ISL ENGINEERING COLLEGE
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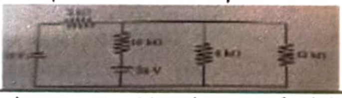
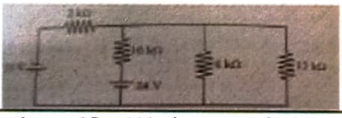
Subject Code: ISL24UES104EC

MODEL PAPER 2 (REFERENCE ONLY)
B.E.I SEMESTER END EXAMINATION (MAIN) JAN-FEB 2025

Subject: BEE | Branch:IT/AI&DS/ECE
Time: 3 hours | Max Marks: 60M

Note: This Question Paper contains two Parts A and B
- **Part A is compulsory which carries 12 marks. Answer all the questions.**
- **Answer any 4 questions out of 6 Questions in Part-B. Each question carries 12 marks.**

	PART-A 6Q x 2M =12 Marks	CO	BTL	Marks
	Answer All the Questions			
1 a.	State Thevenins Theorem	CO1	BTL3	2M
b.	The equation for an alternating current is given by I=66sin314t.Find the peak value,frequency,time period and instantaneous value at t= 3ms	CO2	BTL1	2M
c.	State the merits and demerits of auto transformer over two winding transformer	CO3	BTL5	2M
d.	Why is induction motors are called asynchronous motors	CO3	BTL4	2M
e.	List out the disadvantages of a single phase induction motor over 3 phase induction motor.	CO4	BTL2	2M
f.	List out the characteristerics of batteries	CO5	BTL3	2M
PART-B4Q x 12M =48Marks				
Answer any Four (4)Questions				
2 a)	Calculate the necessary resistor size for R1 to make the total circuit current equal to 30 milli amps. 	CO1	BTL3	6M
b)	Using 10 Ω the superposition theorem, find the current through 4k ohm for the circuit shown below. 	CO1	BTL1	6M
3 a)	A 10 ohm resistor. 10 mH inductor and 10 micro F capacitor are connected in series with a 10 KHz voltage source. The rms current through the circuit is 0.2A. Find the rms voltage drop across each of the 3 elements.	CO2	BTL2	6M
b)	Show that $V_L = \sqrt{3}\, V_{ph}$ in 3-Phase balanced star connected system with the help of phasor diagram.	CO2	BTL4	6M
4 a)	Explain the generation of rotating magnetic field in 3 phase induction motor.	CO3	BTL3	6M
b)	A Transformer rated at 100KVA. At full load the copper loss is 1200W and its iron losses are 950W. Calculate i) The efficiency at full load,UPF ii) Efficiency at half load, 0.8 pf iii) The efficiency at 85% full load, 0.7 pf lag,	CO3	BTL4	6M
5 a)	Describe the construction and working of capacitor start capacitor run induction motor and list out its applications.	CO4	BTL5	6M
b)	A 6 pole lap wound DC Generator has 100 slots having 5 conductors per slot. If each conductor can carry 200 A and if flux/pole is 0.03 wb, calculate the speed of generator for giving 220V on open circuit.	CO4	BTL2	6M
6 a)	Give the power, voltage and current equations for different types of DC motors.	CO4	BTL3	6M
b)	A 440V , 3 phase, 50Hz supply is fed to three coils, star connected each having a resistance of 30 ohm and an inductive reactance of 25 ohm. Calculate a) line current b) power factor c) power supplied.	CO2	BTL5	6M
7 a)	What is earthing? Why earthing is required? With the help of neat sketch explain plate earthing.	CO5	BTL4	6M
b)	Discuss the disadvantages of low p.f	CO5	BTL1	6M

*** ***

Ans : Any linear network having an active voltage and current sources with two terminals *A* and *B* can be replaced by an equivalent voltage source (V_{Th}) and equivalent resistance (R_{Th}) in series combination forming a simple equivalent circuit.

Where, V_{Th} is the open circuit voltage across the terminals *A* and *B* and R_{Th} is the equivalent resistance as seen from the terminals *A* and *B* when the independent sources are deactivated.

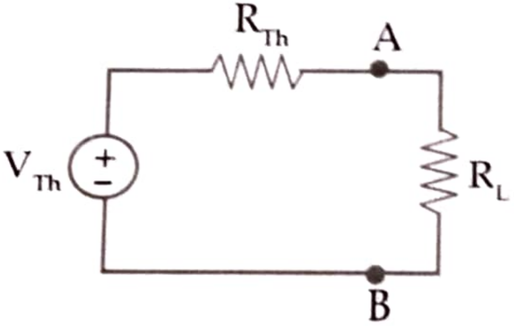


Figure: Thevenin's Equivalent Circuit

1 b) The Equation for an alternating Current is given by $I = 66 \sin 314 t$. Find the peak value, frequency, time period & instantaneous value at $t = 3ms$.

Sol Given:

Eqn for an alternating Current, $I = 66 \sin 314 t$

Time, $t = 3ms = 3 \times 10^{-3} s$

To Determine,

1. peak value ? 2. Frequency-?
3. Time period-? 4. Instantaneous value-?

W.K.T

$I = I_m \sin \omega t$ — General eqn. $I = 66 \sin 314 t$

1. peak value, $I_m = 66 A$

2. Frequency:

$f = \frac{\omega}{2\pi} = 314 / 2 \times 3.14 = 50 Hz$

3. Time period $T = \frac{1}{f} = \frac{1}{50} = 0.02 s$

4. Instantaneous value at $t = 3ms$.

$I = 66 \sin(314 \times 3 \times 10^{-3})$.

Advantages of Auto-transformer

1. High volt-ampere rating can be transfer when compared to the two winding transformer of same size.

2. Voltage variation is smooth and continuous.

3. Amount of conductor (copper) required for winding is less. Saving of conductor material of auto-transformer = $K \times$ Conductor winding in two winding transformer.

   If $K = 0.1$ = Saving is 10%

   If $K = 0.9$ = Saving is 90%

   Hence use of auto-transformer is economical when 'K' is nearest to unity.

4. Window dimensions are decided from consideration of insulation and conductor material. For an auto-transformer a reduction in conductor material means lower window area and therefore reduced core length hence for the same core area weight of auto-transformer core is decreased. Hence saving in both the conductors and core material is affected by the use of auto-transformer.

5. As there is reduction in conductor and core material, there is reduction in ohmic loss in conductor and core loss in core. This results in increase in efficiency than in two winding transformer for same output.

6. Reduction in conductor material means, lower value of ohmic resistance. A part of winding being common, leakage flux and therefore leakage reactance is less. Hence it has superior voltage regulation than two-winding transformer for the same output.

Disadvantages of Auto-Transformers

1. If '*K*' differs from unity the economic advantages of auto-transformer over two winding transformer decreases.

2. The main disadvantage is due to the direct electrical connection between L.V and H.V.

If the primary is supplied at H.V, then an open circuit in '*BC*' results high voltage on L.V. This high voltage is dangerous for windings as well as the person working there, therefore protection is required.

(d) Why is induction motors are called asynchronous motors.

Ans : The rotor of the induction motor never rotates in synchronous speed continuously because at synchronous speed there is no flux cutting action and no induced e.m.fs thereby no torque produced. Then speed tends to decrease, thus rotor always rotate at lagging synchronous speed. Hence, induction motors are called as asynchronous motors.

Ans : The disadvantages of a single phase induction motor when compared with a 3-phase induction motor are as follows,

1. Single phase induction motors are not self-starting, whereas 3-phase induction motors are self starting.
2. The power factor of single phase induction motors are lower than 3-phase induction motorss.
3. Single phase induction motors have lower efficiency.
4. For the same rating, the output of single phase induction motor is half that of 3-phase induction motors.
5. For the same output, single phase motors are costlier than 3-phase motors.

Ans : The capacity of a battery is defined as the product of current (in Amperes) and the time (in hours). It is measured in Ampere-hours (Ah).

Mathematically, it is expressed as,

Capacity = $I \times T$

Where,

I - Current (in Amperes)

T - Time (in hours).

For answer refer Unit-5, Q18.

(ii) **Rate of Discharge :** The rate at which current discharges from the battery is known as 'Rate of discharge'.

Generally, the capacity of the battery is inversely proportional to the rate of discharge i.e., as the rate of discharge decreases, the capacity increases.

A rapid increase in the rate of discharge decreases the potential difference of the cell. It also significantly weakens the acid present in the pores of the plate. This inturn causes a significant decrease in the capacity of the battery.

Figure represents the graphical representation of capacity versus rate of discharge.

