Oral Questions

Chapter 1 : DC Circuits

Q. 1 Write the expression for current in a parallel combination.

Ans. :

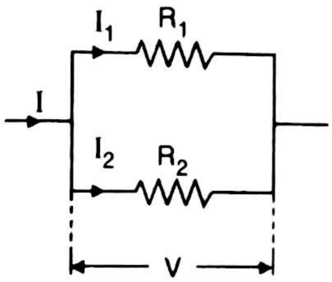


Fig. 1.1

$$V = I_1 R_1$$

Also, $$V = I R_{eq} \qquad \therefore \quad V = I\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

$$\therefore \quad I_1 R_1 = I\left(\frac{R_1 R_2}{R_1 + R_2}\right)$$

$$\therefore \quad I_1 = \frac{IR_2}{R_1 + R_2}, \quad \text{Similarly } I_2 = \frac{I R_1}{R_1 + R_2}$$

Q. 2 What is the internal resistance of an Ammeter and what should it be replaced with Short circuit or Open Circuit ?

Ans. : 0 Ω (Short circuit)

Q. 3 What is the internal resistance of an Voltage source and what should it be replaced with Short circuit or Open Circuit ?

Ans. : 0 Ω (Short circuit)

Q. 4 What is the internal resistance of Voltmeter and what should it be replaced with Short circuit or Open Circuit ?

Ans. : ∞ Ω (Open circuit)

Q. 5 What is the internal resistance of an Current Source and what should it be replaced with Short circuit or Open Circuit ?

Ans. : ∞ Ω (Open circuit)

Q. 6 Write the expressions for star connected resistors in terms of delta connected resistors.

Ans. :

$$\therefore \quad R_1 = \frac{R_{12}\ R_{31}}{R_{12} + R_{23} + R_{31}}; \quad R_2 = \frac{R_{12} R_{23}}{R_{12} + R_{23} + R_{31}} \quad \text{and} \quad R_3 = \frac{R_{23} R_{31}}{R_{12} + R_{23} + R_{31}}$$

Q. 7 Write the expressions for delta connected resistors in terms of star connected resistors.

Ans. : $$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1} \quad \text{and} \quad R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2}$$

Q. 8 State Kirchhoff's laws.

Ans. :

KCL (Kirchhoff's Current Law)

KCL states that a junction or a node cannot store energy, hence the algebraic sum of currents at any junction is equal to zero i.e., (incoming current = outgoing current). Node is a point where three or more connections meet. Mathematically this can be expressed as :

$$\sum_{\text{Node n}} \text{Currents entering node n} = \sum_{\text{Node n}} \text{Current coming out of node n}$$

KVL (Kirchhoff's Voltage Law)

KVL states that the algebraic sum of voltages and potential drop in a closed loop is equal to zero. i.e. , if one starts from a point in a circuit travels through any path but comes back to the same point adding all the voltages and potential drops, the sum will be equal to zero. Mesh or loop is defined as a set of branches forming a closed path. This is mathematically expressed as :

$$\sum_{\text{loop}} \text{Voltage across the elements} = 0$$

Q. 9 State Superposition Theorem.

Ans. : Superposition theorem states that current through a branch with multiple sources acting simultaneously is equal to the algebraic sum of the currents flowing through that branch with one of the source acting at a time and remaining sources replaced by their internal resistance.

Q. 10 State Thevenin's Theorem.

Ans. : Thevenin's theorem states that any complex network with multiple sources as seen by the load resistance can be replaced with a voltage source in series with a resistance

where, the voltage source (V_{oc} or V_{TH})) is the voltage between open circuited terminals of R_L and

R_{oc} (or R_{TH}) is the resistance across the open circuited R_L.

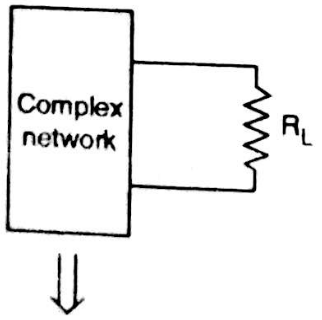


Fig. 1.2 : Complex network

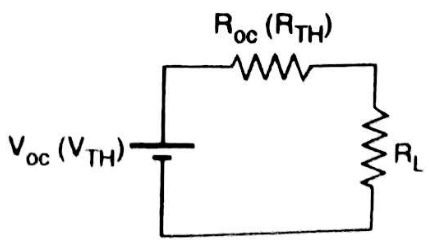


Fig. 1.3 : Thevenin's equivalent circuit

$$I_{RL} = \frac{V_{oc}}{R_{oc} + R_L}$$

Q. 11 How to find Thevenin's Voltage source value ?

Ans. :

1. Open circuit R_L (load resistance i.e. the resistance through which the current is to be found) and name its nodes as A and B.
2. Use mesh analysis to find the loop current.
3. Find V_{AB} (i.e. V_{oc} or V_{TH}) using KVL.

Q. 12 How to find Thevenin's Resistance ?

Ans. :

1. Open circuit R_L and name the terminals as A and B and also replace the sources by their internal resistance.
2. Find R_{AB} (R_{oc}).

Q. 13 State Norton's Theorem.

Ans. : Norton's theorem states that any complex network with multiple sources can be replaced with a current source (I_N or I_{SC}) in parallel with a resistance (R_N or R_{OC}).

where, I_{sc} is the current through the short circuit path of R_L and, R_{oc} is the resistance across the open circuited R_L.

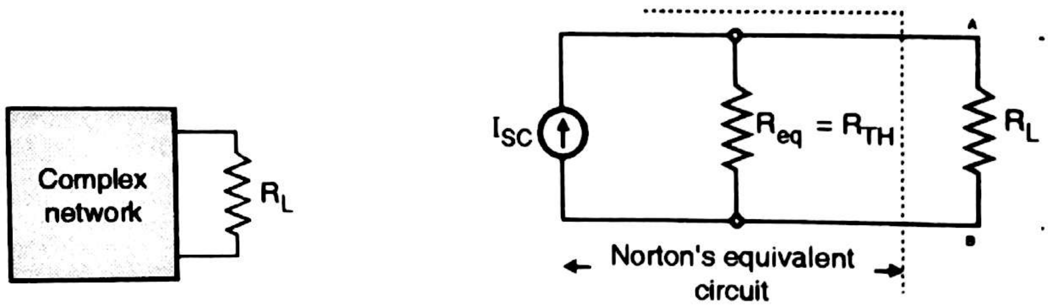
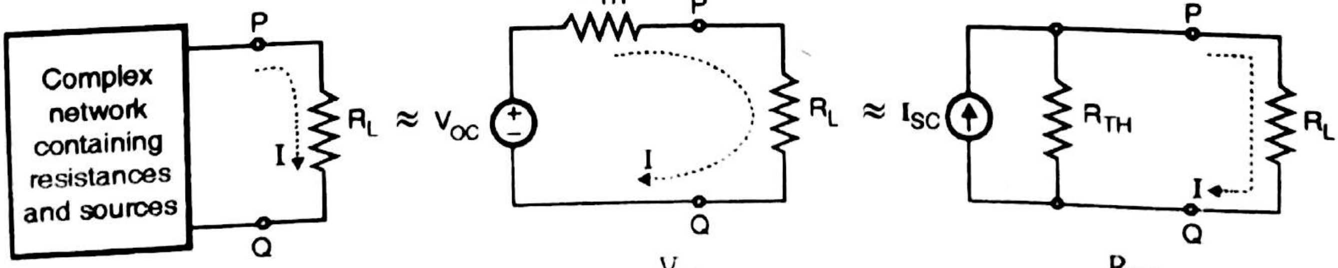


Fig. 1.4 : Norton's equivalent circuit

Q. 14 Explain the relationship between the Thevenin's and Norton's equivalent Circuit.

Ans. : The Thevenin's and Norton's theorems are called as the equivalent circuit theorems. The Norton's equivalent circuit can be derived from the Thevenin's equivalent circuit as shown in Fig. 1.5.



$$I = \frac{V_{OC}}{(R_{TH} + R_L)}$$

$$I = \frac{R_{TH}}{R_L + R_{TH}} \times I_{SC}$$

(a) Given network (b) Thevenin's equivalent (c) Norton's equivalent

Fig. 1.5

Thus $I_{SC} = \frac{V_{OC}}{R_{TH}}$ or $V_{OC} = I_{SC} \times R_{TH}$

By using these transformation equations we can obtain the Norton's equivalent circuit from the Thevenin's equivalent circuit.

Q. 15 Explain the relationship between the Thevenin's and Norton's resistance.

Ans. : They are same.

Q. 16 How to find Norton's current source value ?

Ans. :

I. Short circuit the load resistance and mark the terminals A and B.

II. Use mesh analysis to find the loop currents

III. Find I_{AB} or I_{SC} using the loop currents.

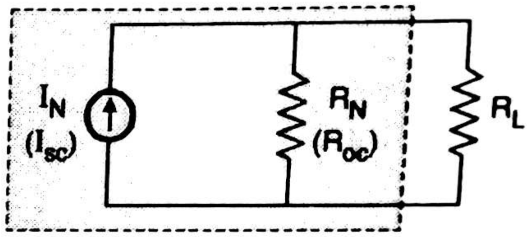


Fig. 1.6

Q. 17 How to find Norton's Resistance ?

Ans. :

1. Open circuit R_L and name the terminals as A and B and also replace the sources by their internal resistance.
2. Find R_{AB} (R_{oc}).

Q. 18 State the maximum power transfer theorem.

Ans. : Maximum power transfer theorem states that "For maximum power to be dissipated in R_L, R_L should be equal to R_{OC}".

Q. 19 Prove Maximum power transfer theorem.

Ans. :

Proof :

We know, $I_{RL} = \frac{V_{OC}}{R_{OC} + R_L}$

$$P_{RL} = I_{R_L}^2 \times R_L = \frac{V_{OC}^2}{(R_{OC} + R_L)^2} \times R_L$$

For, P_{max}, $\frac{d}{d R_L} (P_{RL}) = 0$

$$\therefore \quad \frac{d}{d R_L} \left[\frac{V_{OC}^2 \times R_L}{(R_{OC} + R_L)^2} \right] = 0$$

$$V_{OC}^2 \times \frac{d}{d R_L} \left[\frac{R_L}{(R_{OC} + R_L)^2} \right] = 0$$

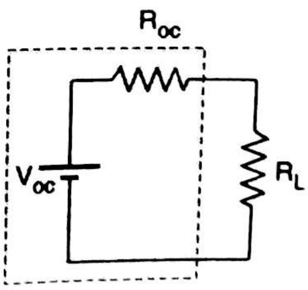


Fig. 1.7 : Thevenin's Equivalent Circuit

$$\therefore \frac{d}{d R_L}\left[R_L (R_{OC} + R_L)^{-2} \right] = 0$$

$$\therefore \left[\frac{-2 R_L}{(R_{OC} + R_L)^3} + \frac{1}{(R_{OC} + R_L)^2} \right] = 0$$

$$\therefore \left[\frac{-2 R_L + 1 (R_{OC} + R_L)}{(R_{OC} + R_L)^3} \right] = 0$$

$$\therefore -2 R_L + R_{OC} + R_L = 0 \qquad \therefore \mathbf{R_L = R_{OC}}$$

Q. 20 What is the node voltage if there is a voltage source between a node and the reference node ?

Ans. : The node voltage is equal to the value of such a voltage source

Q. 21 What is a supermesh?

Ans. : In case there is a current source in the common arm of two minor loops, it is called as a supermesh.

Q. 22 How to solve supermesh ?

Ans. : KVL is taken across the major loop or the supermesh in such case and the current in the common arm gives another equation.

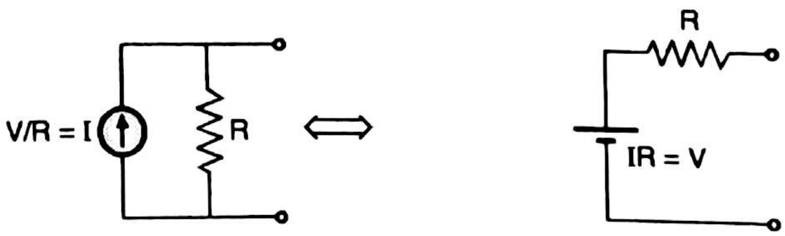
Q. 23 What is a supernode ?

Ans. : In case there is a voltage source between two nodes, it is called as a supernode.

Q. 24 Explain the formula for voltage to current source transformation.

Ans. :

The relationship of the resistor, current source and voltage source is as showing in Fig. 1.8.



(a) (b)

Fig. 1.8

Chapter 2 : AC Circuits

Q. 1 What are the advantages of AC signal over DC signal ?

Ans. :

Advantages

1. Transmitting AC signal at a long distance is easy and cheaper compared to the DC signal.

2. AC signal is comparatively safer to handle than equivalent DC signal.
3. Some devices that work on Faraday's law require AC signal.

Q. 2 **Explain with examples steady state DC, pulsating DC, and AC.**

Ans. : Steady state DC signal is one which has constant magnitude.

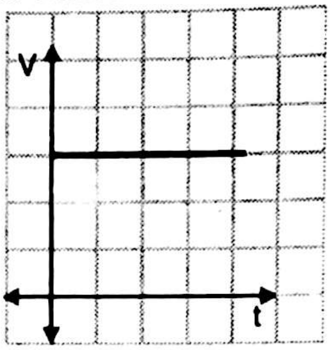
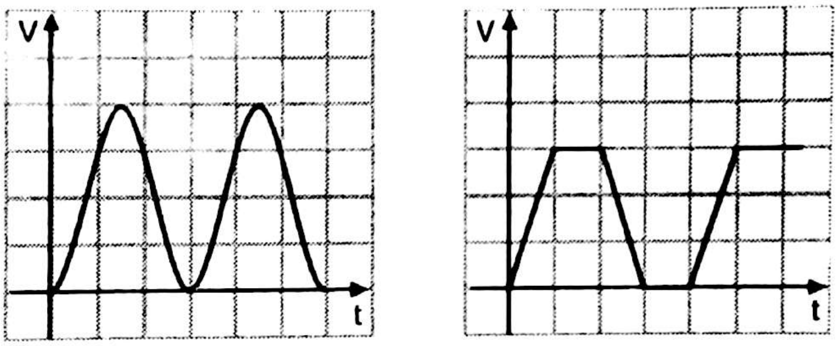


Fig. 2.1 : Constant DC signal or steady state DC

Pulsating DC

It is a signal which has the same polarity throughout but varying magnitude.

