Code No.: EE204ES | R20 | H.T.No. | | | 8 | R | | | | |

CMR ENGINEERING COLLEGE: : HYDERABAD
UGC AUTONOMOUS
I–B.TECH–II–Semester End Examinations (Supply) - June- 2025
BASIC ELECTRICAL ENGINEERING
(Common for CSM, ECE, AI&DS)

[Time: 3 Hours] **[Max. Marks: 70]**

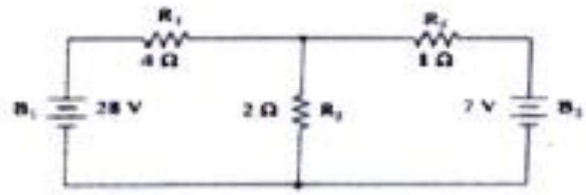
Note: This question paper contains two parts A and B.
Part A is compulsory which carries 20 marks. Answer all questions in Part A.
Part B consists of 5 Units. Answer any one full question from each unit. Each question carries 10 marks and may have a, b, c as sub questions.

PART-A (20 Marks)

1. a) Define KCL, KVL. [2M]
   b) What are the limitations of Ohm's law? [2M]
   c) Define Average value. [2M]
   d) Write the relationship between line voltage, line current, and phase voltage phase current in star. [2M]
   e) What is a Transformer? [2M]
   f) Write the applications of Auto Transformer. [2M]
   g) What are the parts of DC machine? [2M]
   h) List the various methods of speed control of DC motor. [2M]
   i) Define slip. [2M]
   j) Why single - phase induction motor is not self-starting? [2M]

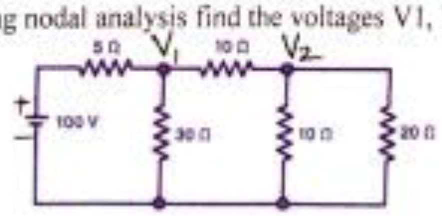
PART-B (50 Marks)

2. State Thevenins Theorem and find the current in 2ohm using Thevenins theorem. [10M]



OR

3. Using nodal analysis find the voltages V1, V2. [10M]



4. Derive the relationship between line voltage, line current, phase voltage, phase current in star connected system [10M]

OR

5.a) Obtain the average value of sinusoidal waveform ($v=V_m \sin wt$). [5M]
   b) A 230V,50Hz AC supply is applied to a coil of 0.06H inductance and 2.5ohm resistance connected in series with a capacitor of 6.5 micro Farad. Calculate impedance, current, phase angle, power factor. [5M]

6.a) Explain in detail losses in a transformer. [5M]

b) Explain three phase transformer connections. [5M]

OR

7.a) Explain in detail construction of an Auto transformer. [5M]

b) In a 25KVA transformer, 2000/200V transformer the constant and variable losses are 350W, 400W. Calculate efficiency at full load and half load. [5M]

8. A Compound generator is to supply a load of 250 lamps, each rated at 100w, 250v.The armature, field, shunt resistances are 0.06ohm, 0.04 ohm and 50ohm respectively. Determine the generated Emf when machine is connected in long shunt and short shunt. [10M]

OR

9. Explain performance characteristics of a DC shunt machine. [10M]

10. Explain in detail construction and working of three phase induction motor. [10M]

OR

11.a) Explain the concept behind the generation of rotating field in a three phase induction motor. [5M]

b) The frequency of the EMF in the stator of a 4-pole induction motor is 50Hz, and that in the rotor is 2Hz. What is the slip and at what speed is the motor running? [5M]

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BASIC ELECTRICAL ENGINEERING

SCHEME OF EVALUATION

SUPPLY [R-20] June - 2025

PART- A

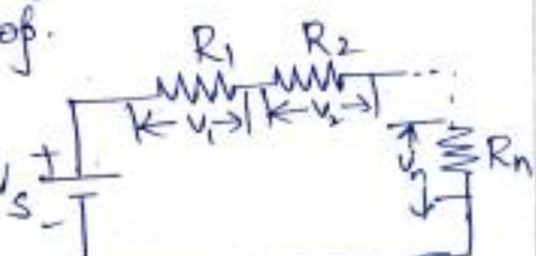
Q1. a) Define KCL, KVL.

Ans. KCL :- It states that the current flowing through towards the node is equal to the algebraic sum of currents moving away from the node.

$$i_1 + i_2 = i_3 + i_4 + i_5$$

KVL :- It states the the algebraic sum of the source voltages equal to the algebraic sum of the voltage drops in a closed loop.

$$V_s = V_1 + V_2 + \cdots + V_n$$



b) What are the limitations of Ohm's laws?

Ans. Ohm's law is not applicable when

(i) temperature varies

(ii) for non metallic conductors

(iii) for semiconductor drives

(iv) for flourescent lamps.

c. Define Average value.

Ans. The average value is defined as the averaging of all the instantaneous values along time axis with time being one full period (T) (or)
The quotient of the area under the waveform w.r.t time. It is given as

$$V_{avg} = \frac{1}{T}\int_0^T v(t).dt$$

d. Write the relationship between line voltage, line current and phase voltage phase current in star

Ans.

$$V_{ph} = \frac{V_L}{\sqrt{3}}, \quad I_L = I_{ph}$$

e. What is a transformer?

Ans. A transformer is a static device which transfers energy from one circuit to another circuit without change in the frequency but with a desired change in the voltage and current.

f. Write the applications of Autotransformer.

Ans. ① It can be used as starters for Induction motors.
② Voltage boosters in AC feeders.

g. What are the parts of DC machine

Ans. (i) Yoke (ii) poles (iii) Armature core (iv) armature windings (v) field windings (vi) commutation (vii) brushes (viii) Shaft

h. List the various methods of speed control of DC motors

Ans. (i) flux control method

(ii) armature control

(iii) voltage control

(i) Define slip.

Ans. It is defined as the difference between the synchronous speed of the rotating magnetic field produced by the stator and the actual rotor speed.