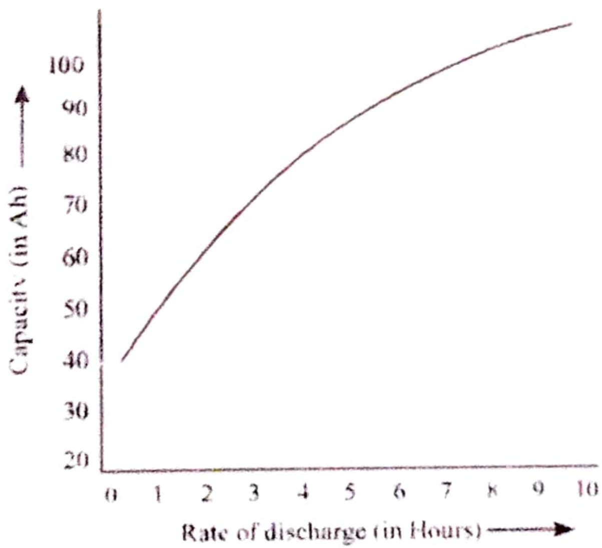


Figure: Variation of Capacity with Rate of Discharge

(iii) **Temperature** : The capacity of a battery is directly proportional to the temperature i.e., as the temperature increases, the capacity also increases.

At low temperature the voltage and capacity of the cell decreases rapidly (even in fully-charged conditions)

(iv) **Density of the Electrolyte** : Capacity of a battery is directly related to the density of the electrolyte in other words increase in density of the electrolyte increases the capacity of the battery.

(v) **Watt-Hour Efficiency** : Watt-hour efficiency of a cell can be defined as the ratio of output energy to the input energy. It is denoted as η_{wh} and is given by,

Equation

Watt-hour efficiency,

$$\eta_{wh} = \frac{\text{Engery released during discharge}}{\text{Energy taken on charge}} \times 100$$

$$\eta_{wh} = \frac{V_d \times I_d \times T_d}{V_c \times I_c \times T_c} \times 100$$

Where,

V_d - Discharge potential

I_d - Current during discharge

T_d - Discharging time

V_c - Charging potential

I_c - Current during discharge

T_c - Charging time.

vi) **Ampere-Hour (A-H) Efficiency** : Ampere-hour efficiency of a cell can be defined as the ratio of output Ampere-hours to the input Ampere hours. It is denoted as η_{Ah} and is given by,

$$\eta_{Ah} = \frac{\text{Ampere-hours during discharge}}{\text{Ampere-hours of charge}} \times 100$$

$$\eta_{Ah} = \frac{I_d \times T_d}{I_c \times T_c} \times 100$$

Where,

I_d - Current during discharge

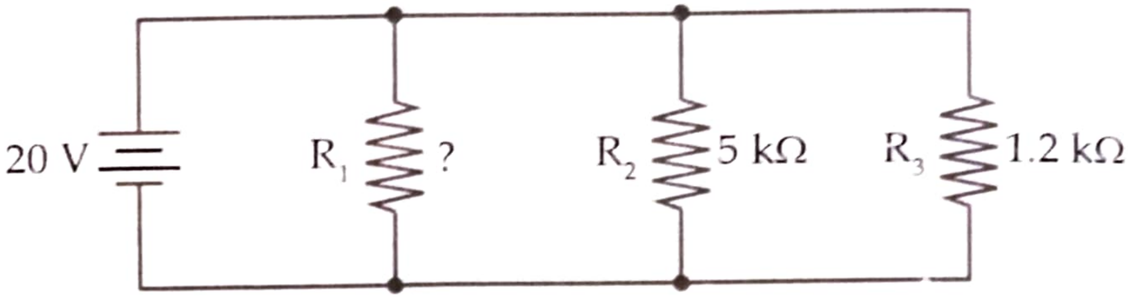
T_d - Discharging time

I_c - Current during charging

T_c - Charging time.

vii) **Shelf Life** : Some batteries stores current for many years without self discharge of current. So, it is necessary that shelf of good quality must be used.

Q2. (a) **Calculate the necessary resistor size for R1 to make the total circuit current equal to 30 milliamps:**



Ans : Given circuit is shown in figure (1).

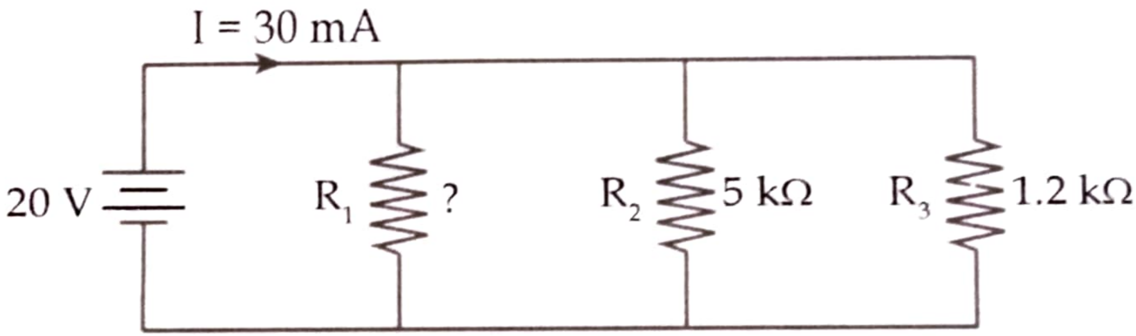


Figure (1)

Also given total current in circuit, $I = 30$ mA

From figure (1), it is clear that, resistors R_2 and R_3 are connected in parallel.

$$\therefore \quad R_2 \,||\, R_3 = \frac{R_2 R_3}{R_2 + R_3} = \frac{5 \times 1.2}{5 + 1.2} = 0.9677 \text{ k}\Omega$$

Now, figure (1), will be modified as shown in figure (2).

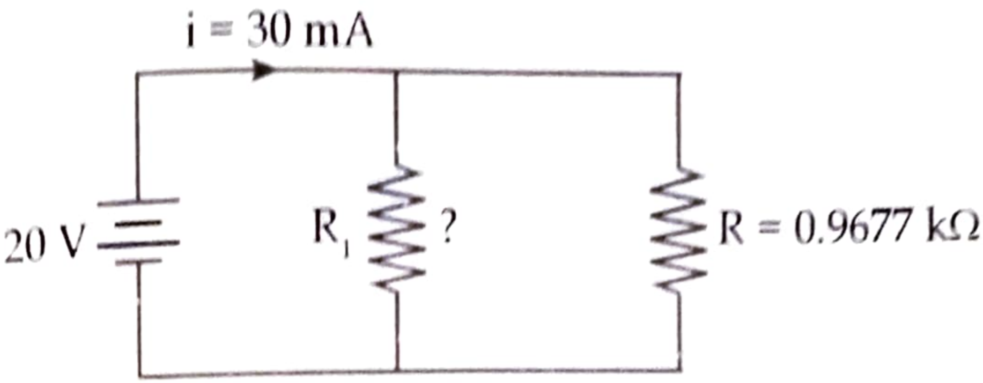


Figure (2)

From figure (2), resistors R and R_1 are parallel.

$$R_{eq} = R \,||\, R_1 = \frac{0.9677 \times R}{0.9677 + R} \text{ k}\Omega$$

We know that,

$$V = IR_{eq}$$

$$\therefore \quad R_{eq} = \frac{V}{I}$$

$$\Rightarrow \quad \frac{0.9677 \times 10^3 R}{(0.9677 \times 10^3) + R} = \frac{20}{30 \times 10^{-3}}$$

$$\Rightarrow \quad 0.9677 \times 30 \times R = 20(0.9677 \times 10^3 + R)$$

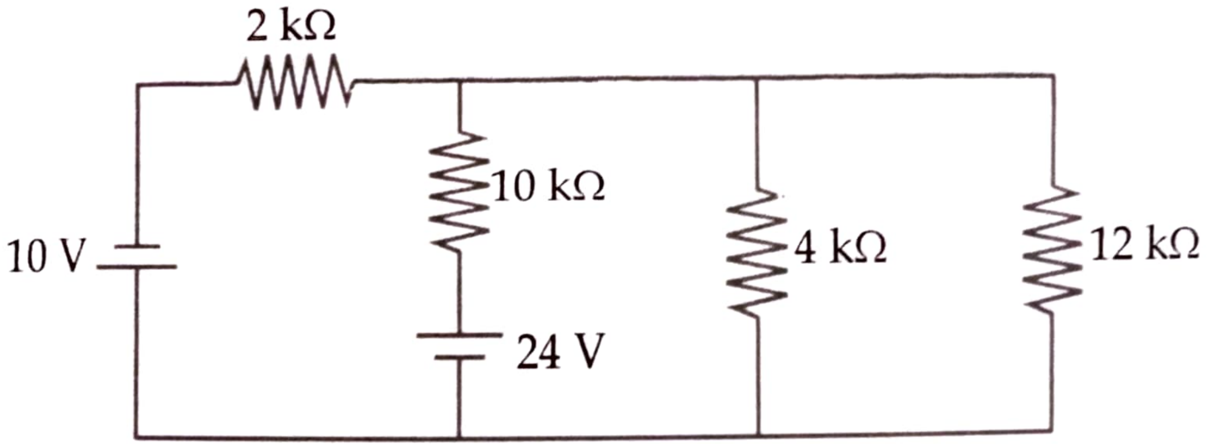
$$\Rightarrow \quad 29.031R = 19.354 \times 10^3 + 20R$$

$$\Rightarrow \quad (29.031 - 20)R = 19.354 \times 10^3$$

$$\Rightarrow \quad 9.03R = 19.354 \times 10^3$$

$$\Rightarrow \quad R = \frac{19.354}{9.03} \times 10^3 = 2.143 \text{ k}\Omega$$

(b) Using the superposition find the current through 4 kΩ for the circuit shown below.



Ans : The given circuit is shown in figure (1).

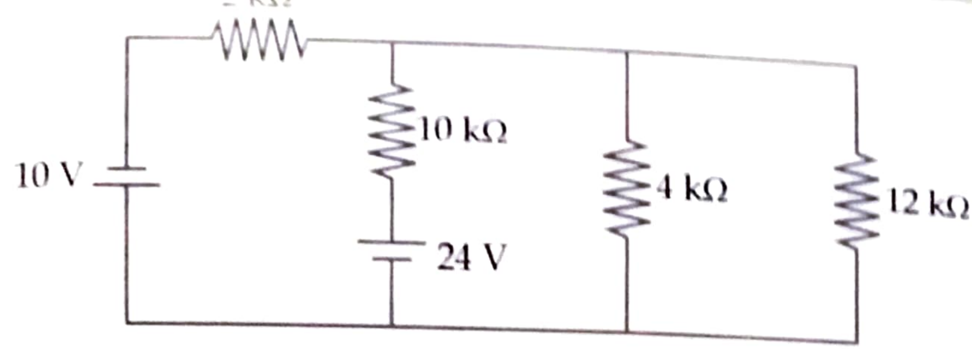


Figure (1)

We know that in superposition theorem, only one source is active and the remaining voltage sources are short circuited and current sources are open cirucited.

Now, keep only 10 V voltage source active and figure (1), will be modified as shown in figure (2).

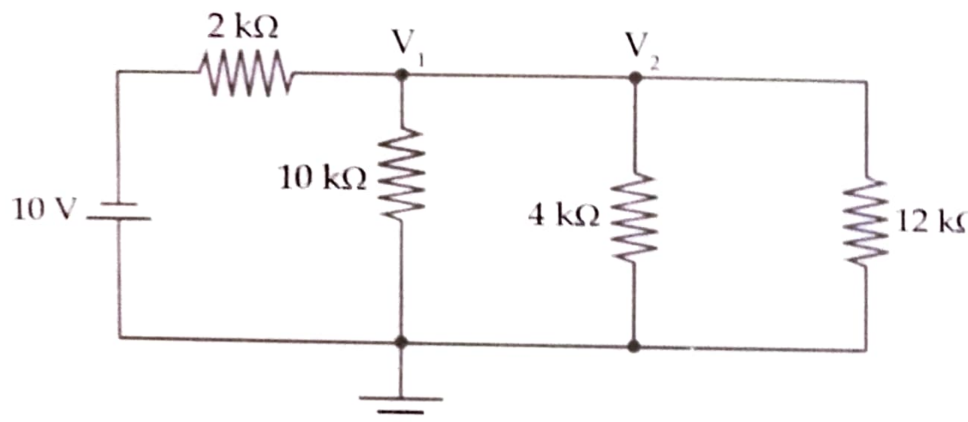


Figure (2)

Applying KCL at node 'V_1', we get,

$$\Rightarrow \quad \frac{V_1 + 10}{2K} + \frac{V_1}{10K} + \frac{V_1}{4K} + \frac{V_1}{12K} = 0$$

$$\Rightarrow \quad 30(V_1 + 10) + 6V_1 + 15V_1 + 5V_1 = 0$$

$$\Rightarrow \quad 30V_1 + 300 + 6V_1 + 15V_1 + 5V_1 = 0$$

$$\Rightarrow \quad 56V_1 = -300$$

$$\Rightarrow \quad V_1 = \frac{-300}{56} = -5.357 \text{ V}$$

Current 'I_1' is flowing through 4 kΩ resistor.

$$\Rightarrow \quad I_1 = \frac{V_1}{4K}$$

$$\Rightarrow \quad I_1 = \frac{-5.357}{4K} = -1.339 \text{ mA}$$

Now, keep only 24 V voltage source active and figure (1), will be modified as shown in figure (3).

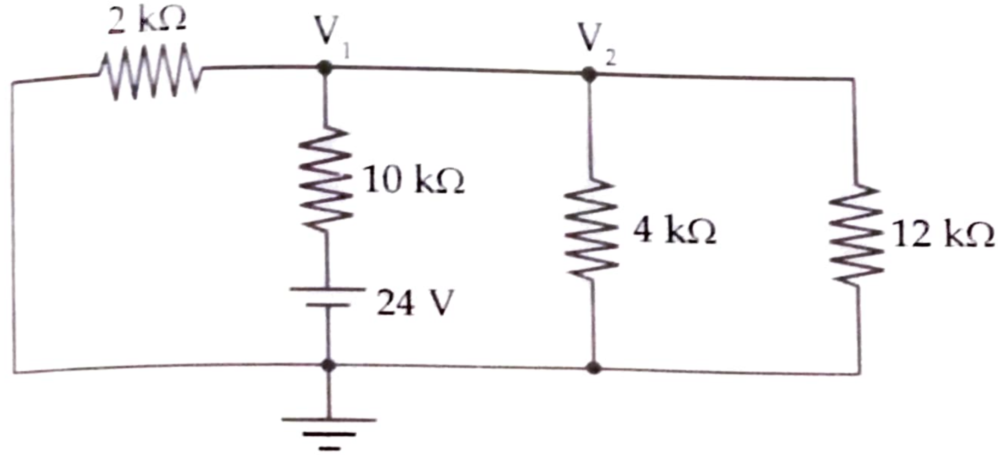


Figure (3)

Applying KCL at node 'V_2', we get,

$$\Rightarrow \quad \frac{V_2}{2K} + \frac{V_2 - 24}{10K} + \frac{V_2}{4K} + \frac{V_2}{12K} = 0$$

$$\Rightarrow \quad 30V_2 + 6(V_2 - 24) + 15V_2 + 5V_2 = 0$$

$$\Rightarrow \quad 30V_2 + 6V_2 - 144 + 15V_2 + 5V_2 = 0$$

$$\Rightarrow \quad 56V_2 = 144$$

$$\Rightarrow \quad V_2 = \frac{144}{56} = 2.571 \text{ V}$$

Current 'I_2' is flowing through 4 kΩ resistor 24 V voltage source is active.

$$\Rightarrow \quad I_2 = \frac{V_2}{4K}$$

$$\Rightarrow \quad I_2 = \frac{2.571}{4K}$$

$$\Rightarrow \quad I_2 = 0.642 \text{ mA}$$

Now, when both 10 V voltage source and 24 V voltage source are active the total current 'I', through 4 kΩ resistor is given as,

$$I = I_1 + I_2$$

$$= -1.339 \text{ mA} + 0.642 \text{ mA}$$

$$\therefore \quad I = -0.697 \text{ mA}$$

Ans : Given that,

Resisstor, $R = 10\ \Omega$

Inductor, $L = 10$ mH

Capacitor, $C = 10\ \mu$F

RMS current, $I_{RMS} = 0.2$ A

Supply frequency, $f = 10$ kHz

Also given that, all the above elements are connected in series. Hence, same current passes through them.

To determine,

RMS voltage, V_{rms} across all the elements = ?

We know that,

Angular frequency, $\omega = 2\pi f$

$$= 2 \times 3.14 \times 10 \times 10^3 \qquad [\because f = 10 \text{ kHz}]$$

$$= 62800 \text{ rad/sec}$$

Inductive reactance, $X_L = j\omega L$

$$= j(62800 \times 10 \times 10^{-3}) \qquad [\because L = 10 \text{ mH}]$$

$$X_L = 628j$$

Capacitive reactance, $X_C = \dfrac{1}{j\omega c}$

$$= \frac{1}{j(62800 \times 10 \times 10^{-6})} \qquad [\because c = 10\ \mu\text{F}]$$

$$X_C = -1.592j$$

RMS voltage drop across resistor, $V_{R(RMS)} = I_{rms} \times R$

$$= 0.2 \times 10 \qquad [\because I_{rms} = 0.2 \text{ A}]$$

$$\therefore \quad V_{R(RMS)} = 2 \text{ V}$$

RMS voltage drop across inductor, $|V_{L(RMS)}| = I_{rms} \times |X_L| = 0.2 \times 628$

$$\therefore \quad |V_{L(RMS)}| = 125.6 \text{ V}$$

RMS voltage drop across capacitor, $|V_{C(RMS)}| = I_{rms} \times |X_C| = 0.2 \times 1.592$

$$\therefore \quad |V_{C(RMS)}| = 0.3184 \text{ V}$$

Three phase AC Systems

R, Y, B

2 possible connections.

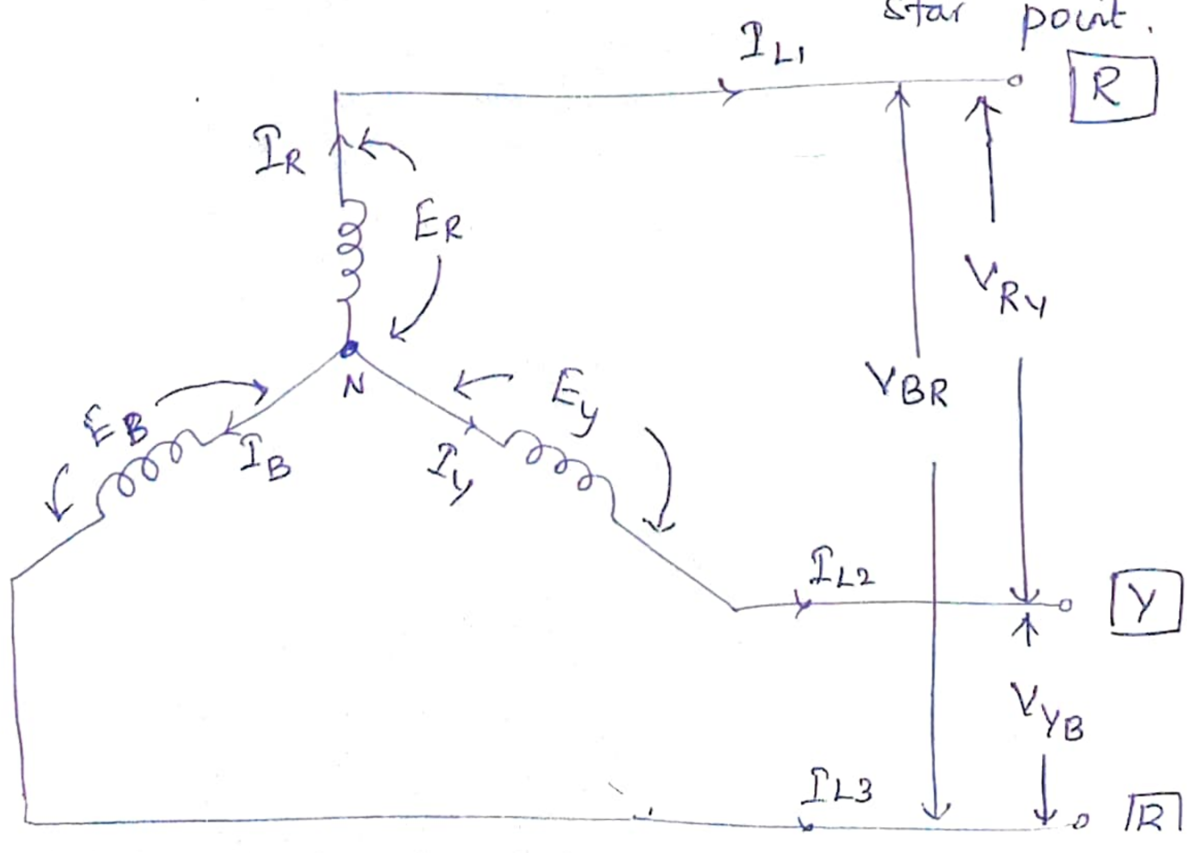
① Star (or) Y
② Delta (or) Mesh

} governed by characteristics equation relating to I & V.

* phasor diagram play a vital role.

STAR CONNECTION

↳ 3 similar ends are joined together
↳ common point
↳ Neutral point (or) Star point.



$I_R, I_Y, I_B \rightarrow$ Phase currents.

$I_{L1}, I_{L2}, I_{L3} \rightarrow$ Line currents.

$E_R, E_Y, E_B \rightarrow$ phase voltage.

$V_{RY}, V_{YB}, V_{BR} \rightarrow$ Line voltage.

<u>In a balanced</u> System

$$E_R = E_Y = E_B = E_P$$

$$V_{RY} = V_{YB} = V_{BR} = V_L$$

$$I_R = I_Y = I_B = I_P$$

$$I_{L1} = I_{L2} = I_{L3} = I_L$$

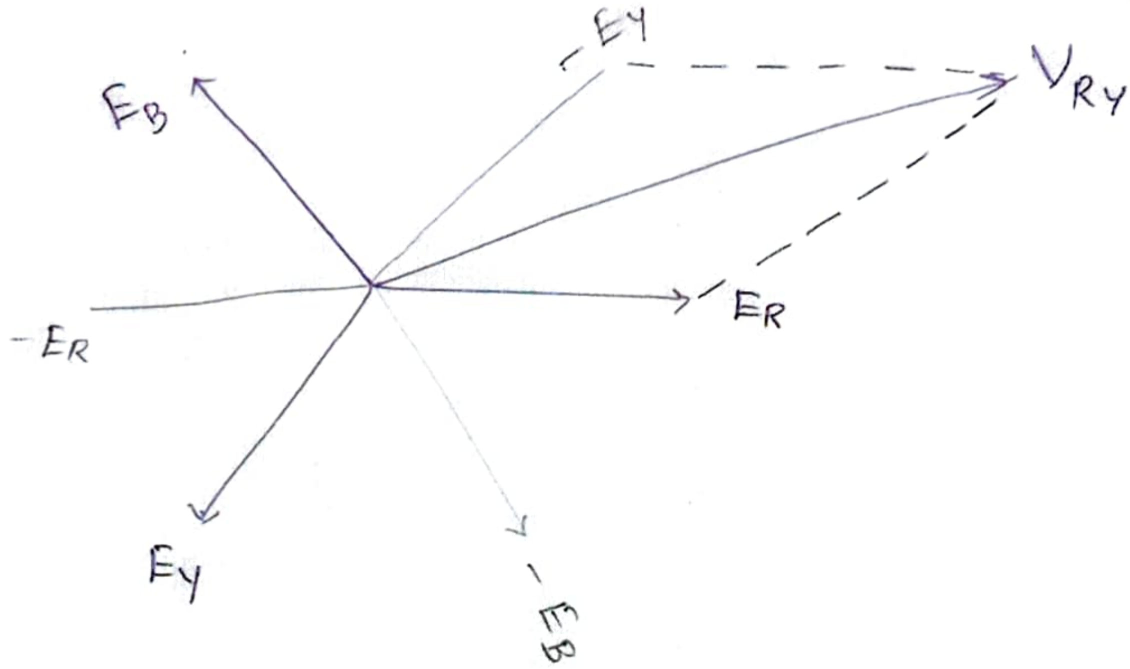
<u>Apply KCL</u>

$$I_R = I_{L1}$$

$$I_Y = I_{L2}$$

$$I_B = I_{L3}$$

Phase current = Line current



Apply KVL

$$E_R - E_y = V_{Ry}$$

$$V_{Ry} = \sqrt{E_R^2 + E_y^2 + 2 E_R E_y \cos 60^\circ}$$

$$= \sqrt{E_p^2 + E_p^2 + 2 E_p E_p \cos 60^\circ}$$

$\rightarrow 1/2$

$$= \sqrt{3 E_p^2}$$

$$V_{Ry} = \sqrt{3} E_p$$

Similarly

$$E_Y - E_B = V_{YB} \Rightarrow V_{YB} = \sqrt{3} E_p$$

$$E_B - E_R = V_{BR} \Rightarrow V_{BR} = \sqrt{3} E_p$$

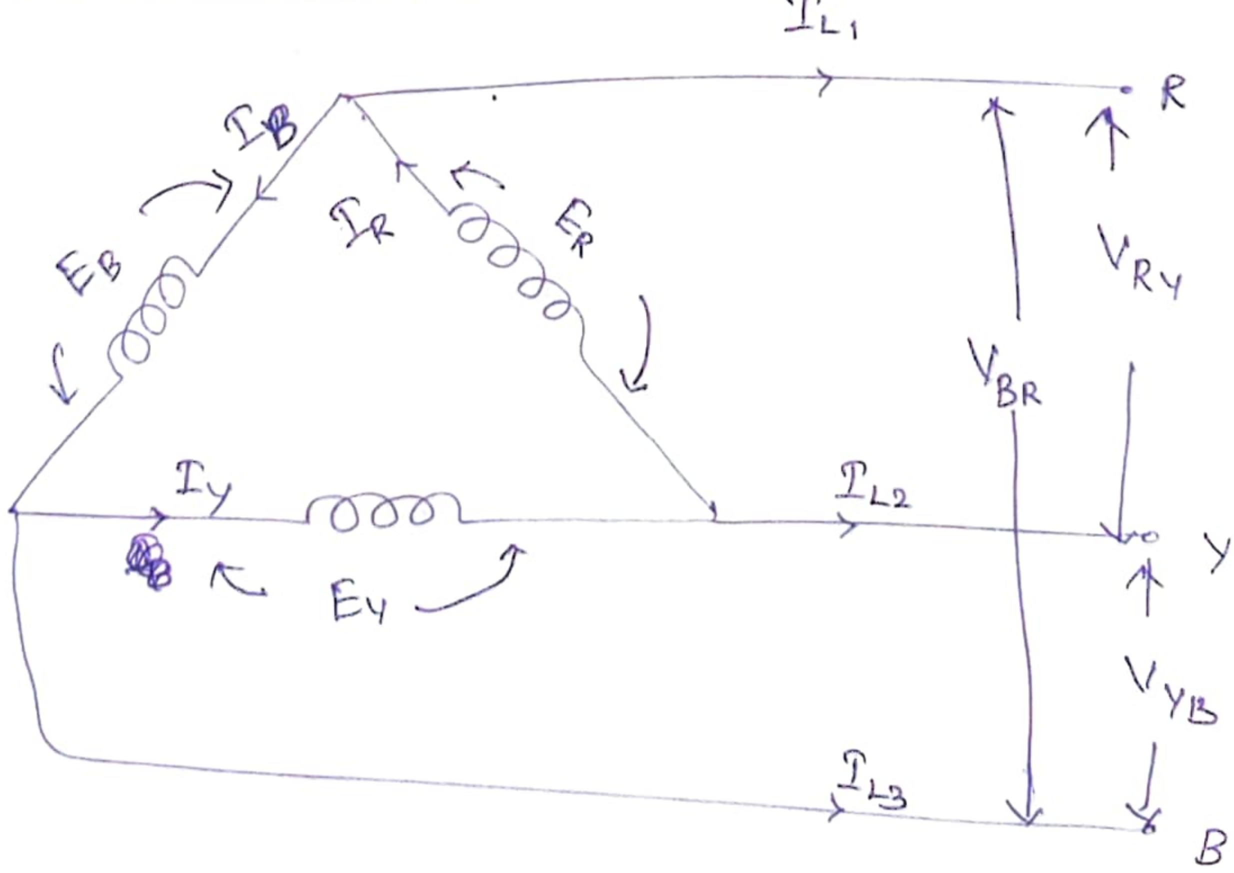
Thus

$$V_L = \sqrt{3}\ E_P$$

line voltage = $\sqrt{3}$ phase voltage.

$$\text{Phase voltage} = \frac{\text{Line voltage}}{\sqrt{3}}$$

DELTA CONNECTION



Dissimilar ends of 3 φ coils connected together. → Delta Δ connection.

$E_R, E_Y, E_B \rightarrow$ Phase voltages

$I_R, I_Y, I_B \rightarrow$ Phase currents.

$I_{L1}, I_{L2}, I_{L3} \rightarrow$ Line current.

$V_{RY}, V_{YB}, V_{BR} \rightarrow$ Line voltage.

In Balanced system

$$E_R = E_Y = E_B = E_P$$

$$I_R = I_Y = I_B = I_P$$

$$V_{RY} = V_{YB} = V_{BR} = V_L$$

$$I_{L1} = I_{L2} = I_{L3} = I_L$$

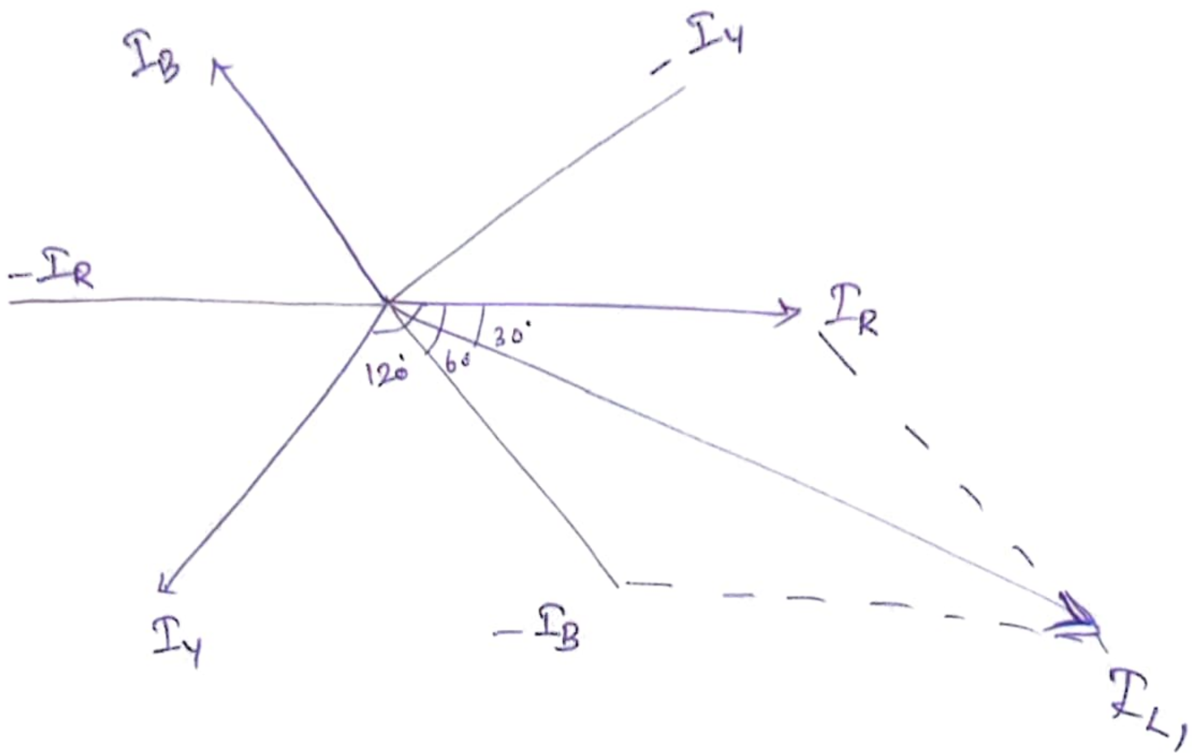
Apply KVL

$$E_R = V_{RY}$$

$$E_Y = V_{YB}$$

$$E_B = V_{BR}$$

Phase voltage = Line voltage



$$I_{L1} = \sqrt{I_R^2 + I_B^2 + 2 I_R I_B \cos 60°}$$

$$= \sqrt{I_p^2 + I_p^2 + 2 I_p I_p \cos 60°}$$

$$I_{L1} = I_p \sqrt{3}$$

Similarly $I_Y - I_R = I_{L2} \Rightarrow I_{L2} = \sqrt{3}\, I_p$

$I_B - I_Y = I_{L3} \Rightarrow I_{L3} = \sqrt{3}\, I_p$

$$I_L = \sqrt{3}\, I_p$$

Line current = $\sqrt{3}$ Phase current

$$\boxed{\text{Phase current} = \frac{\text{Line current}}{\sqrt{3}}}$$

Power relationship. ↳ $\cos\phi \rightarrow PF$.

Power / phase = $E_{ph} I_{ph} \cos\phi$.

Total power in all 3 phases $3 E_{ph} I_{ph} \cos\phi$.

Star

Total power = $3 E_p I_p \cos\phi$.

$$P = 3 \frac{V_L}{\sqrt{3}} I_L \cos\phi$$

$$\boxed{P = \sqrt{3} V_L I_L \cos\phi}$$

Delta

Total power = $3 E_p I_p \cos\phi$

$$= 3 V_L \frac{I_L}{\sqrt{3}} \cos\phi$$

$$\boxed{P = \sqrt{3} V_L I_L \cos\phi}$$

Similarly. Total reactive power $\sqrt{3} V_L I_L \sin\phi$

Total Apparent power. $\sqrt{3} V_L I_L$

Ans A 3-ϕ induction motor consist of two parts, they are the stator and the rotor. The principle of operation of a 3-ϕ Induction motor is just like a transformer. The only difference in 3-ϕ induction motor is the secondary i.e., rotor is not stationary but it is rotating.

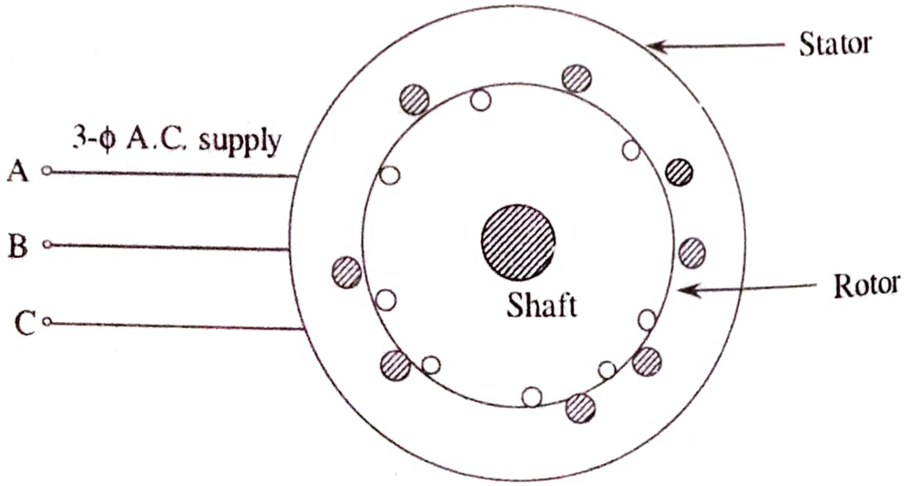
Whenever the stator (primary) of the 3-ϕ induction motor is fed from a 3-ϕ supply, a revolving magnetic field is set up which rotates at a speed called synchronous speed given as $N_s = 120f/p$. This rotating magnetic field passes through the air gap and cuts the rotor conductors. As the flux cuts the rotor conductors an e.m.f is inducted in it according to Faraday's law of electromagnetic induction. As the rotor circuit is closed, i.e., either permanently short circuited in case of squirrel cage IM or through external resistance in case of slip ring IM, a current is set up in the rotor circuit. Whose direction is given by Lenz's Law. It states that the direction of current produced is such that it opposes the every cause which is responsible to produce it. The relative speed between the rotor conductor and the rotating flux is the cause, hence, the rotor starts rotating in the same direction as that of rotating magnetic filed, i.e., N_s so as to reduce it. However, rotor cannot attain the synchronous speed and if it does so then the relative speed will be zero and the rotor will stop. Hence the actual speed of rotor is always less than the synchronous speed. This difference in speeds is expressed as slip and is given as,

$$\text{Slip, } s = \frac{N_s - N}{N_s}$$

$$\%\ s = \frac{N_s - N}{N_s} \times 100$$

Reason for Same Direction of R.M.F and Rotor

We know that whenever a 3-ϕ supply is expressed across the stator winding, flux is set up in it which is rotating at a speed of $N_s = \frac{120f}{p}$ which is known as synchronous speed. The flux is cut by the rotor conductor and hence, e.m.f and current is produced in it. The direction of current is such that it opposes the very cause, i.e., relative speed between r.m.f and rotor. Hence, so as to reduce the relative speed, the rotor rotates in the same direction as that of r.m.f



Figure

(b) A transformer is rated at 100 kVA. At full load is copper loss is 1200 W and its iron losses is 960 W. Calculate

(i) The efficiency at full load, UPF

(ii) Efficiency at half load, 0.8 p.f

(iii) The efficiency at 75% full load, 0.7 p.f lag

(iv) Load kVA at which maximum efficiency occurs.

Ans : Given that,

Rating of a transformer = 100 kVA

Full load copper loss, W_{cu} = 1200 W

Iron loss, W_i = 960 W

To find,

(i) The efficiency at full load, unity power factor

(ii) The efficiency at half load, 0.8 power factor

(iii) The efficiency at 75% of full load, 0.7 power factor

(iv) The load kVA at which maximum efficiency will occur.

(i) **Full Load Efficiency at Unity Power Factor**

We have,

$$\text{Output} = \text{Rating} \times \text{p.f} \times \text{Desired load}$$
$$= 100 \times 1 \times 1$$
$$= 100 \text{ kW}$$

$$\text{Total losses} = \text{Iron loss} + \text{Full load copper loss}$$
$$= W_i + W_{cu}$$
$$= 960 + 1200$$
$$= 2160 \text{ W}$$
$$= 2.16 \text{ kW}$$

$$\Rightarrow \quad \text{Input} = \text{Output} + \text{Losses}$$
$$= 100 + 2.16$$
$$= 102.16 \text{ kW}$$

$\therefore$ Efficiency,

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100$$
$$= \frac{100}{102.16} \times 100$$
$$= 97.88\%$$

(ii) **Efficiency at Half-load at 0.8 Power Factor**

$$\text{Output} = \text{Rating} \times p.f \times \text{Desired load}$$
$$= 100 \times 0.8 \times \frac{1}{2}$$
$$= 40 \text{ kW}$$

Iron loss,

$W_i = 960$ W (Same at all load)

Copper loss at half load,

$$W'_{cu} = \left(\frac{1}{2}\right)^2 \times \text{Full load copper loss}$$

$$= \left(\frac{1}{2}\right)^2 \times 1200$$

$$= 300 \text{ W}$$

$$\text{Total losses} = W_i + W'_{cu}$$

$$= 960 + 300$$

$$= 1260 \text{ W}$$

$$= 1.26 \text{ kW}$$

$$\Rightarrow \quad \text{Input} = \text{Output} + \text{Losses}$$

$$= 40 + 1.26$$

$$= 41.26 \text{ kW}$$

∴ Efficiency,

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100$$

$$= \frac{40}{41.26} \times 100$$

$$= 96.95\%$$

(iii) Efficiency at 75% of Full Load, 0.7 Power Factor

$$\text{Output} = \text{Rating} \times p.f \times \text{Desired load}$$

$$= 100 \times 0.7 \times 0.75$$

$$= 52.5 \text{ kW}$$

$$\text{Iron loss} = 960 \text{ W}$$

Copper loss at 75% of full load,

$$W''_{cu} = (0.75)^2 \times \text{Full load copper loss}$$

$$= (0.75)^2 \times 1200$$

$$= 675 \text{ W}$$

$$\text{Total losses} = W_i + W''_{cu}$$

$$= 960 + 675$$

$$= 1635 \text{ W}$$

$$= 1.635 \text{ kW}$$

$$\text{Input} = \text{Output} + \text{Losses}$$

$$= 52.5 + 1.635$$

$$= 54.135 \text{ kW}$$

$\therefore$ Efficiency,

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100$$

$$= \frac{52.5}{54.135} \times 100$$

$$= 96.98\%$$

(iv) Load kVA at Which Maximum Efficiency Occurs

Load kVA corresponding to maximum efficiency is given by,

$$\text{Load kVA} = \text{Full load kVA} \times \sqrt{\frac{\text{Iron loss}}{\text{Full load copper loss}}}$$

$$= 100 \times \sqrt{\frac{960}{1200}}$$

$$= 89.44 \text{ kVA}$$

Q5. (a) **Describe the construction and working of capacitor start capacitor run induction motor and list out is applications.**

Ans : As single-phase induction motors are not self-starting, there should be some means to start them. Capacitor start capacitor run induction motor is also known as two-value capacitor run motor.

One of the methods of splitting the single-phase supply into two-phase is by using the following arrangement of the 1-ϕ induction motor.

Two-value Capacitor Run Motor

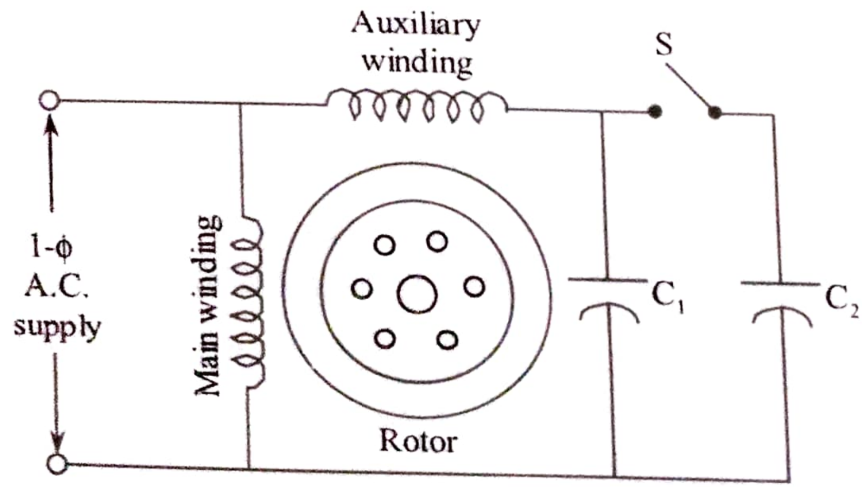


Figure (1): Two-value Capacitor Run Motor

Figure (1) shows the circuit diagram of a two-value capacitor run motor supplied by single-phase supply. It consists of main winding, auxiliary winding, two capacitors C_1, C_2 and switch 'S'. It is similar to the single value capacitor run motor. But the main difference here is the auxiliary winding and a capacitor C_1, are always connected in the circuit. The main function of capacitor C_2, is that, it helps to start the motor. For this purpose, it is called the start capacitor and capacitor C_1 is called the run capacitor. It improves the power factor of the motor. In general, the starting capacitor C_2 is about 10 to 15 times as large as running capacitor C_1. At the time of starting, the centrifugal switch 'S' is closed, both capacitors C_1 and C_2 are in parallel and the total capacitance is the sum of their individual capacitance. After the motor reaches to 75% of the full-load speed the switch is opened, the only capacitor C_1 is present in the auxiliary winding circuit. In this way, best starting performance with high capacitance and best running performance (best torque condition) with low capacitance is achieved. Such motors produce continuous torque thereby reducing the pulsating torques.

By means of the two-value capacitor run motor, it is possible to obtain phase shift (β) equal to 90°. Run capacitor C_1 and auxiliary winding can be designed in such a way that they provide balanced two-phase field. Balanced two-phase field avoids backward rotating field and improves the power factor and efficiency of the motor.

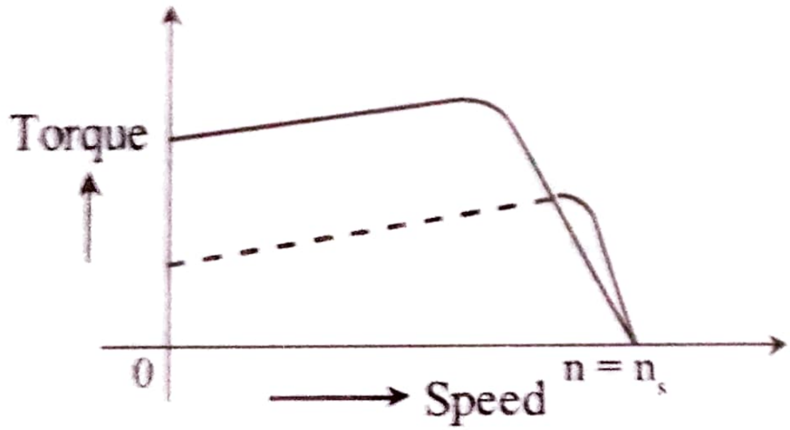


Figure (2): Torque-Speed Characteristics

The torque-speed characteristics of two-value capacitor run motor is shown in figure (2). From the characteristics it can be observed that, when auxiliary winding is used with the main winding, improved torque is obtained.

Applications of Capacitor Start Capacitor Run Induction Motor

1. They are used for high inertia loads such as pumps, compressors, conveyer etc which requires frequent start operation.
2. They are used in places like hospitals, studios etc because they do not produce any noise during running conditions.

(b) A 8 pole lap wound D.C. Generator has 120 slots having 4 conductors per slot. If each conductor can carry 250 A and if flux/pole is 0.05 wb, Calculate the speed of generator for giving 240 V on open circuit. If the voltage drops to 220 V on full load, find the rated output of the machine.

Ans : Given that,

A lap wound D.C generator

No. of poles, $P = 8$

Since it is a lap wound generator. Therefore No. of parallel paths in armature, $A = P = 8$

No. of slots = 120

No. of conductors/slot = 4

Current across each condcutor, I = 250 A

Flux, ϕ = 0.05 Wb

Generated voltage, E_g = 240 V

Full load voltage, V = 220 V

To determine,

(i) Speed of the generator, N = ?

(ii) Rated output of the machine, P = ?

(i) **Speed of Generator**

The EMF equation of a DC generator is given as,

$$E_g = \frac{P\phi ZN}{60A} \quad \text{... (1)}$$

Since, we know that,

The total number of conductors, Z = number of slots × number of conductors/slot

$\therefore \quad Z = 120 \times 4 = 480$

Substitute given values in equation (1), we get,

$$\Rightarrow \quad 240 = \frac{8 \times 0.05 \times 480 \times N}{60 \times 8}$$

$$\Rightarrow \quad N = \frac{240 \times 60}{480 \times 0.05} = 600 \text{ rpm}$$

$\therefore$ Speed, N = 600 rpm

(ii) **Rated Output of the Machine**

The total current at full-load, I = Current in each parallel path × No. of parallel paths = 250 × 8 = 2000 A [$\because$ No. of parallel paths = 8]

The rated of the machine, $P = V \times I = 220 \times 2000$

= 440000 W

= 440 kW

(b) A 440 V, 3 phase, 50 Hz supply is fed to three coils, star connected each having a resistance of 25 Ω and an inductive reactance of 20 Ω. Calculate (a) line current (b) power factor (c) power supplied.

Ans : Given that,

A 3-phase star connected network

Line voltage, $E_L = 440$ V

Frequency, $f = 50$ Hz

Resistance per phase, $R_{ph} = 25\ \Omega$

Reactance per phase, $X_{ph} = 20\ \Omega$

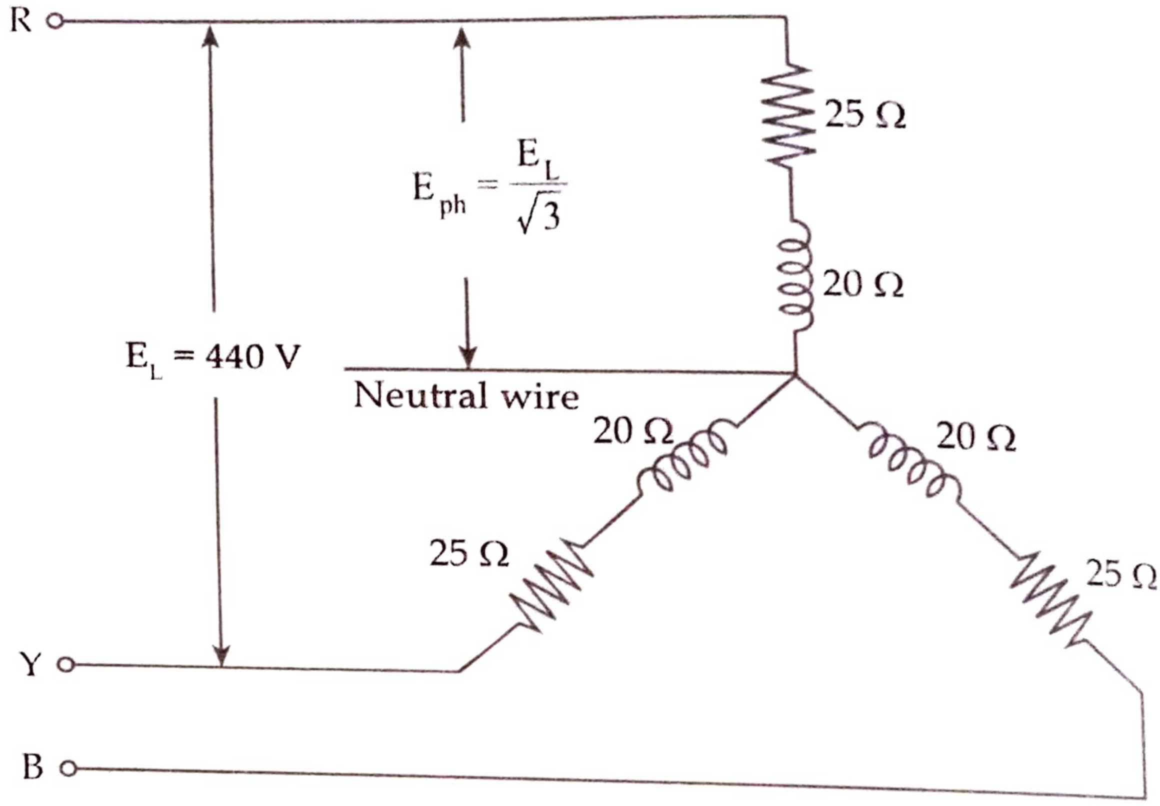
To determine,

(i) Line current = ?

(ii) Power factor = ?

(iii) Power supplied = ?

The 3-phase star connected network is shown in figure.



