B.Tech.

FIRST SEMESTER EXAMINATION, 2008-09

ELECTRICAL ENGINEERING

(EEE-101)

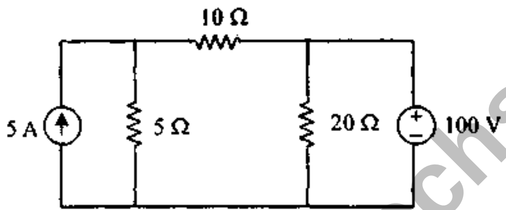
Time : *3 Hours]* *[Total Marks : 100*

SECTION A

Q. 1. Attempt all the parts of the following : **$10 \times 2 = 20$**

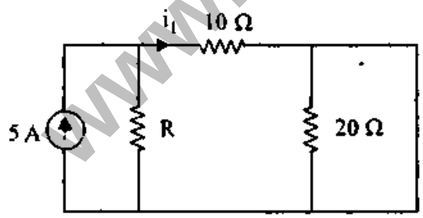
(Fill in the hlanks/choose/match)

(i) For the circuit shown in the following figure, the value of R such that the same amount of power is supplied to the 10 Ω resistance hy the current and hy the voltage source will be .... **(Unlt-1)**

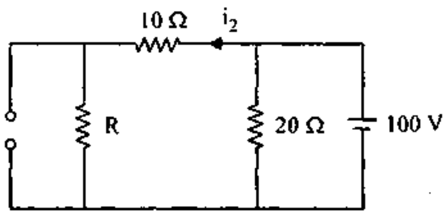


Ans. By superposition

$$i_1 = \frac{5R}{R+10}$$



$$i_2 = \frac{5R}{R+10}$$



Power will be same if $i_1 = i_2$

$$\frac{5R}{R+10} = \frac{100}{R+10}$$

$R = 20\ \Omega$

(ii) Maximum transmission voltage in India is **(Unit-4)**

(a) 220 kV (h) 400 kV

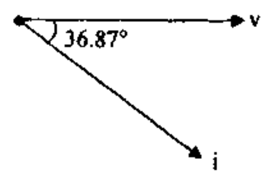
(c) 765 kV (d) 1200 kV

Ans. (c) 400 kV

(iii) The instantaneous voltage and current for an ac circnit are $v = 155.6 \sin 377t$ V,

$i = 7.07 \sin(377t - 36.87°)$A. Represent these in a phasor diagram. **(Unit-2)**

Ans.



(iv) A voltage source of 100 V has internal impedance 2 Ω and supplies a load having that same impedance. The power absorbed by the load is .... **(Unit-1)**

Ans. $P = \frac{V^2}{4R_L} = \frac{(100)^2}{4 \times 2} = \frac{10000}{8} = 1250$

W = 1.25 kW

(v) A moving coil ammeter has a full scale deflectlon of 50 μA and a coil resistance of 100 Ω. The value of the shunt resistance required for the

instrument to he converted to read a full-scale reading of 1 A will be .... (Unit-3)

Ans. 0.005 Ω

$$\left[\begin{array}{l} I_m = 50 \times 10^{-6}\ A,\ R_m = 100\ \Omega, I = 1A \\ R_{sh} = \dfrac{I_m R_m}{I - I_m} = \dfrac{50 \times 10^{-6} \times 100}{1 - 0.00005} \\ R_{sh} = 0.005\ \Omega \end{array}\right]$$

(vi) If $W1$, $W2$ and $W3$ are the readings of three wattmeters used to measure the power in 3-phase, 4-wire circuit, the total power of load circuit will he .... (Unit-3)

Ans. $W_1 + W_2 + W_3$

(vii) Match the following (marks will be awarded if all matching are correct) : (Unit-5)

(i) Series resonance (a) Electric fan

(ii) Single phase induction motor (h) condenser

(iii) Overexcited synchronous motor (c) Unity power factor

(iv) Eddy current loss (d) Thin laminated plates

Ans. (i) Series resonance → (c) unity P.f.

(ii) Single phase induction motor→ (a) Electric fan

(iii) Overexcited synchronous motor → condenser

(iv) Eddy current loss → (d) Thin laminated plates

(viii) A single phase transformer working at maximum efficiency. The copper losses are 100 W, the iron losses would be .... (Unit-5)

Ans. 100 W (For maximum efficiency

$P_i = P_c$

(ix) Tbe current drawn by a 120 V dc motor of armature resistance 0.4 Ω and hack e.m.f. 112 V is .... (Unit-5)

Ans. 20 A ⟶

$$\left[I = \frac{E - E_f}{R} = \frac{120 - 112}{0.4} = 20\ A \right]$$

(x) The rotor speed of a six pole 50 Hz induction motor is 960 rpm the percentage slip is (Unit-5)

(a) 3% (b) 4% (c) 5% (d) 2%.

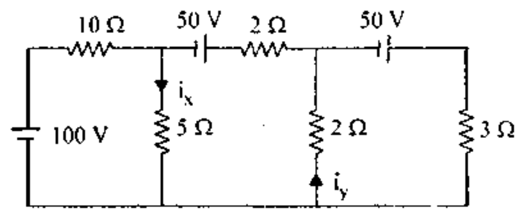
Ans. 4%

$$\left[\begin{array}{l} N_s = \dfrac{120f}{P} = \dfrac{120 \times 50}{6} = 1000\ \text{rpm} \\ S = \dfrac{N_s - N_g}{N_s} \times 100 = \dfrac{1000 - 960}{1000} \times 100 \\ = 4\% \end{array}\right]$$

SECTION B

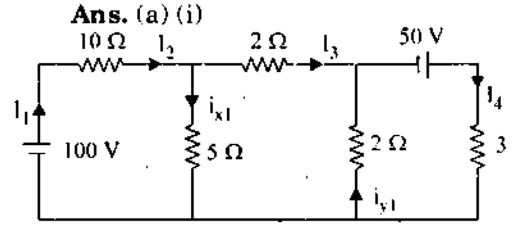
Q. 2. Attempt any three part of the following: $10 \times 3 = 30$

(a) (i) Determine the current i_x and i_y in the following network. Sate theorem used. (Unit-1)



(ii) What do you understand by unilateral and hilateral elements ? Give examples. (Unit-1)

Ans. (a) (i)



By superposition theorem

we replaced 50 V & 50 V source by short ckt

$$Req_1 = \frac{3\times 2}{3+2} + 2 \,\Big\|\, 5 + 10 = \frac{\frac{16}{5}\times 5}{\frac{16}{5}+5} + 10$$

$$= \frac{16\times 5}{41} + 10$$

$$= \frac{80}{41} + 10 = 11.95\,\Omega$$

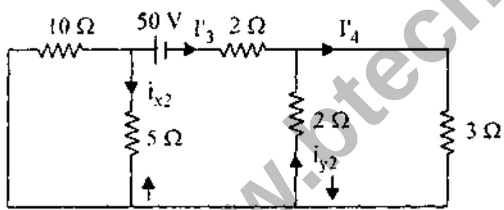
$$I_1 = \frac{100}{11.95} = 8.37\text{ A}$$

$$I_3 = I_1\,\frac{5}{5+\frac{16}{5}} = \frac{8.37\times 25}{41} = 5.10\text{ A}$$

$$I_{x_1} = I_1 \times \frac{16/5}{5+\frac{16}{5}} = 8.37 \times \frac{16}{41} = 3.27\text{ A}\downarrow$$

$$I_{y_1} = 5.10 \times \frac{3}{3+2} = 3.06\text{ A}\downarrow$$

Now, we replaced 100 V & 50 V source by short ckt.



