B.Tech.

FIRST SEMESTER EXAMINATION, 2009-10

ELECTRICAL ENGINEERING

Time: **3** *Hours* *Total Marks:* **100**

Note: (1) *Attempt all questions.*

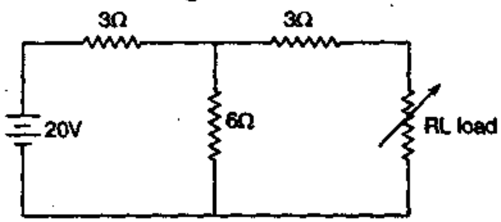
(2) *All questions carry equal marks.*

SECTION—A

Q. 1. Attempt all parts: **(10 × 2) = 20**

(Fill in the blank/choose/match/determine)

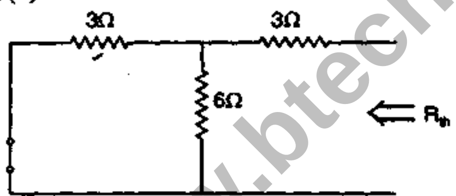
(*i*) The maximom power that can be supplied to the load in the following circuit is



(*a*) 10 W (8.88 W) (*b*) 20 W

(c) 30 W (*d*) 40 W

Ans. (*a*)

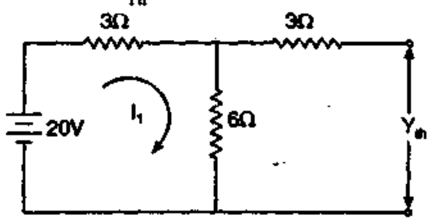


Step. 1

$$R_{Th} = (3116)+3$$

$$= \left(\frac{3\times 6}{9}\right)+3 = 5\Omega$$

Step. 2 To find V_{Th}



$$I_1 = \frac{20}{3+6} = \frac{20}{9} A$$

V_{Th} = Voltage across 6W register

So $$V_{Th} = \frac{20}{9}\times 6 = \left(\frac{40}{3}\right) V$$

Maximum power supplied to the load

$$P_{max} = \frac{V_{Th}^2}{4R_{Th}}$$

$$= \frac{40\times 40}{9\times 20} = \frac{80}{9}$$

$$P_{max} = 8.88 \text{ W} \quad \textbf{Ans.}$$

(*ii*) The coupling between two magnetically coupled coils is sald to be ideal if the coefficient of coupllog is

(*a*) zero (b) 0.5

(c) 0.75 (d) 1

Ans. (*d*) The cofficient of coupling for two magnetically coupled coils is one.

(*iii*) A sinusoldal current having rms value of $8\angle 0°$ *A* is added to another sloosoidal current of rms value $6\angle 90° A$. The rms value of resultant current is ——————.

Aos. $8\angle 0° = 9\cos 0 + J8\sin 0 = 8 + J0$

$\{\because \angle\theta° = r\cos\theta + jr\sin\theta$

$6\angle 90° = 6\cos 90 + J6\sin 90 = 0 + 6J.$

By adding

$8\angle 0° + 6\angle 90° = 8 + 6J$

Now in polar form

$$r = \sqrt{8^2+6^2}$$

$$\begin{cases} a+bj \\ r = \sqrt{a^2+b^2} \end{cases}$$

$$\theta = \tan^{-1}\left(\frac{b}{a}\right)$$

$$r = \sqrt{100} = 10$$

$$\theta = \tan^{-1}\left(\frac{6}{8}\right)$$

$$\theta = 36.86°$$

Ans in polar form = $10\angle 36.86°$ **Ans.**

(iv) Which of the following condition is common to both series and parallel resonance ?

(a) Current is maximum

(b) Power is low

(c) Impedance is minimum

(d) Power factor is unity

Ans. (*d*) At resonance condition the angle between V and current is zero, because circuit is resistive. So $\theta = 0$, then power factor

$$= \cos\phi$$
$$= \cos 0$$
$$= 1 \quad \textbf{Ans.}$$

(v) Which of the following formulae is used to express active power in a balanced three phase circuit ?

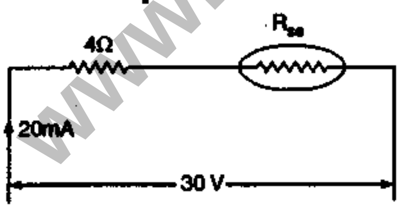
(a) $V_L I_L \cos\phi$ **(b)** $\sqrt{3}\ V_L I_L \cos\phi$

(c) $V_{ph} I_{ph} \cos\phi$ **(d)** $\sqrt{3}\ V_{ph} I_{ph} \cos\phi$

Ans. (*b*) Active power in a balance three phase circuit is $\sqrt{3}\ V_L I_L \cos\phi$

(vi) A moving coil instrument gives full scale deflection with 20 mA. The resistance of coil is 40 hm. The value of series resistance needed for the instrument to read upto 30 V is————.

Ans.



$$30 = 20 \times 10{-}3\,(4 + R_{se})$$

$$4 + R_{se} = \frac{30}{20 \times 10^{-3}}$$

$$R_{se} = \frac{3}{2} \times 10^3 - 4$$

$$R_{se} = 1500 - 4$$

$$R_{se} = 1496\ \text{W} \quad \textbf{Ans.}$$

(vii) A 100 kVA single phase-transformer operating at 0.9 power factor has 90% maximum efficiency. The iron loss will be————.

Ans. At maximum efficiency,

Constant iron loss = Variable copper loss

$$P_i = P_c,\ P_i + P_c = 2P_i$$

Now, $$\eta_{max} = \frac{VI\cos\phi}{VI\cos\phi + P_i + P_i}$$

$$0.9 = \frac{100 \times 1000 \times 0.9}{100 \times 1000 \times 0.9 + 2P_i}$$

$$\{\because p_i = P_c\}$$

$$1.8\,P_i = 90000 - 81000$$

$$P_i = \frac{9000}{1.8}$$

$$P_i = 5000$$

$$P_i = 5\ \text{kW} \quad \textbf{Ans.}$$

(viii) A 4-pole lap wound dc generator generates 200 V at 1000 rpm. If this generator is now wave wound and runs at 500 rpm, the generated voltage will be————.

Ans. We know that

$$E_1 = \frac{N_1 P\phi Z}{60\,A}$$

for lap wound $A = P = 4$

$E_1 = 200$ V $N_1 = 1000$ rpm

$$200 = \frac{1000\,\phi Z}{60 \times 4}$$

$$200 = \frac{1000}{60}\phi Z$$

$$\phi Z = 12$$

Now for wave wound $A = 2$, $N_2 = 500$ rpm

$$E_2 = \frac{N_2 P\phi Z}{60\,A}$$

$$E_2 = \frac{500 \times 4 \times 12}{60 \times 2}$$

$$E_2 = 200\ \text{V} \quad \textbf{Ans.}$$

(ix) A 3-phase induction motor connected from a 3-phase Hz ac supply runs at 720 rpm and has 4% slip. The number of poles in the motor are

(a) 4 **(b) 6**

(c) 8 **(d) 16**

Ans. (*c*) We know that

$$N_r = 720 \text{ rpm}$$

$$S = \frac{N_s - N_r}{N_s} \qquad S = 4\% = 0.04$$

$$0.04 = \frac{N_s - 720}{N_s}$$

$$.94 N_s = 720$$

Or

$$N_s = \frac{720}{.94} = 765.95 \simeq 766 \text{ rpm}$$

and $$N_s = \frac{120 f}{P}$$

$$P = \frac{120 \times 50}{766} \qquad \left\{ \begin{array}{l} \because f = 50 \text{ Hz} \\ N_s = 766 \text{ rpm} \end{array} \right\}$$

$$P = 7.83 \simeq 8 \text{ Poles.}$$

(x) Match the following (marks will be awarded if all matching are correct)

Type of Motor	Application
(*i*) dc series motor	(*a*) Centrifugal pumps
(*ii*) Synchronous motor	(*b*) Cranes
(*iii*) 3-phase squirrel cage	(*c*) Hair dryer
(*iv*) Single phase shaded	(*d*) Condenser

Ans. (*i*) → (*b*)

(*ii*) → (*d*)

(*iii*) → (*a*)

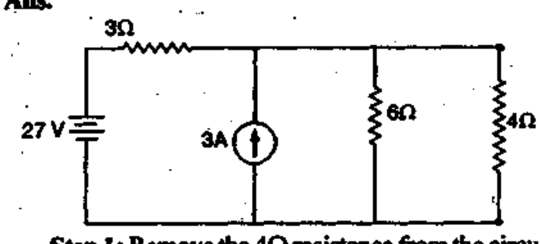
(*iv*) → (*c*)

SECTION—B

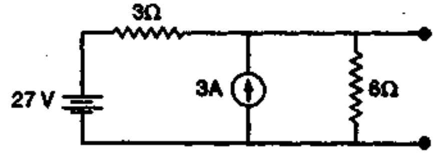
Q.2. Attempt any three parts of the following: (10 × 3 = 30)

(*a*) (*i*) Determine current in 4Ohm resistance using Thevenin's theorem in the following circuit.

