$$

5. Short Time Rating:

It is the time for which the breaker can withstand fault current without excessive heating. Its value is 3 sec if $\frac{I_{Asy}}{I_{FL}} \leq 40$.

Otherwise, it is 1 sec.

6. Duty cycle:

It is the time interval between the ON and OFF periods of the breaker.

1. For non auto-reclose:

In these breakers, the breaking is done automatically and making is done manually.

The duty cycle is expressed in two forms.

a) $O - t - CO - t' - CO$

b) $O - t'' - CO$.

where t & t' are around 3 minutes and t'' is 5 - 15 seconds.

2) For auto reclose:

In this type both breaking and making are done automatically.

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3-5.
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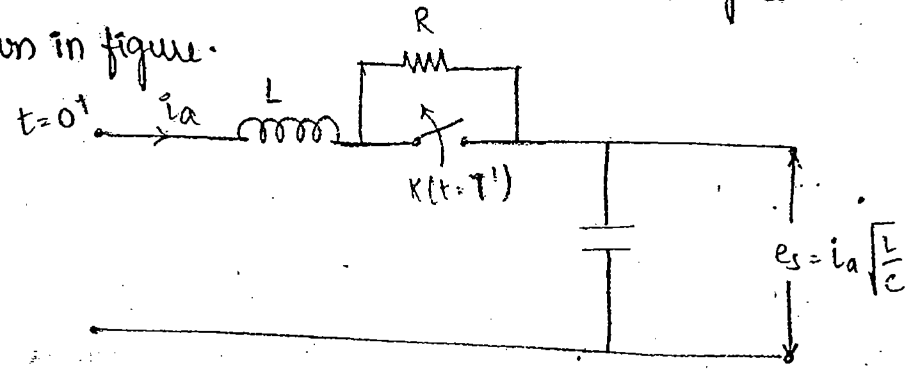
Duty cycle is expressed as D - DT - MB

where Dt is delay time which is expressed in cycles. Usually 3-5.

Current chopping:

Breaking the current before its natural current zero is called current chopping. This can be obtained by providing a series switch with an inductance shunted by a resistance as shown in figure.



The resistance here has to serve two purposes.

i) It has to minimise the transient recovery voltages to be lesser than the restriking levels.

ii) It has to cause equivalisation by dissipating the energy released by switching.

For the Ist purpose, the resistance should be as low as possible. For the II purpose, it should be as high as possible. This is the contraversy.

As a compromise, we should have to consider a critical value that is $R_c = \frac{1}{2}\sqrt{\frac{L}{C}}$.

This value will not give transient oscillations in the operation of breaker.

1. A C.B of 132 KV, has a equalent inductance of 5H + capacitance of 0.01 μF. The transient arc current is 5A. Find
   i) The voltage developed across the breaker contacts
   ii) Critical value of resistance which will not give transient oscillations.

$e_s = i_a \sqrt{L/C} = 5\sqrt{\frac{5}{0.01\times10^{-6}}} = 111.8 \text{ KV}$

ii) $R_c = \frac{1}{2}\sqrt{L/C}$

A ckt breaker is rated as 3-φ, 2000 MVA, 33 KV, 3 cycle. Find it M.C & B.C.

$$I_b = \frac{2000 \times 10^3}{\sqrt{3} \times 33} = 34.99 \text{ KA}$$

$$I_M = 2.55\, I_b$$

$$= 89.22 \text{ KA}$$

3. A CB is connected to 132 KV line. It has X_L of 3 Ω, equivalent capacitance is 0.015 μF. The operating frequency is 50 Hz. Find a) Natural freq of oscillations
b) Max^m possible restriking voltage.
c) RRRV.

Sol

$$X_L = 3\,\Omega$$

$$2\pi f L = 3$$

$$L = \frac{3}{2\times\pi\times50} = 9.54 \text{ mH}$$

a) $f_n = \frac{1}{2\pi\sqrt{LC}} = 13.304 \text{ KHz}$

b) $V_R = V_m\left(1 - \cos\frac{t}{\sqrt{LC}}\right)$

$$V_R = 2V_m = 2\times\frac{\sqrt{2}}{\sqrt{3}}\times132 \text{ KV}$$

$$= 215.55 \text{ KV}$$

c) $RRRV = \frac{2V_m}{\pi\sqrt{LC}}$

$$f_n = \frac{1}{2\pi\sqrt{LC}} \Rightarrow 2f_n = \frac{1}{\pi\sqrt{LC}}$$

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4. A 132 KV
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~~RRRV~~ = $2f_n = 2 \times 13.304$

$= 26.608$ KHz.

RRRV $= 215.55 \times 10^3 \times 26.608 \times 10^3$

$= 5.735 \times 10^9$

$= 5.735$ KV/μsec

4. A 132 KV breaker has the natural frequency of oscillations 16 KHz. The recovery voltage is 95% of full load voltage. When it is subjected to a s.c test, the fault is grounded and results the P.F of 0.45. Determine rate of rise of restriking voltage.

Sol

$V_{ar} = K V_m \sin\phi$

$\cos\phi = 0.45$

$\sin\phi = 0.893$

$K = 1.0$

$V_{ar} = (1.0)\ 0.95 \times \sqrt{2} \times \frac{132}{\sqrt{3}} \times 0.893$

$= 91.43$ KV

$\frac{1}{\pi\sqrt{LC}} = 2f_n = 2 \times 16 = 32$ KHz.

RRRV $= 2 \times 91.43 \times 10^3 \times 32 \times 10^3$

$= 5.851 \times 10^9$

$= 5851$ KV/μsec.

5. A C.B is connected to a 220KV line has the reactance of 8 Ω and a capacitance of 0.025 μf. The $f_{op} = 50$ Hz. Find

i) Natural frequency of oscillation

ii) Damped frequency of oscillation if a resistance of 600 Ω is shunted.

i) R_c which will not give transient oscillations.

$$L = \frac{X}{2\pi f} = 25.4 \text{ mH}$$

$$f_n = \frac{1}{2\pi\sqrt{LC}} = 6.315 \text{ KHz}.$$

ii) $$f_d = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{1}{4R^2C^2}}$$

$$= 3.427 \text{ KHz}.$$

iii) $$R_c = \frac{1}{2}\sqrt{\frac{L}{C}}$$

$$R_c = 503.9\,\Omega$$

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RELAYS

The device which senses the fault and initiates the operat of the breaker is called Relay.

A functional relay should have the following characteristic

1. Selectivity:

   It is the ability of relay mechanism to select the part of the power system which is under trouble.

2. Speed

   The relay mechanism should possess sufficient speed for quick isolation and protection.

3. Sensitivity:

   It is the ability to respond for low actuating quantities even.

4. Simplicity:

   The relay mechanism should be as simple as possible so that it can operate and maintain easily.

5. Reliability:

   It is the ability to operate for prespecified operating conditions.

6. Economical:

   It is a general criterion.

Basic Terms and Definitions:

1. Pickup Level:

   It is the minimum value of actuating quantity beyond which relay operation starts.

2. Reset Level:

   It is the maximum value of actuating quantity which keeps the relay in off state.

The time elapsed between the instants of current reaches to pickup level to the instant of breaker contacts opened is called pickup time.

4. Reset time:

It is the time elapsed b/w the instant of current reaches to reset level to the instant of breaker contacts reclosed.

5. Reach:

In distance protection the T/L is divided into certain operating zones. Each zone is provided with a relay. This relay is said to operate when the impedance seen by this is other than the prespecified value. Under this circumstances the prespecified value of impedance or the distance is called as Reach.

6. Over Reach:

If the relay is said to operate for the condition $Z > Z_L$ it is called over reach.