$$R_{eq2} = 10 \,\|\, 5 + 2 + 2 \,\|\, 3$$

$$= \frac{50}{15} + 2 + \frac{6}{5}$$

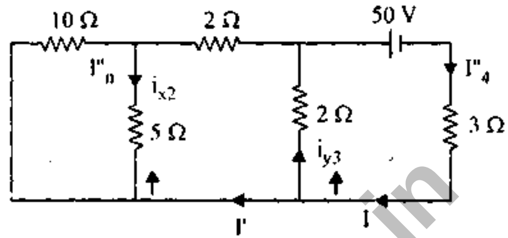
$$= 3.33 + 2 + 1.2 = 6.53\,\Omega$$

$$I_3' = \frac{50}{6.53} = 7.66\text{ A}$$

$$I_{y2} = I_3' \times \frac{3}{5} = 7.66 \times \frac{3}{5} = 4.6\text{ A}\downarrow$$

$$I_{x2} = I_3' \times \frac{10}{15} = 7.66 \times \frac{10}{15} = 5.11\text{ A}\uparrow$$

Now we replaced 100 V & 50 V source by short ckt



$$R_{eq3} = [(10 \,\|\, 5+2) \,\|\, 2] + 3$$

$$= \left[\frac{180}{15} \,\Big\|\, 2\right] + 3 = \frac{12\times 2}{12+2} + 3$$

$$= 4.71\,\Omega$$

$$I_4' = 10.62\text{ A}$$

$$I_{y3} = 10.62 \times \frac{80/15}{\frac{80}{15}+2} = 7.72\text{ A}\uparrow$$

$$I' = 10.62 - 7.72 = 2.9\text{ A}$$

$$I_{x3} = 2.9 \times \frac{10}{15} = 1.93\text{ A}\uparrow$$

$$I_x = I_{x1} + (-I_{x2}) + (-I_{x3})$$
$$= 3.27 - 5.11 - 1.93 = -3.77\text{ A}$$

$$I_y = -I_{y1} - I_{y2} + I_{y3}$$
$$= -3.06 - 4.6 + 7.72 = +0.06\text{ A}$$

Q. 2. (b) Derive the quality factor Q_p the parallel RLC circuit at resonance. Define band width for the same. (Unit-2)

Ans. At parallel resonance, the current circulating between the two branches is many times greater than the line current. This current amplification produced by the resonance is termed as Q-factor of the 'parallel resonant circuit *i.e.*,

Q-factor

$$= \frac{\text{Circulating current between } L \text{ and } C}{I_r}$$

Now, $I_C = V / X_C = \omega_r CV$ and

$I_r = VI(L/CR)$

$\therefore$ Q-factor $= \omega_r CV + \dfrac{V}{L/CR} = \dfrac{\omega_r L}{R}$

$= \dfrac{2\pi f_r L}{R}$ .... *same as for series circuit.*

The Q-factor of a parallel resonant circuit can also be expressed in terms of L and C. Neglecting resistance R, the resonant frequency is given by;

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

$\therefore$ Q-factor

$$= \frac{2\pi f_r L}{R} = \frac{2\pi L}{R} \times \frac{1}{2\pi\sqrt{LC}} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Bandwidth : The bandwidth of a parallel resonant circuit is defined as the range of frequencies over which circuit current is equal to or greater than 70.7% of maximum current.

Bandwidth, BW $= \dfrac{f_r}{Q} = f_1 - f_2$

Lower cut-off frequency, $f_1 = f_r - \dfrac{BW}{2}$

Upper cut-off frequency, $f_2 = f_r + \dfrac{BW}{2}$

Q. 2. (c) What is the necessity and advantage of 3-phase system ? Derive $V_L = \sqrt{3}V_{ph}$ for star connected system.

(Unit-3)

Ans. Necessity And Advantage of 3-phase System

(i) 3-phase power has a constant magnitude whereas single-phase power pulsates from zero to peak value at twice the supply frequency.

(ii) A 3-phase system can set up a rotating magnetic field in stationary windings. This cannot be done with a single-phase current.

(iii) For the same rating, 3-phase machines (*e.g.*, generator motors, transformers) are smaller, simpler in construction and have better operating characteristics than single phase machines.

(iv) To transmit the same amount of power over a fixed distance at a given voltage, the 3-phase system requires only three-fourth the weight of copper that is required by the single-phase system.

(v) The voltage regular of a 3-phase transmission line is better than that of a single phase line.

Relationship between Line & phase voltage in star system :

P.D. between line R and Y,* $Y_{RY} = E_{RN} - E_{YN}$ .... *phasor difference*

P.D. between lines Y and B,

$V_{YB} = E_{YN} - E_{BN}$ ... —do—

P.D. between lines B and R,

$Y_{BR} = E_{BN} - E_{RN}$ ... —do—

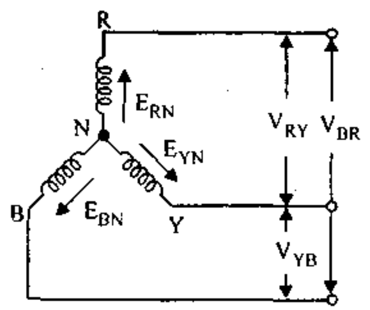


Fig. 1

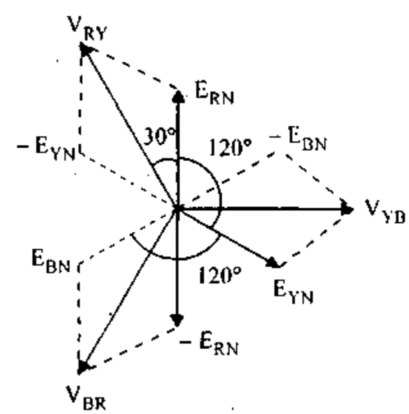


Fig. 2

1. Relation between line voltage and phase voltage

Considering the lines R and Y, the line voltage V_{RY} is equal to the phasor different of E_{RN} and E_{YN}. To subtract E_{YN} from E_{RN}, reverse the phasor E_{YN} and find its phasor sum with E_{RN} as shown in the phasor diagram in Fig. 2. The two phasor E_{RN} and $-E_{YN}$ are equal in magnitude ($= E_{ph}$) and are 60° apart.

$$V_{RY} = 2E_{ph}\cos(60°/2)$$

$$= 2E_{ph}\cos 30° = \sqrt{3}\,E_{ph}$$

Similarly $V_{YB} = E_{YN} - E_{BN}$ ...*phasor difference*

$$= \sqrt{3}\,E_{ph}$$

and $V_{BR} = E_{BN} - E_{RN}$ ...*phasor difference*

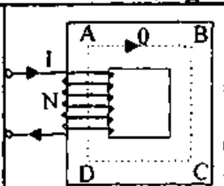
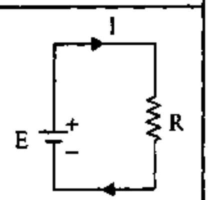
$$= \sqrt{3}\,E_{ph}$$

Hence in a balanced 3-phase Y-connection.

(i) Line voltage $V_L = \sqrt{3}\,E_{ph}$

Q. 2. (d) Describe the analogies that can be made between electric and magnetic circuit regarding the following items : driving force, field intensity, impedance drops, equivalent circuits.