Ans.



Step 1: Remove the 4Ω resistance from the circuit

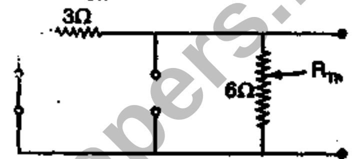


Step 2: To find R_{Th}, voltage source is not circuit and current source open circuit

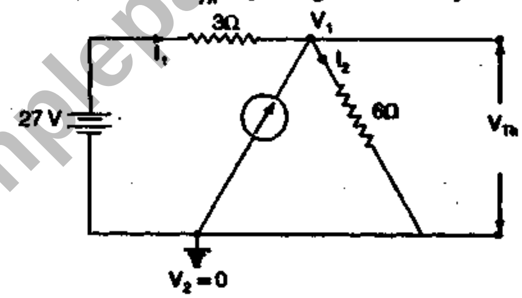
$$R_{Th} = 3\Omega \| 6\Omega$$

$$= \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2\Omega$$

$$R_{Th} = 2\Omega$$



Step 3: Find V_{Th}, By using Nodel Analysis



⇒ Assume V_2 as reference voltage, so $V_2 = 0$

Nodel eq^n at Node V_1, Applying $KCL, I_1 + 3 = I_2$

Now $$\frac{0 - (-27) - V_1}{3} + 3 = \frac{V_1 - 0}{6}$$

$$\frac{27 - V_1}{3} + 3 = \frac{V_1}{6}$$

$$\frac{36 - V_1}{3} = \frac{V_1}{6}$$

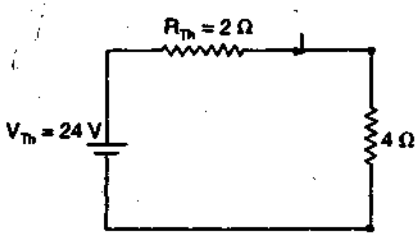
$$36 - V_1 = \frac{V_1}{2}$$

$$3 V_1 = 72$$

$$V_1 = 72/3 = 24$$

So, $$V_{Th} = V_1 = 24$$

Step 4: Draw the Thevenin equivalent circuit, and connect the 4Ω resistance.



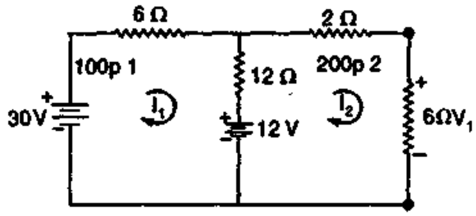
⇒ Current in 4Ω resistor. is

Applying *KVL*

$$-24 + 2I + 4I = 0$$
$$6I = 24$$
$$I = 24/6 = 4$$
$$I = 4\,A$$

(*ii*) Find the voltage across 6 ohm resistance in the followiag circuit using loop analysis method:

Ans.



Step 1: Assume the current I_1 for loop 1 and I_2 for loop 2.

Step 2: Applying *KVL* in loop 1 (Mesh 1)

$$-30 + 6I_1 + 12(I_1 - I_2) + 12 = 0$$
$$18I_1 - 12I_2 = 18$$

or $\quad 3I_1 - 2I_2 = 3 \quad$ ...(*i*)

Step 3: Applying *KVL* in loop 2 (Mesh 2)

$$2I_1 + 6I_2 - 12 + 12(I_2 - I_1) = 0$$
$$-12I_1 + 20I_2 = 12$$
$$-3I_1 + 5I_2 = 3 \quad ...(ii)$$

Step 4: By adding the eqn (*i*) and (*ii*)

$$3I_2 = 6$$
$$I_2 = 2\text{A}$$

Step 5: Now the voltage V_1 across 6Ω resistor is

$$V_1 = 6 \times I_2 = 6 \times 2$$
$$V_1 = 12\,V \text{ Ans.}$$

(*b*) A coil having resistance of 6 ohm nnd inductance of 0.02554 is connected across a 230 V 50 Hz ac supply. Calculate

(*i*) Current

(*ii*) Power factor

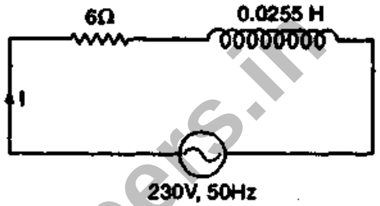
(*iii*) Active power

(*iv*) Reactive power

(*v*) Apparent power

(*vi*) It is desired to improve power factor to 0.8. What value of capacitance to be connected in series R and what is reduction in reactive power?

Ans.



$$L = 0.02554$$

then $\quad X_L = 2\pi f L$

$$= 2 \times 3.14 \times 50 \times 0.0255$$
$$X_L = 8\,\Omega$$

Now, $\quad Z = \sqrt{R^2 + X_L^2} \qquad \phi = \tan^{-1}\left(\frac{8}{6}\right)$

$$= \sqrt{6^2 + 8^2} \qquad \phi = 53.13$$
$$Z = \sqrt{100} = 10$$

Now, $\quad Z = 10\angle 53.13°$

(*i*) Current $I = \dfrac{V}{Z} = \dfrac{230}{10\angle 53.13} = 23\angle -53.13$ **Ans.**

(*ii*) Power factor $\cos\phi = \dfrac{R}{Z} = \dfrac{6}{10}$

$= 0.6$ (lagging) **Ans.**

(*iii*) Active power $= VI\cos\phi$

$= 230 \times 23 \times 0.6$

$= 3174$ Watts **Ans.**

(*iv*) Reactive power $= VI\sin\phi$

$= 230 \times 23 \times 0.8$

$= 4232$ VAR **Ans.**

(*v*) Apparent power(s) = VI

$= 230 \times 23 = 5290$ VA **Ans.**

(*vi*) When power factor is improved to 0.8 then

$$\frac{R}{Z} = 0.8$$

$$Z = \frac{R}{0.8} = \frac{6}{0.8} = 7.5\,\Omega$$

Now, $Z = 7.5\,\Omega$

$\therefore$ $X = Z\sin\phi = 7.5 \times 0.6$

$$\left[\begin{array}{l}\cos\theta = 0.8 \\ \text{then} \\ \sin\phi = 0.6\end{array}\right]$$

$X = 4.5\,\Omega$

Now, $X_L - X_C = 4.5$

$X_C = X_L - 4.5 = 8 - 4.5$

$X_C = 3.5\,\Omega$

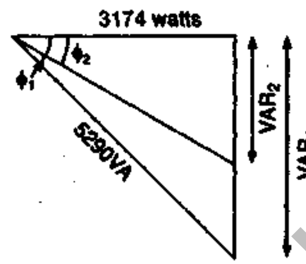
$\therefore$ $X_C = \dfrac{1}{2\pi F_C}$

So, $C = \dfrac{1}{2\pi F X_C}$

$= \dfrac{1}{2 \times 3.14 \times 50 \times 3.5}$

$C = 909.9\,\mu F$ Ans.

Now New Reactive Power = 3174 $X \tan\phi_2$



$= 3174 \times \dfrac{\sin\phi_2}{\cos\phi_2}$

= New Reactive Power

= 2380.5 VAR

Now Reduction in Reactive Power

= 4232 − 2380.5

= 1851.5 VAR Ans.