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

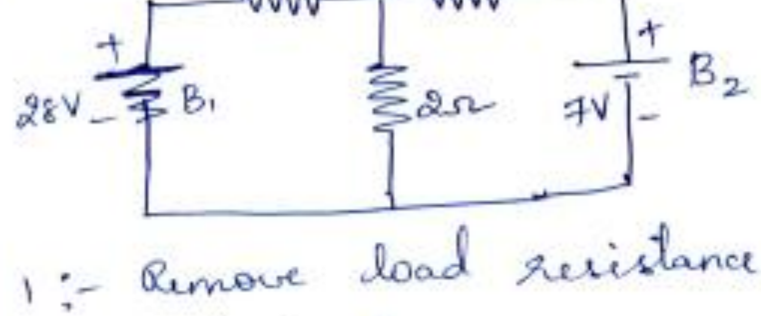
j. Why single phase Induction motor is not self starting?

Ans. Single phase induction motor are not self starting because the magnetic field produced by a single phase supply is pulsating, not rotating.

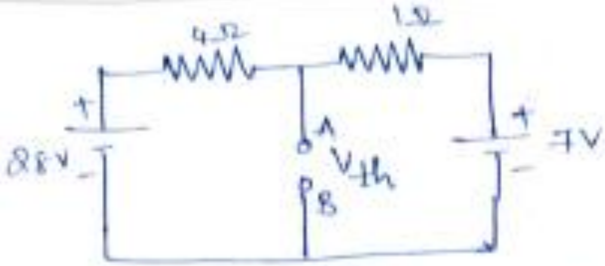
PART-B

2. State Thevenins theorem and find current in 2Ω using thevenins theorem.

Sol.



Step 1 :- Remove load resistance 2Ω and open circuit the terminals.



Step 2:- Find V_{th} between the terminals A & B

$V_{th} = 28 - V_{4\Omega}$

$V_{4\Omega} = ?$

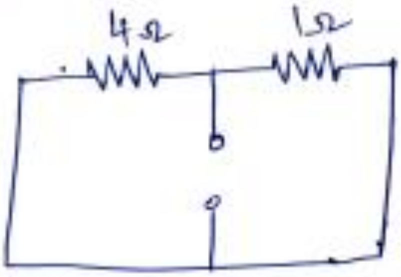
$28 = 4I + 1I + 7$

$21 = 5I \Rightarrow I = \frac{21}{5} = I = 4.2A$

$V_{4\Omega} = 4 \times 4.2 \Rightarrow V_{4\Omega} = 16.8V$

$V_{th} = 28 - 16.8 \Rightarrow \boxed{V_{th} = 11.2V}$

Step 3:- Find R_{th} b/w A & B short circuiting the sources 28V, 7V.

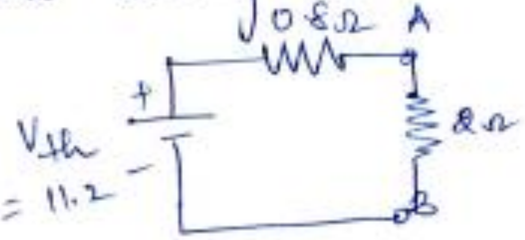


$R_{th} = [4 \| 1]$

$= \frac{4 \times 1}{5}$

$\boxed{R_{th} = 0.8\Omega}$

Step 4:- Replace the ckt with eq. circuit i.e voltage source in series with resistance and add load resistance

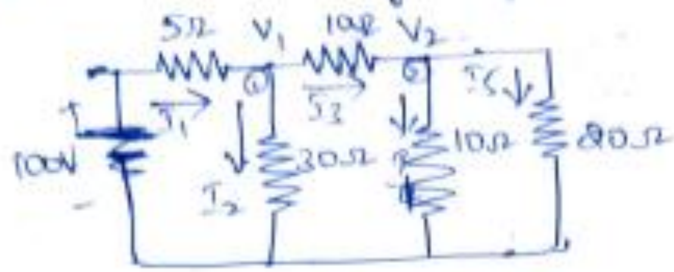


$I_{2\Omega} = \frac{V_{th}}{R_{th} + R_L} = \frac{11.2}{0.8 + 2}$

$\boxed{I_{2\Omega} = 4\Omega}$

3. Using nodal analysis find voltages V_1, V_2.

Sol.