This relay is used for overvoltage protection. $\uparrow Z = \frac{V\uparrow}{I}$

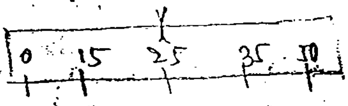
7. Under Reach:

If the relay is said to operate for the condition $Z < Z_L$ then it is called underreach.

This relay is used for overcurrent protection. $\downarrow Z = \frac{V}{I\downarrow}$

8. Current Setting:

It is the set value of current for which the relay has to operate.



9. Time Setting:

It is the set value of time for which the relay has to operate.

This is adopted in the relays where time is considered as pickup.

10. Plug Setting Multiplier:

It is the ratio between fault current and pick up level.

$$PSM = \frac{\text{Fault Current}}{\text{Pick up level}}$$

$$= \frac{I_f}{\text{CT ratio} \times \text{Current setting}}$$

Classification of Relays:

Relays are classified into 3 types.

1) As per location
2) As per time of operation
3) As per construction.

1. As per location:

On the power system, every component is provided with its own kind of protection. Under abnormal conditions the relay in the protection scheme should be activated. This is called primary Relay.

If this relay failed to operate, the master relay which is kept at the starting of the subsection has to operate. This is called secondary

For low power operating systems, one primary and one back up relays are provided and for high power system, one primary and two back up relays are provided.

2. As per time of operation:

As per time of operation, relays are classified into 3 types.

1) Instantaneous
2) Inverse Time Relays
3) IDMT Relays

Instantaneous Relay

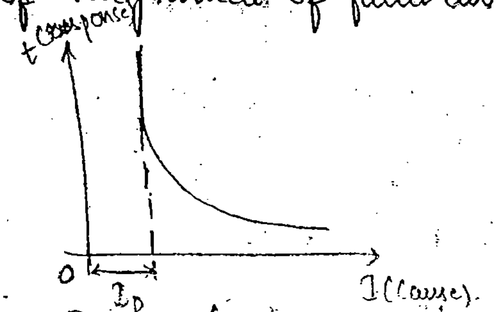
This relay gets operated at the instant of f... occurance.

Inverse Time Relay:

The time of operation of this relay is inversely proportional to the square of magnitude of fault current.

$$t \propto \frac{1}{I^2}$$

$$I^2 t = K$$



3. Inverse Definite minimum Time Relays (IDMT)

This relay does not gets operated until the fault current ~~not~~ reaches to certain level. This relay offers certain minimum time delay irrespective of magnitude of fault currents.

This can be achieved by setting the ~~EER~~ relay operation when its core gets saturated only.

The saturation saving limit is above a certain percentage of pick up level.

∴ These relays are most widely used in modern practise.

i. As per Construction:

Relays are classified into four types.

1. Electromagnetic
2. Thermal relays
3. Static relays
4. ~~Dy~~ Microprocessor based relays

1. Elec...

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ii) Sole...
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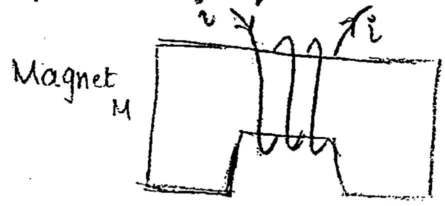
Friday

1. Electro Magnetic Relays:

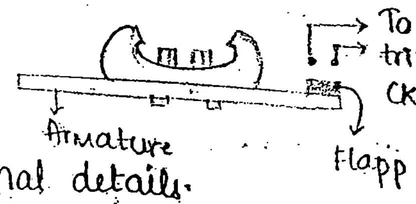
These relays will work on the principle of electromagnetic attraction or induction. The relays based on attraction principle can be used for AC and DC supplies.

The relays based on induction principle can be exclusivel used for AC supply. These relays are fundamental form perform actual relay operation. These are further classified as

i) Attracted Armature Type
ii) Solenoid Type
iii) Induction disc type
iv) Induction cup regulator.



i) ATTRACTED ARMATURE TYPE:



The figure shows the constructional details.

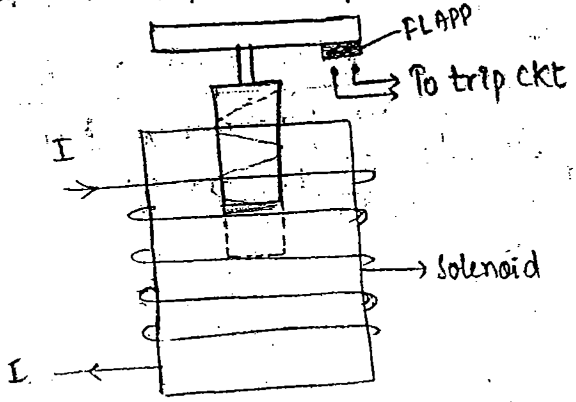
Initially the magnetic properties of magnet M and physica properties of armature are designed in such a way that the magnetising force produced by magnet M for normal operating currents could not be able to lift the armature.

Under the occurance of fault, due to excess current, the magnetising force produced by the magnet M is more and the armature is attracted. In the upward movement, the flapp attached to armature closes the trip circuit and the trip circuit is activated.

This relay is mostly used in industries as a localised protecting device. It is mostly polarised with DC supply.

ii) SOLENOID TYPE:

When the current is more than the normal value, the magnetising force produced by the solenoid increases and will attract plunger ... In the downward movement, the flapp attached pulled down. In the downward movement, the flapp attached closes the trip circuit contacts. This is the most general form of relay used in many applications. This relay is mostly polarised with DC supply.



ii) INDUCTION DISC TYPE

The shunt magnet is connected in parallel with the supply will take the max^m component of voltage and the flux produced by this magnet canbe treated as "restraining flux".

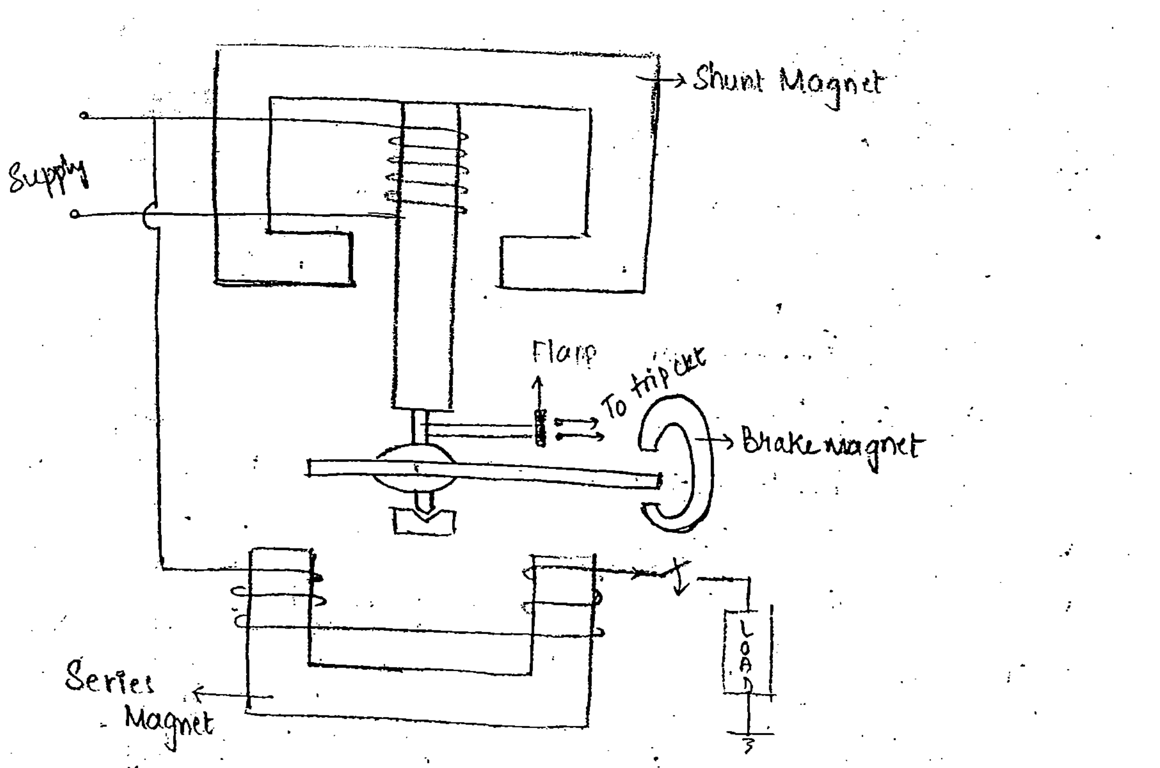
The series magnet is connected in series with supply and load and is polarised by current. This flux can be treated as deflecting flux.