(c) A balanced star connected inductive load is connected to a 400 V, 50 Hz ac supply-two wattmeters used to measure supply power indicate 8000 W and 4000 W respectively. Determine

(i) Line current

(ii) Impedance of each phase

(iii) Resistance and inductance of each phase

Ans. $W_1 = 8000$ W

$W_2 = 4000$ W

We know that $W_1 = V_L I_L \cos(30 - \phi)$

$W_2 = V_L I_L \cos(30 + \phi)$

Now, $W_1 + W_2 = \sqrt{3}\, V_L I_L \cos(30 + \phi)$

$(8000 + 4000) = \sqrt{3} \times 400 \times I_L \cos\phi$ ...(i)

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

$\tan\phi = \dfrac{\sqrt{3}\,(800 - 4000)}{(8000 + 4000)}$

$\tan\phi = \dfrac{1}{3}$

$\phi = 30°$

for inductive load $\phi = -30°$, $\cos(-30°) = \dfrac{\sqrt{3}}{2}$

Put the value of $\cos\phi$ in equation (1)

(i) $I_L = \dfrac{12000}{\sqrt{3} \times 400 \times \dfrac{\sqrt{3}}{2}}$

$I_L = 20$ A Ans.

(ii) $Z = \dfrac{V_{Ph}}{I_{ph}} = \dfrac{40/\sqrt{3}}{20\angle -30°}$

$Z = 11.54\angle 30°$ Ans.

(iii) $R = Z\cos\phi$

$= 11.54 \times \dfrac{\sqrt{3}}{2}$

$= 9.99 \simeq 10\,\Omega$ Ans.

Now, $X_L = X\sin\phi$

$= 11.54 \times \dfrac{1}{2} = 5.77\,\Omega$

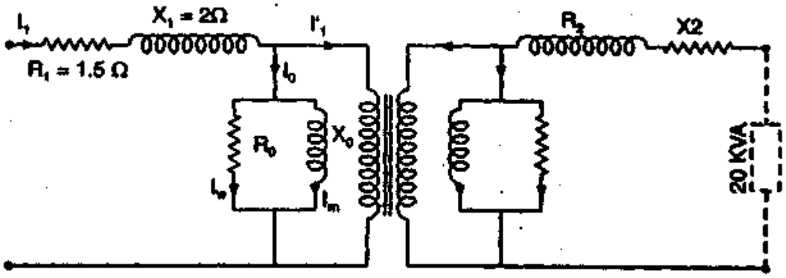
$\therefore$ $X_L = 2\pi f L$

So, $L = \dfrac{5.77}{2 \times 3.14 \times 50} = 0.01838$ H

$L = 18.38$ mH Ans.

(d) A 20 kVA, 2000 V/200 V, single phase 50 Hz transformer has a primary resistance of 1.5 ohm and a reactance of 20 hm. The secondary resistance and reactance are 0.015 ohm and 0.02 ohm respectively. The no load current of transformer is 1A at 0.2 power factor. Determine–

(i) Equivalent resistance, reactance and impedance referred to primary



(ii) Supply current

(iii) Total copper loss

Draw approximate equivalent circuit.

Sol. 20 k VA, 2000/200 Volts, $1-\phi$, 50 Hz transformer as shown in above figure

Now, $I_1 = I_0 + I'_1$

and $k = \dfrac{V_2}{V_1} = \dfrac{200}{2000} = 0.1$

$k = 0.1$

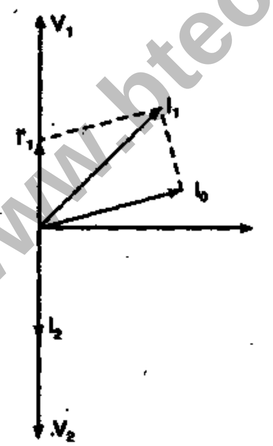
(i) R_{eq} = Equivalent resistance referred to primary

$$= R_1 + \frac{R_2}{k^2}$$

$$= 1.5 + \frac{0.015}{(0.1)^2}$$

$$= 1.5 + 1.5$$

$R_{eq} = 3\,\Omega$ **Ans.**



Now, $X_{eq} = X_1 + \dfrac{X_2}{k^2}$

$$= 2 + \frac{0.02}{(0.1)^2}$$

$X_{eq} = 4\,\Omega$ **Ans.**

$Z_{eq} = 3 + 4J$

$$= \sqrt{3^2 + 4^2}\ \angle \tan^{-1}\frac{4}{3}$$

$Z_{eq} = 5\angle 53.13$ **Ans.**

(ii) $I_1 = 1\text{A}, I_2 = \dfrac{20\times 10^3}{200} = 100\text{ A}$

So $\dfrac{I_2}{I_1} = \dfrac{V_1}{V_2} = \dfrac{1}{k}$

or $\dfrac{V_2}{V_1} = \dfrac{I'_1}{I_2} = \text{k}$

$I'_1 = 1A, \quad I_2 = \dfrac{20\times 10^3}{200} = 100\text{ A}$

So $\dfrac{I_2}{I_1} = \dfrac{V_1}{V_2} = \dfrac{1}{k}$

or $\dfrac{V_2}{V_1} = \dfrac{I'_1}{I_2} = k$

$I'_1 = k I_2 = 0.1\times 100$

$I'_1 = 10 A$

Now from the phasor diagram

Supply current load at unity power factor

$$I_1 = \sqrt{I_1'^2 + I_0^2 + 2\, I_1'\, I_0 \cos\phi}$$

$$= \sqrt{100 + 1 + 2\times 10\times 1\times 0.2}$$

$$= \sqrt{105}$$

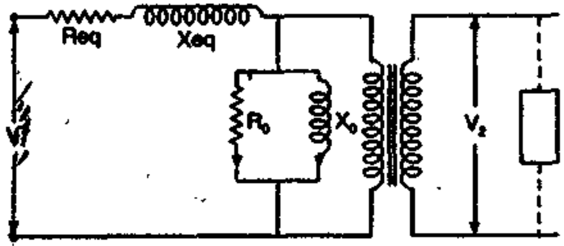
$I_1 = 10.24\text{ A}$ **Ans.**

(iii) Total copper losses $= I'_1 = R_{eq}$

$= (10.24)^2 \times 3$

Copper loss = 314.57 Watt **Ans.**

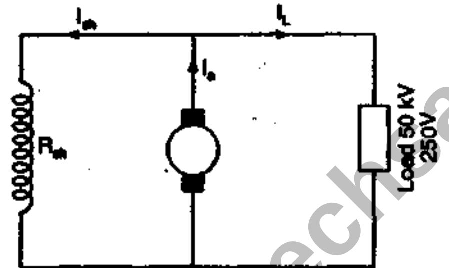
Equivalent circuit



(e) A dc shunt generator delivers 50 kW at 250 V when running at 500 rpm. The armature and field resistance are 0.05 ohm and 125 ohm respectively. Calculate the speed of the same machine and developed torque when running as a shunt motor and taking 50 kW at 250 V. Allow 1 volt per brush for contact drop.

Sol.

$$P = 50\,\text{kW}$$
$$V = 250\,\text{V}$$
$$R_a = 0.05\,\Omega$$
$$R_{sh} = 125\,\Omega$$



$$I_L = \frac{P}{V} = \frac{50 \times 10^3}{250} = 200\,A$$

$$I_{sh} = \frac{250}{125} = 2A$$

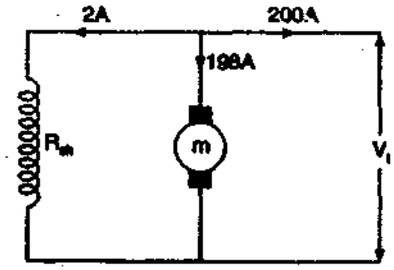
$$I_a = I_c + I_{sh}$$
$$= 200 + 2 = 202\,A$$

Now

$$E = V_t + I_a R_a + V_{brush}$$
$$= k\Omega W_g$$
$$k\Omega W_g = (250 + 202 \times 0.05 + 2)$$
$$= 262.1 \text{ Volt} \quad ...(i)$$

For motor

$$k\Omega W_m = V_t - I_a R_a - V_{brush}$$
$$k\Omega W_m = 250 - (198 \times 0.05) - 2$$
$$k\Omega W_m = 238.1 \quad ...(ii)$$



From equation (i) and (ii)

$$\frac{W_g}{W_m} = \frac{262.1}{238.1}$$

$$\therefore \quad \frac{W_g}{W_m} = \frac{N_g}{N_m}$$

So $$N_m = \frac{W_m \times N_g}{W_g} = \frac{238.1 \times 500}{262.1}$$

$$= 454.21 \text{ rpm} \quad \textbf{Ans.}$$

Now, Torque $T = k\phi I_a$

$$\therefore \quad E_a = k\phi W_m$$

Then, $$T = \frac{E_a \times I_a}{W_m}$$

{Given $N_m = 500$ rpm}

$$= \frac{E_a \times I_a}{2\pi \frac{n}{60}} = \frac{60 \times E_a \times I_a}{2 \times 3.14 \times 500}$$

$$= \frac{60 \times 262.1 \times 198}{2 \times 3.14 \times 500}$$

$$= 991.63 \text{ N.M} \quad \textbf{Ans.}$$

Q. 3. State and explain superposition theorem

5 marks

or

State and Explain superposition theorem. Mention its limitations.

or

Explain the procedure for analyzing a circuit by superposition theorem.