Apply KCL at node ①

$$I_1 = I_2 + I_3$$

$$\frac{100 - V_1}{5} = \frac{V_1}{30} + \frac{V_1 - V_2}{10}$$

$$20 = \frac{V_1}{30} + \frac{V_1}{5} + \frac{V_1}{10} - \frac{V_2}{10}$$

$$20 = 0.03\,V_1 + 0.2V_1 + 0.1V_1 - 0.1V_2$$

$$20 = 0.33V_1 - 0.1V_2 \quad \text{—①}$$

Apply KCL at node ②

$$I_3 = I_4 + I_5$$

$$\frac{V_1 - V_2}{10} = \frac{V_2}{10} + \frac{V_2}{20}$$

$$\frac{V_1}{10} = \frac{V_2}{10} + \frac{V_2}{20} + \frac{V_2}{10}.$$

$$0.1V_1 - 0.1V_2 - 0.05V_2 - 0.1V_2$$

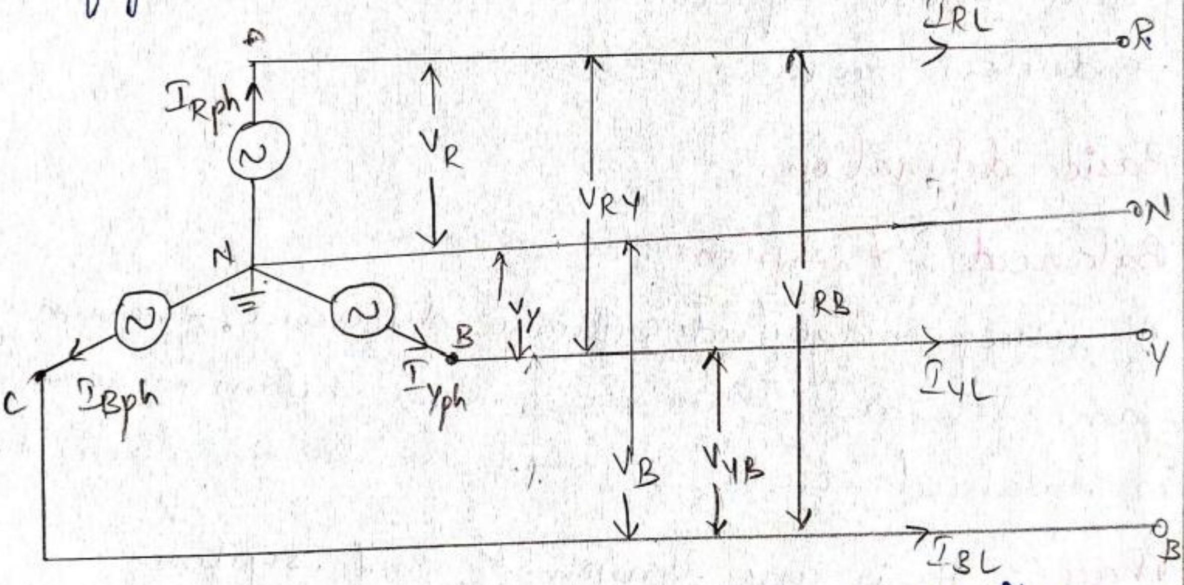
$$0.1V_1 - 0.25V_2 = 0 \quad \text{—②}$$

$$V_1 = 68.96\,V, \quad V_2 = 27.58\,V$$

Q4. Derive the relationship between line voltage, line current, phase voltage, phase current in star connected system.

Y-connected 3-ϕ system :-

- The Y-connected three phase system is shown in the fig.



In the above system, the neutral of all three individual 1-ϕ systems connected together to form single (N), to other ends of all three phases connected to lines as shown in fig.

In the above phasor diagram, V_Y is extended in opposite direction which divides the angle (120°) b/w V_B and V_R equally as 60° ∴ the angle b/w V_Y, V_R is 60°

- Now vector sum of V_Y, V_R is given by V_{RY}

$$\boxed{V_{RY} = \bar{V}_R + \bar{V}_Y}$$

- OABC is a parallelogram,

∴ From parallelogram law we have

$$OB^2 = OA^2 + OC^2 + 2OA \cdot OC \cos(\text{angle } OA, OC)$$

$$V_{RY}^2 = V_R^2 + V_Y^2 + 2 \cdot V_R \cdot V_Y \cos 60$$

$$V_L^2 = V_{ph}^2 + V_{ph}^2 + 2 V_{ph} \cdot V_{ph} \cdot \frac{1}{2}$$

$$V_L^2 = 3 V_{ph}^2 \Rightarrow \boxed{V_{ph} = \frac{V_L}{\sqrt{3}}}$$

- The phase voltage is $1/\sqrt{3}$ times the line voltage.
- In Y connected systems, relations b/w V_{ph} & V_L, I_p, I_L is given as

$$\boxed{I_{ph} = I_L \quad , \quad V_{ph} = \frac{V_L}{\sqrt{3}}}$$

Power relations :-

- In 1-ϕ system, power is given by

$S_{1\phi} = V_{ph} I_{ph}$ (apparent power)

$P_{1\phi} = V_{ph} I_{ph} \cos\phi$ (active power)

$Q_{1\phi} = V_{ph} I_{ph} \sin\phi$ (reactive power)

- AN, BN, CN are phases, AR, BY, CB are lines
- V_R, V_Y and V_B are called phase voltages
- V_{RY}, V_{YB} and V_{BR} are called line voltages.
- I_{Rph}, I_{Yph}, I_{Bph} are phase currents, I_{RL}, I_{YL}, I_{BL} are line currents.
- In Y connected systems, the line (conductor wire) connected in series with phase. so same current flows through line and phase.

$$\boxed{I_{Rph} = I_{RL} = I_{ph} = I_L}$$

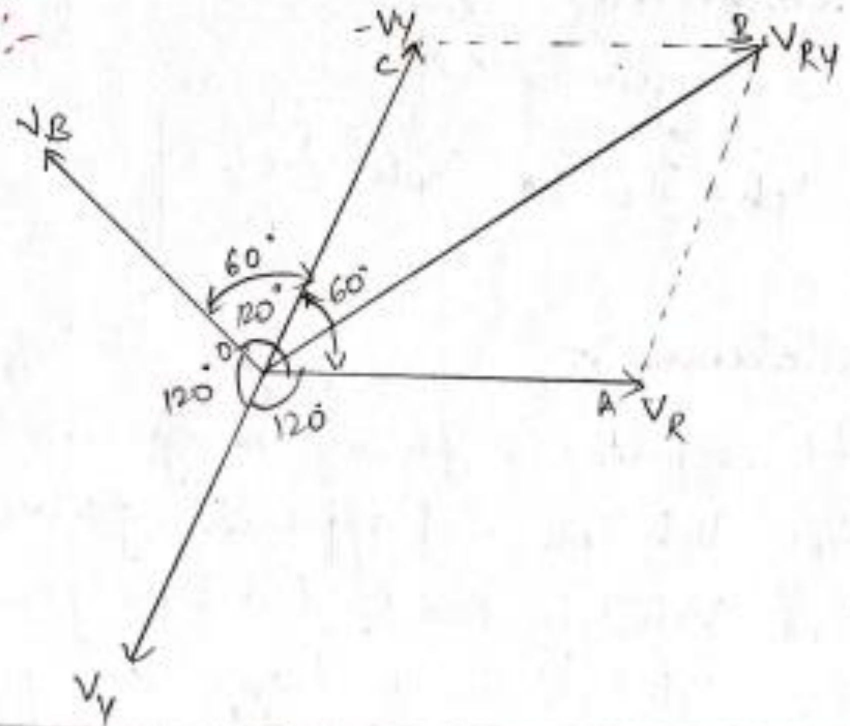
(R phase is taken as reference)

- But line voltage is not equal to phase voltage.

$$V_R \neq V_{RY} \Rightarrow \boxed{V_{RY} = \bar{V}_R + \bar{V}_Y}$$

- V_{RY} is line voltage. Vector sum of phase voltages $\bar{V}_R$ and $\bar{V}_Y$. The relation b/w V_{RY}, V_R is obtained from phasor diagram.