(Unit-4)

	Magnetic Circuit	**Electric Circuit**
	Analogies	
Circuit		
1. Definition	The closed path followed by magnetic flux is called a magnetic circuit.	The closed path followed by an electric current is called an *electric circuit*.
2. Driving force	MMF is required to establish flux ϕ in the magnetic circuit and is measured in ampere-turns (AT) or amperes.	EMF is required to cause flow of current in an electric circuit and is measured in volts.
3. Impedance	Reluctance, $S = \frac{1}{\mu_0\mu_r a}$ $= \frac{1}{\mu a}$ AT / wb	Resistance, $R = \rho\frac{l}{a}$ ohms
(a) For series circuits	$S = S_1 + S_2 + S_3 + \ldots$	$R = R_1 + R_2 + R_3 +$
(b) For parallel circuits	$S = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \ldots}$	$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$
4. Field intensity	Magnetic field intensity, $H = \frac{MMF}{l}$ $= \frac{NI}{l}$ in AT / m	Electric field intensity $= \frac{E}{l}$ in volts / metre
5. Drop	MMF drop $= \phi \times$ reluctance $= \phi S$	Voltage drop $= I \times$ Resistance $= IR$

(ii) Explain Hysteresis and eddy current loss. How they are minimized ?

(Unit-4)

Ans. Hysteresis Loss : If the magnetisation is carried through a complete cycle, the energy wasted is proportional to the are of the hysteresis loop and the shape of hysteresis loop depends upon the nature of the ferromagnetic material. Hysteresis loss is equal to the energy consumed in magnetising and demagnetising a magnetic material.

Hystresis Loss, $P_h = K_h\, Vf\, (B_{max})^{1.6}$ watts

Where, K_h = Steinmetg's coefficient

V = Volume of the material, m^3

B_{max} = Maximum flux density

f = Frequency of magnetic reversal.

Eddy Current Loss : When a material is linked with a variable or alternating flux, an emf is induced in the magnetic material itself according to Faraday's laws of electromagnetic induction. This induced emf circulates a current in the body of the magnetic material. These circulating currents are called Eddy currents and the power losses due to the flow of this current are called Eddy current losses. Eddy currents always tend to flow in planes perpendicular to the magnetic flux as they are induced due to variation of this flux through the circuit. Applications of eddy current include eddy current braking in induction energy meters and eddy current damping in permanent magnet moving coil instruments.

Eddy current Loss,

$P_e = K_e V f^2 t^2 (B_{max})^2$ watts

Where, K_e = Characteristics constant of a material

t = thickness of material

The hystresis loss can be reduced by selecting good quality magnetic material like ferromagnetic (nickel, cobalt) materials.

The eddy current loss can be reduced by using thin laminations for the core.

Q. 2. (e) Briefly discuss the principle of operation of alternator and also give its applications. Draw V curve for synchronous motor. (Unit-5)

Ans. Principle of Operation of An Alternator : The alternators work on the principle of **electromagnetic induction**. When there is a relative motion between the conductors and the flux, e.m.f. gets induced in the conductors. The d.c. generators also work on the same principle. The only difference in practical alternator and a d.c. generator is that in an alternator the conductors are stationary and field is rotating. But for understanding purpose we can always consider relative motion of conductors with respect to the flux produced by the field winding.

Consider a relative motion of a single conductor under the magnetic field produced by two stationary poles. The magnetic axis of

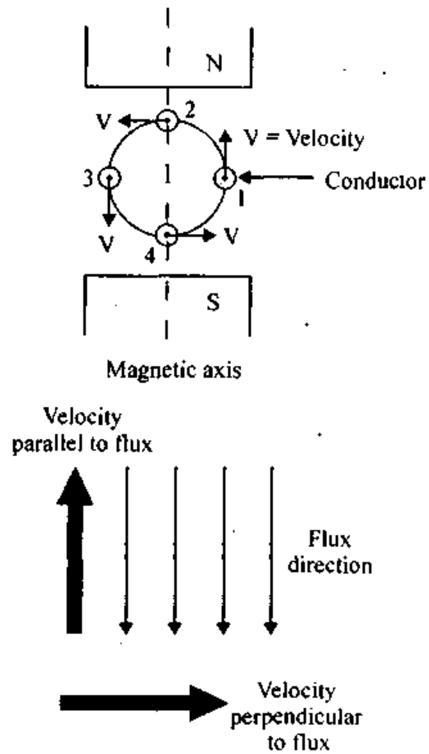


Fig. Two pole alternator

the two poles produced by field is vertical, shown dotted in the Fig.

Let conductor starts rotating from position1. At this instant, the entire velocity component is **parallel** to the flux lines. Hence there is not cutting of flux lines by the conductor. So $\frac{d\phi}{dt}$ at this instant is zero and hence induced e.m.f. in the conductor is also zero.

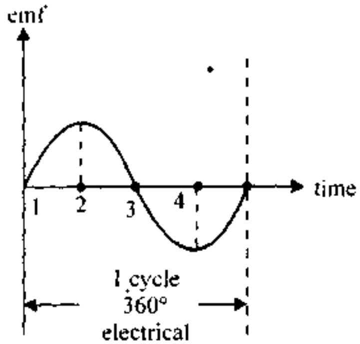


Fig. Alternating nature of the induced e.m.f

As the conductor moves from position 1 towards position 2, the part of the velocity component becomes perpendicular to the flux lines and proportional to that, e.m.f gets induced in the conductor. The magnitude of such an induced e.m.f increases as the conductor moves from position 1 towards 2.

At position 2, the entire velocity component is **perpendicular** to the flux lines. Hence there exists maximum cutting of the flux lines. And at this instant, the induced e.m.f. in the conductor is at its maximum.

As the position of conductor changes from 2 towards 3, the velocity component perpendicular to the flux starts decreasing and hence induced e.m.f. magnitude also starts decreasing. At position 3, again the entire velocity component is parallel to the flux line and hence at this instant induced e.m.f. in the conductor is zero.

As the conductor moves from position 3 towards 4, the velocity component perpendicular to the flux lines again starts increasing. But the direction of velocity component now is opposite to the direction of velocity component existing during the movement of the conductor from position 1 to 2. Hence an induced e.m.f in the conductor increases but int he opposite direction.

At position 4, it achieves maxima in the opposite direction, as the entire velocity component becomes **perpendicular** to the flux lines.

Again from position 4 to 1, induced e.m.f. decreases and finally at position 1, again becomes zero. This cycle continues as conductor rotates at a certain speed.

So if we plot the magnitudes of the induced e.m.f. against the time, we get an alternating nature of the induced e.m.f. as shown in the Fig.

Applications : (i) *Salient pole type machines* (alternators) are operated at low speeds and are coupled with water turbines at *hydro-electric power plants.* These machines have large number of poles, larger diameter and smaller length. *(ii) Non-salient pole type machines* (alternators) are operated at high speeds and are coupled with steam turbines at *thermal power plants.* These machines have small number of poles, smaller diameter and large length.

16. V-Curves

While changing the excitation of a 3-phase synchronous motor, keeping the load to be the same, the *curve plotted between field current I_f and armature or load current is called* **V-curve,**

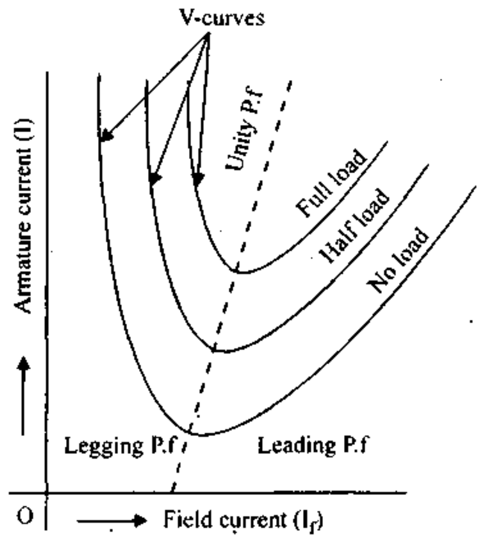


Fig.