Ans: Superposition the orem for dc networks: Superposition the orem states that "A linear, active, dc network containing more that one independent energy source (voltage source of current source), the over all response (that is, current through or voltage across) in any branch is equal to the algebraic sum of the responses due to each independent source acting one at a time with all other to ideal independent source set equal to zero"

⇒ Idal voltage source equal to zero means that sources is replaced by shot circuit because the internal resistance of ideal voltage source is zero.

⇒ Source replaced by its internal resistance.

⇒ Ideal voltage source, internal resistance is intinite. So the ideal current source is replaced by open circuit.

Procedure for Analyzineg a Circuit by Superposition Theorem:

Step 1: Select any one source in the circuit

Step 2: Replace all other independent source by their internal resistance

⇒ If their is independent ideal voltage source replaced by shot circuit

⇒ If their is independent ideal current source replaced by open circuit.

Step 3: Keep the dependent source in the circuit undisturbed. it is created as a circuit elements.

Step 4: Determine the magnitude and direction of the current through the desired branch by using *KVL*, *KCL*, etc, by one source which is selected in step1.

Step 5: Repeat the procedure step1 to step 4 for each source,

Step 6: Algebraically add all the component of current to obtain the desired brance current.

This sum is the actual current when the all source acting simultaneously.

Limitations:

1. Superposition theorem is not applicable for non-Linear network
2. Dependent sources are not rehoused. It is treated as circuit elements.
3. Superposition Theorem is nt applicable for power calculations.
4. Itis applied for more than one independent sources.

(b) Discuss the Voltage source and current source and show the classification of sources.

Ans. Voltage Source: A hypothetical generator which maintains its value of potential independent of the output current.

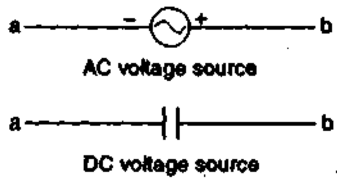
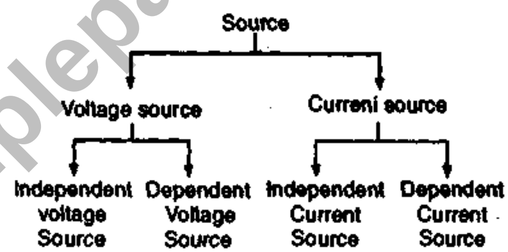


Fig. 1

Current Source: A generator which maintains its output current independent independent of the voltage across its terminds.

The current source will be indicated by a circle enclosing on arrow for reference current direction.

The Voltage source and current source can be classified as.



(c) Explain star - delta transformation.

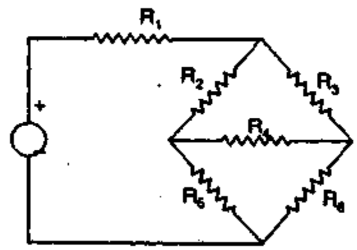
or

When is the $\Delta - \gamma$ transformation usefull in network reduction? I eestrate.

Explain star-delta transformation and vice-versa.

Ans: Siteeation often arise in the circuit in the analysis when the resistors are neither in parallet nor in series.

For example: Consider a bridge circuit in fig. How de we combine resister R_1 through R_6 when the resistorsare neither in series nor in parallel?



To simplify this circuit we use three-terminal equivalent networks.

(i) Wye (γ) or tee (T) Network, as shown in Fig.

(ii) Delta (Δ) of pi (Π) Network, as shown in Fig.

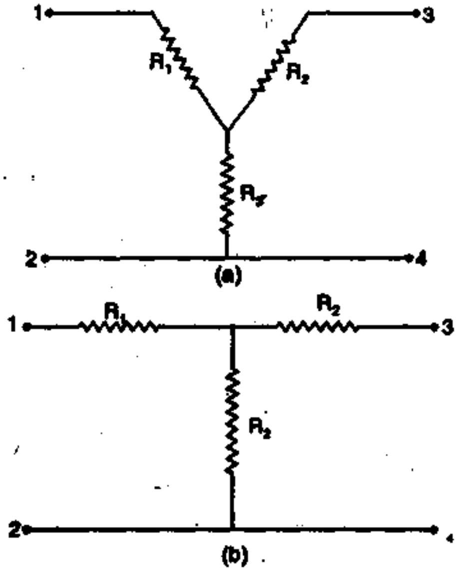


Fig. Two forms of the same network (a) Y (b) T

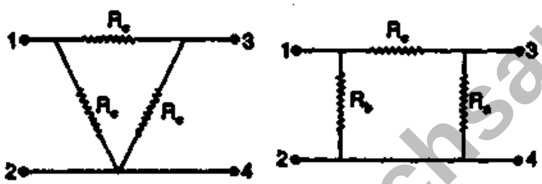


Fig. Two forms of the same network (a) Δ and (b) Π (Pi)

Delta Wye Conversion (Δ to γ conversion)

or Π to T conversion: To obtain the equivalent resistance in the γ network we company the two network and make sure that the resistance between each pare of nodes in the Δ (or Π) network is the same as the resistance between the same pair of nodes in the γ (or *T*) network.

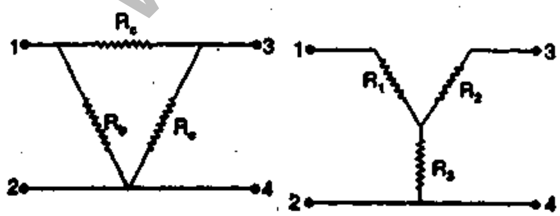


Fig. (a) (b)

From fig. (*a*) & (*b*)

$$R_{12}\ (\gamma) = R_1 + R_3$$

$$R_{12}(\Delta) = R_b \| (R_a + R_c)$$

For equivalence

$$R_{12}(\Delta) = R_{12}(\gamma)$$

$$R_{12} = R_1 + R_3 = \frac{R_b(R_a + R_c)}{R_a + R_b + R_c} \quad \text{... (i)}$$

In this way

$$R_{13} = R_1 + R_2 = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} \quad \text{... (ii)}$$

$$R_{34} = R_2 + R_3 = \frac{R_a(R_b + R_c)}{R_a + R_b + R_c} \quad \text{... (iii)}$$

Now subtracting Eq (iii) from eq (I)

$$\text{We get } R_1 - R_2 = \frac{R_c(R_b - R_a)}{R_a + R_b + R_C} \quad \text{... (iv)}$$

by Adding the Eq (II) & (IV)

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \quad \text{... (v)}$$

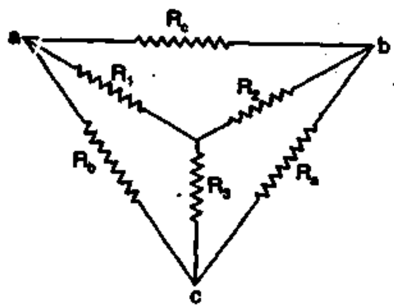


Fig. Superposition Δ to Y Networka as an aid in transforming once to the other.

Now by subtracting eq^n (V) from (II)

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c} \quad \text{... (vi)}$$

and by subtracting eq^n (V) from (I)

$$R_3 = \frac{R_a R_b}{R_a + R_b R_c} \quad \text{... (vii)}$$

Wye to Delta conversion (Y to Δ conversion)

T to Π transformation:

To obtain γ to Δ network from eq (V), (VI) and (VII), weget

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_aR_bR_c\left(R_a + R_bR_c\right)}{\left(R_a + R_b + R_C\right)^2}$$

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_aR_bR_c}{\left(R_a + R_b + R_C\right)} \quad \text{...}(viii)$$

Now by eq (*viii*) /(*v*)

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} \quad \text{...}(ix)$$

And by eq (*viii*)/(*vi*)

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} \quad \text{...}(x)$$

And $$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} \quad \text{...}(xi)$$

⇒ Each reistor in the Δ network is the sum of all possible products of γ resistors taken two at atime, divided by the opposite γ resistor as Eqn (ix), (x), follows the fig (1.20)

Balanced Network. The Δ and γ network are said to be balanced when

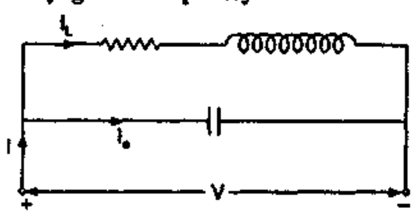
$$R_1 = R_2 = R_3 = R_y,$$
$$R_a = R_b = R_c = R_\Delta$$

Under these condition.

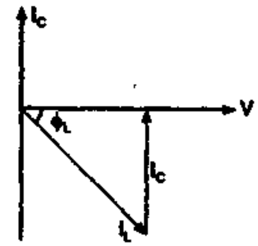
$$R_Y = \frac{R_\Delta}{3} \quad \text{or} \quad R_\Delta = R_y$$

Q. 4. (*a*) Explain parallel resonance and draw graph of α, β, and γ against frequency

Ans.



(a) Parallel Resonant Circuit



(b) Phasor diagram

The most common from of parallel resonant circuit in practical use is shown in Fig. (*a*). It is called a tank circuit.

A coil of inductance L and effective series resistance R is connected in parallel with capacitor.

The admittance of the circuit is

$$\gamma = JWC + \frac{1}{R + JWL}$$

$$= JWC + \frac{R - JWL}{R^2 + W^2L^2}$$

$$= \frac{R}{R^2 + W^2L^2} + JW\left(C - \frac{L}{R^2 + W^2\,L^2}\right)$$

All the resonance the J term is zero and $W = W_0$, so that

$$C - \frac{L}{R^2 + W_0^2\,L^2} = 0$$

$$R^2 + W_0^2\,L^2 = \frac{L}{C}$$

$$W_0^2\,L^2 = \frac{L}{C} - R^2$$

$$W_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

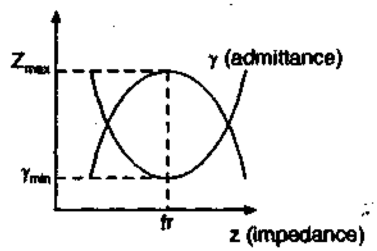
Resonant frequency in hertz

$$f_0 = \frac{W_0}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

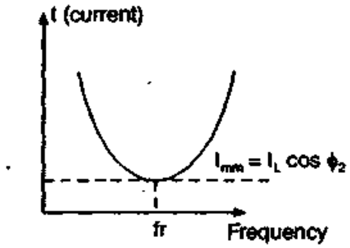
If R is small so that (R^2/L^2) may be neglected in comparison with $1/(LC)$.

So,

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$



(c) Variation of impedance and admittance with frequency



(d) Variation of current I with frequency

Q. 4. (b) What is meant by power factor? What is its significance? How will you obtain power factor from kVA triangle.

Ans. Power factor : It is defined as the cosine of the angle between voltage and current of the same circuit. It is also defined as the ratio of active power to apparent power. It is denoted by cos ϕ, where ϕ is the angle between voltage and current.

$$\text{Power factor} = \cos\phi = \frac{\text{Active Power}}{\text{Apparent Power}}$$

$$= \frac{VI\cos\phi}{VI}$$

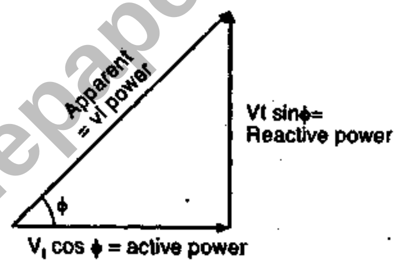
Significance of Power Factor :

1. The significance of power factor lies in the fact that utility companies supply consumers with volt-amperes, but bill them for watts.
2. Lower power factor indicates that a very small percentage of total power is being actually utilized.
3. If the power factor is low, then a large power is required to be generated to deliver the required power to the load. This increases generation cost and transmission cost.

For example: If the power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled. (Since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers and switchgear would be increased in size (and cost) to carry the extra current.

4. Power factor gives the information that the Circuit's resistive inductive or capacitive.

Power triangle :



From Power Triangle :

$$\frac{\text{Active Power}}{\text{Apperant Power}} = \cos\phi$$

Or $$(\text{Active Power})^2 = (\text{Apperant Power})^2 - (\text{Reactive Power})^2$$

$$VI\cos\phi = \sqrt{(VI)^2 - (VI\sin\phi)^2}$$

$$\cos\phi = \frac{\sqrt{(VI)^2 - (VI\sin\phi)^2}}{VI}$$

Q. 4. (c) For two phasors $A = a_1 + jb_1$ and $B = a_2 - jb_2$, obtain their multiplication and division using polar form of representation.

Ans. Phasor $A = a_1 + jb_1$

In polar form $r_1 = \sqrt{a_1^2 + b_1^2}$

$$\phi_1 = \tan^{-1}\frac{b_1}{a_1}$$

$$A = \sqrt{a_1^2 + b_1^2}\,\angle\tan^{-1}\left(\frac{b_1}{a_1}\right)$$

for Phasor

$$B = a_2 - jb_2$$

$$r_2 = \phi_2 = \tan^{-1}\left(\frac{-b_2}{a_2}\right)$$

$$B = \sqrt{a^2+b^2}\,\angle\tan^{-1}\left(\frac{-b_2}{a_2}\right)$$

(i) Multiplication

$$A \times B = (a_1 + jb_1)(a_2 - jb_2)$$

$$= \left(\sqrt{a_1^2+b_1^2}\,\angle\tan^{-1}\frac{b_1}{a_1}\right)$$

$$\left(\sqrt{a_2^2+b_2^2}\,\angle\tan^{-1}\left(\frac{-b_2}{a_2}\right)\right)$$

$$= \left(\sqrt{a_1^2+b_1^2}\right)\left(\sqrt{a_2^2+b_2^2}\right)$$

$$\angle\tan^{-1}\frac{b_1}{a_1} + \tan^{-1}\left(\frac{-b_2}{a_2}\right) \quad \textbf{Ans.}$$

Division :
$$\frac{A}{B} = \frac{\sqrt{a_1^2+b_1^2}\,\angle\tan^{-1}\left(\frac{b_1}{a_1}\right)}{\angle a_2^2+b_2^2\,\angle\tan^{-1}\left(\frac{b_2}{a_2}\right)}$$

$$= \frac{\sqrt{a_1^2+b_1^2}}{\sqrt{a_2^2+b_2^2}}\angle\tan^{-1}\left(\frac{b_1}{a_1}\right) - \tan^{-1}\left(\frac{-b_2}{a_2}\right) \quad \textbf{Ans.}$$

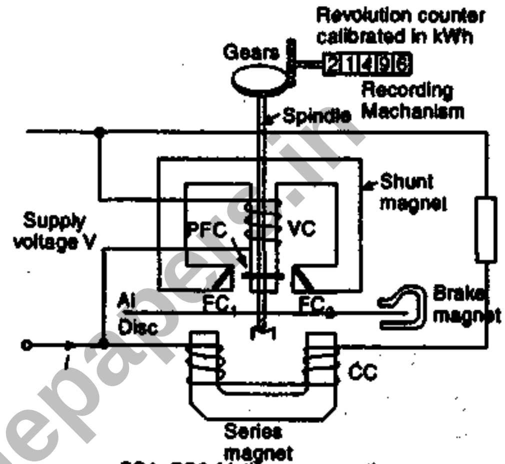
Q. 5. Explain construction and working principle of a single phase induction type energy meter. How is energy measured?

Ans. An instrument which measure electrical energy is called an energy meter or watt hower (Wh) meter.

The single phase induction type energymeters are vary commonly used to measure electrical energy consumed in domestic, commercial and industrial installations. The meter measure electrical energy in kilowatthours (kWh).

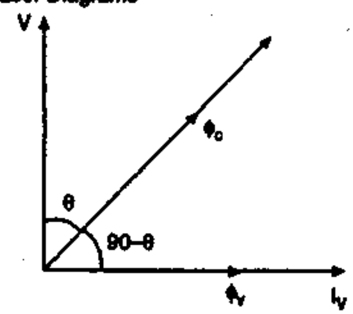
Construction: A single-phase induction type energy meter consists of the following parts:

(a) Driving system
(b) Moving system
(c) Braking system
(d) Registering system



FC1, FC2-friction compnsation
PFC-Power factor compenstor
CC-current coil
VC-voltage coil

Phaser Diagrams



(a) Driving system : The driving system of the energy meter consists of two silicon steel laminated electromagnets M_1 and M_2 as shown in Fig. The magnet M_1 is called the series magnet and the magnet M_2 is called the shunt magnet.

→ The series magnet M_1 carries a coil consisting of few turns of thick wire and carries the load current or definite fraction of it. This coil is called the current coil (CC) and it is connected in series with the circuit.

→ The shunt magnet M_2 carries a coil consisting of many turns of thin wire. This coil is called the voltage coil (VC) and is connected across the supply. The voltage coil carries a current proportional to the supply voltage.

(*b*) **Moving system :** The moving system consists of a thin aluminium disc (rotor) mounted on a spindle. The disc is placed in the air gap between the series and shunt magnets so that it cuts the fluxes of both the magnets. A deflecting torque is produced by the flux of each magnet with the eddy current induced in the disc by the flux of the other magnet.

(*c*) **Braking system :** The braking system consist of a permanent magnet known as break magnet. It is placed near the edge of the aluminium disc.

When the disc rotates in the field of the brake magnet, eddy currents are induced in it. These eddy currents react with the flux and exert a braking or retarding torque.

→ Breaking torque is proportional to the speed of the disc.

The amount of braking torque can be adjusted by adjusting the position of the brake magnet.

→ In some meters two diagonally placed brake magnets are provided to obtain greater braking torque.

Registering system : The disc spindle is connected through a set of gears to a counting mechanism. This mechanism records a number which is proportional to the number of revolution of the disc and indicates the energy consumed directly in kilowatthours (kWh).

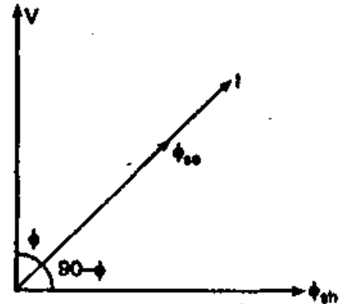
Working : When induction type energy meter is connected in the circuit to measure energy, the shunt magnet carries current proportional to supply voltage.

→ The series magnet carries the load current. This induces eddy current in the AI disc. The reaction of the eddy currents and the field creates a torque on the disc. This makes the disc to rotate. With gear system arranged on the spindle, the counter moves. In this way the energy consumed by the load can be measured.

Torque equation : Let the load current lag the circuit voltage by an angle ϕ as shown in phasor diagram.

By adjusting the position of shading bands, the flux of the shunt magnet is made to lag behind the circuit voltage by 90°.

Assume hysteresis loss and iron losses in iron core are negligible.



Series magnet flux ϕ_{se} is taken proportional and in phase with load current. Then angle between load current and shunt magnet flux is (90 – ϕ). The expression for driving torque is —

$$T_d \propto \phi_{sh}\,\phi_{se}\,\sin\angle_{\phi_{sh}}^{\phi_{se}}$$

$$T_d \propto VI \sin(90 - \phi) \; VI\cos\phi$$

$$T_d \propto \text{True Power}$$

Now, the breaking torque is due to the eddy current induced in the *Al* disc.

Since, the magnitude of the eddy currents is directly proportional to the speed of the disc, the braking torque T_b will also be proportional to the disc speed (n)

Braking Torque

$$T_b \propto n$$

for steady speed of rotation

$$T_d = T_b$$

$$\text{power} \propto n$$

Or

If we multiply both sides by time, t then

$$\text{Power} \times t \propto nt$$

$$\text{Energy} \propto N$$

{where nt = N = Total number of revolutions in time t}

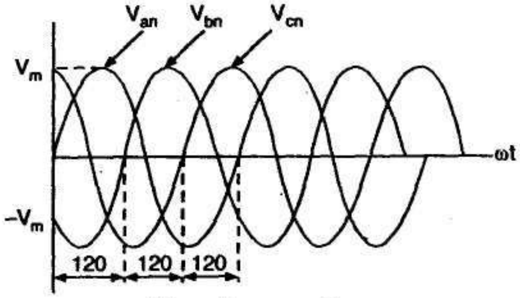
Energy = **Power × Time**

Unit = Watt-hour or kilowatt-hour (Wh) or (kWh).

Q. 5 (*b*). What is a three phase system? Give its necessity and advantages. What is meaning of phase sequence and how can it be changed?

Ans. Introduction: Three-phase power was invented by Croatian-American engineer "Nikola Testa (1856-1943)". He proved that the three phase power was most efficient way to produce, transmit and consume electricity.

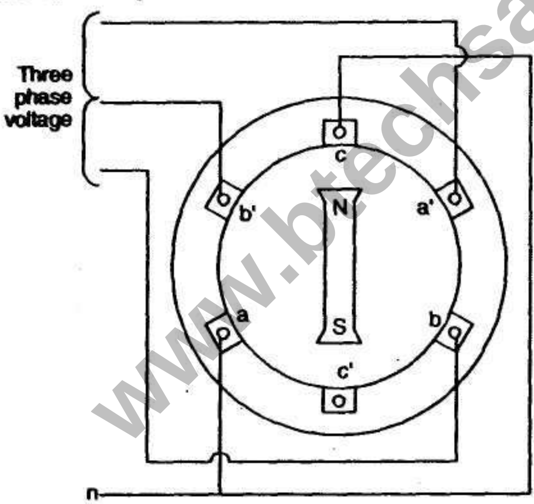
Three-phase voltage : In three phase system, we used three armature windings. These armature winding are placed at 120° away from each other.



Three phase wave form

→ Three phase voltage are often produced with a three-phase ac generator (or alternator) whose cross-sectional view is shown in Fig. next page.

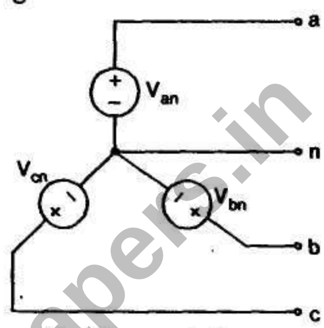
The generator basically consists of a rotating magnet (called threaten) surrounded by a stationary winding (called stator). Three separate winding or coils with terminals *a-a'*, *b-b'* and *c-c'* are physically placed 120° apart around the stator.



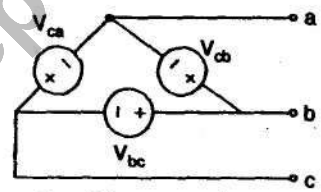
A three phase generator

When the rotor rotates, its magnetic field 'cuts' the flux from the three coils and induces voltages in the coils. Because the coils are placed 120° apart, the induced voltage in the coils are equal in magnitude but out of phase by 120° as shown in Fig.

Three phase system : A typical three phase system consist of three voltage sources connected to loads by three or four wires (or transmission lines). A three phase system is equivalent to three single phase circuits. The voltage sources can be either star connected as shown in Fig. or delta connected as shown in Fig.



Star (Y) connected source



Star (Δ) connected source

Necessity and Advantages of Three phase system:

1. More Output. For the same size, the output of three phase machine is always height than of the single phase machine. Typically the three phase machine produce about 45% higher power.

2. Smaller size. For producing the same output, the size of three phase machine is always smaller than that of single phase machines.

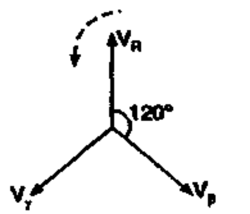
3. 3-phase motors are self starting. As the three phase ac supply is capable of producing a rotating magnetic field when applied to stationary windings, the three phase ac motors are self starting. The single phase motors need to use an additional starter winding.

4. More power is transmitted. In the transmission system it is possible to transmit more power using a three phase system, than the single phase system, by using the conductors of same cross-sectional area.

5. Smaller cross-sectional area of conductors. If the same amount of power is to be transmitted then the cross-sectional area of the conductors used for the three phase system is small as compared to that for the single phase system.

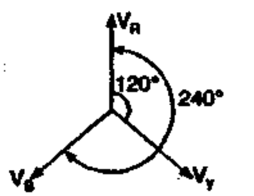
6. Better power factor. The power factor of three phase machine is better that of the single phase machines.

Concept of Phase sequence : The phase sequence is defined as the sequence in which the three phase reach their maximum positive values. Normally the phase sequence is R-Y-B.



R-γ-B sequence

→The phase rotate in anticlockwise direction.



R-γ-B sequence

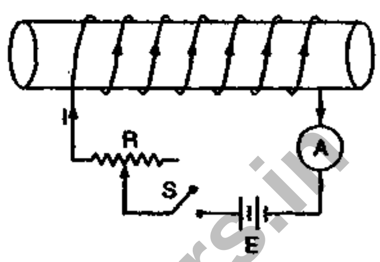
→The direction of rotating of the three-phase machine depends on the phase-sequence. If the phase sequence is changed e.g. R-B-y then the direction of rotation will be reversed. In order to avoid such things, the phase sequence of R-y-B is always maintained.

In R-y-B phase sequence, as the phasors rotate in the counterlakwise direction with frequency ω, they pass throughout the horizontal axis in a sequence RBy RByR.... This describes the RBy sequence. The phase sequence is important in three phase power distributed. It determines the direction of the rotation of motor connected to the power source.

Q.6 (a) Draw and explain hysteresis loop what is its significance?

Ans. When B-H curve is drawn for one complete cycle of magnetization (increasing current) and demagnetizing (decreasing current) then it is called a hysteresis curve or hysteresis loop or magnetic hysteresis.

→ The setup to plot the hysteresis loop is shown in Fig. It consists of a battery, an ammeter to measure the magnetizing current, a variable resistance R to vary the magnetizing current, and a reversible switch *S* in order to reverse the current direction.

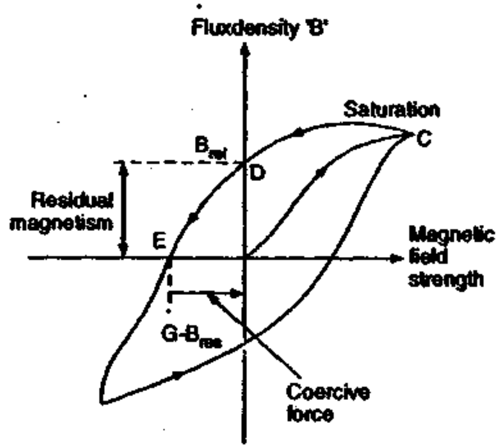


Set up to plot the hysteresis curve

Procedure to plot the hysteresis loop

Step 1. Adjust the variable resistance R to be at its maximum value, so that the initial current I is negligibly small (almost zero).

Step 2. Increase current In + ve direction : Now reduce the resistance R current will increase. Increase the current in suitable steps and for each value of *I*, calculate the values of B and H. The portion of hysteresis loop corresponding to this step OAC.



Step 3. Decrease the current without changing its direction: Now increase the value of R from its minimum value to maximum value. The magnetizing current will decrease. Decrease this current in suitable steps upto zero and for each value of I, calculate the value of B and H. It is increasing to note that the value of magnetic flux density B is not zero for *I* = 0

and $H = 0$. This non-zero value of B is called as the residual magnetism B_{res} as shown in Fig. The portion of hysteresis loop corresponding to this step is C to D. The residual flux density is also called as remanent flux density. This property of a magnetic material is called as the Retentivity.

Step 4. Increase current in the negative direction : To reverse the direction of current, throughout the reversible switch. The direction of current and flux ϕ will reverse. Now decrease the value of R from its maximum to minimum value. As the current become negative, H becomes negative but H does not become negative instantaneously as showing Fig. position D to E, the magnetic flux density reduces from its residual value to zero.

→ The value of magnetic field strength required to wipe out the residual flux density is called as coercive force (H_C).

→ The process of reducing the magnetic flux density to zero is called as demagnetization of the core.

→ If we increase the reverse current further then the magnetic flux density becomes negative and reaches its saturation value EF as shown in Fig.

Step 5. Decrease the negative current: By varying the resistance towards its maximum value, we can decrease the negative current. Due to reduction in the –ve current, the negative flux density will reduce from its saturation value.

→ As $I = 0$, $B = -B_{res}$ such that the residual flux density in the negative direction as shown in Fig. position F to G.

Step 6. Make the current positive and increase its value: The current can then be made positive by the reversible switch S. This increase its value with the help of R.

→ The hysteresis curve, now follow the path G to H and then H to C.

Thus, the hysteresis loop as showing Fig has been drawn for one complete cycle of magnetization and demagnetization.

Significance:

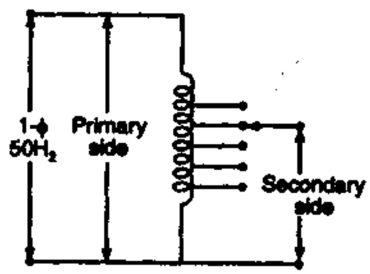
1. The magnetic materials used for different applications need to have different characteristics. A proper magnetic material can be selected for a given application by looking at its hysteresis loop.
2. The area and the shape of the magnetic material are the important parameters which decide the suitability of a material for a particular application.
3. The hysteresis effect can be used when connecting complex circuits with the so-called passive matrix addressing. This scheme is praised as a technique that can be used in modern nonelectronic, electrograms cells, memory effect etc.

Q.6 (*b*). Explain single phase autotransformer and give its application.

Ans. Autotransformer: An autotransformer is an electrical transformer with only one winding. Single winding acting as primary as well as secondary winding.

→ The winding has at least three electrical connection points called taps. The voltage source and the load are each connected to two taps.

One tap at the end of the winding is a common connection to both.



Single phase autotransformer

Circuit (source and load). Each tap correspond to a different source or load voltage.

→ Autotransformer is also known as VARIAC or DIMMER

Operation. The ratio of secondary to primary voltage is equal to the number of turns of the winding they connect to, for example, connecting at the middle and bottom of the autotransformer will have the voltage. Depending on the application, that portion of the winding used solely in the higher-voltage (lower current) portion may be wound with wire of a smaller gauge, though the entire winding is directly connected.

Applications:

1. It is used for low voltage application.
2. Autotransformers are frequently used in power applications to interconnect systems operating at a different voltage classes, for example, 11 kV to 66 kV for transmission.
3. Another application is in industry to adopt machinery built for 480 V supplies to operate on a 600 V supply.
4. On long rural power distribution lines, special autotransformers with automatic tap-changing equipment are inserted as voltage regulators, so that constumer at the far end of the line receive the same voltage as those closer to the source.
5. In audio applications, tapped autotransformers are used to adapt speakers to constant-voltage audio distribution systems, and for impedance matcbing sucb as between a low-impedance microphone and a high-impedance amplifier input.

Q.6 (c). Derive e.m.f equation of a single phase transformer and obtain relation for secondary to primary winding voltages.