Phasor diagram:-



Q5 a) *Obtain the average value of sinusoidal waveform (v=Vmsinwt).*

AVERAGE VALUE :-

The average value of any function v(t), with period T is given by $\boxed{V_{av} = \frac{1}{T}\int_0^T v(t).dt}$

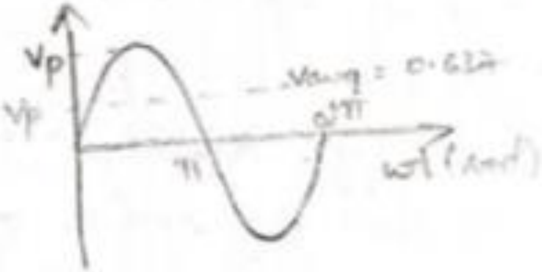
i.e the average value of a curve is the total area under the complete curve divided by the distance of the curve.

The average value of a sine wave over one complete cycle is always zero.

The average value of the sine wave is the total area under the half cycle curve divided by the distance of the curve.

∴ The average value of the sine wave is

$v(t) = V_p \sin\omega t$ is given by



$$V_{av} = \frac{1}{\pi}\int_0^{\pi} V_p \sin\omega t \, d(\omega t)$$

$$= \frac{1}{\pi}\left[-V_p \cos\omega t\right]_0^{\pi}$$

$$= \frac{2V_p}{\pi} = 0.637\,V_p$$

Average value is shown by dotted line.

- It is defined as Alternating Quantity the value which is obtained by averaging all the instantaneous values over a period of half cycle.

5b) A 230V, 50Hz AC supply is applied to a coil of 0.06H inductance and 2.5Ω resistance connected in series with a capacitor of 6.5μF. calculate impedance, current, phase angle, power factor.

$V = 230V,\ f = 50Hz,\ L = 0.06H,\ R = 2.5\Omega,\ C = 6.5\mu F$

$Z = ?,\ I = ?\ \ \phi = ?\ \ \cos\phi = ?$

(i) $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$X_L = 2\pi f L = 2\times 3.14 \times 50 \times 0.06 = 18.84\,\Omega$

$X_C = \frac{1}{2\pi f C} = 1/2\times 3.14 \times 50 \times 6.5\times 10^{-6}$

$= 0.00048995 \times 10^{6}$

$X_C = 489.95\,\Omega$

$Z = \sqrt{(2.5)^2 + (18.84 - 489.95)^2}$

$\boxed{Z = 471.11\,\Omega}$

(ii) $I = \frac{V}{Z} = \frac{230}{471.11}$

$\boxed{I = 0.488\ A}$

(iii) $\phi = \tan^{-1}\left[\frac{X_L - X_C}{R}\right] = \tan^{-1}(188.44)$

$\boxed{\phi = 89.7^\circ}$

(iv) $\cos\phi = \cos(89.7)$

$\boxed{= 0.01745}$

Q6 a) *Explain in detail losses in a transformer.*

Losses in a Transformer :-

In a transformer, there exists two types of losses.

(i) The core gets subjected to an alternating flux, causing core losses.

(ii) The windings carry currents when transformer is loaded, causing copper losses.

Core or Iron losses :-

Due to alternating flux set up in the magnetic core of the transformer, it undergoes a cycle of magnetisation & demagnetisation. Due to hysteresis effect there is loss of energy in this process which is called hysteresis loss.

$\boxed{\text{Hysteresis loss} = K_h B_m^{1.67} f\, v}$ watts

where K_h = Hysteresis constant depends on material.

B_m = Max. flux density.

f = Frequency.

v = Volume of the core.

The induced Emf in the core tries to set up eddy currents in the core and hence responsible for eddy current losses. The eddy current loss is given by,

$$\boxed{\text{Eddy current loss} = K_e B_m^2 f^2 t^2 \text{ watts/unit volume}}$$

where K_e = Eddy current constant

t = Thickness of the core

The flux density B_m in the core and both hysteresis & eddy current losses are constants at all loads. Hence the core losses are also called Constant losses.

The iron losses are denoted as P_i.

Copper losses :-

The copper losses are due to power wasted in the form of I^2R loss due to the resistances of the primary & secondary windings. The copper loss depends on the magnitude of the currents flowing through the windings.

$$\text{Total cu loss} = I_1^2 R_1 + I_2^2 R_2 = I_1^2 (R_1 + R_2') = I_2^2 (R_2 + R_1')$$

$$= I_1^2 R_{1e} = I_2^2 R_{2e}$$

The copper losses are denoted as P_{cu}. If the current through the windings is full load current, we get copper losses at full load. If the load on transformer is half then we get copper losses at half load which are less than full load copper losses. Thus copper losses are called variable losses.

For transformer VA rating is $V_1 I_1$ or $V_2 I_2$. As V_1 is constant, we can say that copper losses are proportional to the square of the KVA rating.