The two magnets are designed in such a way that the fluxes produced by them cancels for full load voltage and full load current.

The current is more than the full load value. The deflecting flux dominates the restraining flux and the disc starts rotating. The rotatory movement of the disc transfers to the flapp through spindle. Then flapp closes the trip ckt contacts.

This relay is mostly used as <u>Overcurrent relay</u> and its wide application as distance Relay.

The position of trip ckt contacts is made around the disc space depending upon time of operation. This is

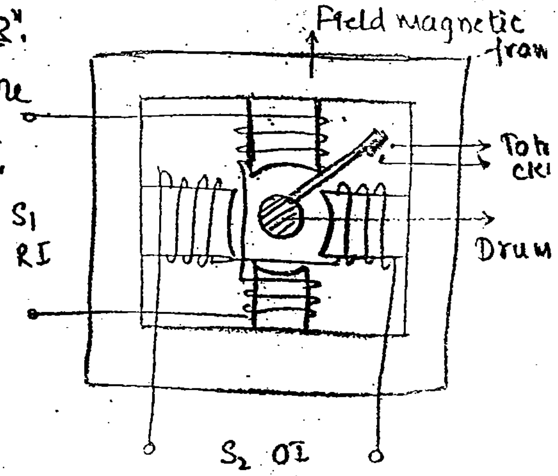


Called "Relay Angle Setting"

iii INDUCTION CUP REGULATOR: (ICR)

This relay basically operates on the principle of Induction motor. This relay is set to operate for the condition $\frac{S_2}{S_1} > 1$. At this condition, the flux in the field magnetic frame is positive. in the drum will induce some flux from it. These two fluxes will interact in the air gap produce an electro-magnetic torque.

With this torque, the drum starts rotating. With this rotary movement, the flapp closes the trip ckt contacts. This relay is mostly used in differential protection and is called as "ELECTRICAL COMPARATOR".



This relay is used in the form of single ICR, Double ICR, Triple ICR. For any no. of field magnetic frames the drum is common. f-400Hz - Operating relay sensitivity

These relays work on the principle of electrothermic effect i.e., Production of heat by electrical energy. This heat is acting as active component for relay operation.

These relays will consist of two parts.

i) Active Element and

ii) Heating Element

The heating element will produce proportional amount of heat to the activating electrical quantity. By sensing this heat the active element performs the relay operation.

These relays are used for the protection of smaller and localised units. These are very much significant at high frequency supplies and for non-sinusoidal AC wave forms.

The active elements are of mainly 3 types

a) Bimetallic

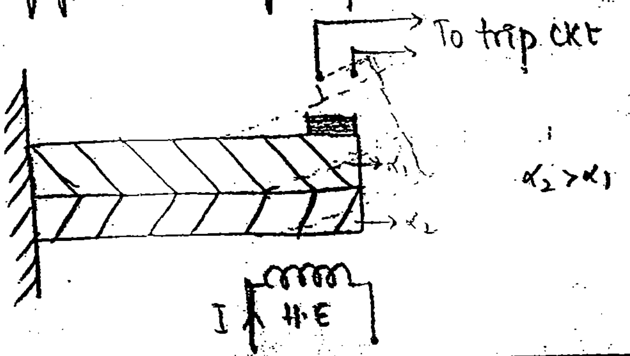
b) Unimetallic

c) Thermocouple

a) Bimetallic Element :

It is a combination of two metal strips having different linear coefficient of expansions. The element is so designed that for normal operating currents, it won't produce any bending movement.

When the current exceeds the prespecified level, the heat produced by heating element is more and the free end of bimetallic element bends in the upward direction as shown in figure. There by trip ckt is closed.



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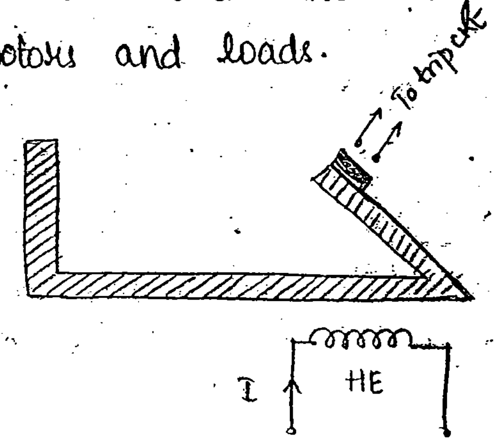
Tungsten 4500°C M.P

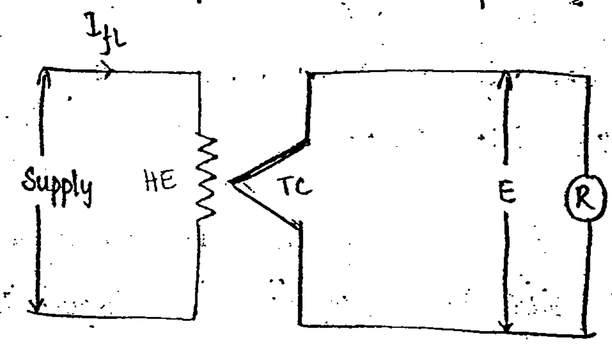
b) Uni Metallic Element :

In this type only one metal strip is used. When the current exceeds the prespecified limit, the metallic element expands. In this expansion the flapp attached to it touches the trip circuit contacts. This relay is used for the protection of small motors and loads.



c) Thermocouple :

It is a combination of two dissimilar metals having the property of Generating emf by grasping heat. The emf generated for the normal operating currents is set as relay pickup. If the current exceeds the prespecified level, the emf generated will be more, it exceeds the pickup level and the relay gets operated. This relay is mostly used for the protection of generators at generating stations.



$$E = a(\Delta T) + b(\Delta T)^2$$

$a \rightarrow$ 40 - 50 $\mu V/°c$

$b \rightarrow$ Few tenths of a

$\Delta T \Rightarrow T_1 \sim T_2$

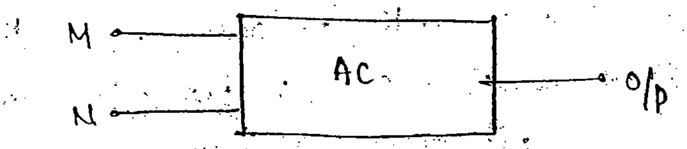
The conventional relays discussed so far can have the sensitivity in the milliamperes range. To trace the signals which are lesser than milli, we need to use solid state devices like diodes, transistors, FET, MOSFET or IC's.

A static relay is a master-slave combination. The master is a solid state device circuitary of differential bridge type of differential amplifier type. Slave is a DC polarised electromagnetic relay. The function of the master is to condition the signal to the sensitive levels of slave.

These relays are mostly considered as comparators. These are of two types.

i) Amplitude Comparator

In this type, the magnitude of the two signals is compared and this relay gets operated for any one of the condition stated below.



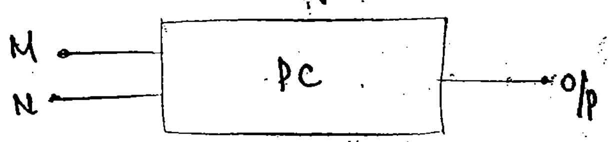
$|M| \sim |N| \neq 0$

$|M| - |N| > 0$.