It is named as V-curve because its shape resembles with the shape of English alphabet ' V'.

$P = 3\,VI \cos\phi$

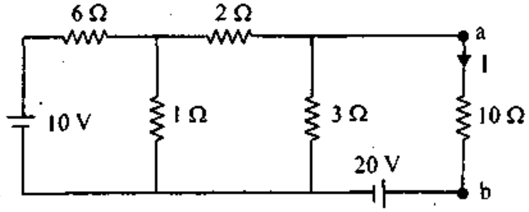
Then for constant power input P and terminal voltage V, only increase in power factor causes decrease in armature current I and vice versa. Armature current will be minimum at unity power factor and increases when the power factor decreases on either side (lagging or leading).

SECTION-C

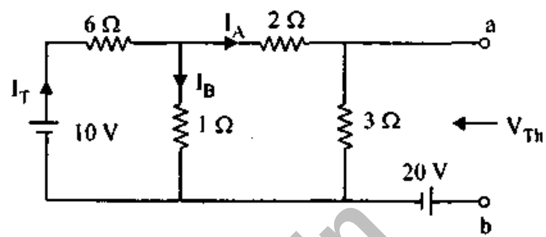
Note: ***Attempt all the question of this section*** **10 × 5 = 50**

Q. 3. At ..mpt any two parts of the following :

(i) Replace the network of following figure to the left of terminals *ab* by its Thevenin equivalent circuit. Hence. determine *I*. (Unit-1)



Ans. Now remove 10 Ω resistance.



$$R_T = [(3+2)\,||\,1] + 6 = \left[\frac{5}{6} + 6\right] = \frac{41}{6} = 6.83$$

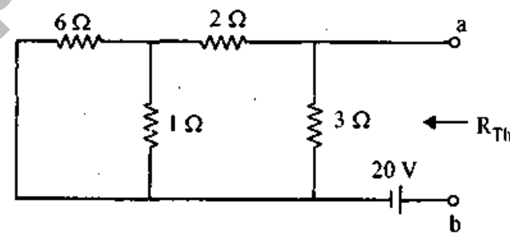
$$I_T = \frac{10}{6.83} = 1.46 \text{ A}$$

$$I_A = 1.46 \times \frac{1}{3+2+1} = 0.24 \text{ A}$$

Voltage drop across 3 Ω resistor

$= 0.24 \times 3 = 0.73$ V

Voltage drop across $ab = -0.73 + 20$

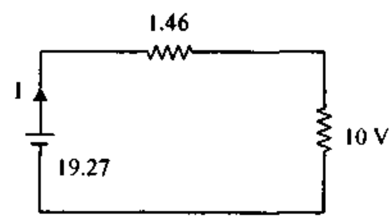


$V_{Th} = -19.27$ V

$$R_{Th} = [(6\,||\,1) + 2]\,||\,3$$

$$= \frac{20}{7} \,\Big\|\, 3$$

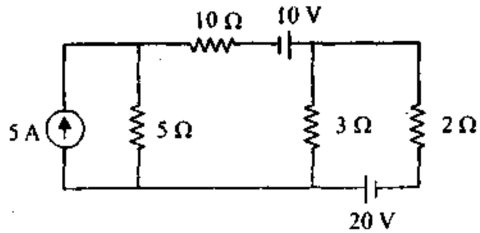
$$= \frac{\frac{20}{7} \times 3}{\frac{20}{7} + 3} = \frac{60/7}{41/7} = 1.46\ \Omega$$



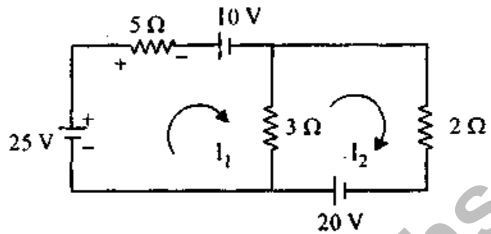
$$I = \frac{19.27}{11.46}$$

$$I = 1.68\ \text{A}$$

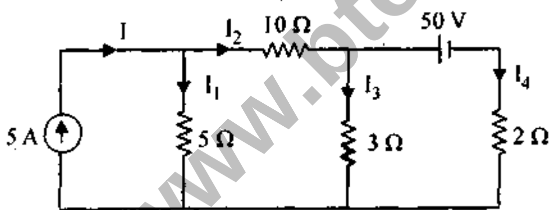
(ii) Find the current in, and voltage across, the 2Ω resistance in the following fig. (Unit-1)



Ans.



By superposition theorem, Now replace in 10 V a& 20 V source by short ckt.

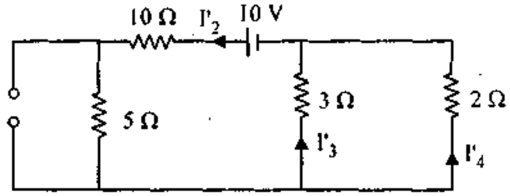


$$I_2 = 5 \times \frac{5}{5 + \frac{6}{6} + 10}$$

$$= \frac{25}{16.2} = 1.54\ \text{A}$$

$$I_4 = 1.54 \times \frac{3}{2+3} = 0.93\ \text{A} \downarrow$$

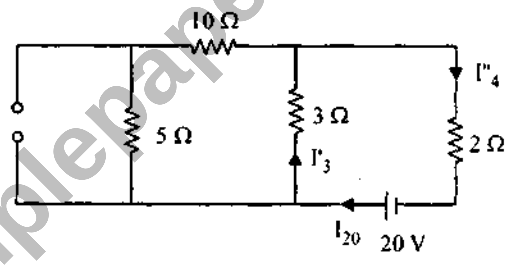
Now replace the 5 A source by open ckt and 20 V source by short-ckt.



$$I_2' = \frac{10}{16.2} = 0.62\ \text{A}$$

$$I_4' = 0.62 \times \frac{3}{5} = 0.37\ \text{A} \downarrow$$

Now replace the 5A source by open ckt and 10 V source by short ckt



$$I_4'' = I_{20} = \frac{20}{4.5} = 4.44\ \text{A} \downarrow$$

Net current in 2Ω = 0.93 − 0.37 + 4.44
= 5 A

Net voltage drop across2Ω = 5 × 2
= 10 V

(iii) State and prove Maximum Power Transfer Theorem. (Unit-1)

Ans. Maximum Power Transfer Theorem

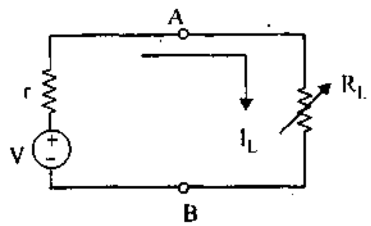
Let us see the statement of the theorem.