Ans. Let the flux at any instant be given by

$$\phi = \phi_m \sin \omega t \qquad ...(i)$$

The instantaneous e.m.f induced in a coil of 'N' turns linked by this flux is given by faraday's law as

$$e = \frac{-d}{dt}(\phi N)$$

$$= -N\frac{d\phi}{dt}$$

$$= -N\frac{d}{dt}(\phi_m \sin \omega t)$$

$$= -N\omega\phi m \cos(\omega t)$$

$$= N\omega\phi m \sin(\omega t - \pi/2) \qquad ...(ii)$$

The term $N\omega\phi m$ is the maximum induced e.m.f. which is given by

$$E_m = N\omega\phi m$$

Now $$e = E_n \sin\left(\omega t - \frac{\pi}{2}\right)$$

for a sine wave, the r.m.s value of e.m.f is given by

$$E_{rms} = E = \frac{E_m}{\sqrt{2}}$$

$$\therefore \quad E = \frac{E_m}{\sqrt{2}} = \frac{N\omega\phi_m}{\sqrt{2}}$$

$$E = \frac{N(2\pi f)\phi_m}{\sqrt{2}}$$

or, Now $$E = \sqrt{2}\pi f \theta_m N$$

$$E = 4.44 f\theta_m N \qquad ...(iii)$$

This equation is called the e.m.f. equation of a transformer. The e.m.f. induced in each winding of the transformer can be calculated from its e.m.f equation.

So, the primary r.m.s voltage is

$$E_1 = 4.44 f\theta_m N_1 \qquad ...(iv)$$

The secondary r.m.s voltage is

$$E_2 = 4.44 f\theta_m N_2 \qquad ...(v)$$

Now from equation (iv) and (v)

$$\frac{E_1}{E_2} = \frac{4.44\,\phi_m\, f\, N_1}{4.44\,\phi_m\, f\, N_2}$$

Or $$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

Or $$E_2 = \frac{E_1 N_2}{N_1}$$

where, $\frac{N_1}{N_2}$ = turns ratio.

Q.7 (a). Drive nn eqnation for generated torque in dc motor.

Ans. We know that there relation between the torque and power is given by

$$P = T\omega$$

where ω = Angular velocity

So, the mechanical power developed by the armature

$$P_m = \omega T$$

$$P_m = 2\pi nT \quad ...(i)$$

We know that

$E I_a$ = Electrical equivalent of gross mechanical power developed by the armature (Electromagnetic power)

T = Average electromagnetic Torque developed by the armature in newton meters (N_m).

Therefore, $P_m = E I_a = WT = 2\pi nT$

but $$E = \frac{nP\phi Z}{A}$$

So, $$\frac{nP\phi Z}{A} I_a = 2\pi nT$$

Or $$T = \frac{PZ}{2\pi A}\phi I_a$$

This equation is called the torque equation of d.c. motor.

Let $$\frac{PZ}{2\pi A} = k = \text{constant}$$

$$\therefore \quad T = k\phi I_a$$

$$T \propto \phi Ia$$

Hence, the torque developed by a d.c. motor is directly proportional to the flux per pole and armature current.

Q.7 (*b*). Draw slip-torque characteristics of a three phase induction motor and explain its various regions of operation.

Ans. Slip-torque characteristics of 3-ϕ induction motor:

We know that

$$\tau = \frac{KS R_2 E_{20}^2}{R_2^2 + (SX_{20})^2}$$

If R_2 and X_{20} are kept constant, then the torque 'τ' depends upon the slip S.

The torque-slip characteristic curve can be divided roughly into three regions:

(*a*) Low-slip region

(*b*) Medium-slip region

(*c*) High-slip region

(*a*) Low-slip region. At synchronous speed, slip $S = 0$, therefore the torque is zero.

When the speed is very near to synchronous speed, the slip is very low and $(5 \times 20)^2$ is negligible in comparison with R_2

So, $$\tau = \frac{K_1 S}{R_2}$$

$$\therefore \quad \frac{K_1}{R_2} = \text{constant}$$

so $\tau \propto s$

Hence, when the slip is small (which is the normal working region of the motor), the torque-slip is a straight line.

(*b*) Medium-slip region. As slip increases (that is as the speed decreases with the increase in load), the term $(SX_{20})^2$ becomes large, so that R_2^2 may be neglected in comparison with $(SX_{20})^2$ and

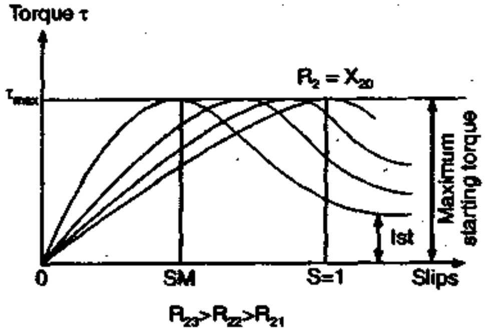
$$\tau = \frac{k_3 R_2}{SX_{20}^2},$$

$$\tau \propto \frac{1}{S}$$

Thus, the torque is inversely proportional to slip towards stand still conditions. The torque slip characteristic is represented by a rectangular hyperbola.

When $R_2 = SX_{20}$, the maximum torque developed in an induction motor is called the "Pull-out torque" or "breakdown Torque". This torque is a measure of the short-time overloading capability of the motor.

(*c*) High-slip region. The torque decreases beyond the point of maximum torque. The result is that the motor slows down and eventually stops. At this stage, the overload protection must immediately disconnect the motor from the supply to prevent damage due to overheating.



Torque slip curves

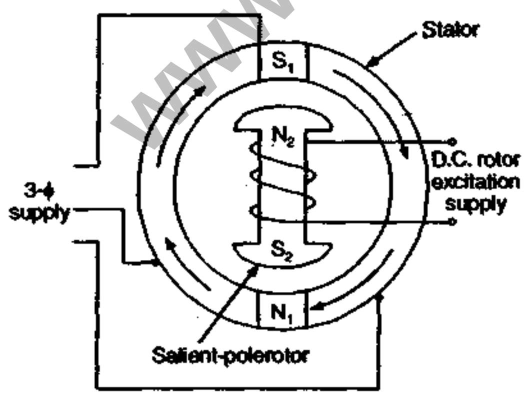
The motor operates for the value of the slip between $s = 0$ and $s = S_M$ where S_M is the value of the slip corresponding to maximum torque.

The Fig. shows the torque-slip curves for various values of rotor resistance.

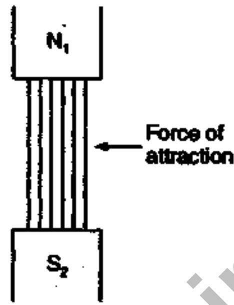
Q.7 (c). Explain principle of operation of a synchronous motor and give its applications.

Ans. Operating Principle. The principle of operation is based on the principle of magnetic looking between the stator and rotor poles.

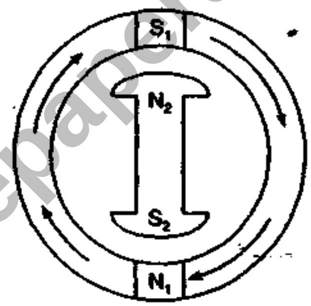
Stator winding is connected to the 3 ϕ ac supply ⇓ Rotating magnetic field at synchronous speed is produced ⇓ Rotor is excited by an external dc source ⇓ Rotor is driven by some external device like a diesel engine in the direction of rotating magnetic field.



(a)



(b)



(c)

Consider the 2-pole synchronous motor shown in Fig. (*a*). When a three phase ac-voltage is applied to the stator winding a rotating magnetic field is produced in the ourgap. The stator field rotates at synchronous speed. Then the two stator poles produced are N_1 and S_1 as shown in Fig. (*c*). These stator poles (N_1 and S_1) rotate in air gap between stator and rotor at synchronous speed in the clockwise direction.

The rotor is then excited by the external DC source. It produce two poles N_2 and S_2 as shown in Fig. (*c*). The rotor is accelerated, to rotate in the clockwise direction by some external engine. This is because the synchronous motor is not self starting.

• If the unlike poles $N_1 - S_2$ and $S_1 - N_2$ comes close to each other, then due to a strong force of attraction, magnetic locking takes place between them as shown in Fig. (*b*). Once the stator and rotor poles are locked magnetically with each other, then rotor will continue to rotate at the synchronous speed along with the rotating magnetic field.

The external engine coupled to the rotor can then be decupled. The rotor will rotate at N_s as long as the magnetic locking between the stator and rotor continues to exist.

In this way the synchronous motor will always rotate at the synchronous speed.

Applications : The constant speed of operation makes the synchronous motor suitable for the following applications:

1. Fans, blowers
2. Centrifugal pumps
3. Grinders
4. Machine tools
5. Textile mills, rolling mills, cement mills

Synchronous motor are also used as power factor correcting device.