The first condition is differential comparision, the second condition is biased differential comparision.

ii) Phase

In this type, the phase of the two signals is compared. This relay is set for operating condition of anyone as stated below.



~~|M|~|N|~~ $\phi_m \sim \phi_n \neq 0$

$\phi_M \sim \phi_N \leq \phi$

where φ
which
very much

MICROPRO

-processor
of operation
programmin
systems w

where ϕ is Angle of coincidence or non coincidence which can have a range from 0 to 180°. These relays are very much used in carrier protection.

MICROPROCESSOR BASED RELAYS:

These relays are similar to static relays with micro-processor interfacing. These relays will operate at exact time of operation and relaying operations are sequenced by suitable programming. These relays are used in the industrial automation systems where all the operations are based on PLC's (Programmable Logic ckt. (Grp control)) (or) DCS (Distributed control syst (Individual con))

Transmission and distribution lines are protected by 3 types of protecting schemes.

1. Over current Protection
2. Distance Protection
3. Carrier Protection (Pilot Relaying)

1. Over Current Protection:

This type of protection is mostly used for Feeders and Distributors.

Over current relays with automatic protection schemes are employed. These are considered to be three types.

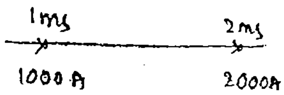
i. Time Based System:

In this system, the sequence of relay operations depends upon time setting of the relays. The relay which is set for lower time of operation operates first independent of magnitude of fault current. This is disadvantageous.

ii Current Based System:

In this system, the sequence of relay operation are based on current setting. The relay which senses higher amount of fault current operates first. The disadvantage in the above system is overcomed here.

iii Current / Time Based System:



This is the combination of both depending upon the priority of time or current this relay gets operated.

2. Distance Protection:

In this type, the line is divided into certain zones of protection. Each zone is provided with one relay as shown in fig.

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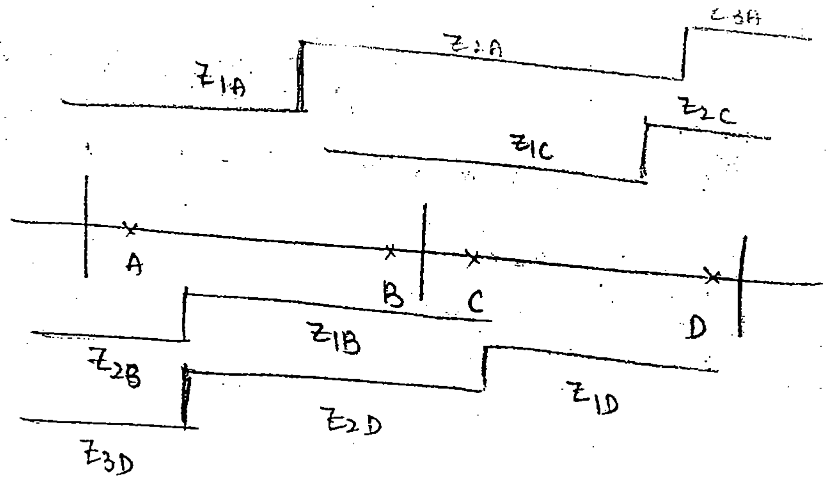


From the starting, upto the distance of 80%, if any fault occurs, the relay A gets operated. The remaining 20% and next 80% is taken care by relay C. Within this zone, if C could not be able to operate, A acts as backup relay.

Each relay is set to operate for 3 zones. In first zone as primary protection and in second and third as backup protection. The operating probabilities are 80%, 20% & 10%.

D & B will serve similar functionalities when current flows in reverse direction.

The relays A, B, C, D can be considered as distance relays. These are categorized as

1. Impedance
2. Reactance
3. Admittance or Mho

Each relay is analysed and its operating characteristic is drawn on R-X plane by making suitable approximations in universal torque equation of fundamental distance relay.

$$T = K_1 I^2 \mp K_2 V^2 + K_3 V I \cos(\theta - \tau) + K_4$$

where K_4 is correction factor which may be +ve or negative

dance Relay:
The distance relay with approximation of $K_3 = 0$ and
is considered as impedance relay, then the torque eqn
ies

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

relay to operate, $T > 0$.

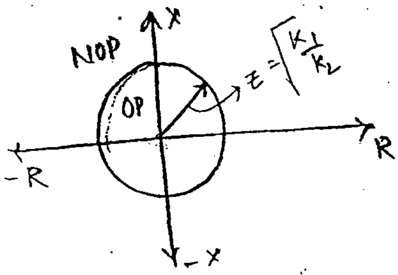
$$K_1 I^2 - K_2 V^2 > 0$$

$$K_1 I^2 > K_2 V^2$$

$$\frac{K_1}{K_2} > \left(\frac{V}{I}\right)^2$$

$$\boxed{Z < \sqrt{\frac{K_1}{K_2}}}$$

At this condition, relay gets operated.
The relay will never operate for $Z > \sqrt{\frac{K_1}{K_2}}$
∴ This relay is set at a pickup of $Z = \sqrt{\frac{K_1}{K_2}}$
This relay is characterised by the parameter of impedence Z
This relay is characterised by the parameter of impedence Z. The locus of Z on R-X plane should be considered.
∴ The locus of Z on R-X plane should be considered. As per the known mathematics, it is a circle centred at origin as shown in fig.



As the operating characteristic is fed for all the four quadrants, this relay can be considered as Non-directional relay. The area of operating characteristic is medium in this type of relays.

NOTE:
The presence of -R, -X signifies current flow in reverse direction.

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2. Reactance Relay: (Negative Seq. relay)

This relay operates when the reactance of the line changes independent of the change in resistance. The change in reactance due to

(i) Change in frequency
(ii) Change in reactive power
(iii) Change in sequence
(iv) With the change in leakage reactance.

This relay responds for any change mentioned above. It is a distance relay with the approximation of $K_2 = 0$ and $K_4 = 0$.

$$T = K_1 I^2 + K_3 VI \cos(\theta - \tau)$$

For reactance as the parameter,
the torque angle is maximum. $\tau = 90°$.

$$T = K_1 I^2 \mp K_3 VI \sin\theta$$

for relay to operate $T > 0$.

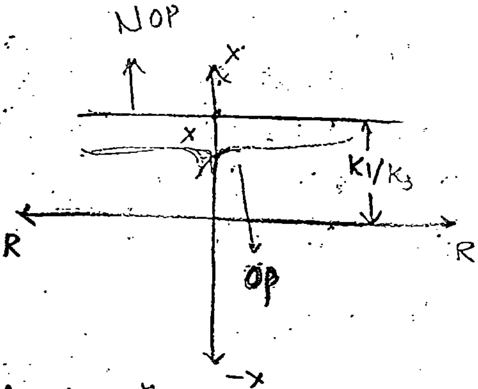
$$K_1 I^2 \mp K_3 VI \sin\theta > 0$$

$$K_1 I > K_3 V \sin\theta$$

$$\frac{K_1}{K_3} > \frac{V}{I} \sin\theta$$

$$\frac{K_1}{K_3} > Z \sin\theta$$

$$\frac{K_1}{K_3} > X$$



$$\Rightarrow \boxed{X < \frac{K_1}{K_3}}$$

This relay is set at a pick up of $X = \frac{K_1}{K_3}$.

This is a non-directional relay having more area of operating characteristic.

1. Admittance Relay:

It is the distance relay with the approximation of $K_1 = 0$ and $K_4 = 0$.

$$T = K_3 V I \cos(\theta - \tau) - K_2 V^2$$

For relay to operate $T > 0$

$$K_3 V I \cos(\theta - \tau) > K_2 V^2$$

$$\frac{I}{V} \cos(\theta - \tau) > \frac{K_2}{K_3}$$

$$Y \cos(\theta - \tau) > \frac{K_2}{K_3}$$

As the operating condition is specified in terms of admittance, this relay is called admittance relay.