Statement : *In an active resistive network, maximum power transfer to the load resistance take place when the load resistance equals to the equivalent resistance of the network as viewed from the terminals of the load.*

Proof of Maximum Power Transfer Theorem

Consider a d.c. source of voltage V volts and having internal resistance of

r ohms connected to a variable load resistance R_L as shown in the Fig.



$$I_L = \frac{V}{r + R_L}$$

The power consumed by the load resistance R_L is

$$P = I_L^2 R_L = \left[\frac{V}{(r + R_L)}\right]^2 R_L$$

If R_L is changed, I_L is also going to change and at particular value of R_L, power transferred to the load is maximum. Let us calculate value of R_L for which power transfer to load is maximum. To satisfy maximum power transfer we can write,

$$\frac{dP}{d R_L} = 0$$

$$\frac{d}{d R_L}\left[\frac{V}{(r + R_L)}\right]^2 R_L = 0$$

$$\therefore \; V^2 \frac{d}{d R_L}\left[\frac{R_L}{(r + R_L)^2}\right] = 0$$

... As voltage is constant

$$\therefore \; (r + R_L)^2 \frac{d(R_L)}{d R_L} - R_L \frac{d}{d R_L}(r + R_L)^2 = 0$$

$$\therefore \quad (r + R_L)^2 (1) - R_L \, 2(r + R_L) = 0$$

$$\therefore \quad (r + R_L - 2R_L) = 0$$

$$\boxed{R_L = r}$$

Max. power can be obtained, substituting $r = R_L$ in expression of power.

$$P_{max} = \frac{V^2}{(R_L + R_L)^2} R_L$$

$$= \frac{V^2}{4 R_L^2} \times R_L$$

$$\boxed{P_{max} = \frac{V^2}{4 R_L} \text{ watts}}$$

Q. 4. Attempt any two parts of the following **(Unit-2)**

(i) Given $v = 200 \sin 377 t \; V$ and $i = 8 \sin (377 t - 30°) \; A$ for an ac circuit.

Determine : (a) The power factor (b) True power (c) Apparent power (d) Reactive power.

Ans. $v = 200 \sin 377 t \; V$

$i = 8 \sin (377 t - 30°) \; A$

(a) Power factor $= \cos\phi = \cos 30° = 0.87$ lagging

$$V = \frac{200}{\sqrt{2}} = 141.42 \text{ V}$$

$$I = \frac{8}{\sqrt{2}} = 5.66 \text{ A}$$

(b) $P = VI \cos\phi = 141.42 \times 5.66 \times 0.87$

True power, $P = 696.38$ VA

(c) Apparent power,

$S = VI = 141.42 \times 5.66 = 800.44$ W

(d) Reactive power, $Q = VI \sin\phi$

$= 800.44 \times 0.5$

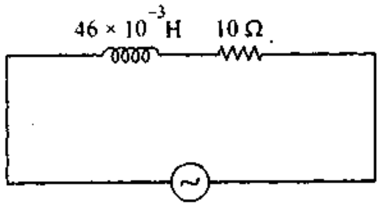
$= 400.22$ VAR.

Q. 4. (ii) A 46 mH inductive coil has a resistance of 10 Ω. **(Unit-2)**

(a) How much current will it draw if connected across a 100 V, 60 Hz, source ?

(b) Determine the value of the capacitance that must be connected across the coil to make the power factor of the overall circuit unity.

Ans.



100 V, 60 Hz

$L = 46 \times 10^{-3} H$

$R = 10\,\Omega$

$X_L = 2\pi f L$

$= 2 \times 3.14 \times 60 \times 46 \times 10^{-3}$

$= 17.33\,\Omega$

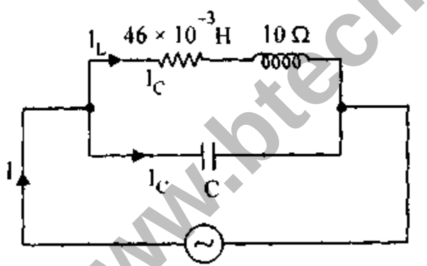
$Z_L = \sqrt{X_L^2 + R^2} = \sqrt{(17.33)^2 + 10^2}$

$= \sqrt{300.33 + 100}$

$Z_L = 20\,\Omega$

(a) $I_L = \dfrac{V}{Z_L} = \dfrac{100}{20} = 5$ A

(b) $\phi_L = \tan^{-1}\dfrac{X_L}{R} = \tan^{-1}\dfrac{17.33}{10}$



100 V, 60 Hz

$\phi_L = 60°$

for unity p.f.

$I_C = I_L \sin\phi_L$

$= 5 \times \sin 60$

$I_C = 4.33$ A

$I_C = \dfrac{V}{X_C}$

$X_C = \dfrac{V}{I_C} = \dfrac{100}{4.33}$

$\dfrac{1}{2\pi f C} = 23.1$

$C = \dfrac{1}{2 \times 3.14 \times 60 \times 23.1}$

$= 1.14888 \times 10^{-4}$ F

$C = 114.89\ \mu$F

Q. 4. (iii) How is the phasor of a sinusoidal quantity defined ? Mention specifically the information that in conveyed by the phasor about the corresponding sinusoidal function.

(Unit-2)

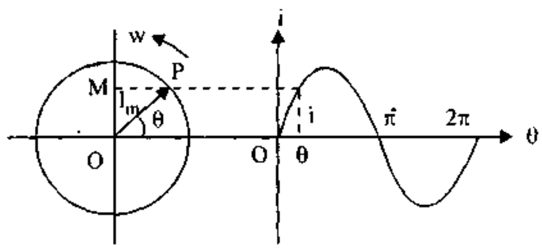
Ans. Phasor Representation of Sinusoidal Quantities : Consider an alternating current represented by the equation $i = I_m \sin\omega t$. Take a line OP to represent to scale the maximum value I_m. Imagine the line OP (or ** *phasor*, as it is called) to be rotating in anticlockwise direction at an angular velocity ω rad/sec about the point O. Measuring the time from the instant when OP is horizontal, let OP rotate through an angle $\theta (= \omega t)$ in the anticlockwise direction. The projection of OP on Y-axis is OM

$OM = OP \sin\theta$

$= I_m \sin\omega t$

$= i$, the value of current at that instant.

Hence the projection of the phasor OP on Y-axis at any instant gives the value of current at that instant. Thus when $\theta = 90°$, the



projection on Y-axis is $OP(=I_m)$ itself. That the value of current at this instant (*i.e.*, at θ or $\omega = 90°$) is I_m can be readily established if we put $\theta = 90°$ in the current equation. If we plot the projections of the phasor on Y-axis *versus* its angular position point by-point, a sinusoidal alternating current wave is generated as shown in Fig.Thus the phasor represents the sine wave for every instant of time.

The following points are worth nothing :

(i) The length of the phasor represents the maximum value and the angle with axis of reference (*i.e.*, axis) indicates the phase of the alternating quantity *i.e.*, current in this case.

(ii) The phasor representation enables us to quickly obtain the numerical values and, at the same time, have a picture before the eye of the events taking place in the circuit. Thus in the position of the phasor OP shown in Fig., the instantaneous value is OM, the phase is θ and frequency is $\omega / 2\pi$.

(iii) A phasor diagram permits addition and subtraction of alternating voltages or currents with a fair degree of ease.

Q. 5. Attempt any two parts of the following

(i) A 3-phase voltage source has a phase voltage of 120 V and supplies star connected load having impedance $36 + j48\,\Omega$ per phase. Calculate. (Unit-3)

(a) The line voltage

(b) The line current

(c) The power factor

(d) The total 3-phase power supplied to the load.

Ans.