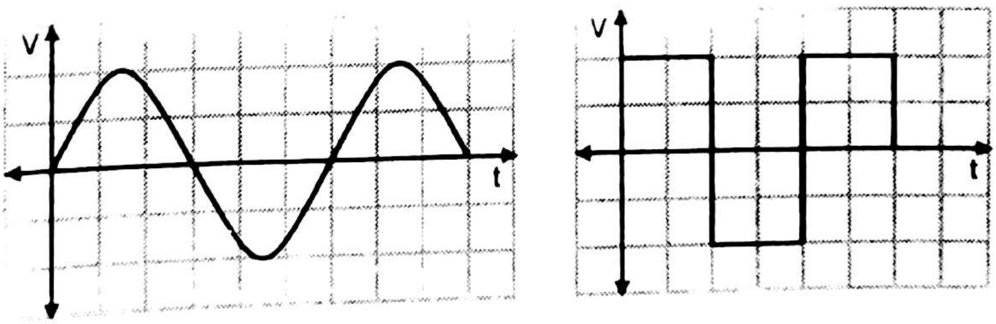


(a) (b)

Fig. 2.2 : Pulsating DC

Alternating signal (AC signal)

It is a signal whose polarity alternates at regular interval.



(a) (b)

Fig. 2.3

Q. 3 Give the mathematical expression of sinusoidal AC signal.

Ans. :

$$e = E_m \sin(\omega t + \phi)$$

Where, E_m is the peak value or maximum value of the signal, ϕ is the phase angle and ωt is the time angle.

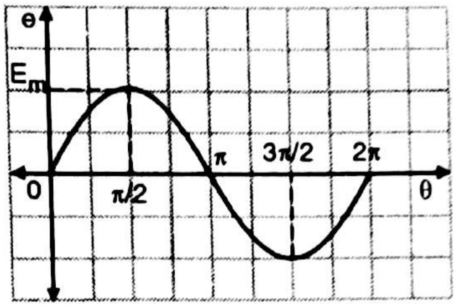


Fig. 2.4

Q. 4 Explain with diagram and mathematical representation the leading and lagging signal.

Ans. :

Case I :

$\phi = \pi/2$

$e = E_m \sin(\theta + \pi/2)$

Leading

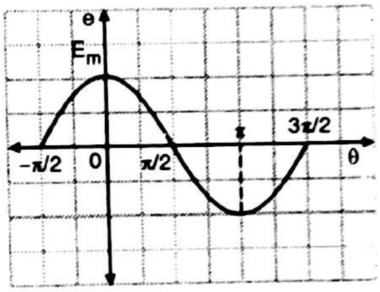


Fig. 2.5

Case II :

$\phi = -\pi/2$

$e = E_m \sin\left(\theta - \frac{\pi}{2}\right)$

Lagging

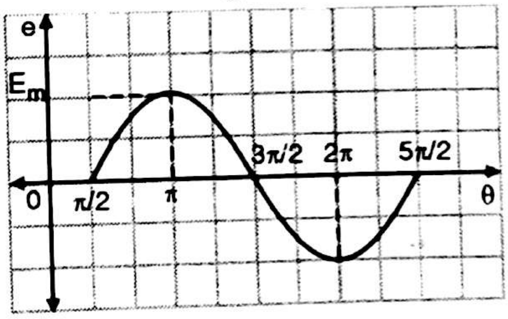


Fig. 2.6

Q. 5 Define Waveform.

Ans. : It is a graphical representation of an electrical quantity on y-axis with time or time angle on X-axis.

Q. 6 Define cycle.

Ans. : It is one repeat of a repetitive signal. For an AC signal, it can be said as one set of all positive and negative value.

Q. 7 Define Time Period(T).

Ans. : It is the time required for one cycle of a repetitive signal.

Q. 8 Define Frequency (in Hz).

Ans. : It is the number of cycles in 1 second.

$$f = \frac{1}{T}$$

Q. 9 Define Amplitude.

Ans. : It is the maximum or peak value obtained by a signal.

Q. 10 Define R.M.S. value and give its mathematical expression.

Ans. : It is that steady state equivalent DC which when flowing through a given circuit for a given amount of time produces the same energy as produce by the AC signal when flowing through the same circuit for the same amount of time.

$$I^2 R\cancel{t} = \frac{i_1^2 R\cancel{t}}{n} + \frac{i_2^2 R\cancel{t}}{n} + \ldots + \frac{i_n^2 R\cancel{t}}{n}$$

$$\therefore \quad I = I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt}$$

Q. 11 Define Average value and give its mathematical expression.

Ans. :

It is defined as that steady state equivalent DC which when flowing a given circuit for a given amount of times produces the same amount of charge as produced by the AC signal when flowing through the same circuit for some amount of time.

$$I_{avg} = \frac{1}{T}\int_0^T i(t)\,dt$$

Q. 12 Define Form factor.

Ans. : It is the ratio of rms value to average value of a given signal,

$$K_F = \left|\frac{\text{Rms value}}{\text{Average value}}\right| \geq 1$$

Q. 13 Define Peak factor.

Ans. : It is the ratio of peak value to RMS value of a given signal,

$$K_P = \left|\frac{\text{Peak value}}{\text{Rms value}}\right| \geq 1$$

Q. 14 Give the RMS value, average value, form factor and peak factor of sinusoidal waveform.

Ans. :

$$V_{avg} = 0.637\ V_m$$

$$V_{rms} = 0.707\ V_m$$

$$\text{Form factor } (K_F) = \frac{\text{Rms value}}{\text{Avg. value}} = \frac{0.707}{0.637} = 1.11$$

$$\text{Peak factor } (K_p) = \frac{\text{Peak}}{\text{Rms}} = \frac{1}{0707} = 1.414$$

Q. 15 Where is the leading phasor to be drawn, clockwise or anti-clockwise ?

Ans. : A leading signal (i.e. with + ve phase angle) is taken anti-clockwise.

Q. 16 Where is a lagging phasor to be drawn, leading or lagging ?

Ans. : A lagging signal (i.e., with – ve phase angle) is taken clock-wise.

Q. 17 What is taken as reference for drawing the phasor diagram in series connection ?

Ans. : For a series circuit, current is considered as reference and the voltage phasors are plotted.

Q. 18 What is taken as reference for drawing the phasor diagram in parallel connection?

Ans. : For a parallel circuit, voltage is considered as reference and current phasors are plotted

Q. 19 Write the current equation of a resistor.

Ans. :

$$i = \frac{v}{R} = \frac{V_m \sin \omega t}{R} = I_m \sin \omega t \qquad \text{where,} \qquad I_m = \frac{V_m}{R}$$

Q. 20 Derive the expression of power for a resistor.

Ans. :

$$P_{avg} = \frac{1}{\pi}\int_0^{\pi} \frac{V_m I_m}{2}(1-\cos 2\theta)\cdot d\theta$$

$$= \frac{V_m I_m}{2\pi}\left[\theta - \frac{\sin 2\theta}{2}\right]_0^{\pi} = \frac{V_m I_m}{2\pi}(\pi) = \frac{V_m I_m}{2} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}} = V_{rms}\, I_{rms}$$

$$\therefore \; P = VI = I^2 R = \frac{V^2}{R}$$

Q. 21 What is the phase angle between the voltage and current of a resistor ?

Ans. : Angle between the voltage and current or angle of opposition.

$$\phi = 0$$

Q. 22 Derive the expression for current of an inductor ?

Ans. :

$$v = L\frac{di}{dt}$$

$$\therefore \; i = \frac{1}{L}\int v \cdot dt = \frac{1}{L}\int V_m \cdot \sin \omega t \cdot dt$$

$$= \frac{V_m}{L}\left(\frac{-\cos \omega t}{\omega}\right) = \frac{-V_m}{\omega L}\left[\sin\left(\frac{\pi}{2} - \omega t\right)\right] = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

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

Q. 23 Prove that the power consumed by an inductor is zero.

Ans. :

$$P = v \cdot i = V_m \sin\theta \cdot I_m \sin\left(\theta - \frac{\pi}{2}\right)$$

$$= -V_m I_m \sin\theta \cdot \cos\theta = -V_m I_m \left(\frac{\sin 2\theta}{2}\right)$$

$$P_{avg} = \frac{1}{\frac{3\pi}{2}-\frac{\pi}{2}} \int_{\pi/2}^{3\pi/2} \frac{-V_m I_m}{2} \sin 2\theta \cdot d\theta$$

$$= \frac{1}{\pi} \int_{\pi/2}^{3\pi/2} \frac{-V_m I_m}{2} \sin 2\theta \cdot d\theta$$

$$= \frac{-V_m I_m}{2\pi} \left[\frac{-\cos 2\theta}{2}\right]_{\pi/2}^{3\pi/2} = \frac{V_m I_m}{2\pi \times 2} [-1-(-1)] = \mathbf{0}$$

Hence, Power consumed by a pure inductor is zero.

Q. 24 What is the phase angle and power factor of a pure inductor ?

Ans. : Phase angle: It is the angle between the voltage and current or angle of opposition.

$$\phi = 90°$$

Power factor: It is the cosine of the phase angle

$$\cos\phi = \cos 90 = 0 \quad \text{(lagging)}$$

Q. 25 Derive the expression of current of a capacitor.

Ans. :

$$i = C \cdot \frac{dv}{dt}$$

$$\therefore\ i = C \frac{d}{dt} (V_m \sin\omega t) = V_m C\omega (\cos\omega t) = \frac{V_m}{\frac{1}{\omega C}} \sin\left(\omega t + \frac{\pi}{2}\right) = I_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

where $I_m = \dfrac{V_m}{\frac{1}{\omega C}}$

Q. 26 Prove that the power consumed by a pure capacitor is zero.

Ans. : $$P = v.i = V_m \sin\theta \cdot I_m \sin\left(\theta + \frac{\pi}{2}\right) = V_m I_m \sin\theta \cdot \cos\theta = \frac{V_m I_m}{2} (\sin 2\theta)$$

$$P_{avg} = \frac{1}{\pi} \int_0^{\pi} \frac{V_m I_m}{2} \sin 2\theta \cdot d\theta$$

$$= \frac{V_m I_m}{2\pi} \left[\frac{-\cos 2\theta}{2}\right]_0^{\pi} = \frac{-V_m I_m}{2\pi \times 2} (1-1) = \mathbf{0}$$

Hence, Power consumed by a pure capacitor is zero.

Q. 27 What is the phase angle and power factor of a pure capacitor ?

Ans. : Phase angle (Angle of opposition)

It is the angle between the voltage and current or angle of opposition.

$$\phi = 90$$

Power factor

It is the cosine of the phase angle

$$\cos\phi = 0 \quad \text{(leading)}$$

Q. 28 Draw the voltage triangle of R-L circuit.

Ans. :

Voltage triangle

$$\bar{V}_T = \sqrt{V_R^2 + V_L^2} \angle \tan^{-1}\left(\frac{V_L}{V_R}\right)$$
$$= V_R + j\,V_L$$

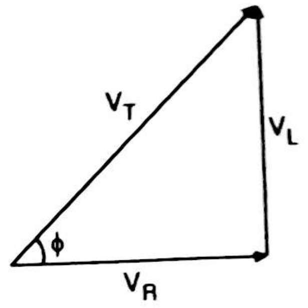


Fig. 2.7

Q. 29 Draw the impedance triangle of R-L circuit.

Ans. :

Impedance triangle

$$\bar{Z} = Z \angle \phi$$
$$= \sqrt{R^2 + X_L^2} \angle \tan^{-1}\left(\frac{X_L}{R}\right)$$
$$= R + j\,X_L$$

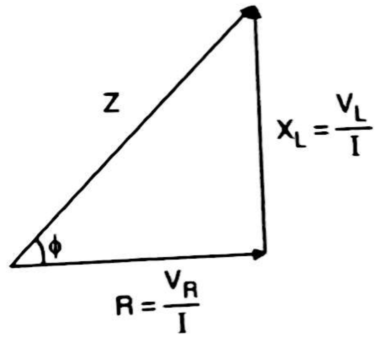


Fig. 2.8

Q. 30 Draw the power triangle of R-L circuit.

Ans. : $$\bar{S} = \sqrt{P^2 + Q^2} \angle \tan^{-1}\left(\frac{Q}{P}\right)$$
$$= P + jQ$$

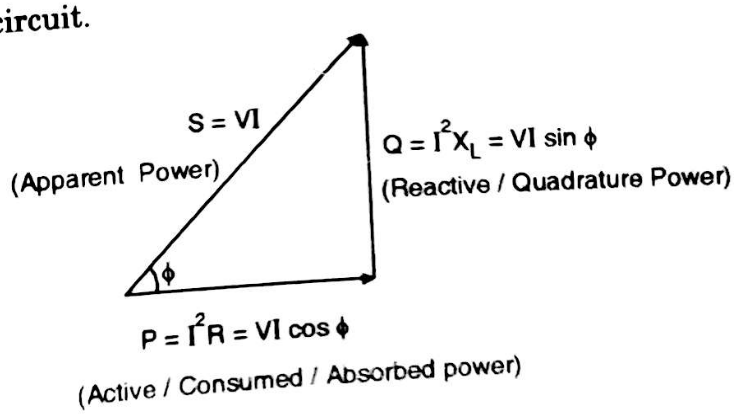


Fig. 2.9

Q. 31 Draw the voltage triangle of R-C circuit.

Ans. :

Voltage Triangle

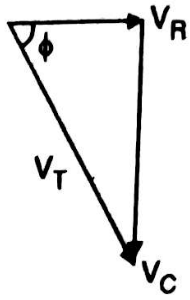


Fig. 2.10

$$\bar{V}_T = V_R - j\,V_C$$

$$= \sqrt{V_R^2 + V_C^2}\ \angle -\tan^{-1}\left(\frac{V_C}{V_R}\right)$$

Q. 32 Draw the impedance triangle of R-C circuit.

Ans. :

Impedance Triangle

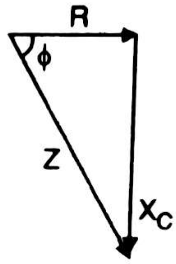


Fig. 2.11

$$\bar{Z} = R - j\,X_C$$

$$= \sqrt{R^2 + X_C^2}\ \angle -\tan^{-1}\left(\frac{X_C}{R}\right)$$

Q. 33 Draw the power triangle of R-C circuit.

Ans. :

Power Triangle

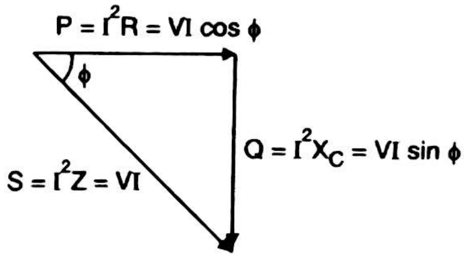


Fig. 2.12

$$S = P - j\,Q$$

$$= \sqrt{P^2 + Q^2}\ \angle -\tan^{-1}\left(\frac{Q}{P}\right)$$

Q. 34 Draw the voltage, impedance and power triangle of R-L-C circuit with $X_L > X_C$.

Ans. :

Case : $X_L > X_C$

1. **Voltage Triangle**

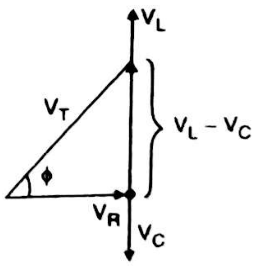


Fig. 2.13

$$V_T = V_R + j\,(V_L - V_C)$$

$$= \sqrt{V_R^2 + (V_L - V_C)^2}\ \angle \tan^{-1}\left(\frac{V_L - V_C}{V_R}\right)$$