So, $$\boxed{P_{cu} \propto I^2 \propto (KVA)^2}$$

Thus for a transformer,

$$\text{Total losses} = \text{Iron losses} + \text{Copper losses}$$

$$= P_i + P_{cu}$$

Q6 b) *Explain the three phase transformer connections.*

3-ϕ Transformer Connections:-

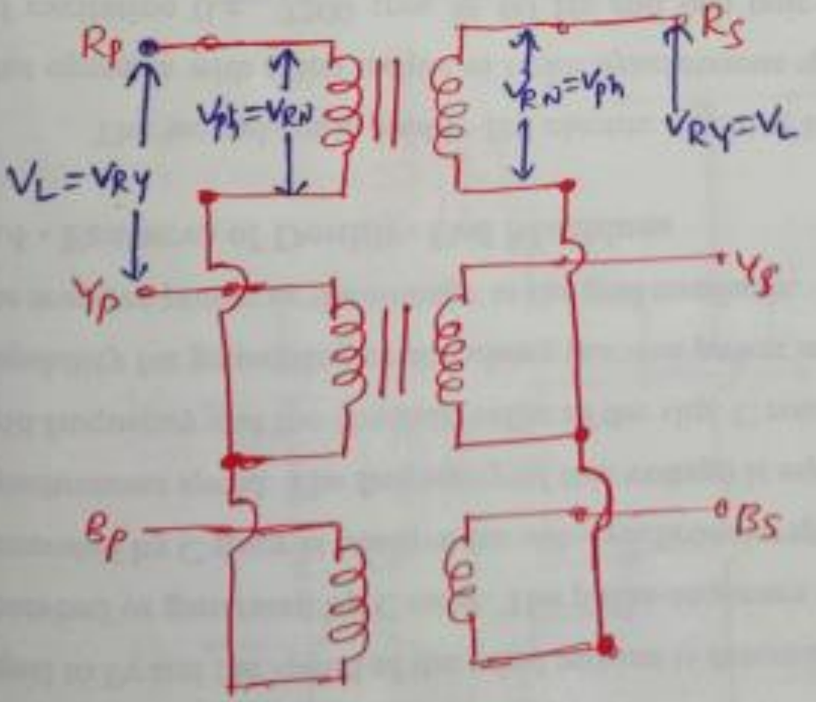
(21)

→ The three phase transformers mainly used in electrical power systems to transmit the large amount of power from Generating station to consumer premises.

→ power transmitting process at various stages voltage is step up (or) step down is done by 3-ϕ transformer

→ The various types of 3-ϕ transformer connection are

1) Y-Y Connection:



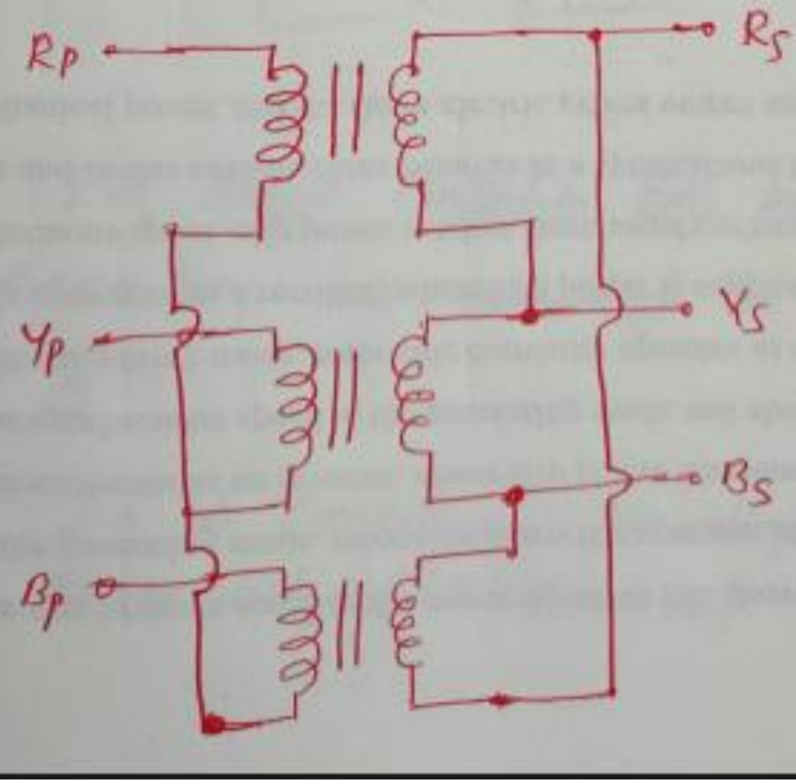
→ In this types of connection primary side and secondary side of 3φ transformer (3-φ transformer) are connected in the form of 'Y'. (22)

→ In this Y/Y Connection $\left(V_{ph} = \frac{V_L}{\sqrt{3}}\right)$ Vph voltage is $\frac{1}{\sqrt{3}}$ times of Line voltage.

∴ phase voltage is very small compare to line voltage. So insulation requirement is very less.

→ This Connection (Y/Y) is economical for high voltages. medium voltage application

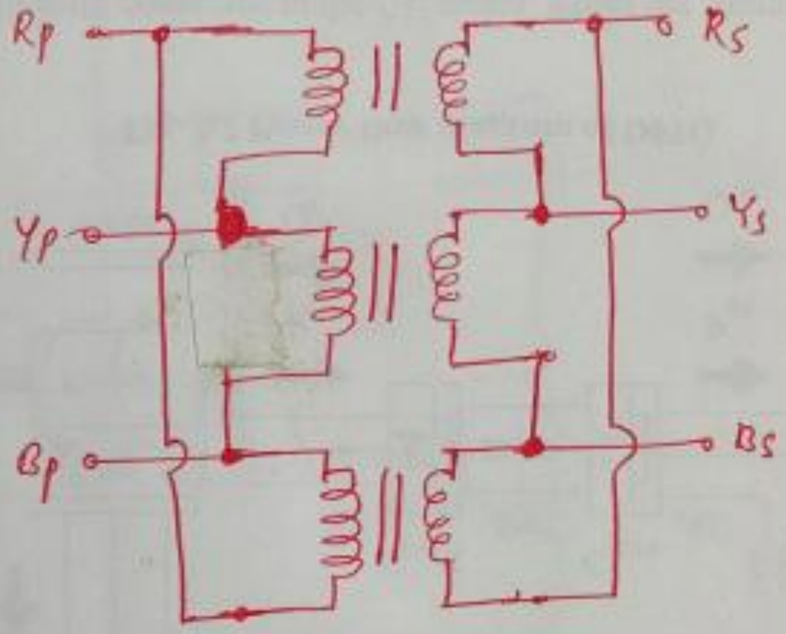
2) Y/Δ Connection:-



→ In the above Connection primary side connected in the form of 'Y', Secondary side is Connected in the form of 'Δ'

→ This Connection is economical for large and high voltage transformer.