$V_P = 120$ V

$\overline{Z} = (36 + J48)\,\Omega$

$R = 36$

$X = 48$

$$Z_P = \sqrt{36^2 + 48^2} = \sqrt{1296 + 2304} = 60\,\Omega$$

In case of star connections

(a) Lin voltage,

$$V_L = \sqrt{3}\,V_P = \sqrt{3} \times 120 = 207.85\text{ V}$$

(b) $I_P = \dfrac{V_P}{Z_P} = \dfrac{120}{60} = 2\text{ A}$

line current, $I_L = I_P = 2A$

(c) $\phi = \tan^{-1}\dfrac{X}{R} = \tan^{-1}\dfrac{48}{36} = 53.13°$

P.f., $\cos\phi = \cos\phi = \cos 53.13°$

$= 0.6$ **Ans.**

(d) Total Three phase power,

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

$$P = \sqrt{3} \times 207.85 \times 2 \times 0.6$$

$$= 432\text{ VA}$$

Q. 5. (ii) Discuss the principle, construction and operation of moving iron type measuring instruments.

(Unit-3)

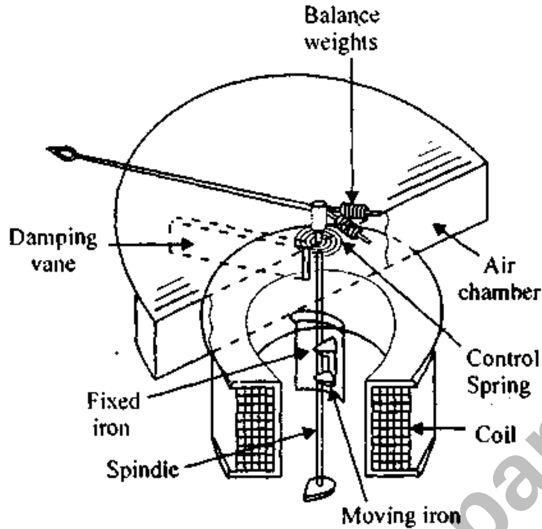
Ans. Moving iron instruments are of two types :

(i) Attraction type, (ii) Repulsion type

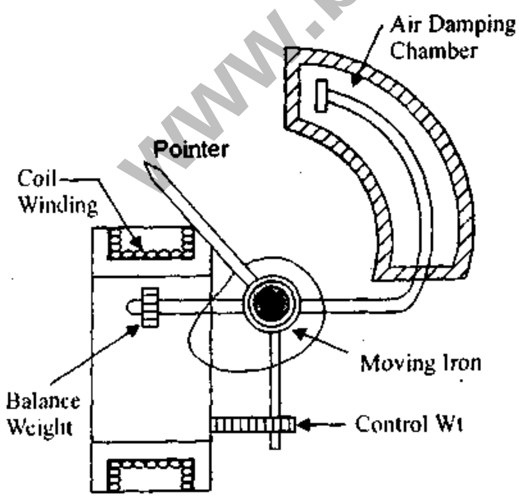
Now we discuss Attraction type moving iron instruments.

Moving Iron Attraction Type Instruments : The basic working principle of these instruments is very simple that a soft iron piece if brought near the magnet gets attracted by the magnet.

Construction : Fig. shows the constructional details of an attraction type moving iron instrument. It consists of a



cylindrical coil or solenoid which is kept fixed. An oval-shaped soft-iron is attached to the spindle in such a way that it can move in and out of the coil. A pointer is attached to the spindle so that it is deflected with the motion of the soft-iron piece. The controlling torque is provided by one spiral spring arranged at the top of the moving element. It should be noted that in this instrument, the springs do not carry the current as the same is carried by the



stationary coil. The ** damping device is an aluminium vane attached to the spindle, as shown in Fig. which moves in a closed air chamber. In some instruments, damping is provided by the movement of a piston inside the curved chamber [See Fig.] the piston being attached to the spindle

Working : When the instrument is connected in the circuit to measure current or voltage, the operating current flowing through the coil set up a magnitude filed. In other words, the coil behaves like a magnet and therefore it attracts the soft-iron towards it. The result is that the pointer attached to the moving system moves from zero position. The pointer will come to rest at a position where deflecting torque is equal to the controlling torque. If current in the coil is reversed, the direction of magnetic field also reverses and so does the magnetism produced in the soft-iron piece. Hence, the direction of the deflecting torque remains unchanged. For this reason, such instruments can be used for both d.c. and a.c. measurements.

Q. 5. (iii) Explain two wattmeter method to determine power in 3 phase system. (Unit-3)

Ans. Two-Watt Meter Method- Balanced Load :

If the 3-phase load (Y or Δ) is balanced, we can also determine the power factor of the load from the wattmeter reading. Fig. shows a balanced Y-connected load ; the p.f. angle of load impedance being ϕ lag. Let V_{RN}, V_{YN} and V_{BN} be the r.m.s values of the three load phase voltages (phase sequence being RYB) and I_R, I_Y and $I_B$the r.m.s values of phase currents. These current will lag behind their respective phase voltages by ϕ as shown in the phasor diagram in Fig.

Current through current coil of $W_1 = I_R$

P.D. across potential coil of

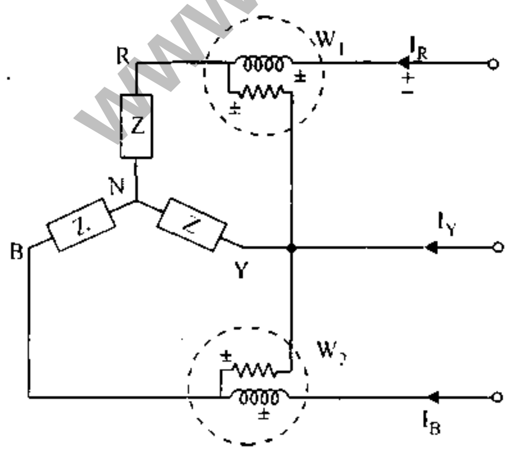
$W_1, V_{RY} = V_{RN} - V_{YN}$ *...phasor difference*

To obtain V_{RY}, find the phasor sum of V_{RN} and $-V_{YN}$ as shown in Fig. It is clear form the phasor diagram that phase angle betwen V_{RY} and I_R is $(30° + \phi)$.

$\therefore \quad W_1 = V_{RY} I_R \cos(30° + \phi)$

Current through current coil of $W_2 = I_B$

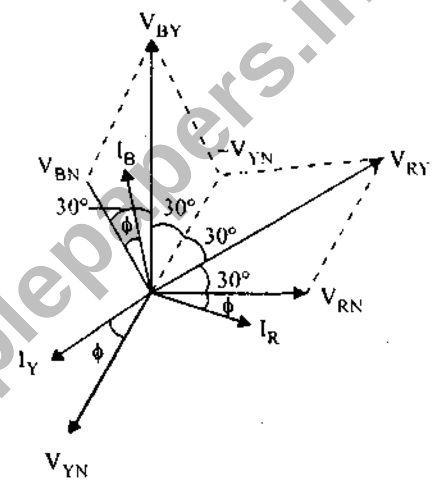
P.D. across potential coil of $W_2, V_{BY} = V_{BN} - V_{YN}$ *...phasor difference*



To obtain V_{BY}, find the phasor sum of V_{BN} and $-V_{YN}$ as shown in Fig. It is clear from the phasor diagram that phase angle between V_{BY} and I_B is $(30° - \phi)$.

$\therefore W_2 = V_{BY} I_B \cos(30° - \phi)$

Since the load is balanced $V_{RY} = V_{BY}$ = Line voltage, V_L and $I_R = I_B$ = Line current, I_L



$\therefore W_1 = V_L I_L \cos(30° + \phi)$ and

$W_2 = V_L I_L \cos(30° - \phi)$

$\therefore W_1 + W_2 = V_L I_L [\cos(30° + \phi) + \cos(30° - \phi)]$

$= V_L I_L (2\cos 30° \cos\phi)$

$= \sqrt{3}\, V_L I_L \cos\phi$ = Total power in the 3-phase load.

Hence, the algebraic sum of the two wattmeter readings gives the total power consumed in the 3-phase load.