Figure

Impedance per phase is given by,

$$Z_{ph} = \sqrt{R_{ph}^2 + X_{ph}^2}$$

$$= \sqrt{(25)^2 + (20)^2}$$

$$= 32\ \Omega$$

Phase voltage, $E_{ph} = \frac{E_L}{\sqrt{3}} = \frac{440}{\sqrt{3}} = 254$ V

Phase current, $I_{ph} = \frac{E_{ph}}{Z_{ph}} = \frac{254}{32} = 7.93 \simeq 8$ A

(i) **Line Current**

We know that, in star connection

Line current = Phase current

$\therefore$ Line current, $I_L = I_{ph} = 8$ A

(ii) **Power Factor**

$$\text{Power factor, } \cos\phi = \frac{R_{ph}}{Z_{ph}} = \frac{25}{32} = 0.78 \text{ (lag)}$$

(iii) **Power Supplied**

$$\text{Power, } P = \sqrt{3}\, E_L I_L \cos\phi$$

$$= \sqrt{3} \times 440 \times 8 \times 0.78$$

$$= 4755.5 \text{ W}$$

Q32. Exp...

Ans : The process of connecting non-current carrying metal parts of an electrical systems to earth is known as earthing of electrical equipment or equipment earthing. The need of earthing of electrical equipments is explained as follows,

1. **Protection from Shocks:** Earthing provides safety against electric shocks to any person or animal when they are in contact with the metal parts. Though some of the systems have fuses or circuit breakers for protection from the fault current or short circuit, the person may receive a shock at the operating point of fuse or breaker. Thus, earthing is necessary for the protection against shock.

2. **Controls Constant Line Voltage:** Earthing controls the constant line voltage in unbalanced load condition.

3. **Prevention of Equipment from Damage:** Without earthing the parts of the electrical equipment may damage either due to fault currents short circuits or the undetected part which causes fire.

4. **Protection against Lightning:** Earthing guards the buildings, towers, machines which are supplied from overhead transmission lines against lightning and thunder storms. Lightning arises because the surge current follows the path of two or more ground connections. The conductors of the lightning must have direct connection to earth in order to prevent from lightning.

5. **Achieves Required Performance:** The earthing installations ensure the desired performance of the earthing systems. It is cost effective process and achieves reliable and improved service. It also provides a drainage path for the currents which are undesirable.

Construction : Plate earthing consists of G.I plate or copper plate with nuts and bolts, charcoal, salt and earth wire. The size of the copper plate is (60 × 60 × 0.318) cm and the size of the G.I plate is (60 × 60 × 0.63) cm. The copper plates are efficient earth electrodes and are independent of the soil moisture. But G.I plate is more commonly used because of high material cost. For copper plate, the nuts and bolts should be made of copper whereas for G.I plate it should be made of galvanized iron. G.I pipe is also used in the construction with a funnel at its top. The cast iron frame with cement work used at the top of the G.I pipe to avoid from watering arrangement. The set up of plate earthing is shown in figure.

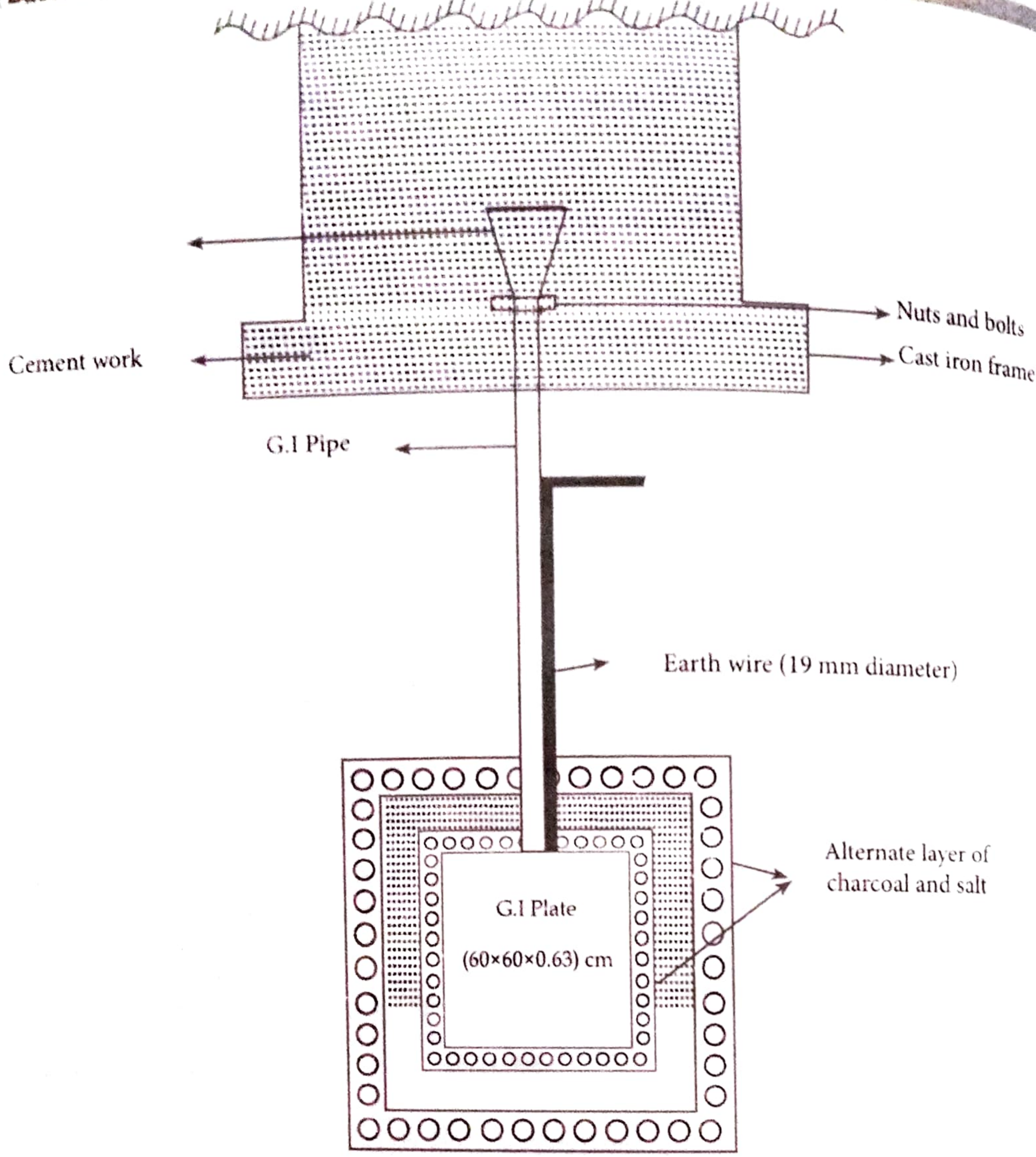


Figure: Plate Earthing

Working : Select the location for plate earthing. Make a hole in the soil of particular depth as per the requirement. The depth is usually not less than 3 m. The plate is then inserted vertically into the hole. Then the alternate layer of charcoal and salt is arranged in the surrounding area of G.I plate. Each layer is minimum of 15 cm in thickness. The mixture of charcoal and salt reduces the resistance of the earth. The earth wire is inserted in the soil through the G.I pipe and gets attached to G.I plate which is of 19 mm diameter and 60 cm below the soil. For performance of the earthing system, salt water is poured into the pipe through funnel periodically. The efficiency of the earthing increases with an increase in the cross-sectional area and depth of the plate. This method cannot check the performance by continuity tests.

Ans : The low power factor in a system not only makes the system un-economical but also reduces the life of the system. The effects of low power factor in a system are listed below.

1. **Effect on Generators :** For low power factor, the kVA and kW capacities of the generators are lowered and for same amount of power, large kVA rating generators are required i.e., the exciter should supply more power. Moreover, the losses of the generators will be increased due to which their efficiency will be decreased.

2. **Effect on Prime Mover :** In a system if the power factor is decreased, then the wattles power generated by the alternator will increase i.e., the alternator develops more reactive kVA, but the alternator requires certain amount of energy to generate this wattless power and the energy is supplied by the prime mover. This means that a part of the prime mover capacity is idle and it represents dead invest. Also the efficiency of the prime mover will be decreased at low power factors.

3. **Effect on Transmission Lines :** At low power factors, the transmission lines will have to carry more current for the same power to be transmitted and if the line's must carry more current then the cross sectional area of the lines should be increased, which inturn increases the capital cost of the lines. The line losses will increase for the increase in current and the efficiency of the line will be decreased.

4. **Effect on Transformer :** If the power factor is decreased, then there will be a decrease in the kW capacity of the transformer. Hence the voltage in it will be increased.

5. **Effect on Switch Gear and Busbars :** For the same amount of power to be delivered at low power factor, the cross sectional area of the busbar must be increased and the contact surface area of the switch gear should be enlarged.

6. **Effect on Voltage Regulation :** In alternators, transmission lines, transformers and distributors, the large current at low lagging power factor causes very high voltage drops which leads to decrease in voltage at the consumer end and this may damage the devices at the consumer end. In order to overcome this, separate device such as voltage regulator is required, which further increases the cost of the system.