2. **Impedance Triangle**

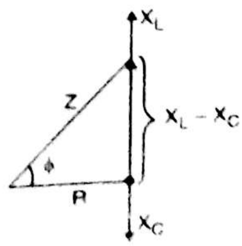


Fig. 2.14

$$Z = R + j\,(X_L - X_C)$$

$$= \sqrt{R^2 + (X_L - X_C)^2}\ \angle \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

3. **Power Triangle**

$$S = P + jQ$$

$$= \sqrt{P^2 + Q^2} \angle \tan^{-1}\left(\frac{Q}{P}\right)$$

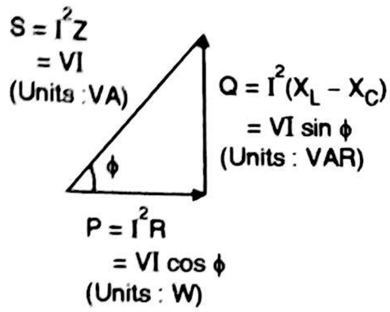


Fig. 2.15

Q. 35 Draw and explain voltage, impedance and power triangle for a R-L-C series circuit with $X_L < X_C$.

Ans. :

Case : $X_L < X_C$

1. **Voltage Triangle**

$$V_T = V_R - j(V_C - V_L)$$

$$= \sqrt{V_R^2 + (V_C - V_L)^2} \angle -\tan^{-1}\left(\frac{V_C - V_L}{V_R}\right)$$

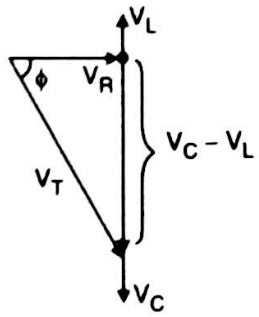


Fig. 2.16

2. **Impedance triangle**

$$Z = R - j(X_C - X_L)$$

$$= \sqrt{R^2 + (X_C - X_L)^2} \angle -\tan^{-1}\left(\frac{X_C - X_L}{R}\right)$$

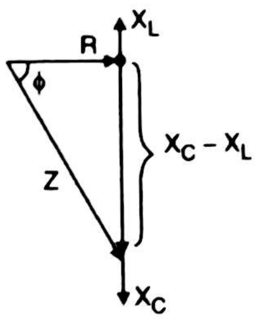


Fig. 2.17

3. **Power triangle**

$$S = P - jQ$$

$$= \sqrt{P^2 + Q^2} \angle -\tan^{-1}\left(\frac{Q}{P}\right)$$

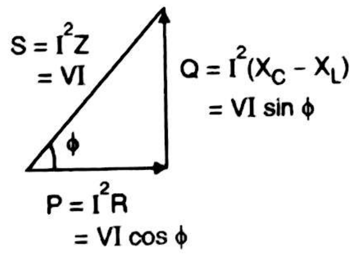


Fig. 2.18

Q. 36 Explain the significance of the terms in admittance and impedance.

Ans. :

Admittance $(\bar{Y}_T) = \frac{1}{\bar{Z}_T}$

$\bar{Z}_T = R \pm jX$

- R: Resistance
- X: Reactance
  - + ve indicates Inductive
  - – ve indicate capacitive

$= Z \angle \phi$

- ϕ → Phase angle
- Z → Scalar impedance

$\bar{Y}_T = G \pm jB$

- G: Conductance
- B: Susceptance
  - + ve indicates Capacitive
  - – ve indicate Inductive

$= Y \angle -\phi$

- $-\phi$ → – ve of ϕ
- Y → Scalar admittance

Q. 37 Derive the expression for resonance frequency in R-L-C series circuit.

Ans. :

Derivation for Resonance Frequency

$$X_{L0} = X_{C0}$$

$$2\pi f_0 L = \frac{1}{2\pi f_0 C} \qquad \therefore \quad f_0^2 = \frac{1}{4\pi^2 LC}$$

$$\therefore \quad f_0 = \frac{1}{2\pi\sqrt{LC}}; \qquad \omega_0 = \frac{1}{\sqrt{LC}}$$

Q. 38 Derive the expression for side frequencies in RLC resonant circuit.

Ans. :

At f_1 and f_2

$$I = \frac{I_0}{\sqrt{2}} = \frac{V}{Z} \qquad \ldots(i)$$

At f_0

$$I_0 = \frac{V}{Z_0} = \frac{V}{R} \qquad \ldots(ii)$$

Dividing Equation (ii) by (i)

$$\frac{I_0}{I_0/\sqrt{2}} = \frac{V/R}{V/Z}$$

$$\therefore \quad \sqrt{2} = \frac{Z}{R}$$

$$\therefore \quad Z^2 = 2R^2$$

$$\therefore \quad R^2 + X^2 = 2R^2$$

$$\therefore \quad R^2 = X^2$$

Case (I) : $X = \pm R$

$$\therefore \quad X_L - X_C = \pm R$$

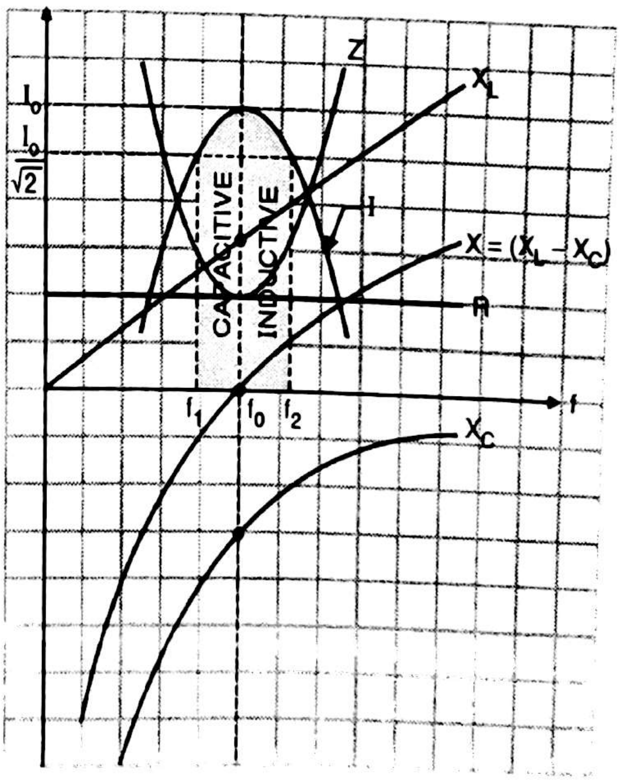


Fig. 2.19

$$\therefore \omega L - \frac{1}{\omega C} = \pm R \qquad \therefore \omega^2 LC - 1 = \pm \omega C R \qquad \therefore \omega^2 \pm \frac{\omega R}{L} - \frac{1}{LC} = 0$$

By formula of quadratic equation,

$$\omega = \frac{\pm\frac{R}{L} \pm \sqrt{\frac{R^2}{L^2} + \frac{4}{LC}}}{2} = \pm \frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} + \frac{1}{LC}}$$

But, $\frac{R^2}{4L^2} << \frac{1}{LC}$ and hence we ignore $\frac{R^2}{4L^2}$

$$\therefore \omega = \pm \frac{R}{2L} \pm \sqrt{\frac{1}{LC}} = \pm \frac{R}{2L} \pm \omega_0$$

Ignoring negative value of ω_0, since frequency cannot be negative

$$\therefore \omega = \omega_0 \pm \frac{R}{2L} \qquad \therefore \omega_1 = \omega_0 - \frac{R}{2L} \quad \text{Lower half power frequency}$$

$$\omega_2 = \omega_0 + \frac{R}{2L} \quad \text{Upper half power frequency}$$

$$f_1 = f_0 - \frac{R}{4\pi L} \qquad f_2 = f_0 + \frac{R}{4\pi L}$$

Q. 39 Prove that the resonant frequency is geometric mean of the side frequencies.

Ans. :

$$R = \pm X = X_{L2} - X_{C2} = X_{C1} - X_{L1} \qquad \therefore X_{L2} - X_{C2} = X_{C1} - X_{L1}$$

$$\therefore \omega_2 L - \frac{1}{\omega_2 C} = \frac{1}{\omega_1 C} - \omega_1 L \qquad \therefore \omega_2 L + \omega_1 L = \frac{1}{\omega_2 C} + \frac{1}{\omega_1 C}$$

$$\therefore L \cancel{(\omega_1 + \omega_2)} = \frac{\cancel{(\omega_1 + \omega_2)}}{\omega_1 \omega_2 C}$$

$$\therefore (\omega_1 \omega_2) = \frac{1}{LC} \qquad \omega_1 \omega_2 = \omega_0^2$$

ω_0 is the geometric mean of ω_1 and ω_2.

Q. 40 Define bandwidth and give its expression.

Ans. :

The range of frequencies for which the power is between P_0 and $P_0/2$ is called band width, and is given by $\Delta\omega$ or Δf.

$$\Delta \omega = \omega_2 - \omega_1 \qquad \text{and} \qquad \Delta f = f_2 - f_1$$

$$\therefore \Delta \omega = \omega_0 + \frac{R}{2L} - \omega_0 + \frac{R}{2L}$$

$$\therefore \Delta \omega = \frac{R}{L} \qquad \text{and} \qquad \Delta f = \frac{R}{2\pi L}$$

Q. 41 Define Quality factor and give the expression for the same.

Ans. : Quality factor is defined as the voltage magnification property of series R-L-C resonance circuit, i.e. the ratio of the voltage across capacitor or inductor to the total voltage at resonance.

$$\text{Q.F.} = \frac{V_{C0}}{V_0} = \frac{V_{L0}}{V_0} > 1$$

$$\therefore \quad \text{Q.F.} = \frac{I_0 X_{C0}}{I_0 R} = \frac{I_0 X_{L0}}{I_0 R} = \frac{X_{C0}}{R} = \frac{X_{L0}}{R} = \frac{1}{\omega_0 C R} = \frac{\omega_0 L}{R} = \frac{\omega_0}{(R/L)} = \frac{\omega_0}{\Delta \omega}$$

$$\therefore \quad \textbf{Q.F} = \frac{1}{\omega_0 C R} = \frac{\omega_0}{\Delta \omega}$$

$$\text{Also, Q.F.} = \frac{\omega_0 L}{R} = \frac{\frac{1}{\sqrt{LC}} L}{R} \qquad \therefore \quad \textbf{Q.F} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Q. 42 What is the condition for resonance for the following circuit ? (Refer Fig. Q. 2.20)

Ans. :

R || L || C

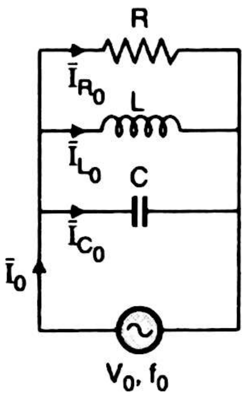


Fig. Q. 2.20

Phasor diagram :

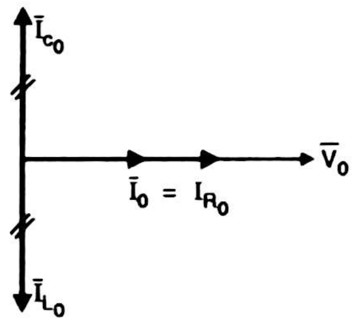


Fig. 2.21

i.e. the condition of resonance is $X_{L0} = X_{C0}$. Hence $I_{L0} = I_{C0}$, hence, $I_0 = I_{R0}$

Q. 43 What is the condition for resonance for the following circuit ? (Refer Fig. Q. 2.22)

Ans. :

R – C || with L

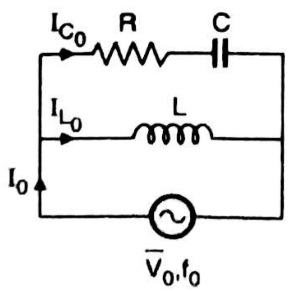


Fig. Q. 2.22

Phasor diagram

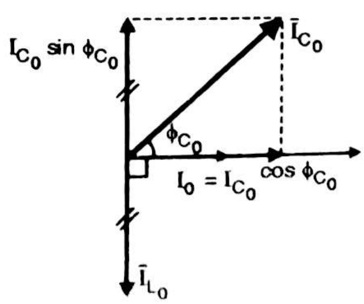


Fig. 2.23

i.e. the condition of resonance

$$I_{L0} = I_{C0} \sin \phi_{C0} \qquad \text{or} \quad I_0 = I_{C0} \cos \phi_{C0}$$

Q. 44 What is the condition for resonance for the following circuit ? (Refer Fig.Q. 2.24)

Ans. :

R – L || R – C

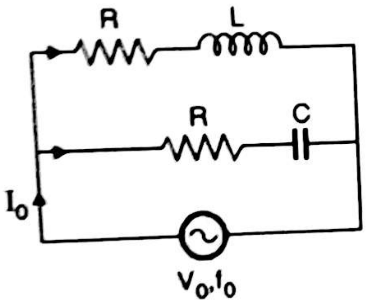


Fig. Q. 2.24

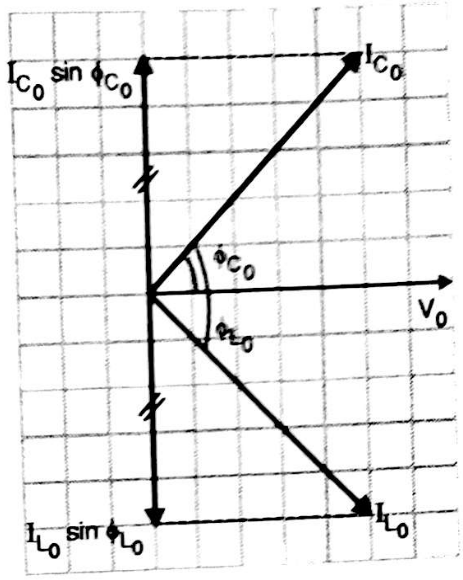


Fig. 2.25

Condition of resonance

$$I_{L0} \sin \phi_{L0} = I_{C0} \sin \phi_{C0} \qquad \text{OR}$$

$$I_0 = I_{L0} \cos \phi_{L0} + I_{C0} \cos \phi_0$$

Q. 45 What is the condition for resonance for the following circuit ? (Refer Fig. Q. 2.26)

Ans. :