Q. 6. Attempt any two parts of the following

(i) Discuss the voltage structure of the electric power system. Give the concept of grid. (Unit-4)

Ans. Line Diagram of A voltage structure in Power :

At the generating station, an electrical power is generated with the help of three phase alternators running in parallel. In the scheme shown, the voltage level is 11 kV but the voltage level may be 6.6 kV, 22 kV or 33 kV depending upon the capacity of the generating station. After the generating station, actual transmission and distribution starts. The overall scheme can be divided into four sections which are,

1. Primary transmission : It is basically with the help of overhead transmission lines. For the economic aspects, the voltage level is increased to 132 kV, 220 kV or more, with the help of step up transformer. Hence this transmission is also called high **voltage transmission.** The primary transmission uses 3 phase 3 wire system.

2. Secondary transmission : The primary transmission line continues via transmission towers till the receiving stations. At the receiving stations, the voltage level is reduced to 22 kV or 33 kV using the step down transformer. There can be more than one receiving stations. Then at reduced voltage

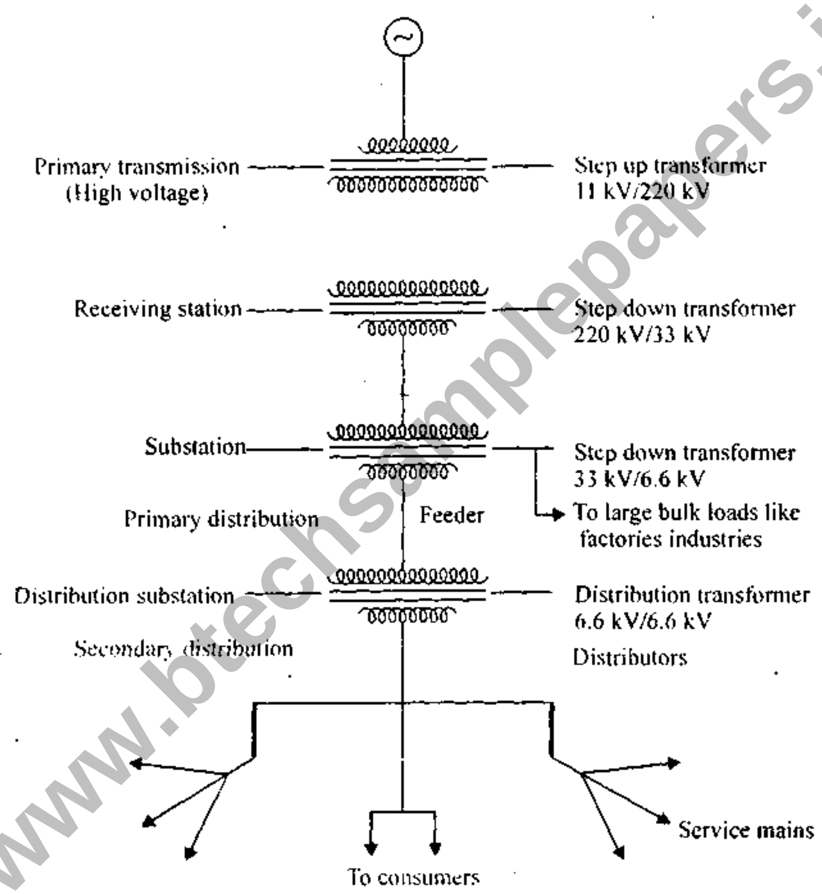


Fig. Line diagram of a typical transmission distribution scheme.

level of 22 kV or 33 kV, the power is then transmitted to various substations using overhead 3 phase 3 wire system. This is secondary transmission. The conductors used for the secondary transmission are called feeders.

3. **Primary distribution** : At the substation the voltage level is reduced to 6.6 kV, 3.3 kV or 11 kV with the help of step down transformer. It uses three phases three wire underground system. And the power is further transmitted to the local distribution centres. this is primary distribution, also called high voltage distribution. For the large consumers like factories and industries, the power is directly transmitted to such loads from a substation. Such big loads have their own substations.

4. **Secondary distribution** : At the local distribution centres, there are step down distribution transformers. The voltage level of 6.6 kV, 11 kV is further reduced to 400 V using distribution transformers. Sometimes it may be reduced to 230 V. The power is then transmitted using distributors and service mains to the consumers. This is secondary distribution, also called low voltage distribution. This uses 3 phases 4 wire system. The voltage between any two lines is 400 V while the voltage between any of the three lines and a neutral is 230 V. The single phase lighting loads are supplied using a line and neutral while loads like motors are supplied using three phase lines.

***Concept of Grid** : The connection of several generating stations in parallel is known as* **interconnected grid system**.

The various problems facing the power engineers are considerably reduced by interconnecting different power stations in parallel. Although interconnection of station involves extra cost yet considering the benefits derived from such an arrangement, it is gaining much favour these days. Some of the advantages of interconnected system are listed below.

(1) Exchange of peak load.
(2) Use of older plants
(3) Ensures economical operation
(4) Increases diversity factor
(5) Reduces plant reserve capacity.
(6) Increases reliability of supply.

Q. 6. (ii) The core of a magnetic circuit of mean length 40 cm and uniform cross-sectional area 4 cm². The relative permeability of the core material is 1000. An air gap of 1 mm is cut in the core, and 1000 turns are wound on the core. Determine the inductance of the coil if fringing is negligible. **(Unit-4)**

Ans. Mean length of case = 40 cm = li

Air gap length = 1 mm = 0.1 cm = la

Length of mean flux path in core

$= 40 - 0.1$

$= 39.9$ cm

$l = 0.399$ m

cross-sectional area $= 4\ \text{cm}^2$

$= 4 \times 10^{-4}\ \text{m}^2$

$a = 0.0004\ m^2$

$\mu_r = 1000, N = 1000$

$$\text{Inductance, } L = \frac{N^2 \mu_0 \mu_r a}{l}$$

$$= \frac{(1000)^2 \times 4\pi \times 10^{-7} \times 1000 \times 0.0004}{0.399}$$

$$= \frac{0.5024}{0.399}$$

$= 1.25$ H

$= 1250$ mH

Q. 6. (iii) The ohmic value of the circuit parameters of a transformer, having a turns ratio of 5, are $R_1 = 0.5\ \Omega$,

$R_2 = 0.021\,\Omega$, $X_1 = 3.2\ \Omega$, $X_2 = 0.12\,\Omega$, $R_c = 350\,\Omega$, **referred to the primary and** $X_m = 98\,\Omega$ **referred to primary. Draw the approximate equlvalent clrcuits of the transformer referred to secondary. Show the numerical values of the circuit parameters.** **(Unit-4)**

Ans. $K = \frac{1}{5}$

$R_1 = 0.5\,\Omega$, $R_2 = 0.21\,\Omega$

$X_1 = 3.2\,\Omega$, $X_2 = 0.12\,\Omega$

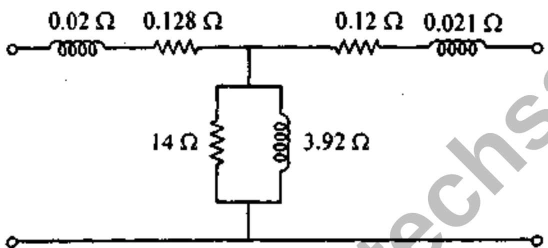
$R_C = 350\,\Omega$ referred to primary

$X_m = 98\,\Omega$ referred to primary

R_1 referred to secondary,

$$R_1' = K^2 R_1 = \frac{1}{5^2} \times 0.5$$

$$= 0.02\,\Omega$$



X_1 referred to secondary,

$$X_1' = K^2 X_1 = \frac{1}{5^2} \times 3.2$$

$$= 0.128\,\Omega$$

R_C referred to secondary,

$$R_C' = K^2 R_C = \frac{1}{5^2} \times 350$$

$$= 14\,\Omega$$

X_m referred to secondary,

$$X_m' = K^2 X_m = \frac{1}{5^2} \times 98$$

$$= 3.92\,\Omega$$

Total resistance of ckt $R = R'_1 + R_2$

$$= 0.02 + 0.021$$

$$= 0.041\,\Omega$$

Total reactance of the ckt,.