The operating characteristic of this relay can be drawn on G – B plane.

* But it should be drawn of on R – X plane because to have the relative comparision with the other two types of relays. Then the above condition should be transformed into impedance.

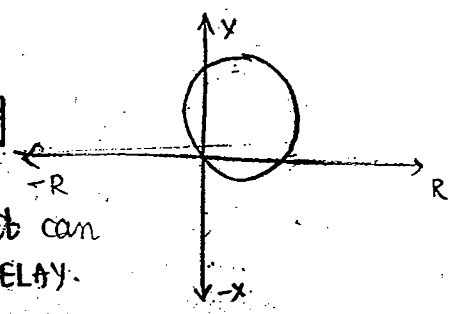
$$\frac{K_3}{K_2} \cos(\theta - \tau) > Z$$

$$\boxed{Z < \frac{K_3}{K_2} \cos(\theta - \tau)}$$

This relay is set at a pick up of $Z = \frac{K_3}{K_2} \cos(\theta - \tau)$

This shows the locus of Z is shifted from origin as a centre and passing through origin as it is cascaded with some directional element.

The max^m area of this operating characteristic is exposed in the first quadrant only. Therefore, it can be considered as 'DIRECTIONAL RELAY'.



the ... compared ... The perf... arc resis... Arc Resi... wh... phase to ... fault. Th... In ca... include th... R... RE... The ea... resistance ... In case ... include th... resistance. ... This arc ... I- ... I ... Under sta... may chan... Rarc ... where S ...

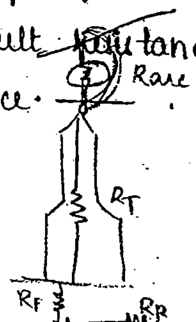
The area of operating characteristic of this relay is small compared to other two types.

The performance of these relays is very much influenced by arc resistance and power swings developed in the power system.

Arc Resistance:

When the flash over occurs from phase to ground and phase to phase, arc resistance exists through the path of fault. This is more significant in high voltage systems.

In case of phase to ground faults, the fault resistance includes the arc resistance and earth resistance.



$$R_F = R_{arc} + R_E$$

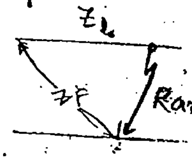
$$R_E = R_T + R_{FT} + R_R$$

(tower, Foot Tower, return path)

The earth resistance includes tower resistance, tower footing resistance and the resistance of return path.

In case of phase to phase faults, the fault impedance includes the line impedance upto the point of fault and arc resistance.

$$Z_F = Z_L + R_{arc}$$



P.F of arc = 1
arc is pure resistive in nature

This arc resistance can be estimated as

$$R_{arc} = \frac{29 \times 10^3 \, l}{I^{1.4}}$$

l - Length of arc.
I - Arc current.

Under stormy weathers due to cross winds the arc resistance may change.

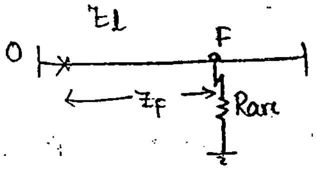
$$R_{arc} = \frac{16300 \, (1.75 s + vt)}{I^{1.4}}$$

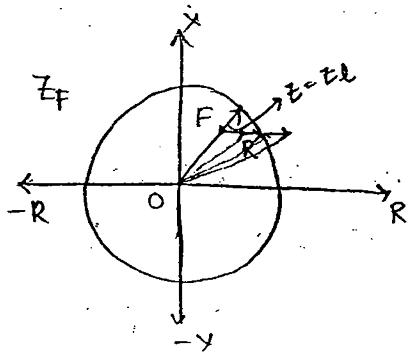
where s is span of arc
v - velocity of wind

t - Time for which the wind sustains

I - arc current.

Effect of Arc Resistance on Impedance characteristic:





Let us consider a line with the impedance of Z_L. The relay kept in this zone of protection has a pickup of Z_L. If a fault occurs at point F, the fault impedance is the summation of the line impedance upto the point F + arc resistance.

$Z_F < Z_L$

$$Z_F = Z_{OF} + R_{arc} \leq Z_L$$

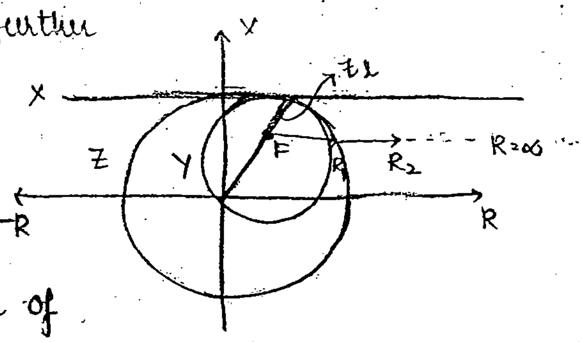
If this arc resistance is small, the relay will be operated. If its value is large, the fault impedance is more than Z_L and relay will not be operated.

If the arc resistance is estimated exactly as R as shown in figure, the relay just operates. Under this condition, if fault occurs beyond the point F, the relay will not be operated. Thereby fault should occur below the point F for the relay to operate. From this, it can be concluded that the arc resistance makes the impedance relay as under reach relay.

Let us consider all the three relays are connected to a line and are setup at a pickup of Z_L. The fault occurs at the point F, the influence of arc resistance on the operation of the relays is discussed here.

If the arc resistance is R_1 (minimum value). The admittance relay does not operate but reactance and impedance relays will be operated.

If the arc resistance is further increased to R_2, the reactance relay only operates.

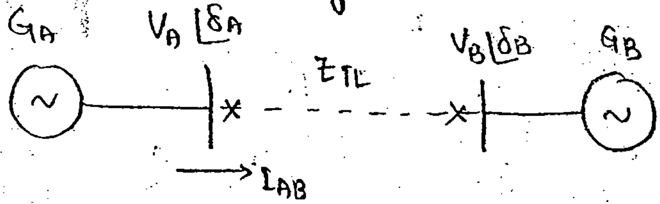


From the figure, it can be seen that for any value of arc resistance, the reactance relay can be operated.

Hereby, we can conclude, for arc resistance, reactance relay is least affected, admittance relay is most affected and impedance relay is moderately affected.

POWER SWINGS:

Let us consider two generators are tied up with a T/L.



The transaction of current from A to B is

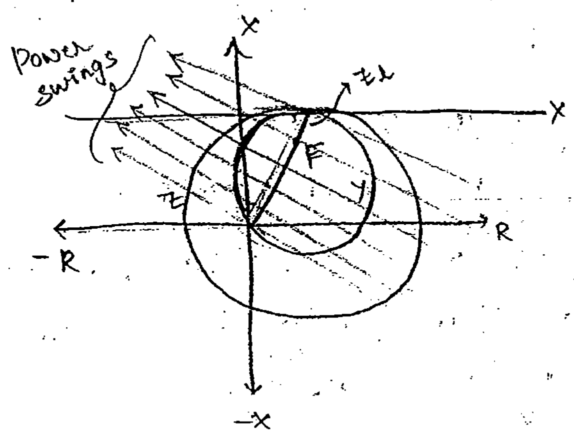
$$I_{AB} = \frac{V_A \angle \delta_A - V_B \angle \delta_B}{Z_A + Z_B + Z_{TL}}$$

This current mostly depends upon load angles. These load angles depends upon the rotor position. The rotors swing by a large angle when a 3-ϕ faults occurs or cleared.

A sudden loading is put on or put off, thereby current changes by large values and is called as current surge or power surge.

If these will repeatedly occurs, it is referred to power swings.

At different levels of fault currents, the impedance seen by the relay changes. i.e the magnitudes of different and currents registered ... of ... at different locations on the line. The following figure shows effect of power swings on the characteristics of all the three lines.



~~From the figure,~~

The relay which offers more area for sustaining of power swings is effected more.

|||ly the relay which offers lesser area for the power swings to sustain is least effected.

From the figure, it is evident that the reactance relay offers more area for power swings. So it is most affected.

The admittance relay offers lesser area. So, it is least affected.

The impedance relay is moderately affected as it offers medium range of area.

Selection of Relays for Protection of Lines:

~~Line~~ In case of short T/ lines, the line impedance is very low and is comparable with arc resistance. Therefore affect of arc resistance is considerable. Power swings are very momentary and are negligible. Therefore, in deciding a relay for short Transmission line, the main criterion is arc resistance. So, we need to establish a relay which is least effected by arc resistance, that is Reactance Relay.

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In case of long T/lines, the line impedance is very high and arc resistance is negligible to this high value of impedance. But the power swings are very heavy and stay for longer time. Therefore, their effect should be considered.

As the admittance relay is least affected by the power swings, it should be the best choice.

→ In case of medium T/L, the effect of power swings and arc resistance both are moderate. So, the impedance relay should be used.

In case of phase to ground faults and earth faults, arc resistance is higher. So reactance relay is preferred.

In fact there is no proper line of barrier for deciding which relay is to be used for which lines.

All these above conclusions are made as per fundamental theoretical principles. In practise there are lots are of overlappin

NOTE:

Out of all the available relays, angle admittance relay offers lesser area for power swings. So it is preferred.

The elliptical relay is having slightly more area than angle admittance relay. It can be considered as next choice.

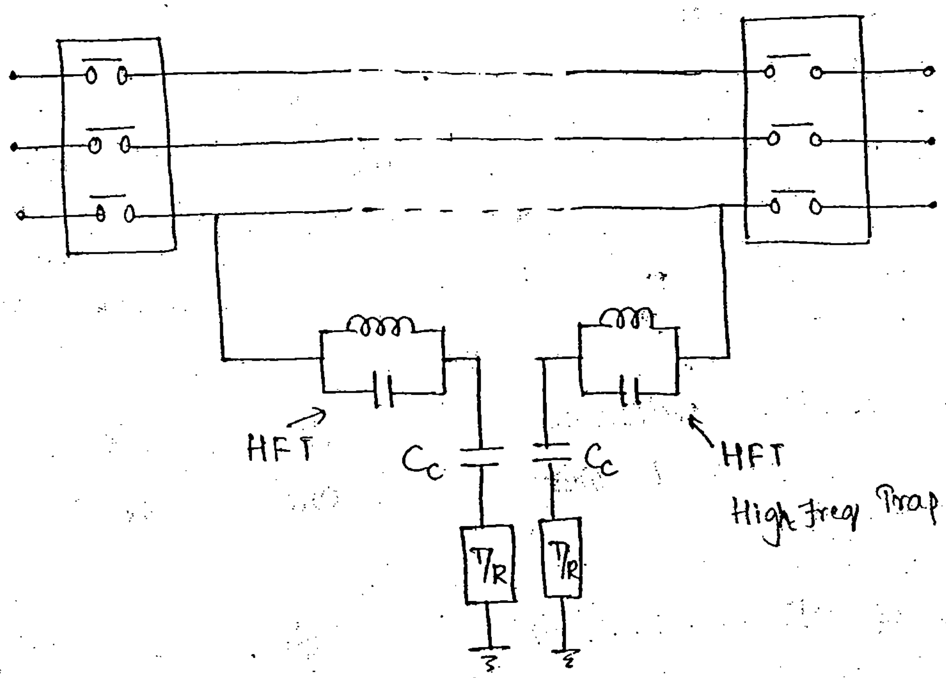
Quadrilateral relay offers slightly more area than elliptical relay. ∴ It can be considered as further choice.

3. PILOT RELAYING :

In this method, pilots (conductors capable of carrying high frequency signals are used hence the name). This system enables us to have high frequency transmission.

The high frequency transmission system is advantageous in communication and faster relaying.

The following figure shows basic scheme of protection for any type of line.



Depending upon the rate of operating frequencies, these are of three types.

1) Wire Pilots.

   The range of frequency is 1 Hz to 1KHz.

2) Carrier Pilots

   The range of frequency is 1KHz to 100KHz.

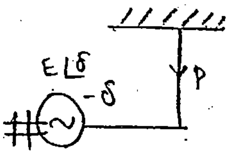
3) Micro wave pilots.

   The frequency range is 3 MHz to 900 MHz.

PROTECTION OF ALTERNATORS

The alternator should be protected from the following abnormalities.

1) Failure of Prime Mover:



If the prime mover is failed, power flow in the reverse direction and the machine continues to run as sync synchronous motor. This is called "Inverted Running".

This is not a dangerous phenomenon and making use of reverse power relays, the power flow in the reverse direction can be ceased.

2. Failure of Field:

When the field is failed, machine will take reactive power from the bus bar and continues to run as induction generator by supplying active power. This is also not a dangerous situation, necessary steps can be taken to re-establish the field.

3. Overcurrent:

Overcurrent is due to overloading or partial breakdown of insulation. Overcurrent relays with automatic protection schemes are used.

4. Overvoltage:

Overvoltage is due to excess of excitation or partial reduction of load. Automatic voltage regulators, automatic excitation controllers are used to regulate the voltage to normal value.

5. Overspeed:

Overspeed is due to load reduction or increase in mechanical input. Mechanical centrifugal systems with automatic load frequency controllers will regulate the speed to normal value.

Overheating is due to

a) Over loading

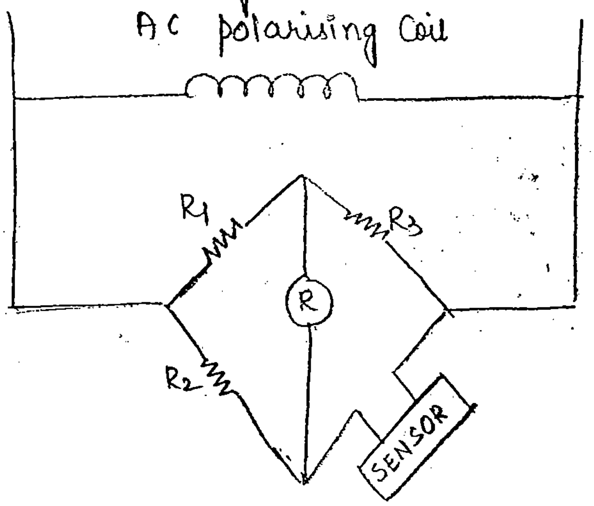
b) Partial breakdown in cooling system

c) Core faults. (Failure of insulation at core bolt and in b/w laminations).

The maxm possible temperature rise inside the alternator is 60°C. This can be detected by two methods

i) By measuring the temperatures at inlet and outlet of the coolant.

ii) By balanced bridge mechanism shown in figure.



The resistances R_1, R_2, R_3 are fixed values. The resistance of sensor is initially so choosen that it should balance the bridge for entire range of normal temperature.

Sensor is a thermistor type normally silicon controlled Resistor (silistor). These sensors are embedded in the stator slots at regular intervals.

If the temp. is more than normal value, the resistance of sensor changes and bridge becomes unbalanced. The unbalancing quantity polarises the relay. Thus the generator is cutoff from main supply.

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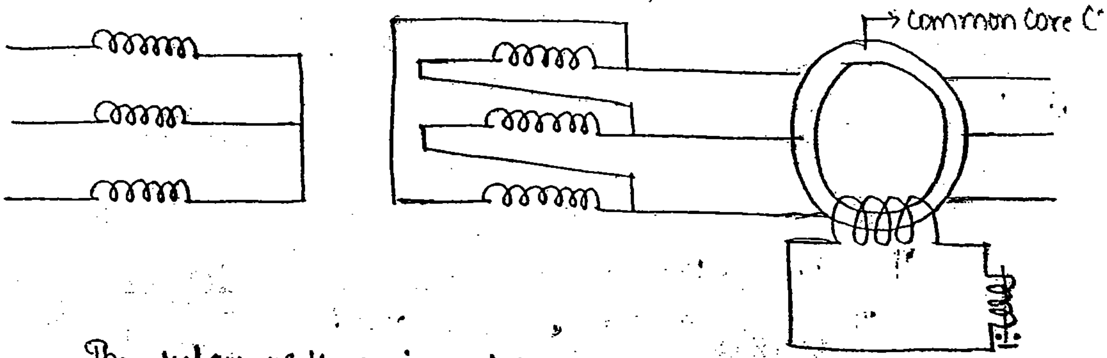
So these should be detected and eradicated initially itself. This is done by common core C.T protection shown in figure.



The relay pick up is set for normal value of leakage curren The leakage currents exceed that value, the relay gets operated and the insulation levels should be modified.

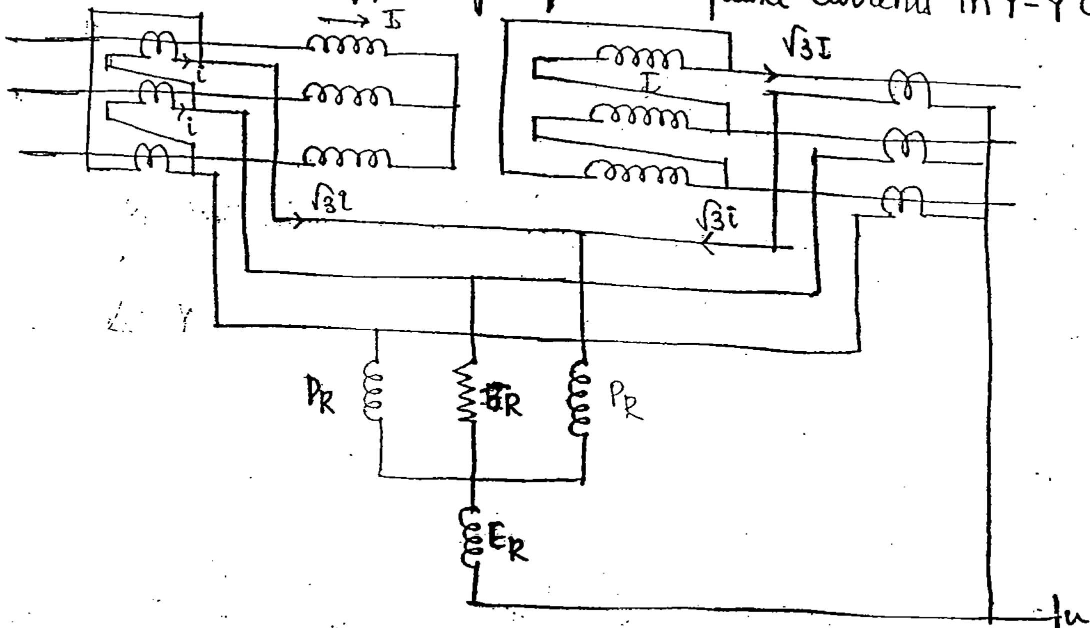
3. Protection against Symmetrical and Unsymmetrical Faults:

Under this, the transformer is protected by Merz-Price scheme of protection similar to alternator, but the C.Ts are connected as delta(Δ) on star side of the T/F and III^ly on Δ side of T/F, they are connected in Y. This is to

i) achieve perfect balance and relaying.

ii) Balancing the 30° phase shift in Y-Δ connection.

iii) For effective bypassing of zero sequence currents in Y-Y connecti



4.

Overheating in the T/F is due to

i) Overloading

ii) Partial failure of cooling mechanism

iii) Core faults.

The maximum allowable temperature inside the T/F is 90° C. The excess in temperature can be detected by "Thermal Imaging Method".

In this method, a C.T is connected to the L.V winding and its terminals are drawn out. Across this terminals, a heating element is connected. The heat produced by this heating element is analogous to heat developed inside the T/F. This heat is sensed by the heat sensor kept near by the heating element. Across this heat sensor thermal relay with a pickup of 90°c is connected in such a way that when temperature exceeds it gets operated. To confine the total heat produced by the heating element to heat sensor only, both are kept in an insulation box.

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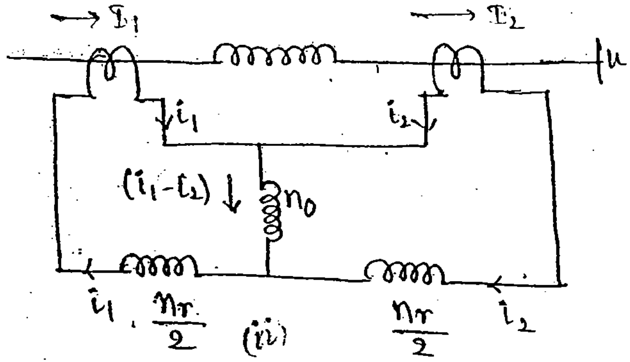


Here, the design of the restraining coil is very critical because if it is of more size, than deserving size, it will offer the restraint for the operating torques under faulty conditions also. It is designed on the basis of

$$T_o \propto n_o(i_1 - i_2)$$

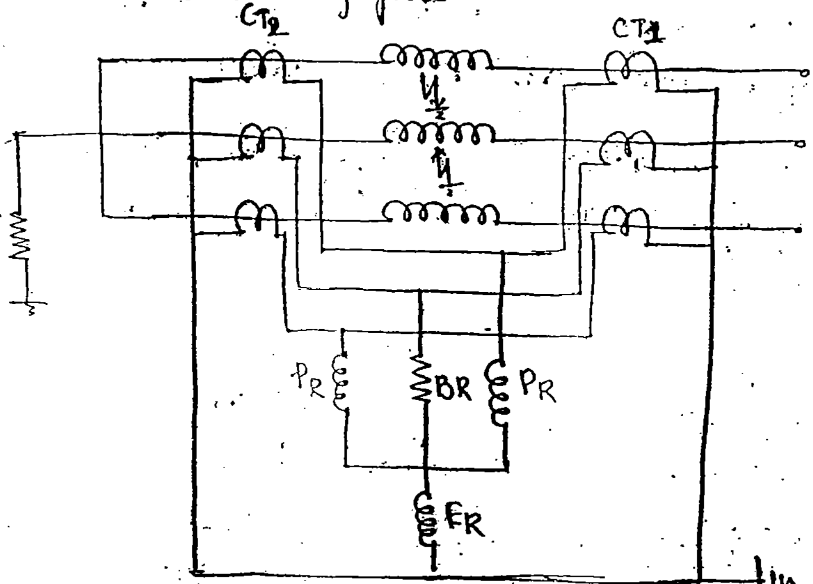
$$T_R \propto (i_1 + i_2)\frac{n_r}{2}$$

At balance, $T_o = T_r$

$$(i_1 - i_2)n_o = (i_1 + i_2)\frac{n_r}{2}$$

$$\frac{n_r}{n_o} = \frac{2(i_1 - i_2)}{(i_1 + i_2)}$$

With all these considerations, alternator is protected by Merz Price scheme of protection against symmetrical and unsymmetric faults as shown in figure.



values of I_1 & I_2.
$i_2 \neq i_1$ then
the relay and
ation is done by
cross the CTs.
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activated. Here,
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Due to this, the
although $I_1 = I_2$.
no fault condition.
under no fault
a restraining coil

In this scheme of protection, [illegible] protection against phase faults and one relay is provided for earth faults. The balancing resistor will achieve perfect balance in the voltage drops on either sides of the relays. The setting of earth relay is always less than phase relay. This is because the earth faults amounts lesser currents than phase faults.

PROTECTION OF TRANSFORMER

Transformer is a device consisting of more no. of integral parts. The protection of T/F is mainly divided into 4 kinds.

1. Protection against internal faults
2. Protection against leakage currents
3. Protection against symmetrical & unsymmetrical faults
4. Protection against overheating.

1. Protection against Internal Faults:

The disturbances like small rise in temperature, slight variation of specific gravity, viscosity of the oil and core faults can be regarded as internal faults. All these disturbances can be taken care by Buch holz Relay.

It is a gas activated Relay and ~~dissipates~~ anticipates the occurence of faults. It is located in between conservator and the main tank.

2. Protection against Leakage currents:

The currents which are flowing through the cross-section of insulation are called leakage currents. These are in the range of milli or micro. The excess of leakage currents will set up severe short circuits within a small span of time.

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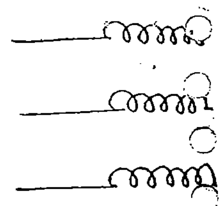

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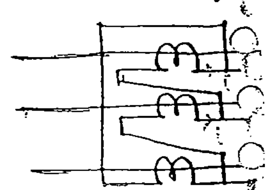
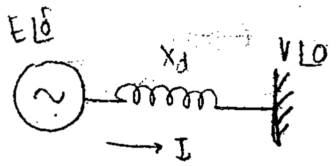


31-5 Tuesday

7. POLE SLIPPING



In SMIB systems, if a sudden disturbance occurs, the ckt breaker gets open. This causes the electrical power to be zero. Then machine accelarates maximum. With this, rotor swing by a large angle and it may loose its pole pitch. This is called pole slipping. By this effect, the group of conductors which have to flow under the north pole will go under the influence of South pole. This leads to dead short ckt or open ckt, which is unwanted.

To reduce this effect, trip the field switch then, speed of the machine decreases inturn acceleration, and there may be a chance of regaining the pole pitch. Otherwise trip the alternator from mechanical coupling also then restart, resynchronise the system.

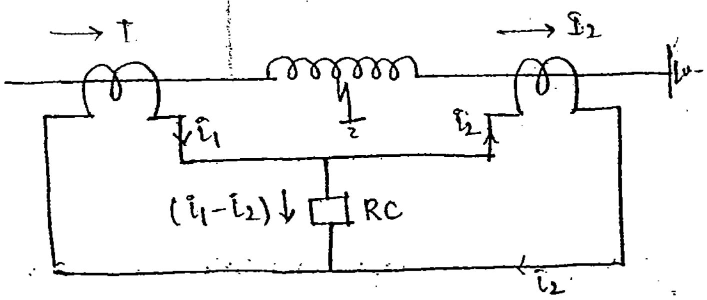
8. SYMMETRICAL AND UNSYMMETRICAL FAULTS

Alternator is protected against symmetrical and unsymmetrical faults by differential protection. In differential protection, the relay is activated by vectorial difference of the two activating quantities. These may be currents or voltages. Differential protection is a unit type of protection (No back up). This is generally of two types.

1. Current Differential.
2. Voltage Differential.

1. CURRENT DIFFERENTIAL

In this method, the relay is activated by the vectorial difference of the currents.



The currents i_1, i_2 are the scaling values of I_1 & I_2. Under no fault condition,

$$i_1 = i_2 \quad \text{as } I_1 = I_2$$

When the fault occurs as $I_2 \neq I_1$, $i_2 \neq i_1$ then the differential value of current activates the relay and relay gets operated.

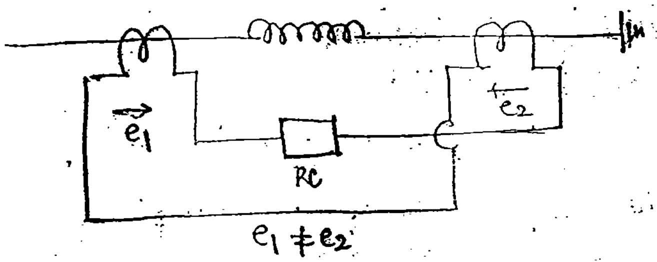
2. VOLTAGE DIFF

In this method, the relay activation is done by the vectorial difference of induced emfs across the CTs.

When faults occurs $e_1 \neq e_2$, the differential voltage appears across the relay coil and it is activated. Here voltage sensitive element is kept at relay.

This kind of balancing is possible when the characteristics of both the series exactly match for all the conditions. But it is not possible. Especially the magnetising characteristics do not match under transient conditions. Due to this, the induction levels changes and $i_1 \neq i_2$ eventhough $I_1 = I_2$. Then the relay will be activated under no fault condition. This is unwanted.

This operating torque of the relay under no fault condition can be restrained by providing a restraining coil shown in figure.



1. A C.T of ratio 400/5 with a setting of 50% is connected to a load. If the fault current is 2000 A, determine the plug Setting Multiplier.

Sol

$$PSM = \frac{I_f}{\text{Pick up level}}$$

$$= \frac{I_f}{\text{C.T ratio} \times \text{CS}}$$

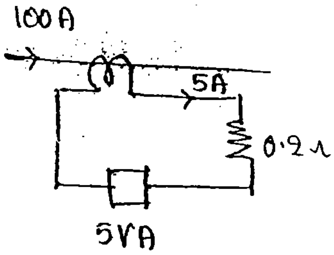
$$= \frac{2000}{400/5 \times 0.5} = 50$$

2. A relay of burden 5VA is connected across CT secondary of $\frac{100}{5}$ A ratio. The CT equivalent secondary resistance is 0.2 Ω. Find the burden of C.T.

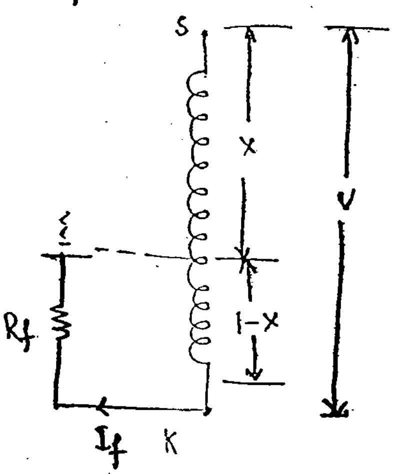
Sol

Burden on C.T $= 5 + 5^2 \times 0.2$

$= 10$ VA



3. *** The neutral of 3-ϕ alternator of 11 KV is connected through the earth through 5 Ω resistor. If the Earth fault relay is set for operation of 0.75 A, the CT connected to the relay is of $\frac{1000}{5}$ ratio. Find the %age of winding of the alternator to be protected.



$$I_f = \frac{(1-x)V}{R_f}$$

$$V = \frac{11}{\sqrt{3}} = 6350$$

$$I_f = 0.75 \times \frac{1000}{5} = 150\text{ A}$$

$$150 = \frac{(1-x)\,6350}{5}$$

$1-x = 0.118$

$x = 0.8819$

i.e. 88.19%

$\frac{600}{5}$ on low voltage side what should be the ratio of CTs on H.V side of T/F of Y–Δ

220V/11KV

CT's ratio on LV side = $\frac{600}{5}$

Sec phase current on LV side = 5 A

Line current = $5\sqrt{3}$

Same current flows in sec. of HV side = $5\sqrt{3}$ A.

$\sqrt{3}\, V_1 I_1 = \sqrt{3}\, V_2 I_2$

$\sqrt{3} \times 220 \times 600 = \sqrt{3} \times 11000 \times I_2$ [I_2 Pri ph. Current on HV side]

$I_2 = 12$.

C.Ts ratio on HV side = $12 : 5\sqrt{3}$