R-L-C || R-L-C

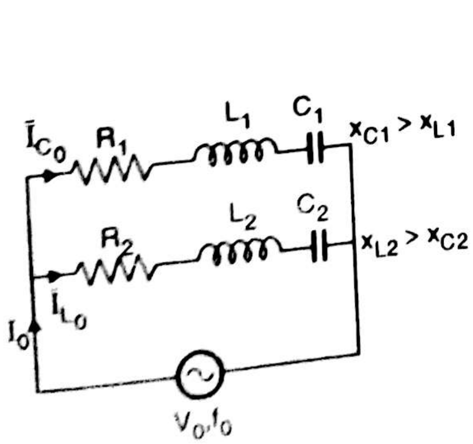


Fig. Q. 2.26

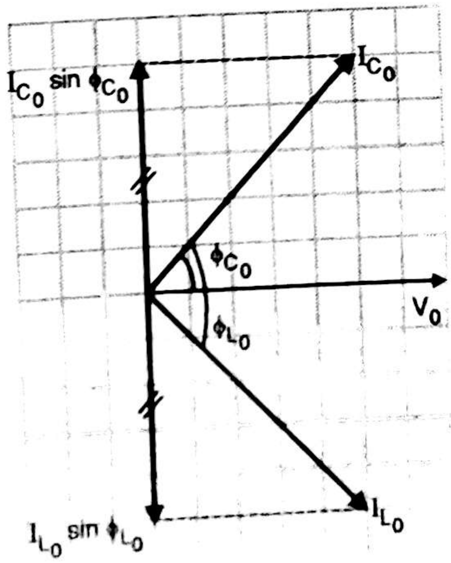


Fig. 2.27

Condition of resonance

$$I_{L0} \sin \phi_{L0} = I_{C0} \sin \phi_{C0} \qquad \text{OR}$$

$$I_0 = I_{L0} \cos \phi_{L0} + I_{C0} \cos \phi_0$$

Q. 46 What is the condition for resonance for the following circuit ?

Ans. :

R-L || Pure C

Phasor Diagram :

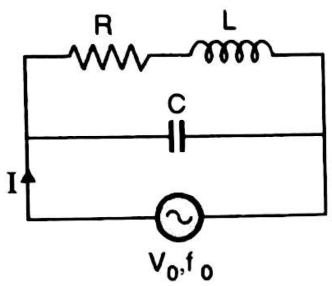


Fig. 2.28

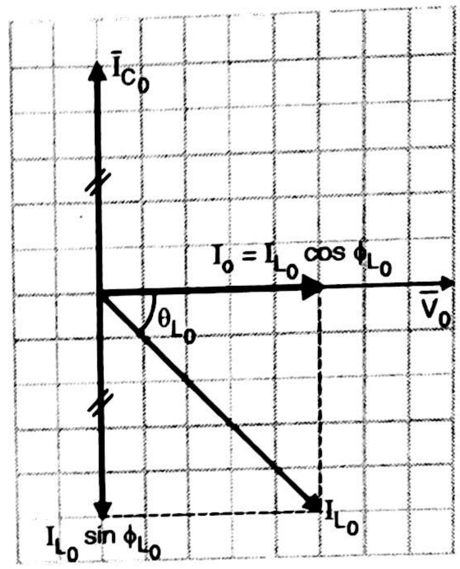


Fig. 2.29

∴ Condition for resonance is

$$I_{C0} = I_{L0} \sin \phi_{L0}$$

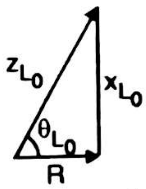


Fig. 2.30

Q. 47 Compare series and parallel resonance.

Ans. :

Sr. No.	Series Resonance	Parallel Resonance
1.	Impedance is minimum $Z_o = R$.	Impedance is maximum $Z_o = \frac{L}{CR}$
2.	Current is maximum $I_o = \frac{V_o}{R}$	Current is minimum $I_o = \frac{V_o}{Z_o} = \frac{V_o}{(L/CR)}$
3.	It is called as Acceptor circuit.	It is called as Rejector circuit
4.	Q factor is voltage magnification property.	Q factor is current magnification property

Sr. No.	Series Resonance	Parallel Resonance
5.	Resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$	Resonant frequency $f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$
6.	Condition of resonance : $X_{L0} = X_{C0}$	Condition of resonance $I_{C0} = I_{L0} \sin \phi_{L0}$

Chapter 3 : Three Phase Circuits

Q. 1 Write mathematical expressions for the three phases of three phase supply.

Ans. : The three phase voltages are given as below:

$$\bar{E}_R = E_R \sin \omega t \qquad \bar{E}_Y = E_Y \sin (\omega t - 120)$$

$$\bar{E}_B = E_B \sin (\omega t - 240)$$

Q. 2 What is the relationship of line and phase currents in star connection ?

Ans. :

$$I_l = I_{ph} \text{ (i.e. line current = phase current)}$$

Q. 3 Derive the expression of line voltage in terms of phase voltage in star connection

Ans. :

$$V_{RY}^2 = E_R^2 + E_Y^2 + 2\, E_R E_Y \cos 60$$

$$\therefore V_l^2 = E_{ph}^2 + E_{ph}^2 + E_{ph}^2 \qquad (\because \text{Balanced supply has } E_{ph} = E_R = E_y = E_B)$$

$$\therefore V_l^2 = 3\, E_{ph}^2$$

$$\therefore \mathbf{V_l = \sqrt{3}\ E_{ph}}$$

Q. 4 What is the relationship of line and phase voltage in delta connection ?

Ans. :

$$V_l = E_{ph}$$

Q. 5 Derive the expression of line current in terms of phase voltage in delta connection.

Ans. :

$$I_1^2 = I_R^2 + I_B^2 + 2\, I_R I_B \cos 60$$

$$\therefore I_l^2 = I_{ph}^2 + I_{ph}^2 + I_{ph}^2 \qquad (\because \text{Balanced supply has } I_{ph} = I_R = I_B)$$

$$\therefore I_l^2 = 3\, I_{ph}^2 \qquad \therefore I_l = \sqrt{3}\ I_{ph}$$

Q. 6 Explain various cases of phase angle for 2 wattmeter method.

Ans. :

Sr. No.	$\phi \rightarrow$ / Parameters	0	+ 60	+ 90	– 60	– 90
1.	cos ϕ	1	0.5 (lagging)	0 (lagging)	0.5 (leading)	0 (leading)
2.	Load	Resistive	Inductive	Pure Inductive	Capacitive	Pure Capacitive
3.	W_1	+ ve	+ ve	+ ve	0	– ve
4.	W_2	+ ve	0	– ve	+ ve	+ ve
5.	Miscellaneous	$P = 2 W_1$ $= 2W_2$ $W_1 = W_2$	$P = W_1$ $W_2 = 0$	$P = W_1 - W_2$ (Considering Magnitudes only)	$P = W_2$ $W_1 = 0$	$P = W_2 -$ W_1(Considering magnitudes only)

Q. 7 Write the expression of phase angle in terms of the reading of the 2 wattmeters in the two wattmeter method.

Ans. :

$$\tan \phi = \frac{\sqrt{3}\,(W_1 - W_2)}{W_1 + W_2}$$

Chapter 4 : Single Phase Transformer

Q. 1 What are the characteristics of an ideal transformer ?

Ans. :

An ideal transformer is the transformer having the following characteristics :

1. The losses are zero (No iron loss, no copper loss).
2. The primary and secondary winding resistances are zero.
3. The leakage flux is zero. Therefore all the flux produced by the primary winding is coupled to the secondary.
4. A small current is required to develop flux inside the core. This happens because the permeability of the core is very large.
5. The external voltage applied to the primary, V_1 is same as the primary induced voltage E_1. This is because the primary winding resistance is zero and so there is no voltage drop across it.

$$\therefore \quad E_1 = V_1$$

6. Similarly the voltage induced in the secondary winding (E_2) will be equal to the load voltage V_2, because the secondary resistance is zero.

$$\therefore \quad E_2 = V_2$$

7. The transformation ratio for an ideal transformer is given by,

$$K = \frac{E_2}{E_1} = \frac{V_2}{V_1}$$

8. Efficiency of an ideal transformer is 100%. This is because there are no losses taking place.

9. The voltage regulation is 0%. That means the secondary voltage will remain constant irrespective of the load current.

Q. 2 Draw the phasor diagram of practical transformer without load.

Ans. :

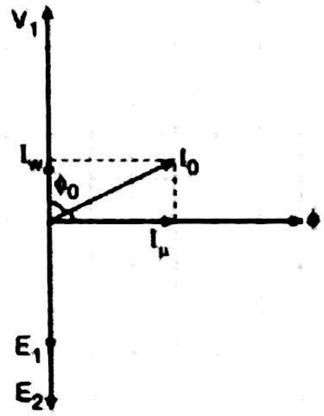


Fig. 4.1

Q. 3 Derive the emf equation of a transformer

Ans. : Average rate of change of flux is given by,

$$\frac{d\phi}{dt} = \frac{\phi_m - 0}{\frac{T}{4} - 0} = \frac{4\,\phi_m}{T} \quad \text{(from Fig. 4.2)}$$

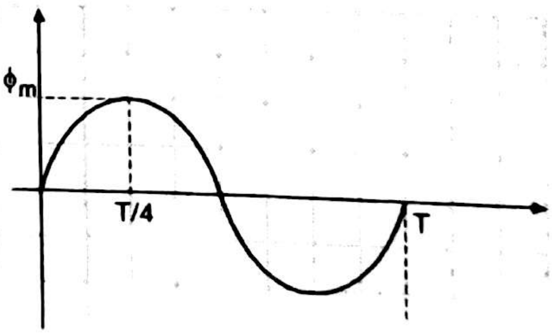


Fig. 4.2

$$\text{But,} \quad T = \frac{1}{f}$$

$$\therefore \quad \frac{d\phi}{dt} = 4f\,\phi_m$$

$$\text{For sine wave,} \quad K_F = \frac{\text{RMS Value}}{\text{Average Value}} = 1.11$$

(as seen in ch-2)

$$\therefore \text{R. M.S value (per turn)} = \text{Average value} \times K_F$$

$$= 4.44\, f\,\phi_m\ V$$

Now there are N_1 turns on primary and N_2 turns on secondary,

$$\therefore \quad E_1 = 4.44\, f\,\phi m\, N_1\ V \qquad \ldots(i)$$

$$E_2 = 4.44\, f\, \phi m\, N_2\, V \quad \text{...(ii)}$$

Q. 4 Write the expression of transformation ratio.

Ans. : The transformations ratio can be obtained by, Equation (ii) ÷ (i)

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K = \frac{V_2}{V_1}$$

This ratio is called as transformation ratio.

Always, $S_1 = S_2$ (Apparent power in primary and secondary is same)

$$\therefore \; V_1 I_1 = V_2 I_2 \qquad \frac{V_2}{V_1} = \frac{I_1}{I_2} \qquad \therefore \; K = \frac{I_1}{I_2}$$

Q. 5 Why is transformer rated in kVA and not in kW ?

Ans. :

- The VA or kVA rating of the transformer simply indicates how much maximum apparent power or total power a transformer can supply.
- It includes the active power (true power) and the reactive power (useless power).
- Output of the total supplied by the transformer (VA or kVA), a part or full will be useful, depending on the load. For a purely resistive load, all the power will be reactive.
- At the time of manufacturing of a transformer, the nature of load is not known. Hence the maximum total (apparent) power supplying capacity is given as the rating.
- Hence the transformer is rated in VA or kVA and not in W or kW.
- An ideal transformer is loss free. But in the practical transformer there are following losses taking place

Q. 6 What is copper loss ?

Ans. :

- The total power loss taking place in the winding resistances of a transformer is known as the copper loss.

  $\therefore$ Copper loss = Primary copper loss + secondary copper loss
- The copper loss is denoted by P_{cu}.

$$\therefore \quad P_{cu} = I_1^2 R_1 + I_2^2 R_2 \quad \text{...(1)}$$

Where $I_1^2 R_1$ = Primary copper loss.

and $I_2^2 R_2$ = Secondary copper loss.

Q. 7 What is iron loss ?

Ans. :

- Iron loss P_i is the power loss taking place in the iron core of the transformer.
- It is equal to the sum of two components called hysteresis loss and eddy current loss.

$$P_i = \text{Hysteresis Loss} + \text{Eddy current loss}$$

Hysteresis losses

Hysteresis loss is directly proportional to frequency f and voltage V. It is given by

$$P_H = K_H B_m^{1.67} f V ...[K_H \text{ constant}] \quad ...(1)$$

The area enclosed by the hysteresis loop of a material represents the hysteresis loss.

Eddy current loss

Eddy current loss is proportional to square of frequency and square of thickness of laminations. It is given by,

$$P_E = K_E \cdot B_m^2 \cdot f^2 \cdot t^2 ...[t = \text{thickness}] \quad ...(2)$$

Due to the time varying flux, there is some induced emf in the transformer core. This induced emf causes some currents to flow through the core body. These currents are known as the eddy currents.

The eddy current loss can be minimized by using laminated core for transformer.

$$\therefore \quad \text{Iron loss} = P_i = P_H + P_E = \text{constant loss}$$

Q. 8 What happens to a component when referred from primary to secondary ?

Ans. : Its value gets multiplied by the transformation ratio "k"

Q. 9 What happens to a component when referred from secondary to primary ?

Ans. : Its value gets divided by the transformation ratio "k"

Q. 10 What is the efficiency of a transformer ?

Ans. :

- The efficiency of a transformer is defined as the ratio of output power to input power. It is denoted by η.

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

$$\therefore \quad \eta = \frac{\text{Input} - \text{loss}}{\text{Input}} = 1 - \frac{\text{loss}}{\text{Input}} = 1 - \frac{W_i + I_1^2 R_{O1}}{V_1 I_1 \cos \phi}$$

Q. 11 What is the value of 'x', in case of maximum efficiency ?

Ans. :

$$\therefore \quad x = \sqrt{\frac{W_i}{W_{CUFL}}}$$

Q. 12 What is voltage regulation and write the expression for voltage regulation of a transformer ?

Ans. :

- With increase in load current, the value of V_2 decreases and the percent regulation increases (becomes poor). Ideal value of voltage regulation is 0 %.
- Voltage regulation is the difference of voltage and no load to the voltage at a particular load divided by voltage at no load.

$$\%VR = \frac{V_{NL} - V_{AnyLOAD}}{V_{NL}} \times 100 \text{ [where, } V_{NL} \Rightarrow \text{Voltage at no laod]}$$

$$= \frac{I_1[R_{O1}\cos\phi \pm X_{O1}\sin\phi]}{V_1} \times 100 = \frac{I_2[R_{O2}\cos\phi \pm X_{O2}\sin\phi]}{E_2} \times 100$$

Q. 13 Explain the operating principle of a transformer.

Ans. :

1. As soon as the primary winding is connected to the single - phase AC supply, an ac current starts flowing through it.

⇓

2. The ac primary current produces an alternating flux ϕ in the core.

⇓

3. Most of this changing flux gets linked with the secondary winding through the core.

⇓

4. The varying flux will induce voltage into the secondary winding according to the Faraday's laws of electromagnetic induction.

Q. 14 What are the different types of transformers ?

Ans. : Based on the value of the transformation ratio K, the transformers are classified as, step up, step down or one to one transformers.

Step up transformer

The transformer having $K > 1$ or $V_2 > V_1$ is called as the step up transformer. We get higher secondary voltage as compared to the primary winding, hence the name step up.

Step down transformer

The transformer having $K < 1$ or $V_2 < V_1$ is called as the step down transformer. We get lower secondary voltage than the primary voltage, hence the name step down.

One-to-one transformer

The transformer having $K = 1$ or $V_1 = V_2$ is called as a one-to-one transformer. It is also used as an isolation transformer which is used for isolating the electrical or electronic circuits under test from the supply.