$$X = X'_1 + X_2$$

$$= 0.128 + 0.12$$

$$= 0.248\,\Omega$$

Total impedance of ckt.

$$Z = \sqrt{0.041^2 + 0.248^2}$$

$$= 0.25\,\Omega$$

Q. 7. Attempt any two parts of the following

(i) Calculatc the voltage induced in the armature winding of a 4-pole, lap wound dc machine having 728 active conductors and running at 1800 rpm. The flux per pole is 30 mWb. If the armature is designed to carry a maximum line current of 100 A, what is the maximum electro magnetic power develop hy the armature ? **(Unit-5)**

Ans. Let dc machine is a shunt generator.

$P = 4\ I_{am} = 100$ A

$Z = 728$

$N = 18$ nm

$\phi = 30 \times 10^{-3}$ Wb

$$E = \frac{\phi ZNP}{60} = \frac{30 \times 10^{-3} \times 728 \times 1800 \times 4}{60 \times 4}$$

$$= 655.2\ \text{V}$$

$$R_a = \frac{655.2}{100} = 6.55\,\Omega$$

$$P_m = E\,I_{am} = 655.2 \times 100$$

$$= 65.52\ \text{kW}$$

Q. 7. (ii) A 4-pole, 3-phase induction motor is energized from a 60 Hz supply, and is running at a load condition for which the slip is 0.03. Determine : (a) Rotor speed, in rpm (b) Rotor current

frequency, in Hz (c) Speed of the rotor's rotating magnetic field with respect to the stator frame, in rpm. (Unit-5)

Ans. $P = 4, F = 60$ Hz, $S = 0.03$ or 3%

$$N_s = \frac{120f}{P} = \frac{120 \times 60}{4} = 1800 \text{ rpm}$$

$$S = \frac{N_s - N_r}{N_s}$$

$$N_r = N_s(1 - s) = 1800 \times (1 - 0.03)$$

rotor speed, $N_r = 1746$ rpm

(b) rotor current frequency, $f' = sf$

$= 0.03 \times 60$

$= 1.8$ Hz

(c) Speed of the rotor's rotating magnetic field with respect to the stator frame

= speed of the stator field with respect to the stator frame.

$= N_s$

= 1800 rpm.

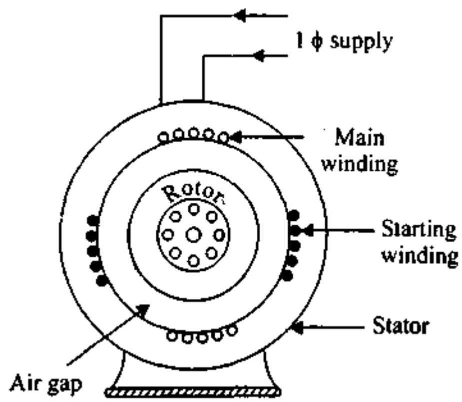
Q. 7. (iii) Discuss the principle of operation of a single phase induction motor. How the motor is started ? Explain any one method of starting. (Unit-5)

Ans. Single-Phase Indnction Motors :

A single phase induction motor is very similar to a 3-phase squirrel cage induction motor. It has (*i*) a squirrel rotor identical to a 3-phase motor and (*ii*) a single-phase winding on the stator.

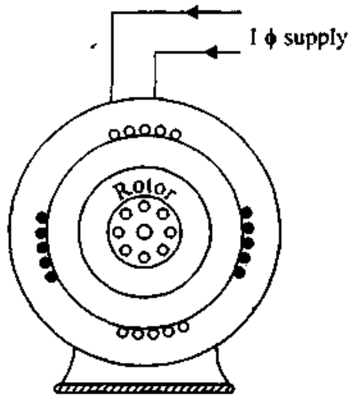
Unlike a 3-phase induction motor, a single-phase induction motor is not self-starting but requires some starting means. The single-phase stator winding produces a magnetic field that pulsates in strength in sinusoidal manner. The field polarity reverses after each half cycle *but the field does not rotate*. Consequently, the alternating flux cannot produce rotation in a stationary squirrel-cage rotor. However, if the rotor of a single-phase motor is rotated in one direction by some mechanical means, it will continue to run in the direction of rotation. As a matter of fact, the rotor quickly accelerates until it reaches a speed slightly below the synchronous speed. Once the motor is running at this speed, it will continue to rotate even though single-phase current is flowing through the stator winding.

Making self-starting : To make s single-phase induction motor self-starting, we should somehow produce a revolving stator magnetic field. This may be achieved by converting a single-phase supply into two phase supply through the use of an additional winding .(See Fig.), When the motor attains

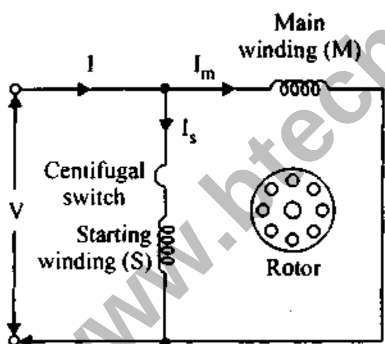


sufficient speed, the starting means (*i.e,* additional winding) may be removed depending upon the type of the motor. As a matter of fact, single-phase induction motors are classified and named according to the method employed to make them self-starting

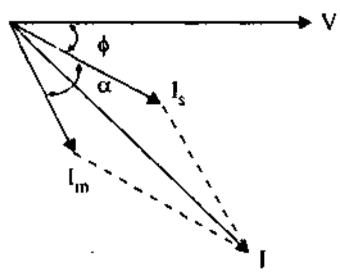
(i) *Split-phase motors*



(i)



(ii)



(iii)

(ii) *Capocitor motors*

(iii) *Shaded-pole motors.*

Split-Phase Induction Motor :

The stator of a split-phase induction motor is provided with an auxiliary or starting winding S in addition to the main or running winding M. The starting winding is located 90° electrical from the main winding [see Fig.(*i*)] and operates only during the brief period when the motor starts up. The two windings are so designed that the starting winding S has a high resistance and relatively small reactance while the main winding M has relatively low resistance and large reactance as shown in the schematic connections in Fig. (*ii*). Consequently, the currents flowing in the two winds have reasonable phase difference α (25° to 30°) as shown in the phasor diagram in Fig. (*iii*).

Operation :

(*i*) When the two stator windings are energised from a single-phase supply, the main winding carries current I_m while the starting winding carries current I_s.

(*ii*) Since main winding is made highly inductive while the starting winding highly resistive, the currents I_m and I_s have a reasonable phase angler α (25° to 30°) between them as shown in Fig. (*iii*).Consequently, a weak revolving field approximating to that of a 2-phase machine is produced which starts the motor. The starting torque is given by;

$$T_s = k\, I_m I_s \sin \alpha$$

where k is a contant whose magnitude depends upon the design of the motor.

(*iii*) When the motor reaches about 75% of synchronous speed, the centrifugal switch opens the circuit of the starting winding. The motor then operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed.