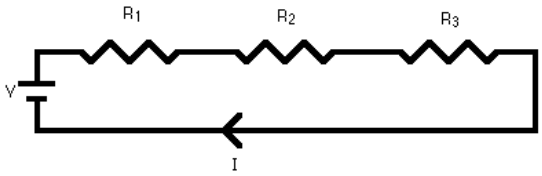
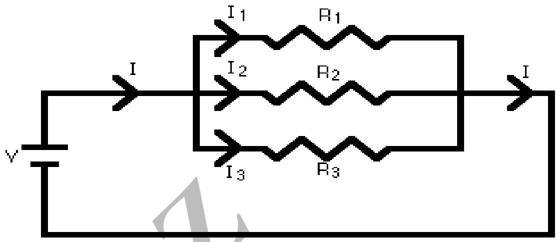
PAPER SOLUTION
WINTER 2023

Subject code : 3110005
Subject Name : Basic Electrical Engineering

Q-1 (a) Compare resistive series and parallel circuits.
Ans :

<table>
<tr><th>Sr. No.</th><th>Series Circuit</th><th>Parallel Circuit</th></tr>
<tr><td>1.</td><td>The connection is as shown

</td><td>The connection is as shown

</td></tr>
<tr><td>2.</td><td>The current passing through all the elements connected in series is the same.</td><td>Voltage across each element connected in parallel is the same.</td></tr>
<tr><td>3.</td><td>There is only one path for flow of current.</td><td>The paths for flow of current are more than one.</td></tr>
</table>

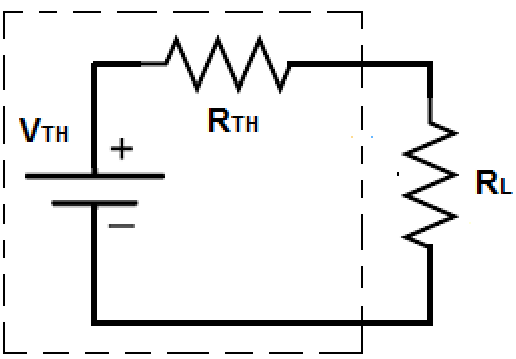
(b) State the Thevenin's theorem with suitable example.
Ans :

→ Statement : Thevenin's Theorem states that any network having a number of energy sources and resistances when viewed from open its output terminal A and B and can be replaced by simple equivalent network consisting of a single equivalent voltage source (V_{Th}) in series with a single equivalent resistance (R_{th}).

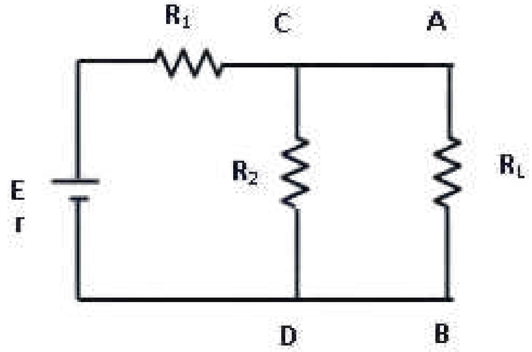
Where

V_{th}= Thevenin's equivalent voltage source
open circuit voltage across AB Terminals

R_{th}= Thevenin's equivalent resistance.
= Equivalent resistance across AB Terminals When all the sources set to zero.



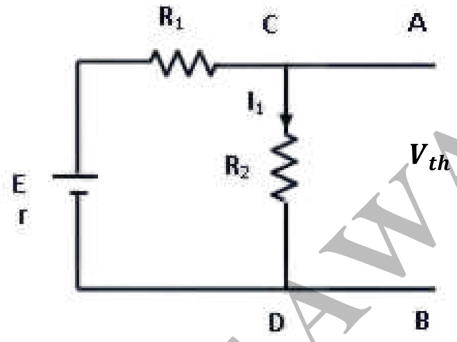
→ Application : The application of this theorem is to determine current in any element of given network .



[Fig 1: $Circuit\ with\ source\ E\ and\ Load\ R_L$]

→ Explanation :- Consider the network shown in fig and we want to find current flowing through R_L remove the resistance R_L in which current is to be determined this open circuit is created between terminal AB

Step 1 : Remove RL from the circuit terminals A and B and redraw the circuit as shown in figure 2. Obviously, the terminal have become open circuited.



[Fig 2: $Circuit\ with\ RL\ removed.$]

Step 2 : Calculate the open circuit Voltages V_{Th} which appears across terminals A and B when they are open .ie. when R_L is removed.

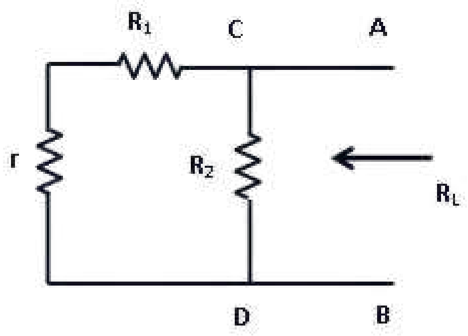
As seen, V_{Th} = drop across R_2= $I\,R_2$ where I is the circuit current when A and B is open.

$$I = \frac{E}{r + R_1 + R_2}$$

$$V_{Th} = I * R_1$$

$$V_{Th} = \frac{E * R_2}{r + R_1 + R_2}$$

Step 3 : Now, imagine the battery to be removed from the circuit, leaving its internal resistance r behind and redraw the circuit as shown in figure 3.



[Fig 3: $Circuit\ with\ R_L\ and\ E\ \ removed$]

When viewed inwards from the terminals A and B, the circuit consists of two parallel paths: one containing R2 and another containing $(R_1 + r)$. The equivalent resistance of the network as viewed from these terminals is given as,

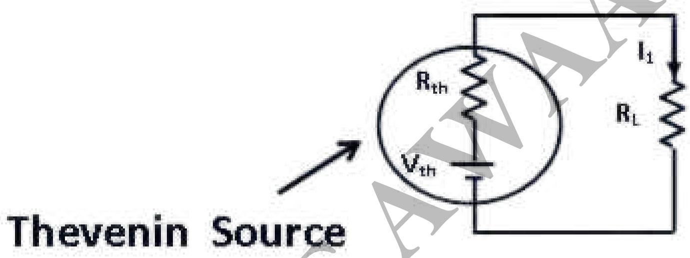
$$R_{Th} = \frac{(R_1 + r) * R_2}{R_1 + R + R_2}$$

The resistance "R_{Th}" is also called Thevenin equivalent resistance.

Consequently , as viewed from terminals A and B, the whole network (excluding R_1) can be reduced to single source (called thevenin's source) whose e.m.f equal to V_{Th} and whose internal resistance equal to R_{Th} as shown in figure 4.

Step 4 : R_L is now connected back across terminals A and B from where it was temporaily removed earlier. Current flowing through R_L is given by,

$$I_1 = \frac{V_{Th}}{R_{Th} + R_L}$$



$[Fig\ 4: Thevenin's\ equivalent\ circuit]$

(c) Derive an expression for equivalent resistances of a star connected network to transform into a Delta connected network.

Ans : It is the replacement of star connected resistance into equivalent delta connected system.

→ Let us consider the three resistances $R_1, R_2\ and\ R_3$ connected in star as shown in fig.

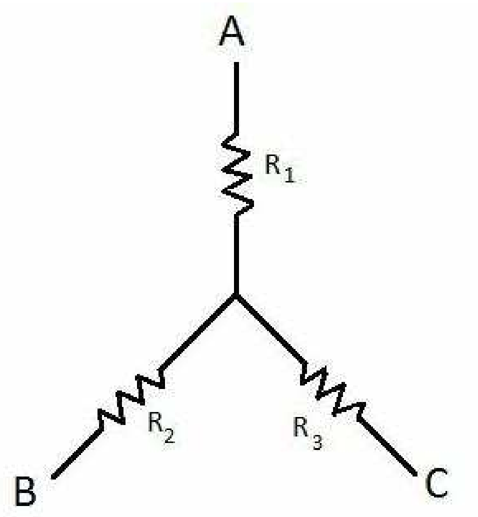
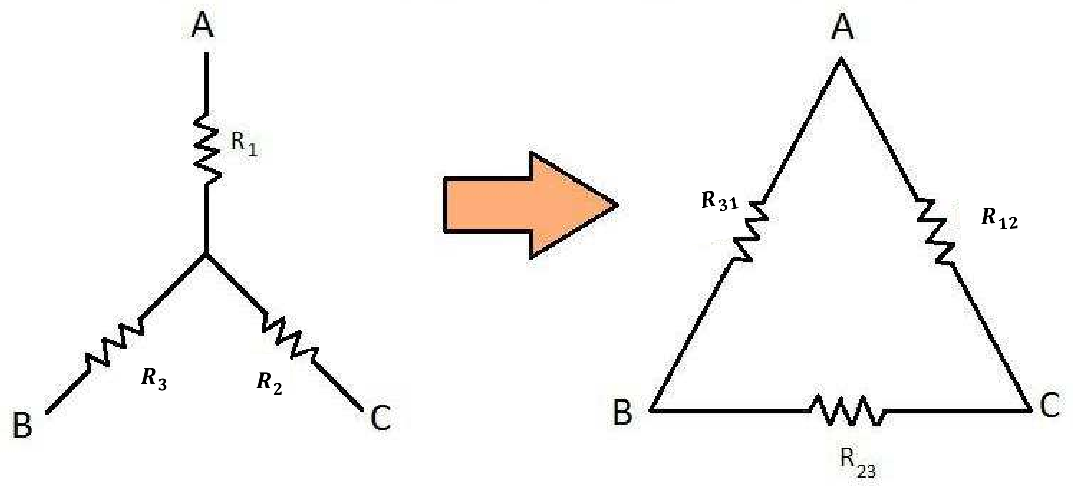


fig 1 Star Connection

→ Now we want to finding out values of R_{12}, R_{23}, R_{31}interms of $R_1, R_2\ and\ R_3$.



Given Star *Equivalent Delta*

fig 2 Star to Delta Transformc

→ From the result of Delta- Star transformation we know that

$$R_1 = \frac{R_{12}R_{31}}{R_{12}+R_{23}+R_{31}} \qquad \text{-------------------- } (1)$$

$$R_2 = \frac{R_{12}R_{23}}{R_{12}+R_{23}+R_{31}} \qquad \text{-------------------- } (2)$$

$$R_3 = \frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}} \qquad \text{-------------------- } (3)$$

→ Multiplying equation (1) to (2) , (2) to (3) and (3) to (1) , we get ,

$$R_1R_2 = \frac{R_{12}^2R_{23}R_{31}}{(R_{12}+R_{23}+R_{31})^2} \qquad \text{-------------------- } (4)$$

$$R_1R_2 = \frac{R_{12}R_{23}^2R_{31}}{(R_{12}+R_{23}+R_{31})^2} \qquad \text{-------------------- } (5)$$

$$R_1R_2 = \frac{R_{12}R_{23}R_{31}^2}{(R_{12}+R_{23}+R_{31})^2} \qquad \text{-------------------- } (6)$$

→ Adding equation (4), (5) , and (6) we get,

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{(R_{12}^2R_{23}R_{31} + R_{12}R_{23}^2R_{31} + R_{12}R_{23}R_{31}^2)}{(R_{12}+R_{23}+R_{31})^2}$$

$$= \frac{R_{12}R_{23}R_{31}(R_{12}+R_{23}+R_{31})}{(R_{12}+R_{23}+R_{31})^2}$$

$$= \frac{R_{12}R_{23}R_{31}}{(R_{12}+R_{23}+R_{31})} \qquad \text{-------------------- } (7)$$

→ The equation (7) can be written as

$$R_1R_2 + R_2R_3 + R_3R_1 = R_{12} \times \left(\frac{R_{23}R_{31}}{R_{12}+R_{23}+R_{31}}\right)$$

$$= R_{12} \times R_3 \qquad [Equation\ (3)\ ]$$

$\therefore R_{12} = \frac{(R_1R_2+R_2R_3+R_3R_1)}{R_3} = R_1 + R_2 + \frac{R_1R_2}{R_3}$

→ Similar from equation (7) we can write

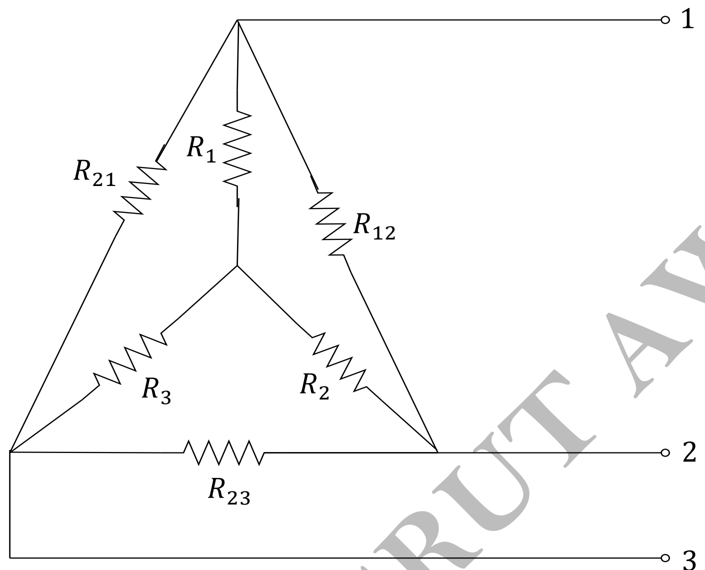
$R_1R_2 + R_2R_3 + R_3R_1 = R_{12} \times \left(\frac{R_{31}R_{12}}{(R_{12}+R_{23}+R_{31})^2}\right)$

$= R_{23} \times R_1$

$\therefore R_{23} = \frac{(R_1R_2+R_2R_3+R_3R_1)}{R_1} = R_2 + R_3 + \frac{R_2R_3}{R_1}$

→ Similarly

$\therefore R_{31} = R_1 + R_3 + \frac{R_1R_3}{R_2}$



Q-2 (a) Define Amplitude, Frequency and Time period for alternating quantities.

Ans :

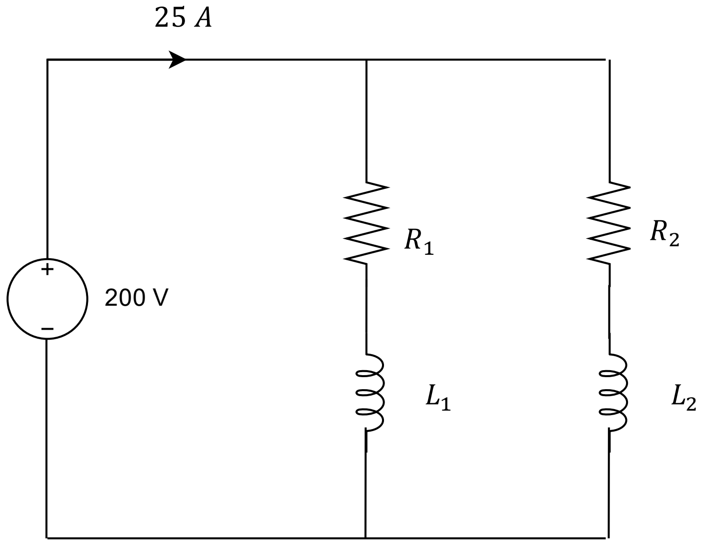
1. Amplitude :-
   → The maximum value of an alternating quantity is known as its amplitude .It is denoted for voltage and current by $E_m and\ I_m$

2. Time Period :-
   → The time taken by an alternating quantity to complete one cycle is called its time period .Its denoted by T and is expressed in second

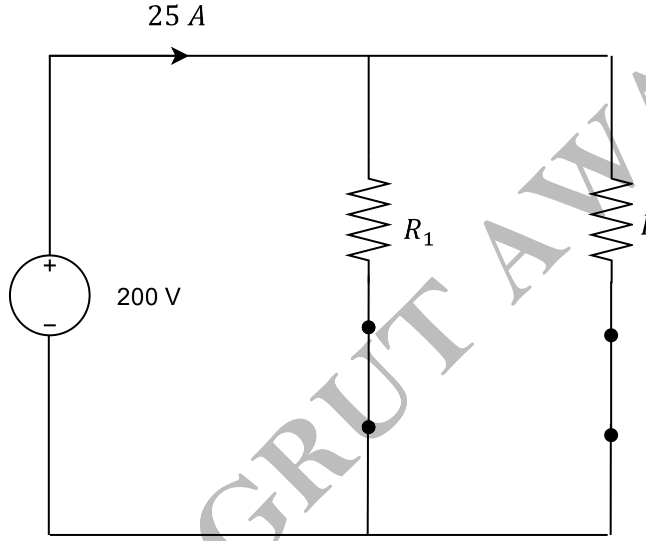
3. Frequency :-
   → The number of cycle completed by an alternating quantity per second is known as Frequency. Its denoted by f and is expressed in hertz (Hz)

(b) Two coils are connected in parallel and a voltage of 200V is applied between the terminals. The total current taken by the circuit is 25 A and power dissipated in one of the coils is 1500 W. Calculate the resistance of each coil.

Ans : According to the data given in the question, we draw the circuit as:



→ DC source of 200 V is connected so, inductors, L_1 and L_2 will be short circuited.



→ Power dissipated in one coil = 1500 W

So, $P = \frac{V^2}{R_1}$

$\therefore R_1 = \frac{(200)^2}{1500}$

$\therefore R_1 = 26.67\ \Omega$

→ The equivalent resistance of the parallel combination will be:

$$R_{eq} = \frac{V}{I} = \frac{200}{25} = 8$$

→ Since , R_1 *and* R_2 *are connected in parallel*.

$$R_{eq} = R_1 \parallel R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$8 = \frac{\left(\frac{80}{3}\right) \times R_2}{\left(\frac{80}{3}\right) + R_2}$$

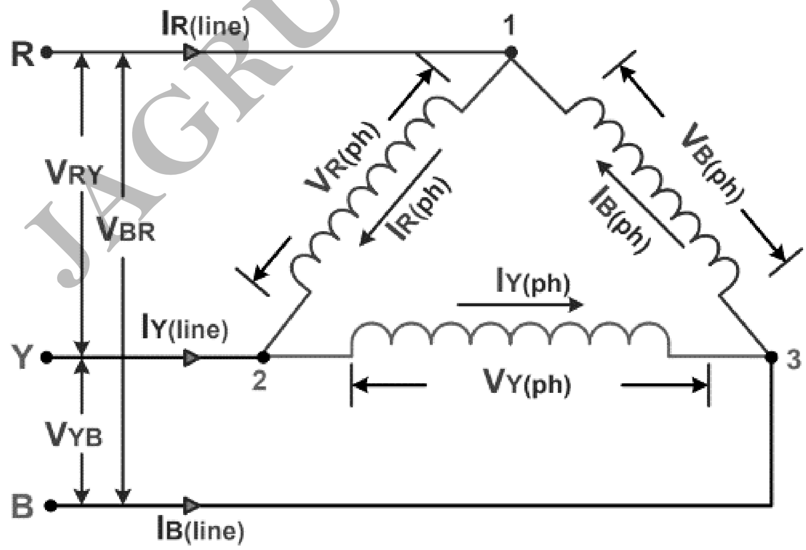
$$8 = \frac{80 \times R_2}{80 + 3R_2}$$

$$R_2 = \frac{80}{7}\,\Omega$$

(c) Obtain the relationship between line and phase values of current in a three phase, balanced, delta connected system.

Ans : Delta (Δ) or Mesh connection, starting end of one coil is connected to the finishing end of other phase coil and so on which giving a closed circuit.

- → In this connection the dissimilar ends of three phase windings are connected together i.e the finish of one winding is connected to the start of next windings and so on to obtain delta connection as shown in fig
- → The circuit diagram resembles the Greek letter delta Δ so this connection is called delta connection the line conductor are joined at junction of the winding of 3 phase system.
- → Again, the voltage induced in each winding is called phase voltage and the current in each winding is call phase current.
- → However, the potential difference between two line conductors is called line voltage and the current flowing through be line conductor is called line current.



Let,
Line voltage, $V_{RY} = V_{YB} = V_{BR} = V_L$
Phase voltage, $V_{R(ph)} = V_{Y(ph)} = V_{B(ph)} = V_{ph}$
Line current, $I_{R(line)} = I_{Y(line)} = I_{B(line)} = I_{line}$
Phase current, $I_{R(ph)} = I_{Y(ph)} = I_{B(ph)} = I_{ph}$

Relation between line and phase voltage

→ For delta connection line voltage V_L and phase voltage V_{ph} both are same.

→ It is seen from the fig that current flowing in each line is vector difference of the two-phase currents.

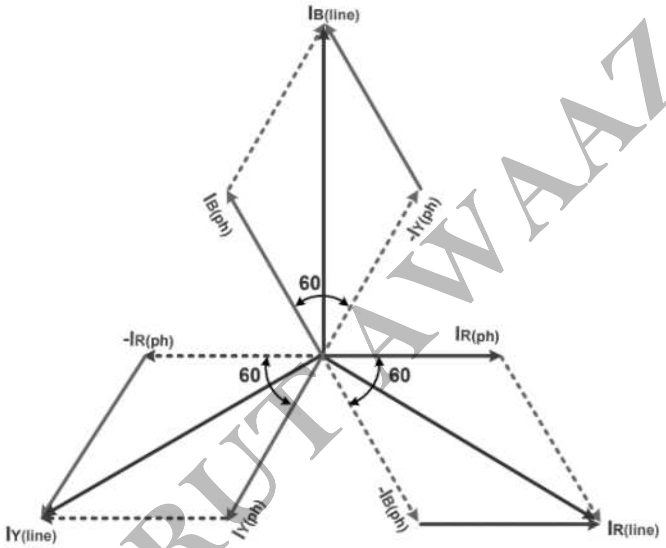
$$V_{RY} = V_{R(ph)}$$
$$V_{YB} = V_{Y(ph)}$$
$$V_{BR} = V_{B(ph)}$$
$$\therefore V_L = V_{ph}$$
$$Line\,Voltage = Phase\ Voltage$$

Relation between line and phase current

→ For delta connection,

$$I_{R(line)} = I_{R(ph)} - I_{B(ph)}$$
$$I_{Y(line)} = I_{Y(ph)} - I_{R(ph)}$$
$$I_{B(line)} = I_{B(ph)} - I_{Y(ph)}$$

→ i.e. current in each line is vector difference of two of the phase currents.



→ So, considering the parallelogram formed by $I_R\ and\ I_B$.

$$I_{R(line)} = \sqrt{I^2_{R(ph)} + I^2_{B(ph)} + 2I_{R(ph)}I_{B(ph)}\cos\theta}$$
$$\therefore I_L = \sqrt{I^2_{ph} + I^2_{ph} + 2I_{ph}I_{ph}\cos 60°}$$
$$\therefore I_L = \sqrt{I^2_{ph} + I^2_{ph} + 2I_{ph}I_{ph}\left(\frac{1}{2}\right)}$$
$$\therefore I_L = \sqrt{3I^2_{ph}}$$
$$\therefore I_L = \sqrt{3}I_{ph}$$

→ Similarly, $I_{Y(line)} = I_{B(line)} = \sqrt{3}I_{ph}$

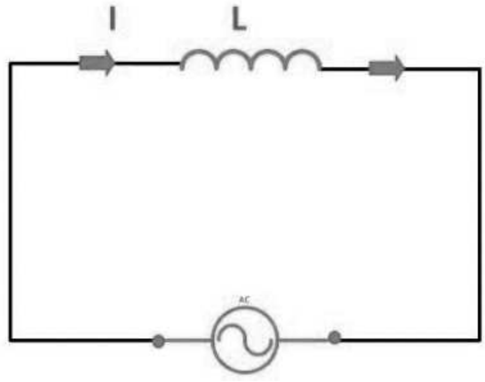
→ Thus, in delta connection Line current = $\sqrt{3}$ Phase current

(c) Prove that the current in purely inductive circuit lags its voltage by 90° and average power consumption in pure inductor is zero.

Ans : Such a circuit theoretically has zero resistance and hence zero loss. A back EMF due to the self-inductance of the coil is produced whenever alternating voltage is applied to a purely inductive circuit. Due to the absence of ohmic resistance, the only force that the applied voltage has to overcome is the circuit's self-inductance.

→ The equation of the alternating voltage that is applied across the circuit is

$$v = V_m sin\omega t \qquad \text{-------------------} \ (1)$$



→ This results in current flow along with an induced emf given by

$$e = -L\frac{di}{dt}$$

→ Since the induced emf is equal and opposite to the applied voltage,

$$v = -\left(-L\frac{di}{dt}\right)$$

$$V_m sin\omega t = L\frac{di}{dt}$$

$$di = \frac{V_m}{L} sin\omega t dt \qquad \text{-------------------} \ (2)$$

→ Integrating both sides of (2) we get,

$$i = \frac{V_m}{\omega L} sin\left(\omega t - \frac{\pi}{2}\right) = \frac{V_m}{X_L} sin\left(\omega t - \frac{\pi}{2}\right) \qquad \text{-------------------} \ (3)$$

→ where XL is the opposition offered by pure inductance to the flow of alternating current and is called inductive reactance.

The maximum current will be when $sin\left(\omega t - \frac{\pi}{2}\right) = 1$

Hence, $I_m = \frac{V_m}{X_L}$ ------------------- (4)

Substituting (3) in (4) we get,

$$i = I_m sin\left(\omega t - \frac{\pi}{2}\right)$$

→ The instantaneous power in a purely inductive circuit can be derived as follows:

$$P = VI$$

$$P = (V_m sin\omega t) I_m sin\left(\omega t + \frac{\pi}{2}\right)$$

$$P = V_m I_m sin\omega t cos\omega t$$

$$P = \frac{V_m I_m}{2} 2sin\omega t cos\omega t$$

$$P = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}} sin2\omega t$$

→ Average power for the cycle,

$$P = \frac{1}{2\pi}\int_0^{2\pi} P.d\theta$$

$$= -\frac{1}{2\pi}\int_0^{2\pi} \frac{V_m I_m}{2} sin2\theta . d\theta$$

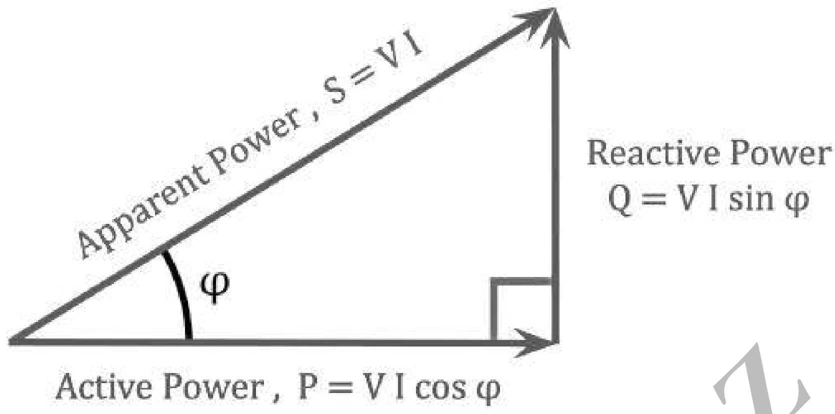
$$= \frac{V_m I_m}{4\pi}\left[-\frac{cos2\theta}{2}\right]_0^{2\pi}$$

$= \frac{V_m I_m}{8\pi}[cos2\theta]_0^{2\pi}$
$= \frac{V_m I_m}{8\pi}[cos4\pi - cos0]$
$= 0$

→ Hence, the average power consumed in a purely inductive circuit is zero.

Q-3 (a) Draw power triangle and define active power, reactive power and apparent power.

Ans :



1. Active Power :-

→ The power which is actually consumed in an a,c circuit is called active power.

→ It is denoted by 'P'

$P = VI\ COS\varphi$

2. Reactive Power :-

→ Power drawn by the circuit due to reactive component of current is called reactive power

→ It is denoted by 'Q'

$Q = VI \sin\varphi$

3. Apparent Power :-

→ The product of r.m.s values of voltage and current in a.c circuit is called apparent power

→ It is denoted by 'S'

$S = VI$

(b) If the waveform of a voltage has a form factor of 1.15 and peak factor of 1.5 and if the maximum value of a voltage is 4500 volts. Calculate the average and r.m.s. values of the voltage.

Ans : Given ,

Form Factor = 1.15
Peak Factor = 1.5
Max value of voltage = 4500 V

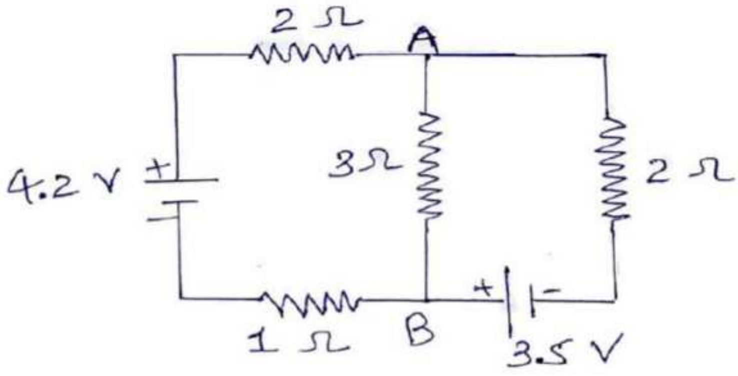
1. $Peak\ Factor\ = \frac{Peak\ value}{R.M.S\ value}$

$R.M.S\ value = \frac{Peak\ value}{Peak\ factor} = \frac{4500}{1.5} = 3000\ V$

2. $From\ Factor = \frac{R.M.S\ value}{Avg\ value}$

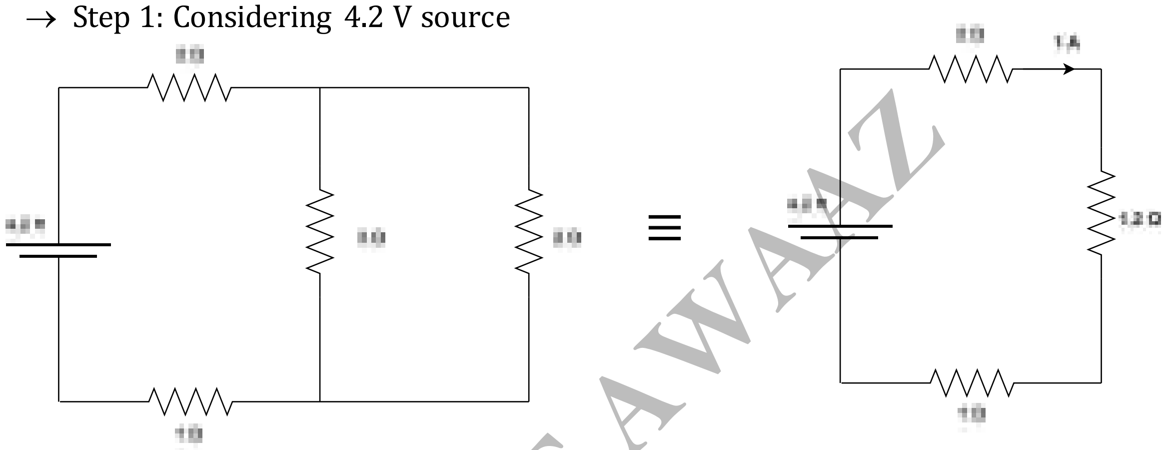
$\therefore Avg\ value = \frac{3000}{1.15} = 2608.69\ V$

(c) Use the superposition theorem to calculate the current in branch AB of the circuit shown in below figure.



Ans :

$\rightarrow$ Step 1: Considering 4.2 V source

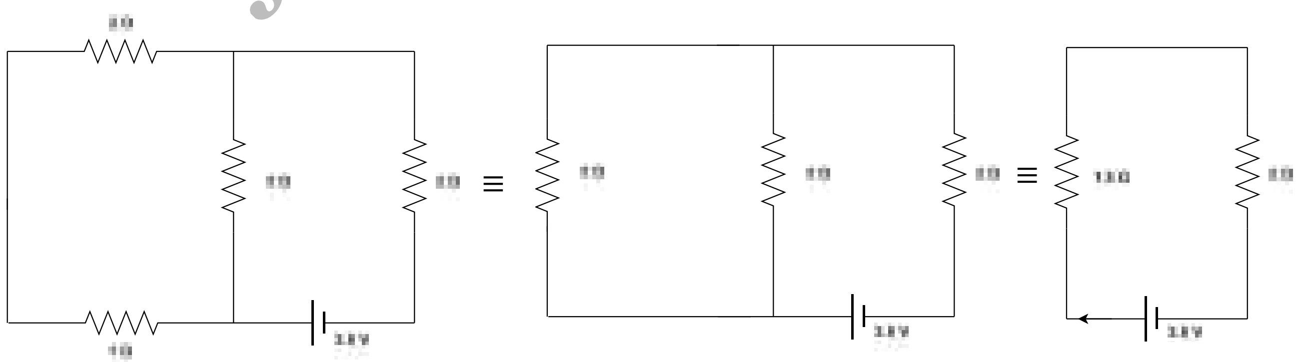


$\rightarrow$ Current from 4.2 V = $\frac{4.2}{4.2} = 1\ A$

$\rightarrow$ 1 A is divided across 3 Ω & 2 Ω.

$$I_1 = 1 \times \frac{2}{3+2} = 0.4\ A$$

$\rightarrow$ Step 2 : Considering 3.5 V source



$\therefore$ Current through 3.5 V = 1 A

$\rightarrow$ Current through 3 Ω in upward direction

$$I_2 = 0.5\ A$$

$\rightarrow$ Apply superstition current through $A\ to\ B\ is$

$$0.4 - 0.5 = -0.1\ A$$

$\rightarrow$ Current is flowing from B to A of value 0.1 A

Q-3 (a) Explain working principle of synchronous motor.

Ans :

→ Synchronous motor works on the principle of magnetic locking between the stator RMF (rotating magnetic field) and the rotor magnetic field. As we know, opposite poles attract each other, therefore the RMF poles attract the opposite rotor poles generating a rotating motion.

→ A synchronous motor is a doubly excited machine i.e. it requires AC and DC supply for both parts stator as well as rotor to achieve synchronism. A three-phase AC is supplied to the stator's windings to generate RMF. The stator is designed to have the same number of poles as the rotor. These poles rotate at the speed that is in sync with the input frequency f is called synchronous speed. It is given by

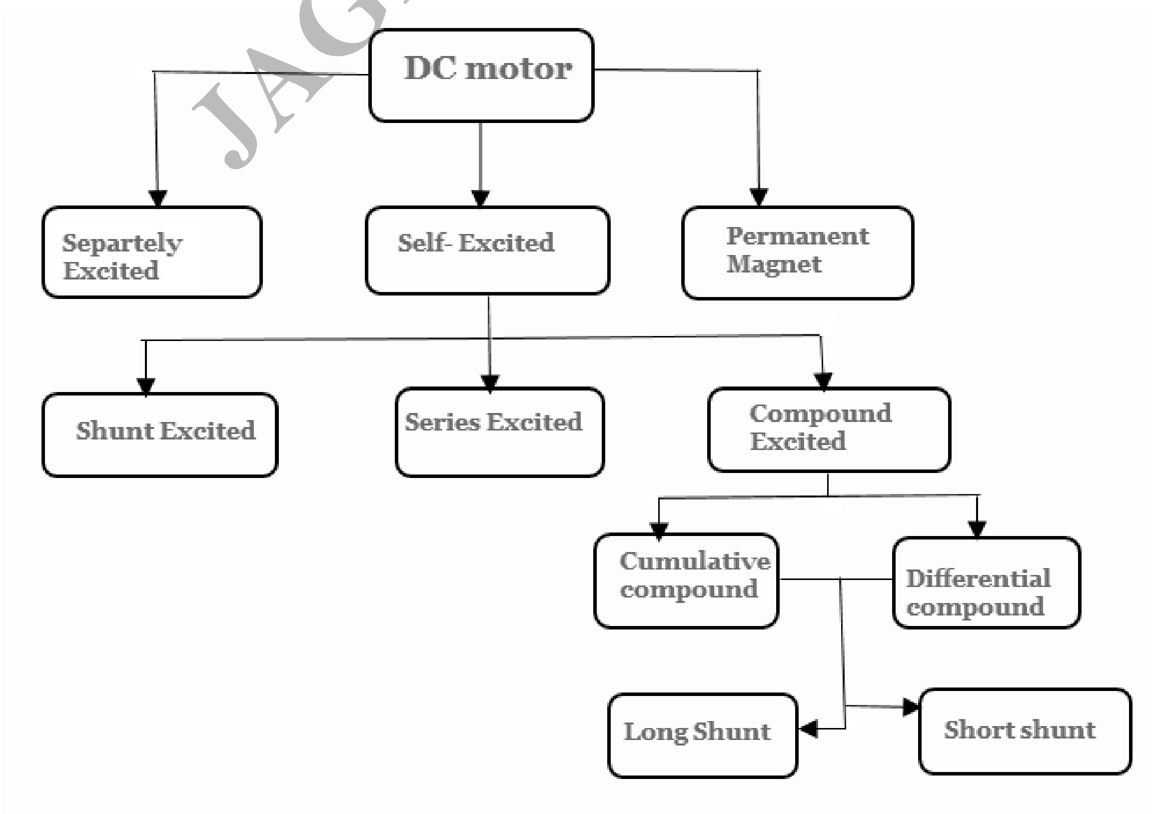
$$NS = \frac{120f}{p}$$

→ A DC supply is provided to the rotor's windings to generate a fixed magnetic field. As the DC source supplies constant current, the rotor's magnetic field does not vary. Magnetic poles are generated at the opposite ends of the rotor. The rotor's poles interact with the RMF of the stator and rotate at the same speed as it attains the synchronous speed.

→ If the rotor rotates at the same speed as the stator RMF, there is no load torque. The rotor and stator poles align with each other. If a mechanical load is applied, the rotor starts oscillating about its new equilibrium position, this phenomenon is known as 'hunting'. The rotor lags a few degrees behind the stator RMF and starts developing torque. As the load is increased the angle between them is increased until the rotor field lags by 90° behind RMF. At this point, the motor provides the maximum available torque called breakdown torque. If the load exceeds this limit, the motor stalls.

(b) Classify and compare various types of D.C. motors.

Ans :



→ Types of DC motor when listed sequentially:

Permanent Magnet DC Motor
Shunt Motor
Series Motor
Compound Motor
- Short Shunt Motor
- Long Shunt Motor
- Differentially Compound
- Cumulative Compound

→ Permanent Magnet DC Motor

In these types of DC motor, the permanent magnet is used to create a magnetic field. In this, no input current is consumed for excitation. These are used in automobile starters, wipers, air conditioners, etc

→ Shunt DC Motor

Here, the field is connected with the armature windings in parallel or also known as a shunt. The shunt field can be separately excited from the armature windings and that is the reason it can be used for greater speed regulation and can also offer very simplified reverse control.

→ Series DC Motor

Here, a large wire carrying the full armature current winds the field with few turns. This kind of motor generates a large amount of starting torque but the speed cannot be regulated here. If they are run with no load then it might face damage. These are not the ideal option for variable speed applications.

→ Compound DC Motor

These have a shunt field which is separately excited. They have a good starting torque but might face problems in variable speed applications.

→ Short Shunt DC Motor

Here, the shunt field winding is only connected with the armature winding and that too in parallel. The field coil, which is in series, is entirely exposed to current before being split up into the armature.

→ Long Shunt DC Motor

Here, the shunt field winding is connected in parallel with the both series field coil and armature which are again connected with each other in series.

→ Differentially Compound DC Motor

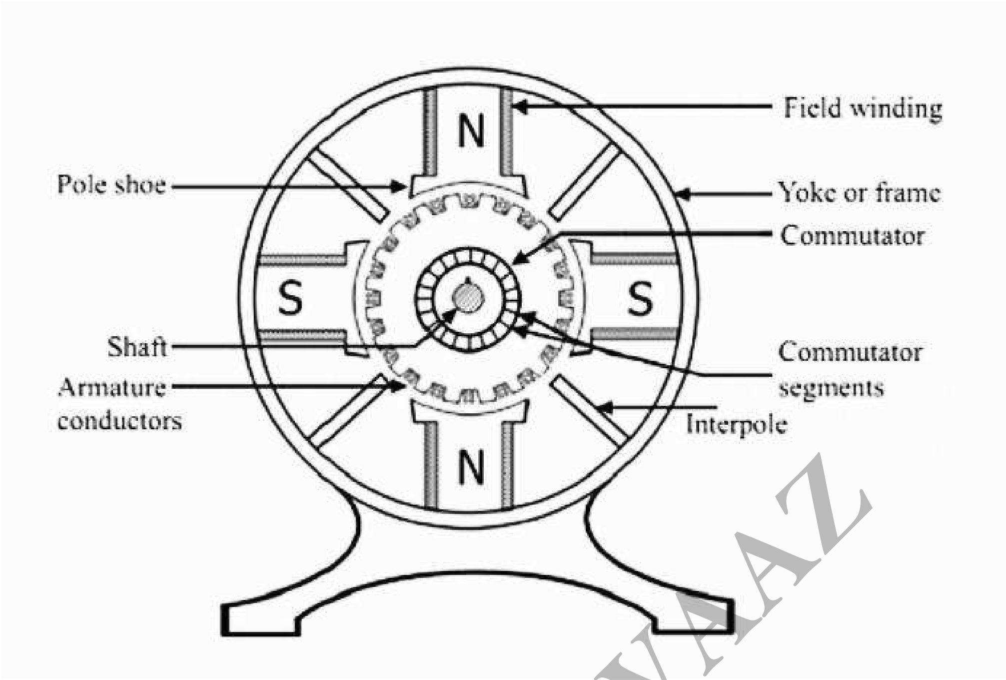
In this type of compound wound DC motor, the flux produced due to the shunt field windings reduces the effect of the main series windings.

→ Cumulative Compound DC Motor

Here, the flux produced by the shunt field windings enhances the effect of the main field flux which is produced by series winding.

(c) Explain construction of DC Machine.

Ans : The construction of the DC machine can be done using some of the essential parts like Yoke, Pole core & pole shoes, Pole coil & field coil, Armature core, Armature winding otherwise conductor, commutator, brushes & bearings. Some of the parts of the DC machine is discussed below.



→ Yoke

Another name of a yoke is the frame. The main function of the yoke in the machine is to offer mechanical support intended for poles and protects the entire machine from moisture, dust, etc. The materials used in the yoke are designed with cast iron, cast steel otherwise rolled steel.

→ Pole and Pole Core

The pole of the DC machine is an electromagnet and the field winding is winding among pole. Whenever field winding is energized then the pole gives magnetic flux. The materials used for this are cast steel, cast iron otherwise pole core. It can be built with the annealed steel laminations for reducing the power drop because of the eddy currents.

→ Pole Shoe

Pole shoe in the DC machine is an extensive part as well as to enlarge the region of the pole. Because of this region, flux can be spread out within the air-gap as well as extra flux can be passed through the air space toward armature. The materials used to build pole shoe is cast iron otherwise cast steed, and also used annealed steel lamination to reduce the loss of power because of eddy currents.

→ Field Windings

In this, the windings are wounded in the region of pole core & named as field coil. Whenever current is supplied through field winding than it electromagnetics the poles which generate required flux. The material used for field windings is copper.

→ Armature Core

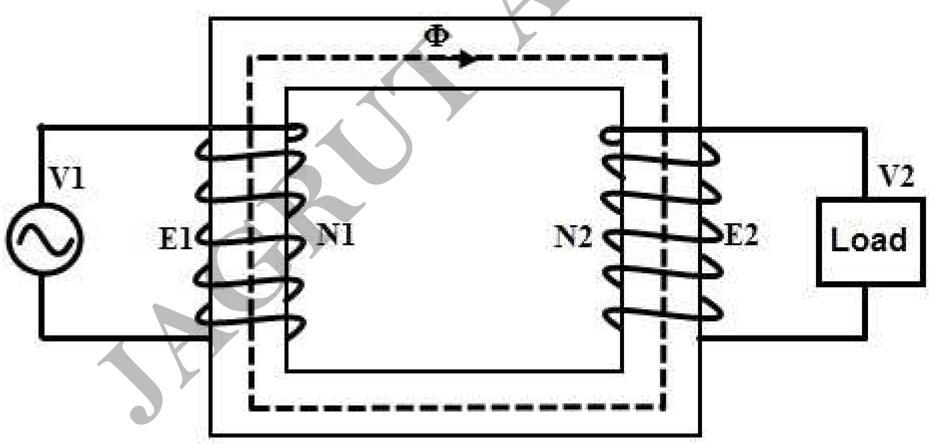
Armature core includes a huge number of slots within its edge. The armature conductor is located in these slots. It provides the low-reluctance path toward the flux generated with field winding. The materials used in this core are permeability low-reluctance materials like iron otherwise cast. The lamination is used to decrease the loss because of the eddy current.

→ Armature Winding
The armature winding can be formed by interconnecting the armature conductor. Whenever an armature winding is turned with the help of prime mover then the voltage, as well as magnetic flux, gets induced within it. This winding is allied to an exterior circuit. The materials used for this winding are conducting material like copper.

→ Commutator
The main function of the commutator in the DC machine is to collect the current from the armature conductor as well as supplies the current to the load using brushes. And also provides uni-directional torque for DC-motor. The commutator can be built with a huge number of segments in the edge form of hard drawn copper. The Segments in the commutator are protected from the thin mica layer.

→ Brushes
Brushes in the DC machine gather the current from the commutator and supply it to the exterior load. Brushes wear with time to inspect frequently. The materials used in brushes are graphite otherwise carbon which is in rectangular form.

Q-4 (a) Derive the EMF equation of single-phase transformer.
Ans :



→ EMF equation for 1ø transformer:-
→ Consider ac sinusoidal flux,

$\emptyset = \emptyset_m \, sinwt$ ---------------------------- ①

Where $\emptyset_m$ is the maximum value of flux , $\emptyset$ is the tancous flux and w is angular frequency.

→ By faraday's law of electromagnetic induction EMF induced is, for a single turn.

$e = \frac{-d\emptyset}{dt}$

For N, number of turn

$e = \frac{-Nd\emptyset}{dt}$

$e = N\left(\frac{-d\emptyset}{dt}\emptyset_m sinwt\right)$

$= -N\emptyset_m coswt.w$

$= -Nw\emptyset_m coswt$

$$e = \emptyset_m N.w \sin\left(wt - \frac{\pi}{2}\right) \qquad \text{-----------------------------} \ ②$$

$$e_{max} = N.\emptyset_m w$$

$$E_{RMS} = \frac{e_{\max}}{\sqrt{2}} = 4.44N\ N\emptyset_m f$$

Primary induced emf,

$$E_1 = 4.44N_1\emptyset_m f$$

$$E_2 = 4.44N_2\emptyset_m f$$

(b) Compare core type and shell type single phase transformers.

Ans :

Sr. No.	Core type transformer	Shell type transformer
1.	L.V winding and H.V winding are normally distributed over two opposite limbs of core	L.V and H.V winding are wound on the central limb of the core
2.	Winding are of cylindrical type.	Winding are of sandwich type.
3.	More suitable for high voltage transformer	More economical for low voltage transformer
4.	Core has two limbs.	Core has three limbs.
5.	It has single magnetic circuit	It has a double magnetic circuit

(c) Explain various connections of three phase transformer with diagram.

Ans : Connections of three-phase transformer:

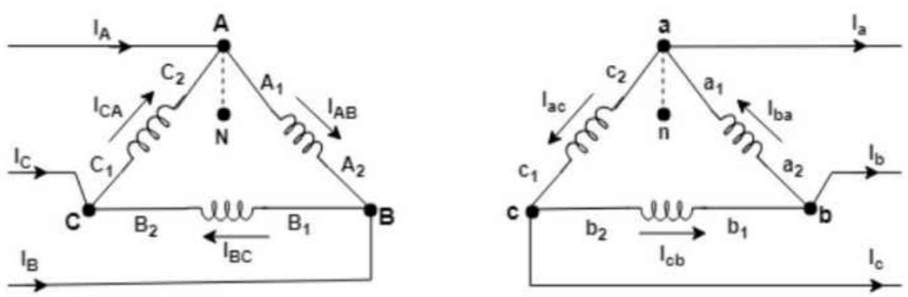
→ A three-phase transformer has three transformers connected in it, either separately or combined on one core. We can connect the primary and secondary winding of a 3-phase transformer in either a star (Y) or delta (Δ). There are four ways to connect the 3-phase transformer bank:

1. Δ - Δ (Delta primary - Delta secondary)
2. Y - Y (Star primary - Star secondary)
3. Δ - Y (Delta primary - Star secondary)
4. Y - Δ (Star primary - Delta secondary)

→ For connecting the transformers into star or delta, we have to assume that the transformers we are connecting, are all of the same KVA ratings.

1. Delta - Delta (Δ - Δ) Connection :

→ In delta-delta connection the line voltage of the transformer is equal to the supply voltage of the transformer.



→ The above diagram shows the delta-delta connection of three windings of single phase transformer. The secondary winding a1 a2 corresponds to the primary winding A1A2, b1b2 corresponds to B1B2, and c1c2 corresponds to C1C2, similarly 'a' corresponds to A, 'b' corresponds to B and 'c' corresponds to C. The terminals 'a1' and A1 have the same polarity. The Phasor diagram drawn above is for lagging power factor cos Φ. For balanced conditions, the line current is $\sqrt{3}$ times the Phase current.

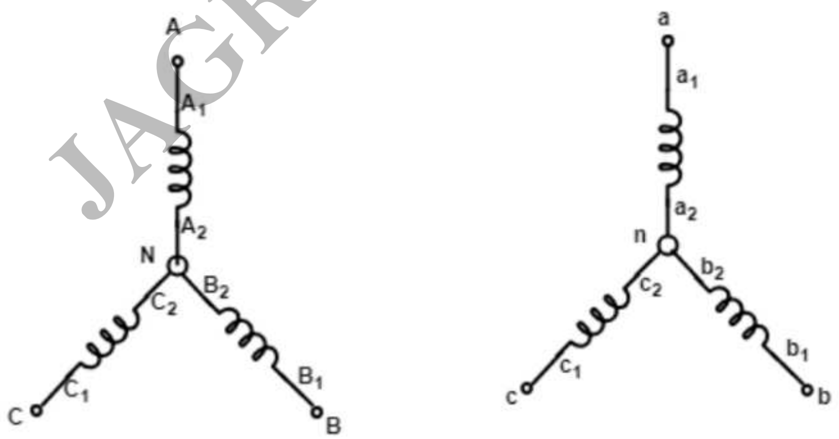
→ The turn ratio for 3 phase transformer is
$$\frac{V_{AB}}{V_{ab}} = \frac{V_{BC}}{V_{bc}} = \frac{V_{CA}}{V_{ca}} = a$$

→ And the current ratio when the magnetizing current is neglected is
$$\frac{I_{AB}}{I_{ab}} = \frac{I_{BC}}{I_{bc}} = \frac{I_{CA}}{I_{ca}} = \frac{I_A}{I_a} = \frac{I_B}{I_b} = \frac{I_C}{I_c} = \frac{1}{a}$$

→ The advantage of Δ - Δ Transformation:
1. The delta-delta connection is good for balanced and unbalanced loading.
2. If a third harmonic is present, it circulates in the closed path and therefore does appear in the output voltage wave.
3. The main advantage of Δ - Δ transformer is that if one transformer stops working, then the other two transformers will keep on working. This is called an open delta connection.

→ The disadvantage of Δ - Δ Transformation:
The disadvantage of Δ - Δ transformer is that it does not contain a neutral point and this can only be used when neither primary nor secondary requires neutral, and the required voltage is low and moderate.

2. Star-Star (Y - Y) Connection :



→ The voltage ratios for ideal transformer are:

$$\frac{V_{AN}}{V_{an}} = \frac{V_{BN}}{V_{bn}} = \frac{V_{CN}}{V_{cn}} = a$$

→ And current ratios are :
$$\frac{I_A}{I_a} = \frac{I_B}{I_b} = \frac{I_C}{I_c} = \frac{1}{a}$$

→ There are two serious problems in star-star connection:

1. In the star-star connection when the load is unbalanced and neutral is not provided, then the phase voltage tends to become severely unbalanced. Therefore, the star-star connection is not suitable for unbalanced loading.

2. The magnetizing current of any transformer is very non-sinusoidal and contains a very large third harmonic, which is necessary to overcome saturation to produce a sinusoidal flux.

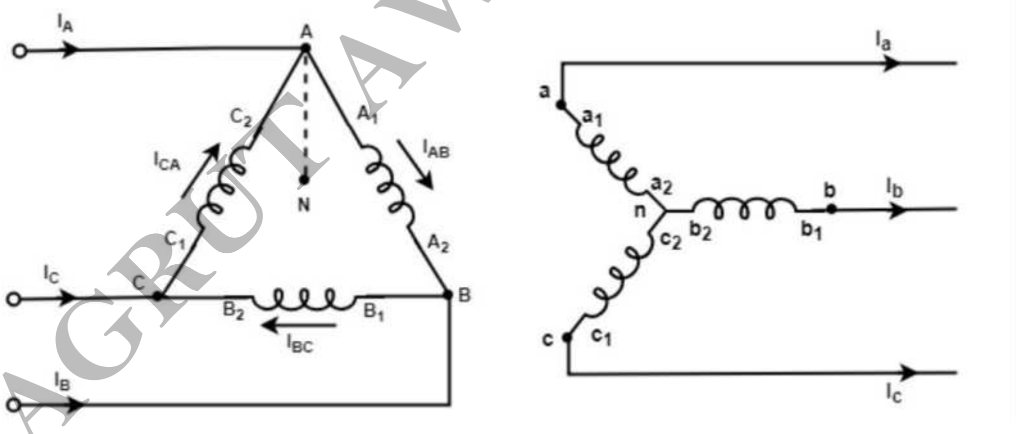
3. Delta-Star (Δ - Y) Connection :

→ In Δ - Y connection of 3-phase transformers, the primary line voltage is equal to the primary phase voltage ($V_{LP} = V_p P$). The relationship between secondary voltages is V_{LS}= $\sqrt{3}\, V_p S$ therefore, the line-line voltage ratio of this connection is

$$\frac{V_{LP}}{V_{LS}} = \frac{V_p P}{\sqrt{3} V_p S}$$

$$\frac{V_p P}{V_p S} = a$$

$$\therefore \frac{V_{LP}}{V_{LS}} = \frac{a}{\sqrt{3}}$$



4. Star-Delta (Y - Δ) Connection :

→ The Y - Δ connection of three-phase transformers is shown below. In this connection, the primary line voltage is equal to $\sqrt{3}$ times the primary phase voltage ($V_{LP} = \sqrt{3}\, VpP$). The secondary line voltage is equal to the secondary phase voltage ($V_{LS} = V_p S$). The voltage ration of each phase is

$$\frac{V_p P}{V_p S} = a$$

→ Therefore line-to-line voltage ratio of a Y - Δ connection is

$$\frac{V_{LP}}{V_{LS}} = \frac{\sqrt{3}\, V_p P}{V_p S} = \sqrt{3} a$$

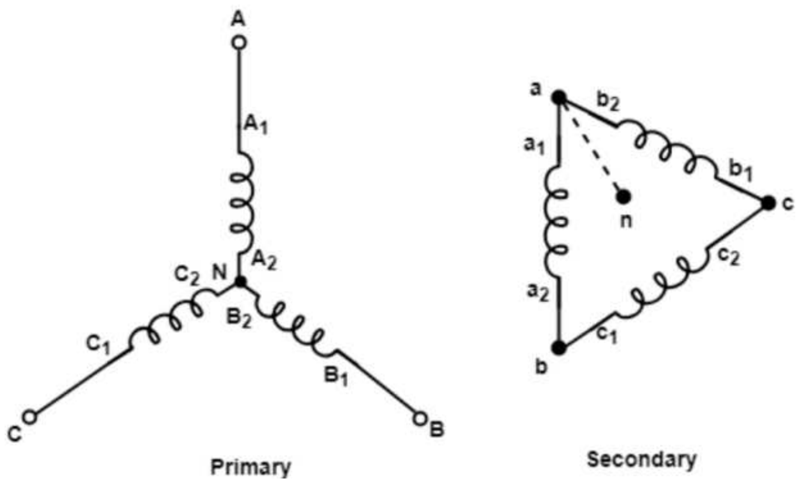


Figure: Y - Δ connection of transformer (Phase shift of 30 ∘ lead)

Q-4 (a) Give a comparison between squirrel cage induction motor and wound rotor induction motor.

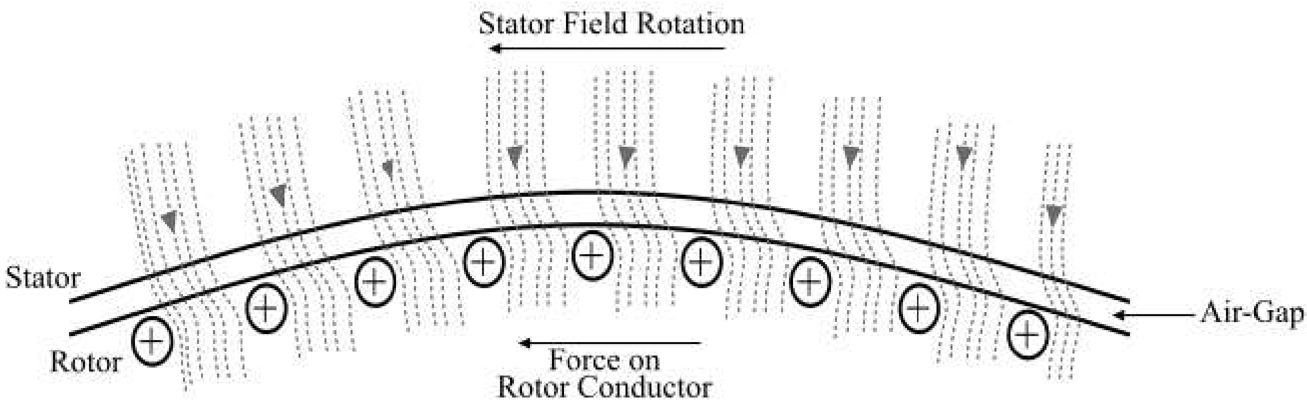
Ans :

Sr. No.	Squirrel Cage Induction Motor	Slip Ring Induction Motor
1.	Construction is very simple	Construction is complicated due to presence of slip ring and brushes
2.	Slip ring and brushes are absent.	Slip ring and brushes are present
3.	Less maintenance is required	Frequent maintenance is required due to presence of brushes.
4.	Cheaper Cost	Cost is slightly higher

(b) Explain in brief working principle of Three Phase Induction Motor

Ans : A three phase induction motor has a stator and a rotor. The stator carries a 3-phase winding called as stator winding while the rotor carries a short-circuited winding called as rotor winding. The stator winding is fed from 3-phase supply and the rotor winding derives its voltage and power from the stator winding through electromagnetic induction. Therefore, the working principle of a 3-phase induction motor is fundamentally based on electromagnetic induction.

→ Consider a portion of a three-phase induction motor (see the figure). Therefore, the working of a three-phase induction motor can be explained as follows –



→ When the stator winding is connected to a balanced three phase supply, a rotating magnetic field (RMF) is setup which rotates around the stator at synchronous speed (Ns). Where,

$$Ns = \frac{120f}{p}$$

→ The RMF passes through air gap and cuts the rotor conductors, which are stationary at start. Due to relative motion between RMF and the stationary rotor, an EMF is induced in the rotor conductors. Since the rotor circuit is short-circuited, a current starts flowing in the rotor conductors.

→ Now, the current carrying rotor conductors are in a magnetic field created by the stator. As a result of this, mechanical force acts on the rotor conductors. The sum of mechanical forces on all the rotor conductors produces a torque which tries to move the rotor in the same direction as the RMF.

→ Hence, the induction motor starts to rotate. From, the above discussion, it can be seen that the three phase induction motor is self-starting motor.

→ The three induction motor accelerates till the speed reached to a speed just below the synchronous speed.

(c) Explain construction of synchronous generator with diagram.

Ans : A synchronous generator is a synchronous machine which converts mechanical power into AC electric power through the process of electromagnetic induction.

→ Synchronous generators are also referred to as alternators or AC generators. The term "alternator" is used since it produces AC power. It is called synchronous generator because it must be driven at synchronous speed to produce AC power of the desired frequency.

→ A synchronous generator can be either single-phase or poly-phase (generally 3phase).

Construction of Synchronous Generator or Alternator :

→ As alternator consists of two main parts viz.

→ Stator – The stator is the stationary part of the alternator. It carries the armature winding in which the voltage is generated. The output of the alternator is taken form the stator.

→ Rotor – The rotor is the rotating part of the alternator. The rotor produces the main field flux.

Stator Construction of Alternator

→ The stator of the alternator includes several parts, viz. the frame, stator core, stator or armature windings, and cooling arrangement.

→ The stator frame may be made up of cast iron for small-size machines and of welded steel for large-size machines.

→ The stator core is assembled with high-grade silicon content steel laminations. These silicon steel laminations reduce the hysteresis and eddy-current losses in the stator core.

→ The slots are cut on the inner periphery of the stator core. A 3-phase armature winding is put in these slots.

→ The armature winding of the alternator is star connected. The winding of each phase is distributed over several slots. When current flows through the distributed armature winding, it produces an essential sinusoidal space distribution of EMF.

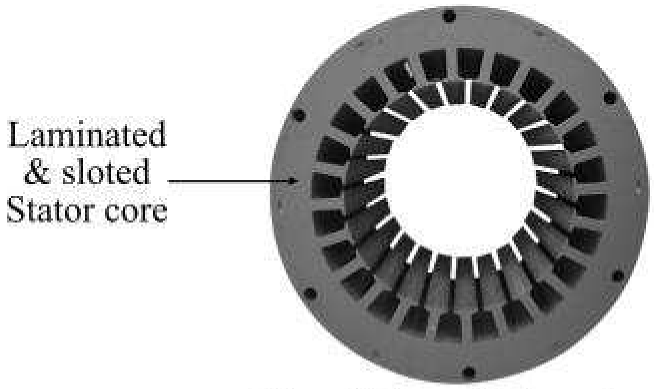


Fig. - Stator of Alternator

Rotor Construction of Alternator

→ The rotor of the alternator carries the field winding which is supplied with direct current through two slip rings by a separate DC source (also called exciter). The exciter is generally a small DC shunt generator mounted on the shaft of the alternator.

→ For the alternator, there are two types of rotor constructions are used viz. the salient-pole type and the cylindrical rotor type.

Salient Pole Rotor

→ The term salient means projecting. Hence, a salient pole rotor consists of poles projecting out from the surface of the rotor core. This whole arrangement is fixed to the shaft of the alternator as shown in the figure. The individual field pole windings are connected in series such that when the field winding is energised by the DC exciter, the adjacent poles have opposite polarities.

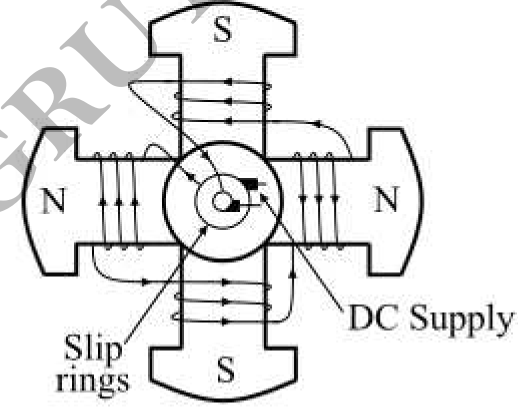


Fig. - Salient Pole Rotor

→ The salient pole type rotor is used in the low and medium speed (from 120 to 400 RPM) alternators such as those driven by the diesel engines or water turbines because of the following reasons –

→ The construction of salient pole type rotor cannot be made strong enough to withstand the mechanical stresses to which they may be subjected at higher speed.

→ If the salient field pole type rotor is driven at high speed, then it would cause windage loss and would tend to produce noise.

→ Low speed rotors of the alternators possess a large diameter to provide the necessary space for the poles. As a result, the salient pole type rotors have large diameter and short axial length.

Cylindrical Rotor

→ The cylindrical rotors are made from solid forgings of high-grade nickel-chrome-molybdenum steel.
→ The construction of the cylindrical rotor is such that there are no-physical poles to be seen as in the salient pole rotor.
→ In about two-third of the outer periphery of the cylindrical rotor, slots are cut at regular intervals and parallel to the rotor shaft.
→ The field windings are placed in these slots and is excited by DC supply. The field winding is of distributed type.
→ The unslotted portion of the rotor forms the pole faces.
→ It is clear from the figure of the cylindrical rotor that the poles formed are non-salient, i.e., they do not project out from the rotor surface.

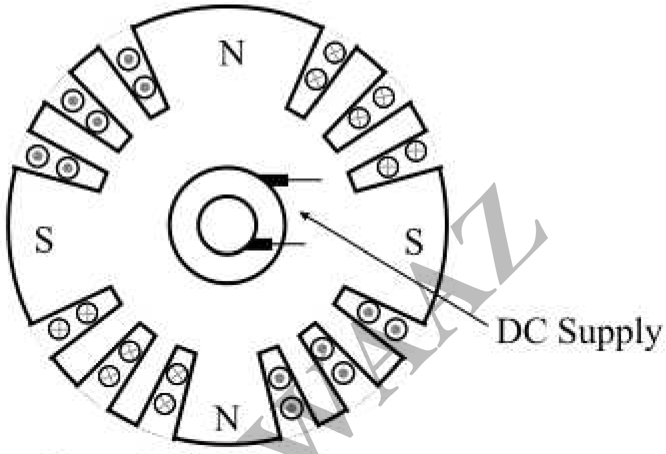


Fig. - Cylindrical Rotor

→ The cylindrical type rotor construction is used in the high-speed (1500 to 3000 RPM) alternators such as those driven by steam turbines because of the following reasons –
→ The cylindrical type rotor construction provides a greater mechanical strength and permits more accurate dynamic balancing.
→ It gives noiseless operation at high speeds because of the uniform air gap.
→ The flux distribution around the periphery of the rotor is nearly a sine wave and hence a better EMF waveform is obtained.
→ A cylindrical rotor alternator has a comparatively small diameter and long axial length. The cylindrical rotor alternators are called turbo-alternators or turbo-generators. The alternator with cylindrical rotor have always horizontal configuration installation.

Q-5 (a) Compute the energy charges for an air conditioner having consumption of 2 kW for the month of April. Daily usage of the air conditioner is 12 hours. Energy charges are Rs 9 per unit.

Ans :

→ Given

Power rating of the air conditioner = 2kw
Cost of electricity per unit = 9 ₹
Time for which the device is operated in a days = 12 hr.

→ Units consumed per day = 2kw*12hr

$= 24\, kwh = 24\, units$

→ Units consumed in 30 days = $24 \times 30 = 720\, units$
→ Electricity bill for 30days = $720 \times 9\, unit = 6480$

(b) Write safety precautions for electrical Applications.

Ans : Safety precautions for electrical applications include:

1. Proper Training: Ensure that personnel working with electrical equipment are adequately trained and knowledgeable about safety procedures and protocols.

2. Use of Personal Protective Equipment (PPE): Wear appropriate PPE such as insulated gloves, safety glasses, and protective clothing to prevent electrical shocks and burns.

3. De-energize Equipment: Always de-energize electrical equipment before performing maintenance, repairs, or modifications. Use lockout/tagout procedures to prevent accidental re-energization.

4. Verify Voltage: Double-check the voltage rating of equipment and ensure it matches the electrical supply to prevent overloading and electrical failures.

5. Inspect Cords and Cables: Regularly inspect power cords, cables, and plugs for damage or wear. Replace any damaged components immediately to prevent electrical hazards.

6. Ground Fault Circuit Interrupters (GFCIs): Install GFCIs in areas where electrical equipment may come into contact with water or moisture to prevent electric shocks.

7. Avoid Overloading Circuits: Do not overload electrical circuits by connecting too many devices or appliances to a single outlet. Use power strips with built-in circuit breakers for additional protection.

8. Maintain Clearance: Keep a safe distance from overhead power lines and ensure that equipment, ladders, and scaffolding are positioned away from electrical hazards.

Following these safety precautions can help prevent electrical accidents and ensure a safe working environment for everyone involved in electrical applications.

(c) Explain different methods of Power factor Improvement.

Ans :

Power Factor: "It is the measurement of how incoming power is being effectively used in electrical power system.

Methods of Power Factor Improvement

1. Static Capacitor (Capacitor Bank)
2. Synchronous Condenser
3. Phase Advancer

Method 1: Static Capacitor

- → We know that most of the industries and power system loads are inductive that take lagging current which decrease the system power factor.
- → For Power factor improvement purpose, Static capacitors are connected in parallel with those devices which work on low power factor.
- → These static capacitors provides leading current which neutralize (totally or approximately) the lagging inductive component of load current (i.e. leading component

neutralize or eliminate the lagging component of load current). Thus, power factor of the load circuit is improved.

→ These capacitors are installed in Vicinity of large inductive load e.g. Induction motors and transformers etc., and improve the load circuit power factor to improve the system or devises efficiency.

Advantages

→ Capacitor bank offers several advantages over other methods of power factor improvement.
→ Losses are low in static capacitors
→ There is no moving part, therefore need low maintenance
→ It can work in normal conditions (i.e. ordinary atmospheric conditions)
→ Do not require a foundation for installation
→ They are lightweight so it is can be easy to installed

Disadvantages

→ The age of static capacitor bank is less (8 – 10 years)
→ With changing load, we have to ON or OFF the capacitor bank, which causes switching surges on the system.
→ If the rated voltage increases, then it causes damage it.
→ Once the capacitors spoiled, then repairing is costly

Method 2: Synchronous Condenser

→ When a Synchronous motor operates at No-Load and over-exited then it's called a synchronous Condenser.
→ Whenever a Synchronous motor is over-exited then it provides leading current and works like a capacitor.
→ When a synchronous condenser is connected across supply voltage (in parallel) then it draws leading current and partially eliminates the re-active component and this way, power factor is improved. Generally, synchronous condenser is used to improve the power factor in large industries.

Advantages

→ Long life (almost 25 years).
→ High Reliability.
→ Step-less adjustment of power factor.
→ No generation of harmonics of maintenance.
→ The faults can be removed easily.
→ It's not affected by harmonics.
→ Require Low maintenance (only periodic bearing greasing is necessary).

Disadvantages

→ It is expensive (maintenance cost is also high) and therefore mostly used by large power users.
→ An auxiliary device has to be used for this operation because synchronous motor has no self-starting torque.
→ It produces noise.

Method 3: Phase Advancer

- → Phase advancer is a simple AC exciter which is connected on the main shaft of the motor and operates with the motor's rotor circuit for power factor improvement.
- → Phase advancer is used to improve the power factor of induction motor in industries.
- → As the stator windings of induction motor takes lagging current 90° out of phase with Voltage, therefore the power factor of induction motor is low.
- → If the exciting ampere-turns are excited by external AC source, then there would be no effect of exciting current on stator windings.
- → Therefore, the power factor of induction motor will be improved. This process is done by Phase advancer.

Advantages

- → Lagging kVAR (Reactive component of Power or reactive power) drawn by the motor is sufficiently reduced because the exciting ampere turns are supplied at slip frequency (fs).
- → The phase advancer can be easily used where the use of synchronous motors is Unacceptable.

Disadvantage

- → Using Phase advancer is not economical for motors below 200 H.P. (about 150kW).

Q-5 (a) Write advantages and disadvantages of ELCB.

Ans :

Advantages of ELCB:

- → This device is not sensitive to faults.
- → It is cheap and efficient.
- → It protects animals and humans from electrical shock.
- → In this process, when the installation has two connections to the earth, a nearby high current lightning strike will cause a voltage gradient in the soil, presenting the ELCB sense coil with enough voltage to cause it to trip.

Disadvantages of ELCB:

- → Failure to respond at certain conditions.
- → ELCB needs a sound earth connection, for load protection.
- → Nuisance trips.
- → Electrical leaky appliances water heater, washing, machine, and coolers may cause CKL to trip.
- → They may be tripped by the external voltage from something connected to the earthing system such as a metal pipe.
- → They do not detect a fault that doesn't pass current through CPC to earth rod.
- → They do not allow a single building system to easily split into multiple sections with independent fault protection because the earthing system is bonded to the pipework.
- → If the electrical installation earth rod is placed close to another earth of a building, then a high earth leakage current from other buildings can raise the local ground potential and cause a voltage difference across the two earth, again tripping the ELCB.
- → ELCBs introduce additional resistance and an additional point of failure into enough voltage to cause it to trip.
- → They may be tripped by external voltage from something connected to the earthing system such as metal pipes, TN-S earth or a TN-C-S combined neutral and earth.

(b) Give comparison between MCB and Fuse.

Ans :

Sr.	Characteristics	FUSE	MCB
1.	Protection	Over load & Short circuit	Over load & Short circuit
2.	Cost	Low	High
3.	Rating(Range)	Low to High	Low to Medium
4.	After Trip	Required to Replace	Not Required to Replace
5.	Short circuit Triping Time	20 ms (1 cycle)	100 ms to 500 ms (5 to 25 cycle)
6.	Overload Sensitivity	Low	High
7.	ON & OFF Status	Not show	Show
8.	Use as Switch	No	Can be
9.	On-Off Operation Speed	Low	High
10.	Safety at Operation	Very Low	Very High
11.	KA Rating	High	Low

(c) Classify different types of Earthing and explain Plate Earthing with diagram

Ans : There are three types of earthing, they are:

1.Pipe earthing
2.Plate earthing
3.Strip earthing

Plate earthing:-

→ Plate Earthing is a method where a plate made of galvanized copper or iron is buried vertically at least 3 meters below ground level. This plate connects all conductors to the earth, providing a path for electrical discharge. The Diagram of Plate Earthing typically illustrates this setup, showing the plate's position in relation to the ground level and the conductors it connects.

→ The Plate Earthing Diagram also often includes the dimensions of the plate. For instance, a copper plate used in this method typically measures 600mm x 600mm x6.35mm. The plate's size and material can vary based on specific requirements, but the principle remains the same, to provide a safe path for fault current to the earth.

→ The diagram of plate earthing shows a plate electrode, which is either made of galvanized iron or steel (with a minimum thickness of 6.3 mm) or copper (with a minimum thickness of 3.15 mm). The plate should be at least 60 cm by 60 cm in size.

→ The plate is buried in the earth, surrounded by alternating layers of charcoal and salt. The charcoal layer is used to retain moisture, which helps to maintain a low earth resistance.

→ A galvanized iron strip is connected to the plate and extends above the ground. This strip is used to connect the plate to the electrical system that is being earthed.

→ A pipe is also shown in the diagram, which is used for watering the earth around the plate. This helps to maintain the moisture levels around the plate, ensuring effective earthing.

→ Finally, an inspection chamber is built around the earth pit. This chamber allows for regular inspection and maintenance of the earthing system.

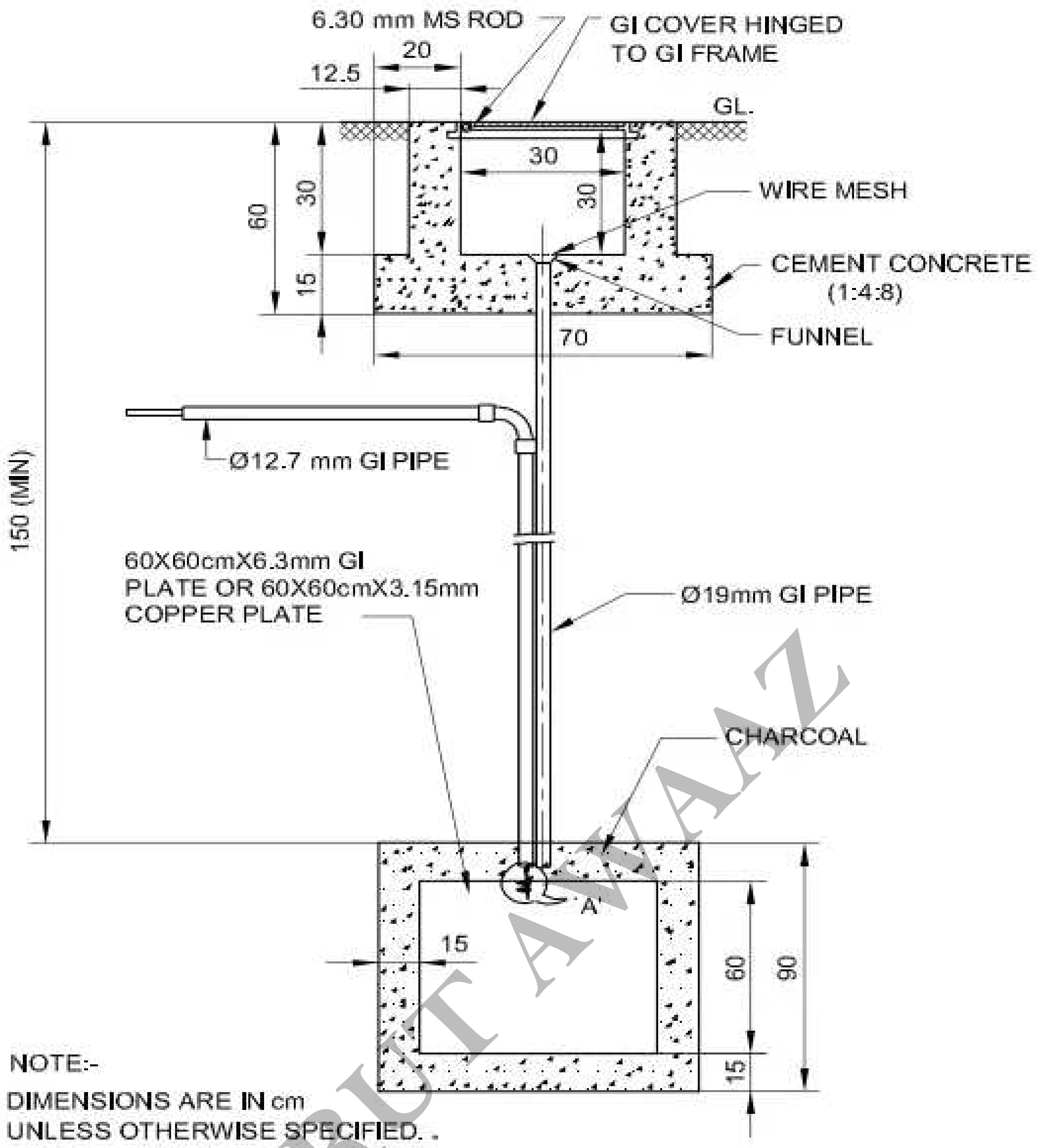


Plate Earthing Procedure:-

→ The procedure for Plate Earthing involves several steps, often illustrated in a Diagram of Plate Earthing:

→ Earth Pit: An earth pit is excavated at a suitable location in the substation, with a minimum size of 900mm x900mm and a depth of 3m below the surface.

→ Plate Electrode: A GI plate of minimum size 600mm x600mm and thickness of 6.3 mm is used. If a copper plate is used, a minimum thickness of 3.15mm is required. The plate is surrounded by alternating layers of charcoal and salt.

→ Earthing Connection: Galvanized Iron strips are fixed and welded to the plate at two different locations. Loose earthing can adversely affect the electrode system resistivity, so these connections are made strong.

→ Water Connection: A pipe is fixed at the top to maintain moist conditions around the earth plate. The pipe is covered with a wire mesh, and water is poured through it. The excavated pit is then filled with stone-free soil.

→ Inspection Chamber: A brick chamber is built over the earth pit on a P.C.C layer. The top cover is placed with cast iron hinges to a CI frame.

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