Q. 15 Explain with example the rating of a transformer.

Ans. : The complete ratings of a transformer includes the ratio of primary and secondary voltages, kVA rating and supply frequency as follows :

3300 V/240 V, 5 kVA, 50 Hz

Where 3300 V is the primary voltage V_1.

240 V is the secondary voltage V_2.

5 kVA is the kVA rating and 50 Hz is the supply frequency.

Q. 16 What is copper loss and why is it variable ?

Ans. :

- The total power loss taking place in the winding resistances of a transformer is known as the copper loss.

  $\therefore$ Copper loss = Primary copper loss + secondary copper loss

- The copper loss is denoted by P_{cu}.

$$\therefore \quad P_{cu} = I_1^2 R_1 + I_2^2 R_2 \qquad ...(1)$$

Where $I_1^2 R_1$ = Primary copper loss.

and $I_2^2 R_2$ = Secondary copper loss.

- The copper loss should be kept as low as possible to increase the efficiency of the transformer. To reduce the copper loss, it is essential to reduce the resistances R_1 and R_2 of the primary and secondary windings.
- Copper losses are also called as **variable losses** as they are dependent on the square of load current. The relation between copper loss at full load and that at half load is as follows :

$$P_{cu\,(HL)} = \left(\frac{1}{2}\right)^2 P_{cu\,(FL)} = \frac{P_{cu\,(FL)}}{4}$$

Q. 17 Explain the relation of V_2 and I_2 based on the load connected to the transformer.

Ans. :

- Due to the load on the secondary, a finite secondary current starts flowing. Depending on the type of load (resistive, inductive or capacitive) the secondary current I_2 will be in phase with or lag or lead the load voltage V_2.

	Type of load	Load current
1.	Purely resistive (R)	I_2 is in phase with V_2
2.	(R + L) type i.e. Inductive	I_2 lags behind V_2
3.	(R + C) type i.e. Capacitive	I_2 lead V_2

Q. 18 Draw the phasor diagram for resistive load of a transformer.

Ans. :

Resistive Load (cos ϕ = 1)

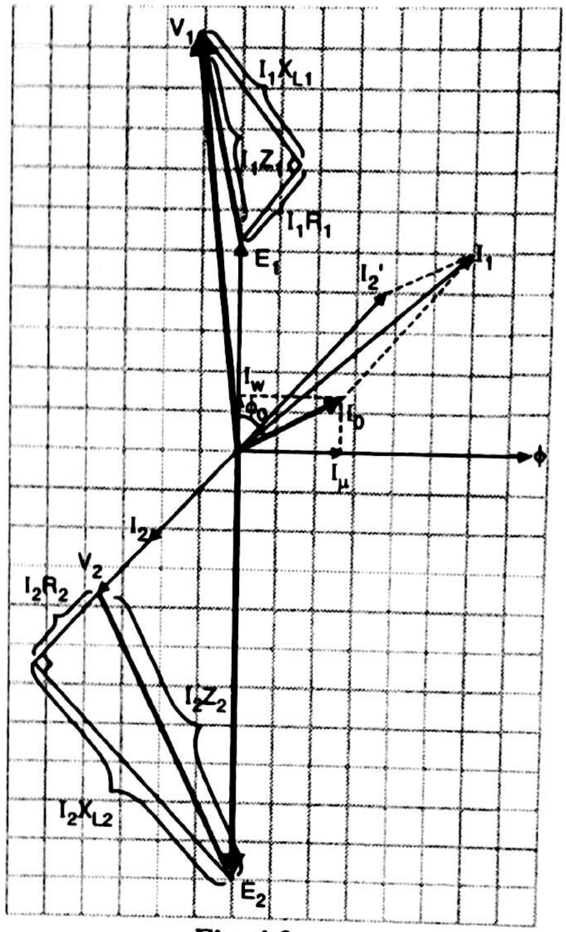


Fig. 4.3

Q. 19 Draw the phasor diagram for lagging load of a transformer.

Ans. :

Inductive load (lagging p.f.)

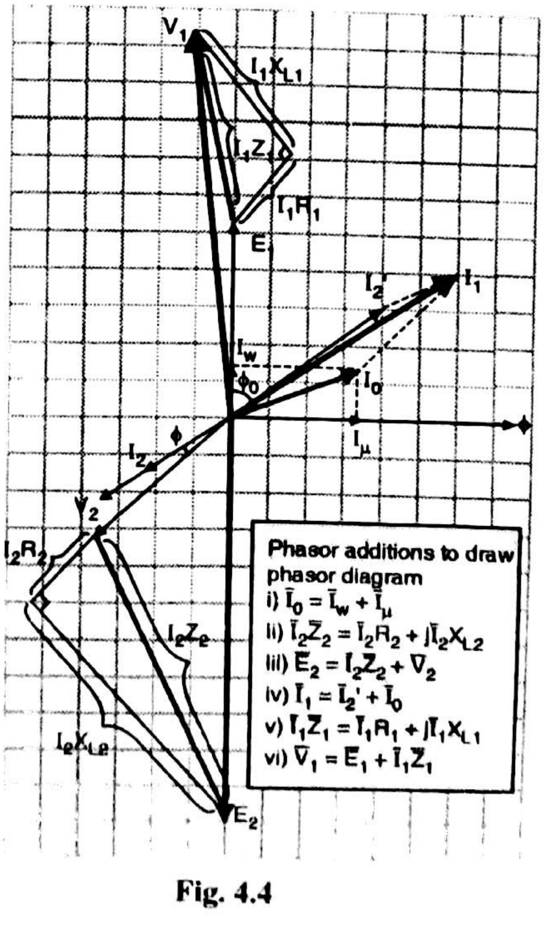


Fig. 4.4

Q. 20 Draw the phasor diagram for leading load of a transformer.

Ans. :

Capacity load (leading pf)

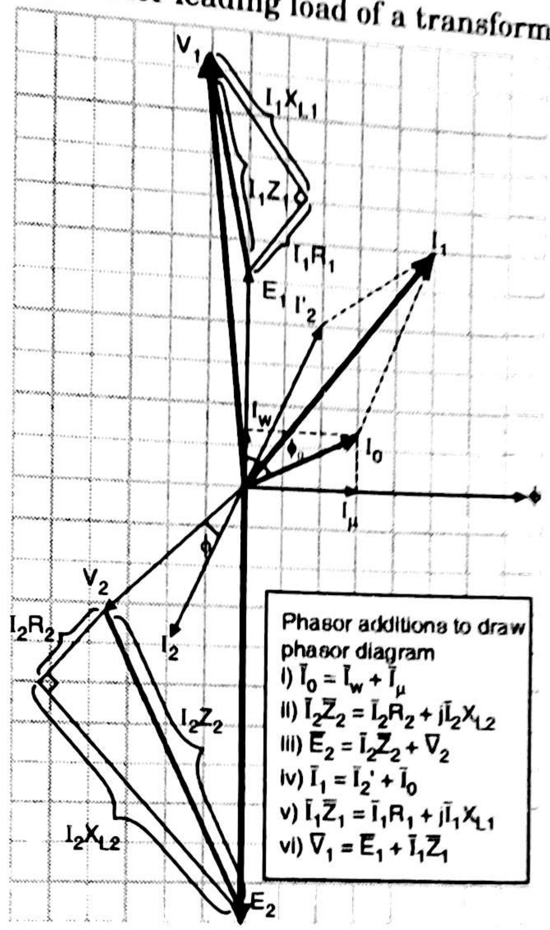


Fig. 4.5

Q. 21 Draw the equivalent circuit of a transformer as referred to the primary.

Ans. :

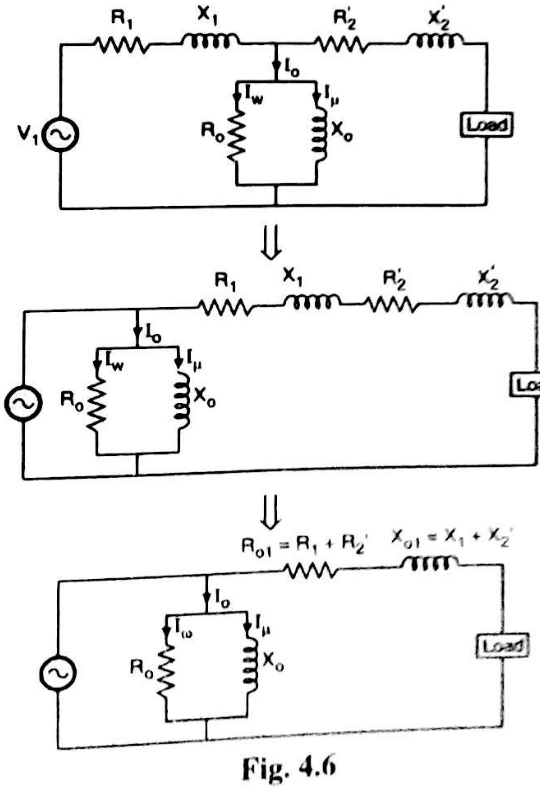


Fig. 4.6

Q. 22 Draw the equivalent circuit of a transformer as referred to the secondary.

Ans. :

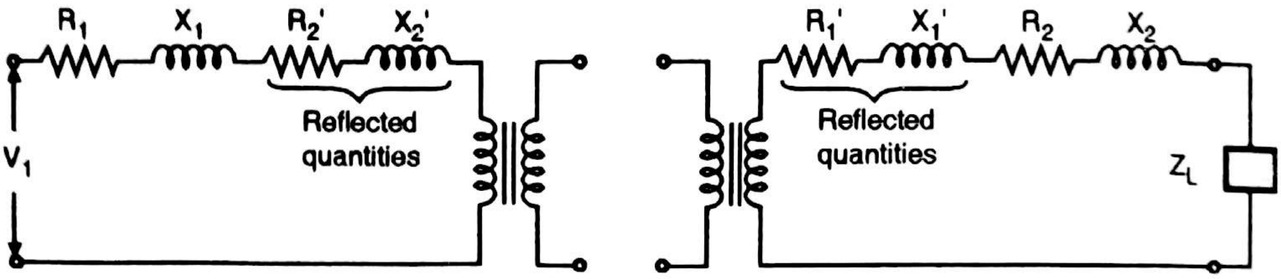


Fig. 4.7

Q. 23 Derive the expression for maximum efficiency of a transformer.

Ans. :

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

$$\therefore \quad \eta = \frac{\text{Input} - \text{loss}}{\text{Input}} = 1 - \frac{\text{loss}}{\text{Input}} = 1 - \frac{W_i + I_1^2 R_{O1}}{V_1 I_1 \cos\phi}$$

$$= 1 - \frac{W_i}{V_1 I_1 \cos\phi} - \frac{I_1^{\cancel{2}} R_{O1}}{V_1 \cancel{I_1} \cos\phi} = 1 - \frac{W_i}{V_1 I_1 \cos\phi} - \frac{I_1 R_{O1}}{V_1 \cos\phi}$$

For η_{max},

$$\therefore \frac{d\eta}{dI_1} = 0 = 0 + \frac{W_i}{V_1 \cos\phi\, I_1^2} - \frac{R_{01}}{V_1 \cos\phi}$$

$$\therefore \frac{R_{O1}}{V_1 \cancel{\cos}\phi} = \frac{W_i}{V_1 \cancel{\cos}\phi\, I_1^2}$$

$$\therefore I_1^2 R_{O1} = W_i \qquad \therefore \quad \mathbf{W_{cu} = W_i} \qquad \text{...(i)}$$

$$W_{cu} = I_1^2 \cdot R_{O1} = x^2 \cdot I_{1rated}^2 \cdot R_{O1}$$

where, x is load factor

$$\therefore \quad W_{cu} = x^2 W_{CUFL}$$

$$\therefore \text{ For } \eta_{max},\ x^2 W_{CUFL} = W_i \qquad \therefore \quad \mathbf{x = \sqrt{\frac{W_i}{W_{CUFL}}}} \qquad \text{...(ii)}$$

Q. 24 What do the terms "no load voltage", "full load voltage" and "voltage regulation" mean ?

Ans. :

- **No load voltage :** The no load voltage is the secondary terminal voltage corresponding to zero load current for a transformer.

$$\textbf{No load voltage} = \mathbf{E_2} \textbf{ volts}$$

- **Full load voltage :** It is the secondary terminal voltage corresponding to the specified load current. Let us denote it by V_2. The percent voltage regulation is given mathematically as :

$$\textbf{\% Regulation} = \frac{\mathbf{E_2 - V_2}}{\mathbf{E_2}} \times 100$$

- Thus with increase in load current, the value of V_2 decreases and the percent regulation increases (becomes poor). Ideal value of voltage regulation is 0 %.
- **Voltage regulation** is the difference of voltage and no load to the voltage at a particular load divided by voltage at no load.

Q. 25 Draw the setup of Open circuit test in a transformer.

Ans. :

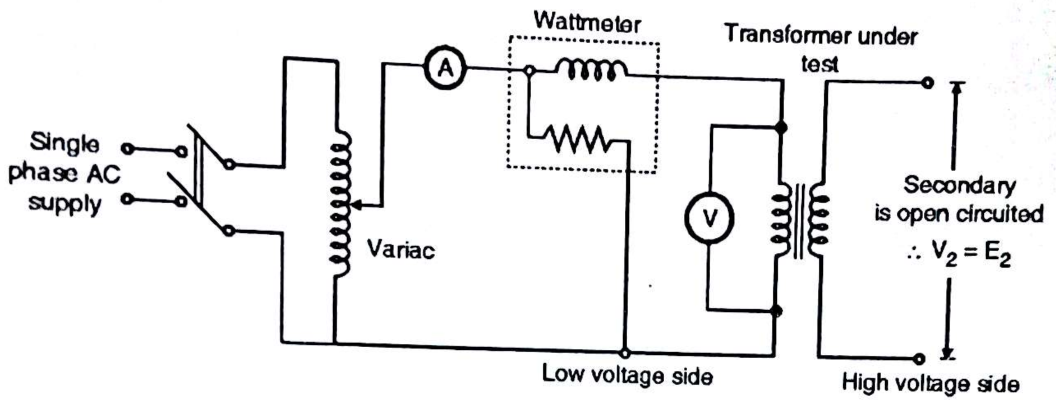


Fig. 4.8

Q. 26 Explain the procedure and readings obtained in open circuit test in a transformer.

Ans. :

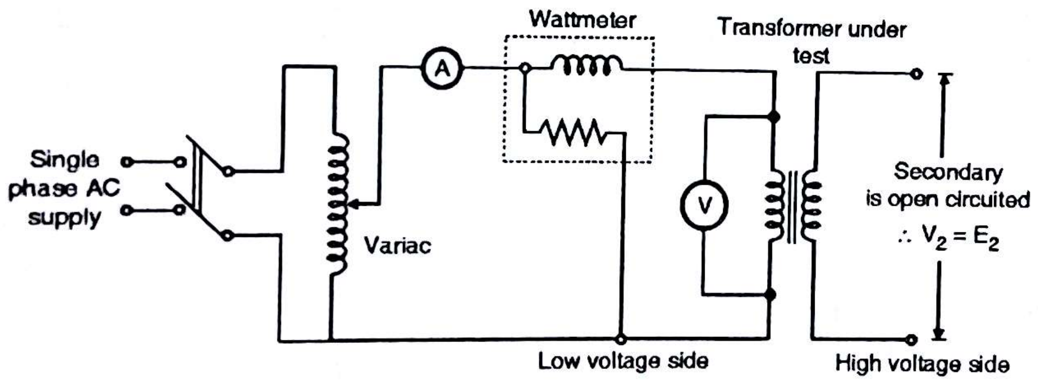


Fig. 4.9

Procedure

1. Connect the circuit as shown in Fig. 4.9.
2. Keep the variac at its minimum voltage position.
3. Switch on the ac power supply and adjust the variac to get the rated primary voltage as measured by voltmeter V across the primary.
4. Now measure the primary current and power using the ammeter and wattmeter respectively.
5. The ammeter reads the no load primary current I_0 whereas the wattmeter measures the no load input power W_0.
6. The observation table for the O.C. test is as follows.

Table 4.1 : Observation table for O.C. test

Voltmeter reading	Ammeter reading	Wattmeter reading
V_1 (Rated voltage)	I_0 (Amp)	W_0 (Watt)

7. The two components of no load current I_0 are,

$$I_m = I_0 \sin \phi_0 \quad \text{and} \quad I_c = I_0 \cos \phi_0$$

8. The no load power factor is given by ϕ_0 and the input power at no load is given by,

$$W_0 = V_1 I_0 \cos \phi_0$$

9. The phasor diagram on no load showing the two components of I_0 is shown in Fig. 4.10.

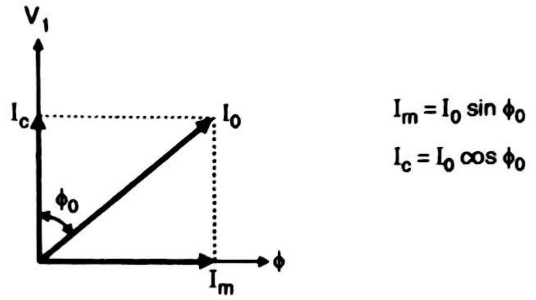


Fig. 4.10 : Phasor diagram showing the two components of the no load current I_0

Q. 27 What parameters are calculated using OC test ?

Ans. :

- The two parameters which can be calculated from the open circuit test are R_0 and X_0. They are calculated as follows.

Step 1 : Calculate no load power factor $\cos \phi_0$

The wattmeter reads the real input power.

$$\therefore \quad W_0 = V_1 I_0 \cos \phi_0 \qquad \therefore \cos \phi_0 = \frac{W_0}{V_1 I_0}$$

Calculate ϕ_0 from this.

Step 2 : Calculate I_m and I_c

$$I_m = I_0 \sin \phi_0 \quad \text{and} \quad I_c = I_0 \cos \phi_0$$

So calculate I_m and I_c from the above equations.

Step 3 : Calculate R_0 and X_0

The values of R_0 and X_0 can be obtained as follows :

$$R_0 = \frac{V_1}{I_c} \Omega \quad \text{and} \quad X_0 = \frac{V_1}{I_m} \Omega$$

- The value of $\cos \phi_0$ is very small. Therefore it is necessary to use the low power factor type wattmeter to avoid any possibility of error in measurements.

Q. 28 Draw the setup of short circuit test in a transformer.

Ans. :

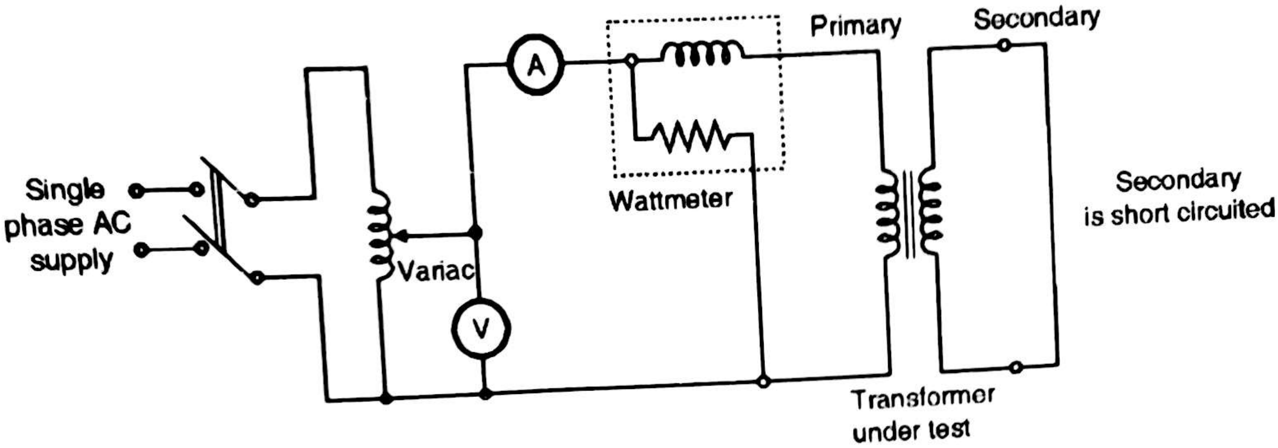


Fig. 4.11

Q. 29 Explain the procedure and readings obtained in short circuit test in a transformer.

Ans. :

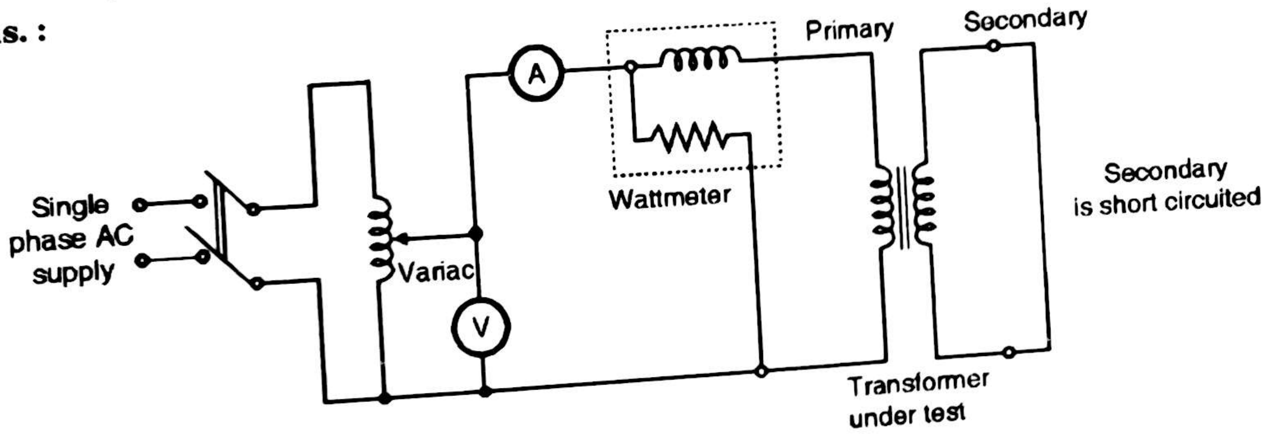


Fig. 4.12

Procedure

1. Connect the circuit as shown in Fig. 4.12.
2. Short circuit the secondary which is a low voltage high current, low resistance winding.
3. Keep the variac at its minimum voltage position and switch on the ac supply voltage.
4. Increase the primary voltage very gradually, and adjust it to get the primary current equal to the rated value I_{SC}. Do not increase the primary voltage further.
5. Note down the wattmeter, voltmeter and ammeter readings. The observation table is as shown in Table 4.2.

Table 4.2 : Observation table for S.C. test

Voltmeter reading	Ammeter reading	Wattmeter reading
V_{SC} volts	I_{SC} (Amp)	W_{SC} Watts

Q. 30 What parameters are calculated using SC test ?

Ans. :

- The primary and secondary currents are the rated currents. Therefore the total copper loss is the full load copper loss.
- The iron losses are a function of applied voltage. As the applied voltage in S.C. test is small, the iron losses will be negligibly small.
- Hence the wattmeter reading W_{SC} corresponds almost entirely to the full load copper loss.

$$\therefore \quad W_{SC} = \text{Full load copper loss} = P_{cu\,(FL)}$$

- We can calculate the parameters R_{1T}, X_{1T} and Z_{1T} of the equivalent circuit from the short circuit (S.C.) test.
- We know that $W_{SC} = V_{SC} I_{SC} \cos \phi_{SC}$
- Hence the short circuit power factor is given by,

$$\cos \phi_{SC} = \frac{W_{SC}}{V_{SC} I_{SC}}$$

- But the wattmeter reading W_{SC} indicates the full load copper loss.

$$\therefore \quad W_{SC} = \text{Copper loss} = I_{SC}^2 \times R_{1T} \qquad \therefore \quad R_{1T} = \frac{W_{SC}}{I_{SC}^2}$$

- Similarly $Z_{1T} = \frac{V_{SC}}{I_{SC}} = \sqrt{R_{1T}^2 + X_{1T}^2}$

$$\therefore \quad X_{1T} = \sqrt{Z_{1T}^2 - R_{1T}^2}$$

- In this way the parameters R_{1T}, X_{1T} and Z_{1T} can be calculated from the S.C. test.
- If the transformation ratio K, it is possible to obtain the parameters referred to the secondary side.

Chapter 5 : DC Machines

Q. 1 What are the types of DC Machines ?

Ans. :

DC machines are basically of two types :

1. D.C. generator 2. D.C. motor.

Q. 2 What are two windings in a DC Machine ?

Ans. : In any dc machine, (motor or generator) there are two windings :

1. Field winding 2. Armature winding.

Q. 3 What is Fleming's Right hand rule ?

Ans. : Let the thumb and first two fingers of the right hand be arranged in right angles with each other.

Let the first finger point in the direction of lines of force (N to S pole), and the outstretched thumb point the direction of conductor motion, then the second finger indicates the direction of the induced e.m.f. (or current).

The magnitude of induced emf is given by

$$e = B \times l \times v \sin \theta \text{ volts}$$

where B = Magnetic flux density Wb/m^2

l = Length of the conductor

v = Velocity of the moving conductor

and θ = Angle between the plane of conductor and the plane of magnetic flux

Q. 4 What are the parts of a DC Machine ?

Ans. : The cross-section of a DC machine reveals that it consists of the following important parts :

1. Yoke
2. Field winding
3. Poles
4. Armature
5. Commutator, brushes and gear
6. Bearings.

Q. 5 What is the function of a brush in the DC Machine ?

Ans. : To collect current from the commutator and apply it to the external load.

Q. 6 Derive the emf equation of DC Machine ?

Ans. :

- When a mechanical device, such as a diesel engine drives the armature drum, armature winding cuts the magnetic flux produced by the pole. An equation for e.m.f. induced can be obtained as under.

  Let P = number of poles of the generator.

  ϕ = flux produced by each pole, Wb.

  N = speed in r.p.m. at which the generator is driven.

  Z = number of conductors of armature winding.

  A = number of parallel paths of armature winding.

- Then according to Faraday's law of induction, magnitude of e.m.f. induced in a conductor is,

$$E = \frac{d\phi}{dt} \quad \text{...(1)}$$

- For one complete revolution of a conductor, the flux cut by the conductor is $(P\phi)$ Wb and time required to complete one revolution is $(60/N)$ seconds. Therefore, Equation (1) may be written as,

$$E = \frac{P\phi}{(60/N)} = \frac{P\phi N}{60} \quad \text{...(2)}$$

- As Z conductors are divided in A parallel groups, there are $\frac{Z}{A}$ conductors in series in each group. Therefore e.m.f. induced in the total armature winding is,

$$E = \frac{P \phi N}{(60)} \cdot \frac{Z}{A} \quad ...(3)$$

- Equation (3) is the e.m.f. equation of a dc generator.

Q. 7 State the different types of generators and their applications.

Ans. :

Shunt generator

1. Lighting loads 2. Battery charging

Series generator

1. For the arc lamps 2. As constant current generators
3. As boosters on d.c. feeders.

Separately excited generators

The applications of these generators have limitations, because they need a separate excitation for the field winding. Some of the applications are electrorefining of materials or electro-plating.

Cumulative compound generators

1. Used for domestic lighting
2. For energy transmission over a long distance.

Differential compound generators : This type of generators are very rarely used, due to their drooping load characteristics. One of its important applications is electric arc welding.

Q. 8 Compare DC Motor and DC Generator ?

Ans. :

Sr. No.	Name of the winding	Connection / operation	
		DC generator	**DC motor**
1.	Field winding (Stationary)	Connected to external DC supply. Produces magnetic field in the air gap between field and armature	Connected to external DC supply. Produces magnetic field in the gap between field and armature
2.	Armature winding (Rotary winding)	Connected to the electrical load. We get electrical energy from the armature.	Connected to external DC supply. Armature rotates in the magnetic field to produce mechanical power.

Q. 9 Explain the principle of operation of a DC motor.

Ans. : The operating principle of a DC motor can be stated as follows : When a current carrying conductor is placed in a magnetic field, it experiences a force.

In case of a DC motor, the magnetic field is developed by the field current i.e. the current flowing in the field winding.

The armature winding is connected to an external dc source, hence it plays the role of the current carrying conductor placed in the magnetic field.

Due to the force exerted on it when placed in the magnetic field, it starts rotating.

The direction of rotation depends on the direction of magnetic field produced by the field winding as well as the direction of armature current. The direction of rotation is decided by Fleming's left hand rule.

Q. 10 Derive the torque equation of a transformer.

Ans. :

- We know that the relation between the torque and power is as follows.

$$P = T \times \omega \text{... where } \omega = \frac{2\pi N}{60} \text{ rad/sec is the angular velocity}$$

- Let $T = T_a$ = Gross torque = Torque developed by armature and $P = P_m$ = Gross mechanical power developed by the motor.

$$\therefore \; P_m = T_a \times \omega \qquad \therefore \; E_a I_a = T_a \times \frac{2\pi N}{60}$$

Substitute $E_a = \frac{P \phi NZ}{60A}$ to get

$$\frac{P \phi NZ}{60A} \times I_a = T_a \times \frac{2\pi N}{60} \qquad \therefore \; T_a = \frac{P \phi Z}{2\pi A} \times I_a = 0.159 \frac{PZ}{A} \phi I_a$$

This is known as the torque equation of a dc motor. The torque is measured in N-m.

- P, Z, and A are constants hence we can say

$$T_a \propto \phi I_a \qquad ...(1)$$

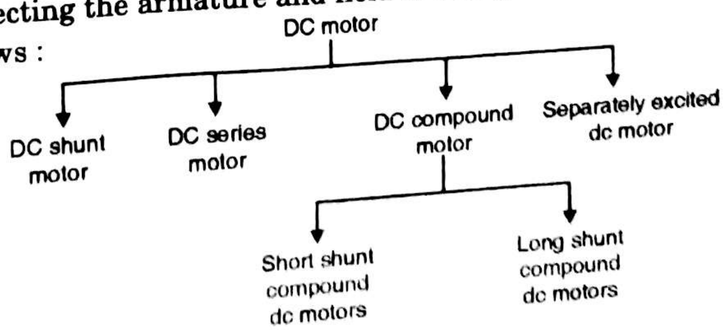
- Thus the torque produced by a dc motor is proportional to the main flux ϕ as well as the armature current I_a.

Q. 11 List the types of DC Motors based on the connection of the field windings.

Ans. :

Depending on the way of connecting the armature and field windings of a d.c. motor, the d.c. motors are classified as follows :

1. DC series motor
2. DC shunt motor
3. Compound motors
4. Separately excited dc motors



Q. 12 Mention the applications of DC shunt motor.

Ans. : Such a motor can be used for the following applications :

1. Various machine tools such as lathe machines, drilling machines, milling machines etc.
2. Printing machinery
3. Paper machines
4. Centrifugal and reciprocating pumps
5. Blowers and fans etc

Q. 13 Mention the applications of Series motor applications.

Ans. : Series motors are very widely used for the following applications :

1. Electric trains,
2. Diesel-electric locomotives,
3. Cranes,
4. Hoists
5. Trolley cars and trolley buses,
6. Rapid-transit systems,
7. Conveyers etc.

Q. 14 Mention cumulative compound motor applications.

Ans. : Cumulative compound motors are used for the following applications :

1. Elevators
2. Rolling mills
3. Punches
4. Shears
5. Planers

Q. 15 How is the DC machine connected to work as a Generator ?

Ans. :

- To operate the dc machine as a generator, the field winding is connected across the dc power supply. A dc current starts flowing through the field winding.
- The field winding then produces a magnetic field in the air gap between the armature and field windings.
- The armature winding is a rotating winding which is mounted on the shaft. The shaft is mechanically coupled to another machine called prime mover as shown in Fig. 5.1(a).

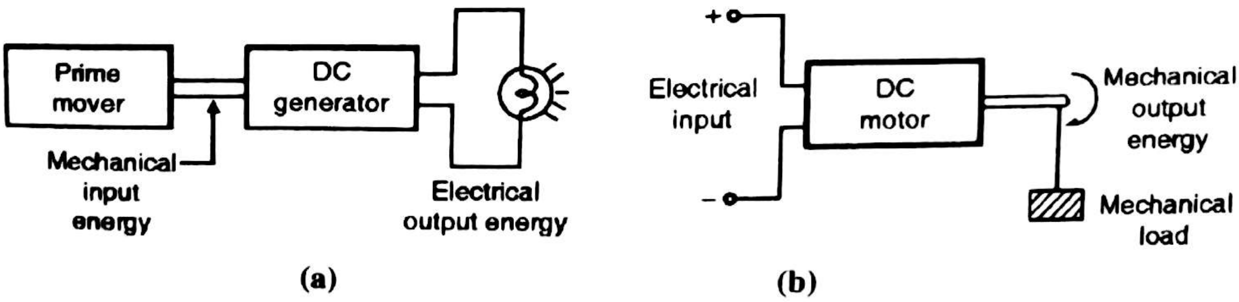


Fig. 5.1

- And the connection of the armature winding are brought out. A load such as electric lamp is connected across the armature winding.
- The dc generator thus takes the mechanical energy as an input energy from the prime mover and delivers an electrical energy to the load.

Q. 16 Explain yoke of a DC Machine.

Ans. : The important information about the Yoke which acts as the outer cover of a DC machine are as given below :

- Yoke is also called as frame. It provides protection to the rotating and other parts of the machine from moisture, dust etc.
- Yoke is an iron body which provides the path for the flux. This is essential to complete the magnetic circuit.
- It provides the mechanical support for the poles.
- Materials used for Yoke are basically the low reluctance materials such as cast iron, silicon steel, rolled steel, cast steel etc.
- The outer frame or Yoke serves the following purpose :
  1. It provides the mechanical support for the poles and acts as a protecting cover for the whole machine and
  2. It carries the magnetic flux produced by the poles.

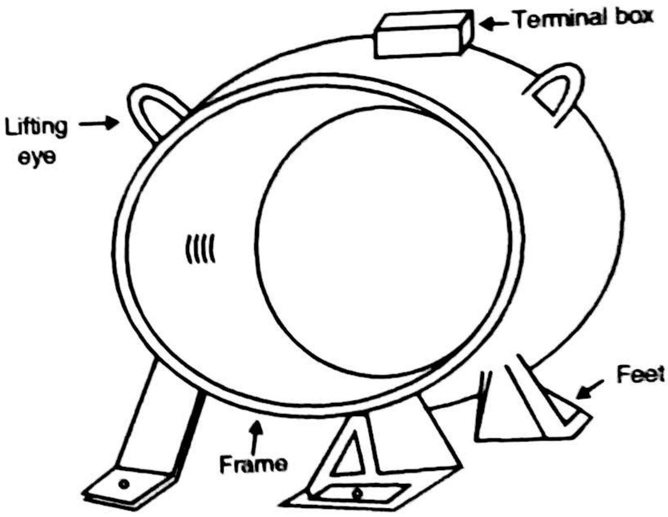


Fig. 5.2 : Magnetic frame or Yoke

- For small dc machines the Yoke are made of cast iron. But for larger machines, cast steel or rolled steel is used.
- The steel slab is rolled around a cylindrical mandrel and then welded it at the bottom to form the Yoke.
- Fig. 5.3 shows the detailed construction of armature core.

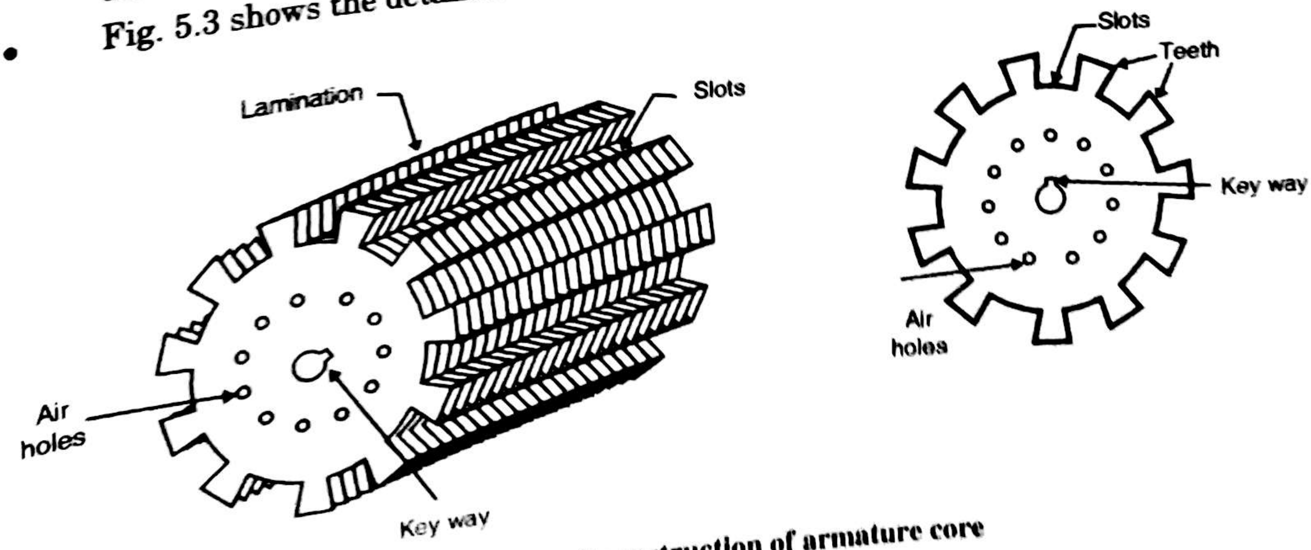


Fig. 5.3 : Detail construction of armature core

Q. 17 Explain what is pole shoe ?

Ans. :

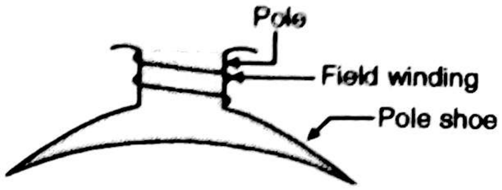


Fig. 5.4

- A pole of a generator is an electromagnet. The field winding is wound over the poles.
- Poles produce the magnetic flux when the field winding is excited.
- Pole shoe is an extended part of a pole. Due to its typical shape, it enlarges the area of the pole.
- Due to this enlarged area, more flux can pass through the air gap to armature.

Q. 18 What is the function of field winding in a DC Machine ?

Ans. :

- The field coils are connected in series to form the field winding.
- Current is passed through the field winding in a specific direction, to magnetize the poles and pole shoes. The magnetic flux ϕ is thus produced in the air gap between the pole shoes and armature.
- The field winding is also called as exciting winding.
- The material used for the field conductor is copper.
- Due to the current flowing through the field winding alternate N and S poles are produced. Which pole is produced at a particular core is decided by the right hand thumb rule for a current carrying circular conductor.

Q. 19 What is the significance of air holes in the armature ?

Ans. : The air holes are provided for the air circulation which helps in cooling the armature core.

Q. 20 What is the significance of lamination in armature ?

Ans. : The laminated construction is used to produce the armature core to minimize the Eddy current losses.

Q. 21 What type of material is used to make armature core ?

Ans. : High permeability, low reluctance materials such as cast steel or cast iron are used for the armature core.

Q. 22 What is the armature winding made up of and why?

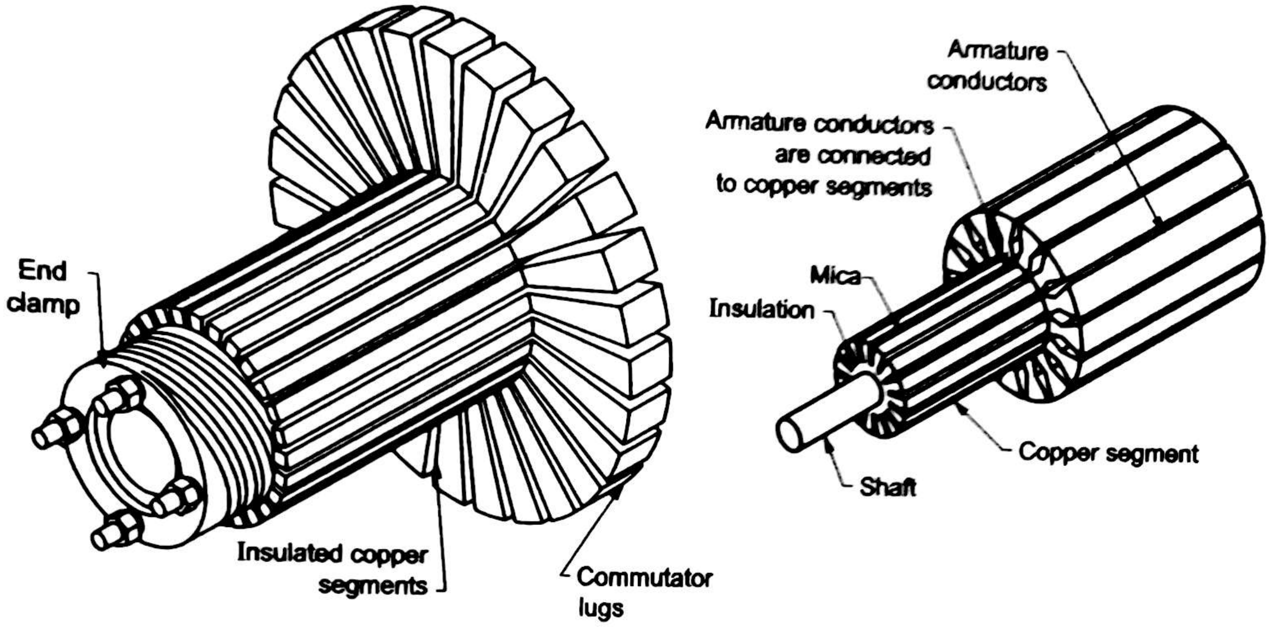
Ans. : The armature conductors made of copper are placed in the armature slots present on the periphery of armature core.

The armature winding is supposed to carry the entire load current. Hence it should be made up of a conducting material such as copper.

Q. 23 What is commutator ?

Ans. : The construction of a commutator is as shown in Fig. 5.5.

- A commutator is a cylindrical drum mounted on the shaft alongwith the armature core.
- It is made of a large number of wedge-shaped segments of hard-drawn copper.
- The segments are insulated from each other by thin layers of mica.
- The armature winding is tapped at various points and these tappings are successively connected to various segments of the commutator.



(a) Commutators **(b) Rotor of a DC Machine**

Fig. 5.5 : Construction of a commutator

Q. 24 What are the functions of commutator ?

Ans. :

Functions of a commutator

1. It convert the alternating emf generated internally in a d.c. voltage. So it basically works like a rectifier.
2. It collects the current from the armature conductors and passes it to the external load via- brushes.
3. For dc motors, it helps to produce a unidirectional torque.

Q. 25 What are the material used to make commutator ?

Ans. : The commutator segments are made of copper and the insulating material between the segments is mica.

Q. 26 What is a brush in DC Machine ?

Ans. :

- Current is conducted from the armature to the external load by the carbon brushes which are held against the surface of commutator by springs.
- Brushes wear with time. Hence they should be inspected regularly and replaced occasionally.

Q. 27 What are the functions of Brushes in DC Machine ?

Ans. : To collect current from the commutator and apply it to the external load.

Q. 28 What is the material used to make brushes in DC Machine ?

Ans. : Brushes are made of carbon. They are rectangular in shape.

Q. 29 Draw separately excited generator connections.

Ans. :

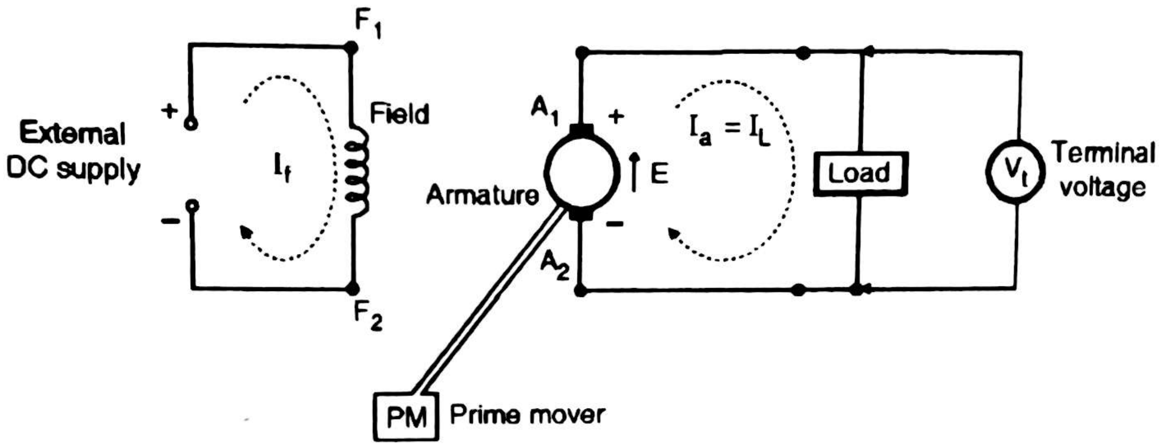


Fig. 5.6

Q. 30 Write the field current and voltage relationship of Separately excited DC Generator.

Ans. :

- Due to the separate excitation, the field current I_f will remain constant.

$$\therefore \quad I_f = \frac{V_f}{R_f} = \text{constant} \quad \text{...(1)}$$

Where V_f = External dc excitation applied to field,

R_f = Resistance of the field winding.

- The flux produced in the air gap is proportional to the field current. Hence with a constant field current, the air gap flux will remain constant.

Q. 31 Write the armature current and voltage relationship of Separately excited DC Generator.

Ans. :

- The load is connected directly across the armature winding. Hence the armature current is equal to the load current.

$$\therefore \quad I_a = I_L$$

$$I_a = I_L = \frac{E - V_t}{R_a} \quad \text{...(1)}$$

$$= \frac{V_t}{R_L} \quad \text{...(2)}$$

where E = Internally induced emf

But $V_t = E - I_a R_a$

$$\therefore \quad I_a = \frac{E - I_a R_a}{R_L}$$

$$\therefore \quad I_a (R_L + R_a) = E$$

$$\therefore \quad I_a = I_L = E / (R_L + R_a) \qquad ...(3)$$

Q. 32 Write the internally induced voltage of Separately excited DC Generator.

Ans. :

- The internally induced emf is denoted by E and it is given by,

$$E = \frac{P\phi NZ}{60 A} \qquad ...(1)$$

- The internally induced emf is proportional to the speed (N) and flux ϕ. For a separately excited generator, if the field current I_f is constant, then the internally induced emf is proportional only to the speed.
- The polarity of internally induced emf is decided by, the direction of rotation. If we reverse the direction of rotation of armature (by reversing the direction of the prime mover), then the polarity of "E" will reverse.

Q. 33 Write the terminal voltage of Separately excited DC Generator.

Ans. :

- The terminal voltage is the actual voltage across the load. It is denoted by V_t. The terminal voltage is not equal to the internally induced voltage. The expression for the terminal voltage V_t is given by,

$$V_t = E - I_a R_a - V_{brush} - \text{Armature reaction drop} \qquad ...(1)$$

Where $I_a R_a$ = Voltage drop across the armature winding resistance

V_{brush} = Voltage drop across the brushes

- In addition to these two voltage drops, there is one more voltage drop called as the **armature reaction drop**.

Q. 34 Explain the connection of shunt connected self excited generator.

Ans. :

- The shunt generator is a self excited generator where the field winding is fed by the armature itself, the two windings being connected in parallel.
- The term shunt indicates the parallel connection. The connections between the armature and field windings are as shown in Fig. 5.7.

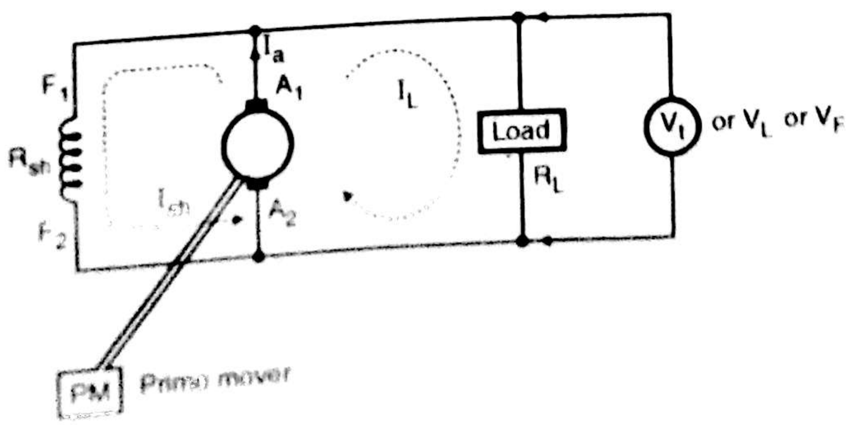


Fig. 5.7 : Shunt generator

Q. 35 Give all the current relations of shunt connected self excited generator.

Ans. :

- The armature has to supply the field current as well as the load current.

$$\therefore \quad I_a = I_{sh} + I_l$$

- The load voltage is equal to the voltage across the shunt field winding. Hence the field current is given by,

$$I_{sh} = \frac{V_t}{R_{sh}}$$

- And the load current is given by,

$$I_L = V_t / R_L$$

Q. 36 Give the voltage relation of shunt connected self excited generator.

Ans. : The relation between the terminal voltage V_t and the internally induced voltage E is given by,

$$V_t = E - I_a R_a - V_{brush} - \text{Armature reaction drop}$$

Q. 37 Give the applications of shunt connected self excited generator.

Ans. :

- The reduction in the load voltage is not large, hence it is said that the terminal voltage (V_t) almost remains constant.
- Hence the shunt generator is used in applications such as battery charging and lighting applications.

Q. 38 Explain the connection of series connected self excited generator.

Ans. :

Series Generator

- In a series generator, the field winding is connected in series with the armature winding as shown in Fig. 5.8.
- The series combination then supplies the load current. Note that in Fig. 5.8, the field winding terminals are marked as S_1 and S_2 instead of F_1 and F_2, just to indicate that the field winding is in series with the armature winding.

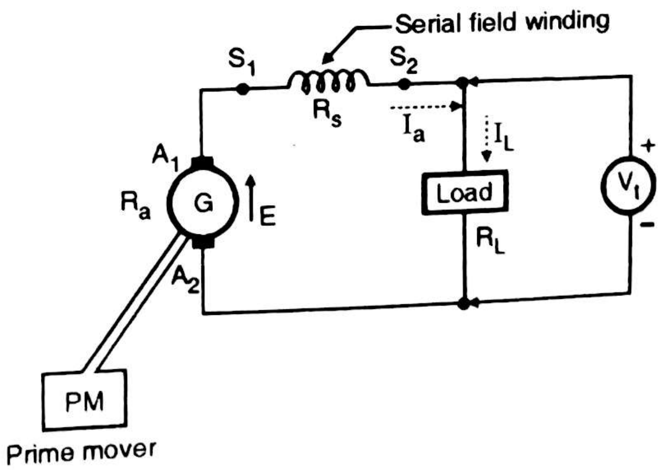


Fig. 5.8 : A series generator

Q. 39 Give the current relation of series connected self excited generator.

Ans. :

$$I_a = I_s = I_L$$

Q. 40 Give the voltage relation of series connected self excited generator.

Ans. :

$$E = V_t + I_a R_a + I_a R_s + V_{brush} + \text{Armature reaction drop}$$

$$\therefore E = V_t + I_a (R_a + R_s) + V_{brush} + \text{Armature reaction drop} \quad ...(1)$$

Q. 41 Give the applications of series connected self excited generator.

Ans. :

1. A series generator has a rising characteristics. Therefore it cannot be used for the lighting applications.
2. It can be used as a voltage booster to compensate for the drop in voltage on dc feeders.
3. Series generators are also used for the applications such as welding generators and arc lamps.

Q. 42 Give the current and voltage relations of a compound connected self excited DC generator.

Ans. :

$$I_a = I_s \qquad \text{and} \qquad I_a = I_{sh} + I_L$$

- The current through shunt field winding is given by,

$$I_{sh} = V_t / R_{sh}$$

where R_{sh} = Resistance of the field winding

- The internally induced emf is given by,

$$E = V_t + I_a R_a + I_s R_s + V_{brush}$$

where R_s = Resistance of series field winding

But $I_a = I_s$ $\qquad \therefore \quad E = V_t + I_a (R_a + R_s) + V_{brush}$

- The terminal voltage V_t is given by,

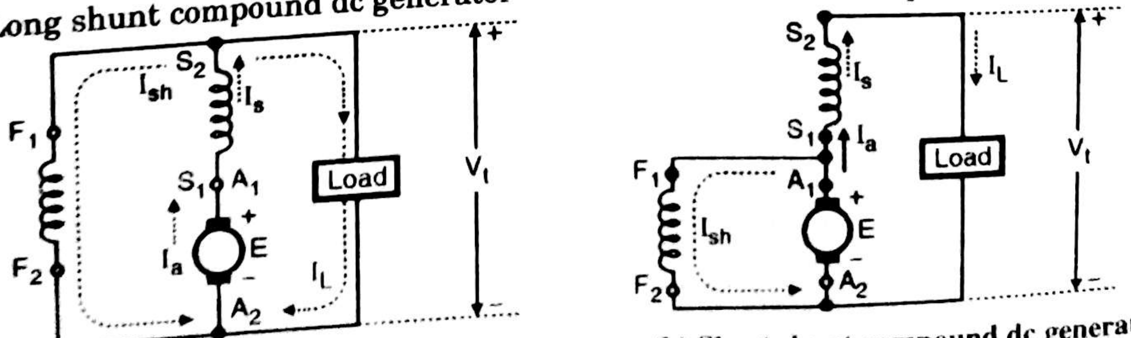
$$V_t = I_L R_L = I_{sh} R_{sh}$$

Q. 43 Draw circuit diagram of short shunt and long shunt type of composite self excited DC generator.

Ans. :

- The two types of compound dc generators shown in Fig. 5.9 are :

1. Long shunt compound dc generator
2. Short shunt compound dc generator



(a) Long shunt compound dc generator

(b) Short shunt compound dc generator

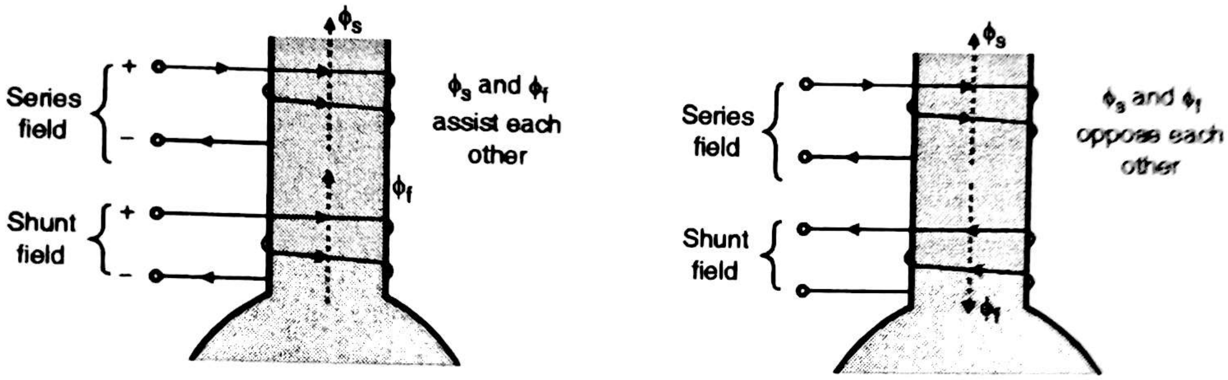
Fig. 5.9

Q. 44 Explain the connection of cumulative and differential compound generator.

Ans. :

Cumulative compound generator

- If the fluxes produced by the series and shunt field windings assist each other (Fig. 5.10(b)), then the type of generator is called as cumulative compound generator.



(b) Cumulative compound generator (c) Differential compound generator

Fig. 5.10

$\therefore$ Total flux $\phi_T = \phi_s + \phi_f$ ...(1)

where ϕ_s = Flux produced by the series winding

ϕ_f = Flux produced by the shunt winding.

Differential compound generator

- If the fluxes produced by the series and shunt field windings oppose each other as shown in Fig. 5.10(b), then the type of generator is called as differential compound generator.

$\therefore$ Total flux, $\phi_T = \phi_f - \phi_s$ ...(2)

Q. 45 What direction does a DC motor move ?

Ans. :

The direction of rotation of a motor depends on the direction of force exerted on the armature winding, and the direction of force experienced by a current carrying conductor is given by **Fleming's left hand rule.**

Q. 46 What is the significance of back emf ?

Ans. :

- When the armature winding of a dc motor starts rotating in the magnetic flux produced by the field winding, it cuts the lines of magnetic flux.
- Hence according to the Faraday's laws of electromagnetic induction, there will be an induced emf in the armature winding.
- As per the Lenz's law, this induced emf acts in opposite direction to the armature supply voltage. Hence this emf is called as the back emf and it is denoted by E_b.

- The back emf thus gets produced due to the generating action that we have discussed earlier and expressed mathematically as,

$$E_b = \frac{P \phi N Z}{60 A} \text{ Volts}$$

Q. 47 What is the effect of increase in the load for a DC motor ?

Ans. : When the mechanical load on the motor is increased

1. The motor slow down. But E_b is proportional to speed.
2. So the back emf E_b decreases.
3. Hence I_a increases.
4. So the force increases since $F = BI_a 1$ Newton
5. Hence motor torque increases and goes closer to T_L
6. The speed increases and I_a decreases.

Q. 48 What is the effect of decrease in the load for a DC motor ?

Ans. : If the mechanical load on the motor shaft is reduced.

1. The motor torque is higher than the load torque.
2. So the motor speed tends to increase.
3. Hence back emf increases.
4. So Ia decreases.
5. This will reduce motor torque.
6. This will stop the increase in speed and bring the motor into equilibrium.
7. Thus the back emf ensures that the reduction in torque takes place quickly.
8. In this way the back emf E_b automatically controls the magnitude of armature current to meet the changing load requirements. This is the practical importance of back emf.

Q. 49 Give the power equation of a DC motor.

Ans. :

$$V I_a = E_b I_a + I_a^2 R_a$$

Q. 50 Give the torque equation of a DC motor.

Ans. :

$$\therefore T_a = \frac{P \phi Z}{2 \pi A} \times I_a = 0.159 \frac{PZ}{A} \phi I_a$$

Q. 51 What are the applications of DC shunt motors ?

Ans. :

1. Various machine tools such as lathe machines, drilling machines, milling machines etc.
2. Printing machinery
3. Paper machines
4. Centrifugal and reciprocating pumps

5. Blowers and fans etc. However a three-phase squirrel cage induction motor which has almost similar characteristics (except availability of speed control over a wide range) is used for most of the applications stated above. The reasons being, induction motor is cheaper in cost, mechanically robust and as it works on a.c. supply, no additional arrangement is required to generate d.c. supply.

Q. 52 What are the applications of DC series motors ?

Ans. :

- Series motors are very widely used for the following applications :
  1. Electric trains,
  2. Diesel-electric locomotives,
  3. Cranes,
  4. Hoists
  5. Trolley cars and trolley buses,
  6. Rapid-transit systems,
  7. Conveyers etc.

Q. 53 What are the applications of cumulative compound DC motors and differential compound dc motor ?

Ans. :

Cumulative Compound Motor Applications

- These motors have high starting torque.
- They can be operated even at no loads as they run at a moderately high speed at no load.
- Hence cumulative compound motors are used for the following applications :
  1. Elevators
  2. Rolling mills
  3. Punches
  4. Shears
  5. Planers

Differential Compound Motors Applications

- The speed of these motors will increase with increase in the load, which leads to an unstable operation.
- Therefore we cannot use this motor for any practical applications.

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