3) Δ/Δ Connection :-



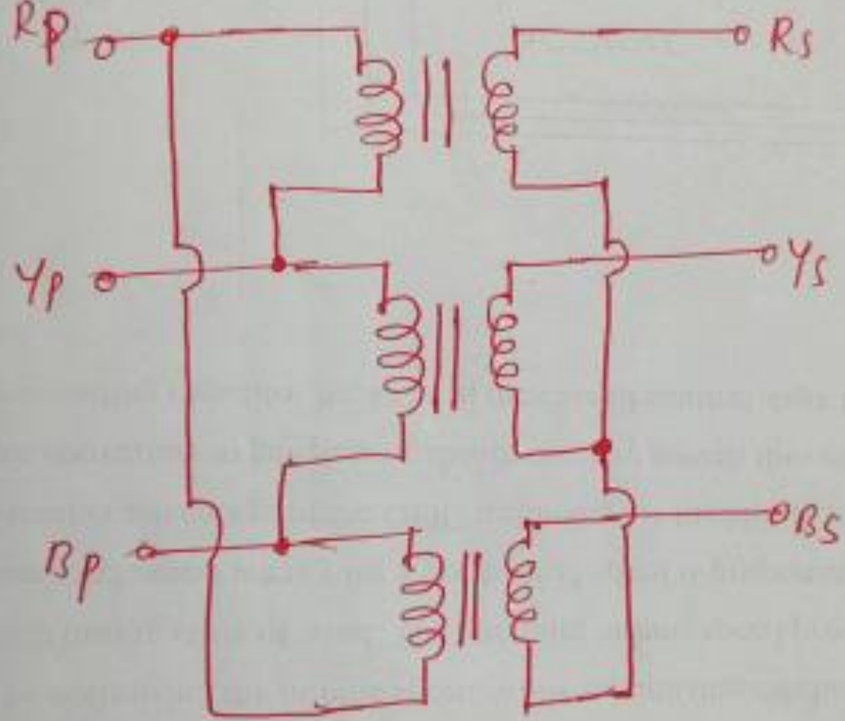
→ In above Connection both primary and secondary are Connected in the form of 'Δ'

→ In Δ Connection Line voltage is equal to phase Voltage (i.e $V_{ph} = V_L$)

→ But phase current is $1/\sqrt{3}$ times of Line current $(I_{ph} = \frac{I_L}{\sqrt{3}})$ (24)

→ This connection is economical for low voltage and high Loads.

A) **Δ/Y Connection :-**



→ In above connection primary is connected in the form of Δ and secondary connected in the form Y

→ In above connection neutral point is available on secondary side. This connection used in distribution transformer (3-ϕ, 4 wire) system

Q7. a) *Explain in detail construction of an autotransformer.*

Auto Transformer:

(6)

Construction:-

→ Auto transformer is special type of transformer in which only one winding is wound on the Laminated iron core.

→ The part of winding which is connected to the supply is called as primary winding

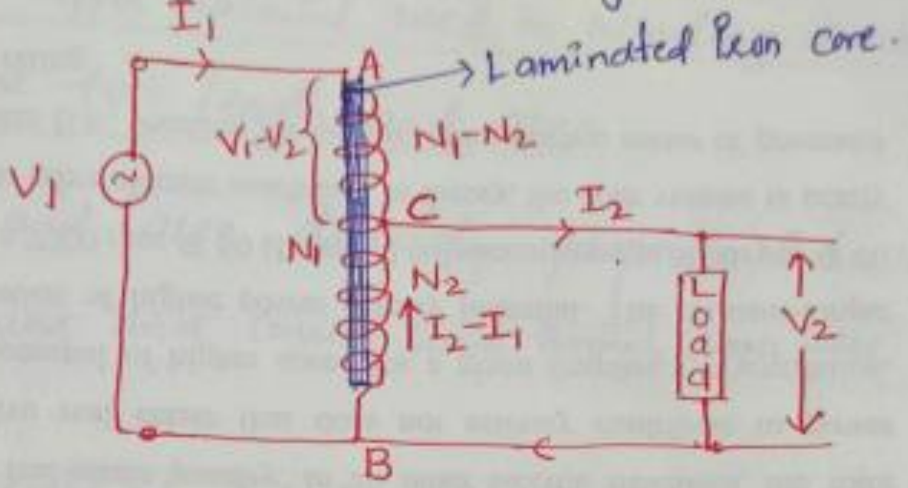
→ The part of winding which connected to the load is called secondary winding

→ Both windings are linked with electrically and magnetically. Where as in 1-ϕ two winding transformer both primary and secondary winding are separated and these winding are electrically separated but magnetically linked.

→ In ~~transformer~~ Auto transformer o/p voltage varied by changing turns in secondary winding so another name for Auto transformer is VARIAC

Diagram :-

Auto transformer shown in figure below



WORKING :-

In above diagram primary winding (AB) having 'N_1' number of turns is connected to the supply voltage 'V_1' which drives the current 'I_1' which produce the alternating magnetic flux. This alternating flux induces a emf in the winding according to Faradays Law.

In this single winding tapping is provided at point 'C' and the load is connected across 'BC' then 'I_2' flows through load due to emf in primary winding 'AB'. The section 'BC' having 'N_2' turns then section 'AC' having '$N_1 - N_2$' turns and 'V_2' is voltage in 'BC', '$V_1 - V_2$' is voltage in section AC

Q7. In a 25KVA transformer, 2000/200V transformer the
b) constant and variable losses are 350W, 400W. Calculate the efficiency at full load and half load.

Given :-

$25 KVA = 25 \times 10^3$

$V_1 = E_1 = 2000V$

$V_2 = E_2 = 200V$

$W_C = 350W$

$I_2^2 R_{2eq} = 400W$

$\eta = ?$ (i) full load (ii) half load

$$\eta = \frac{n \times (\text{KVA rating}) \cos\phi}{n \times (\text{KVA rating}) \cos\phi + W_C + I_2^2 R_{eq}} \times 100$$

$$= \frac{1 \times 25 \times 10^3 \times 1}{1 \times 25 \times 10^3 + 350 + 400} \times 100$$

$$\boxed{\eta = 97.08\%}$$

$$\eta = \frac{1/2 \times 25000 \times 1}{1/2 \times 25000 \times 1 + 350 + 400} \times 100$$

$$\boxed{\eta = 94.33\%}$$

Q8. A compound Generator is to supply a load of 250 lamps, each rated at 100 W, 250 V. The armature, field, shunt resistances are 0.06 Ω, 0.04 Ω, 50 Ω resp. Determine the generated emf when machine is connected in long shunt and short shunt.

Sol.

$P_L = 250 \times 100 = 25000\,W$

$V_t = 250\,V$

$R_a = 0.06\,\Omega$, $R_{se} = 0.04\,\Omega$, $R_{sh} = 50\,\Omega$

(i) long shunt :-

$I_a = I_{se} = I_{sh} + I_L$

$V_t = E_g - I_a R_a - I_{se} R_{se} + V_b$ (V_b is neglected)

$I_{sh} = \frac{V_t}{R_{sh}} = 5A$

$P_L = V_t I_L \Rightarrow I_L = \frac{25000}{250} = 100A$

$I_a = I_{se} = 5 + 100 = 105A$

$250 = E_g - 105(0.06) - 105(0.04)$

$\boxed{E_g = 260.5V}$

(ii) Short shunt :-

$I_a = I_{sh} + I_{se}$

$I_{se} = I_L = 100A$, $I_{sh} = \frac{V_t + I_{se} R_{se}}{R_{sh}}$

$I_{sh} = 5.08A$

$I_a = 105.08A$

$V_t + I_{se} R_{se} = E_g - I_a R_a + V_b$ (V_b - neglected)

$250 + 100(0.04) = E_g - (105.08)(0.06)$

$\boxed{E_g = 260.3V}$

Q9. *Explain the characteristics of DC shunt machine.*

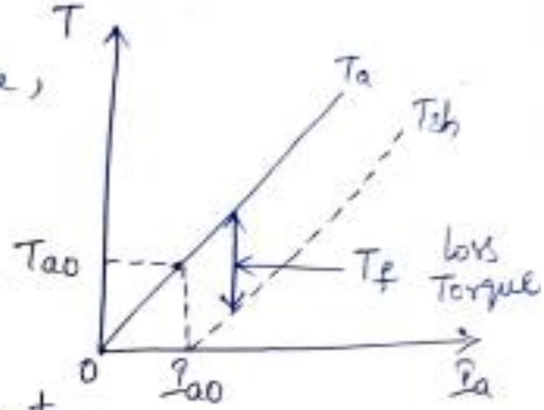
→ Characteristics of D.C shunt Motor :-

(i) Torque - Armature current characteristics :-

(for a d.c motor $T \propto \phi I_a$.

For a constant values of R_{sh} and supply voltage V, I_{sh} is also constant and hence flux is also constant.

$$\therefore \boxed{T_a \propto I_a}$$



The equation represents a straight line, passing through the origin, as shown. As load increases, armature current increases, increasing the torque developed linearly.)

Now if shaft torque is plotted against armature current, it is known that shaft torque is less than the armature torque and the difference between the two is loss torque T_f as shown.

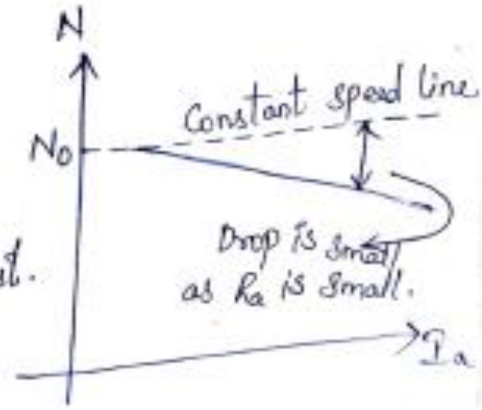
On no load $T_{sh} = 0$ but armature torque is present which is just enough to overcome stray losses shown as T_{ao}. The current required is I_{ao} on no load to produce T_{ao} and hence T_{sh} graph has an intercept of I_{ao} on the current axis.

To generate high starting torque, this type of motor requires a large value of armature current at start. This may damage the motor hence d.c shunt motors can develop moderate starting torque and hence suitable for such applications where starting torque requirement is moderate.

(ii) Speed - Armature current characteristics :-

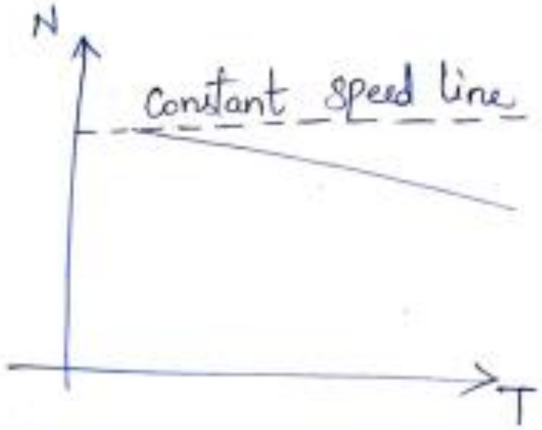
(From the speed equation we get,

$$N \propto \frac{V - I_a R_a}{\phi} \propto V - I_a R_a \quad \text{as } \phi \text{ is const.}$$



As load increases, the armature current increases and hence drop I_aR_a also increases.
Hence for constant supply voltage, $V-I_aR_a$ decreases and hence speed reduces. But as R_a is very small, for change in I_a from no load to full load, drop I_aR_a is very small and hence drop in speed is also not significant from no load to full load. So the characteristics is slightly droping.

(iii) Speed – Torque characteristics :-



These characteristics can be derived from above two characteristics. This graph is similar to speed – armature current characteristics as torque is proportional to the armature current. This curve shows that the speed almost remains constant through torque changes from no load to full load conditions.

Q10. Explain in detail construction and working of three phase induction motor.

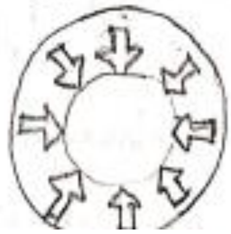
The main parts of an induction motors are
(i) Stator (ii) Rotor.
Induction motors are classified depending on the construction of the rotor. There are two types of induction motors.
(a) wound-rotor (or) slip ring induction motors
(b) squirrel cage induction motor.

(i) Stator :-

The stator is stationary, hollow cylindrical structure made of slotted laminations of sheet steel punching. The stator core is made of laminations which are 0.03 to 0.06 cm thick. These laminations are insulated by a coating of an insulating varnish [oxide coating applied by heat treatment.

- Ventilating ducts are provided at intervals of 5 to 7 cm along the length of the core.
- The stator carries a 3-ϕ winding and is fed from a 3-ϕ supply. It is wound for a definite number of poles [poles determined by requirement of speed]. Greater the no. of poles, lesser the speed.
- These ~~three~~ single phase windings are insulated from each other and separated in space by 120°. These windings are either connected in star or Delta internally.

The stator windings when supplied with 3-ϕ current produce a magnetic field or flux which is of constant value but which revolves (or) rotates at synchronous speed $\left[N_S = \frac{120f}{P}\right]$. This revolving magnetic flux induces an emf in the rotor by mutual Induction.



stator lamination

(ii) Rotor :-

(ii) Rotor :-

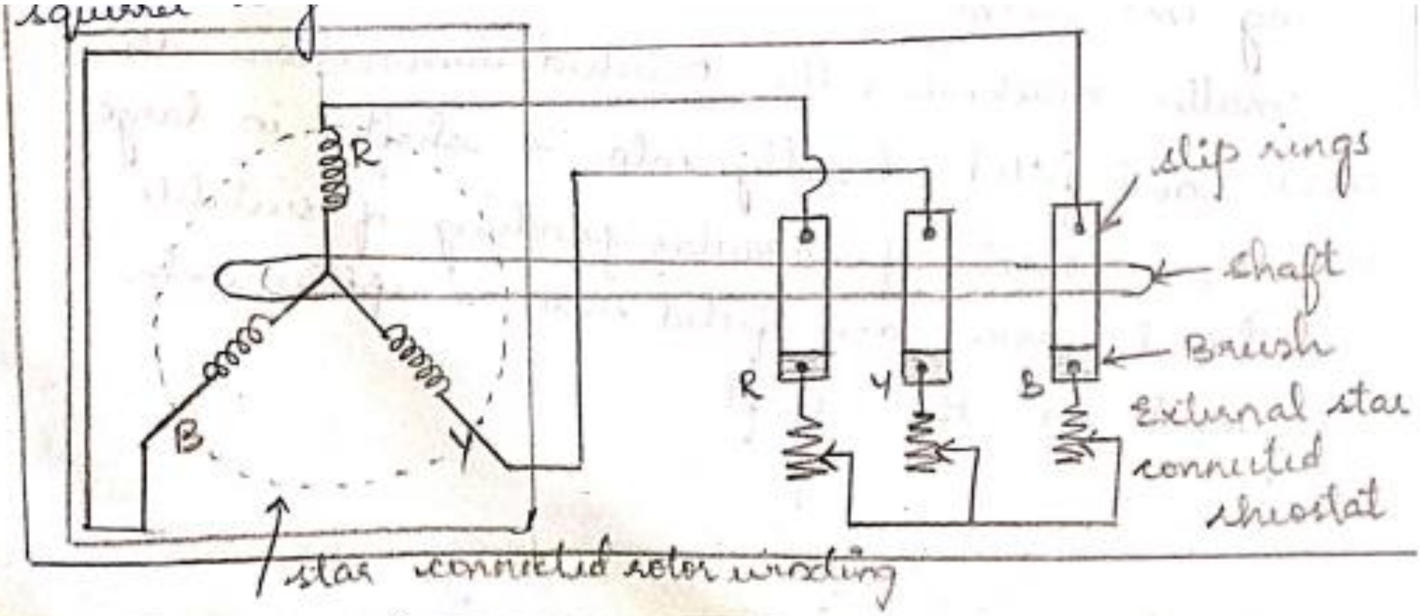
The rotor core is of laminated construction with slots punched in for accommodating the rotor winding (or) rotor bars.

In smaller machines, the punched laminations are stacked and fitted directly into a shaft, in large machines, a stack of annular punching of suitable crossectional area are fitted into a spider web arrangement on the shaft.

a) Wound rotor / slip ring rotor :-

The winding of the rotor is similar to the winding of the stator and is placed in the slots of motor. The no of slots on the rotor is small and also the turns per phase are fewer.

The wound rotor is connected in star, and the three ends of the winding of the three phases are brought out through slip rings. ∴ These type of rotor is known as slip ring induction motor. These type of motors is preferred generally for large machines, where starting torque can be controlled through an external resistance connected to the rotor circuit.



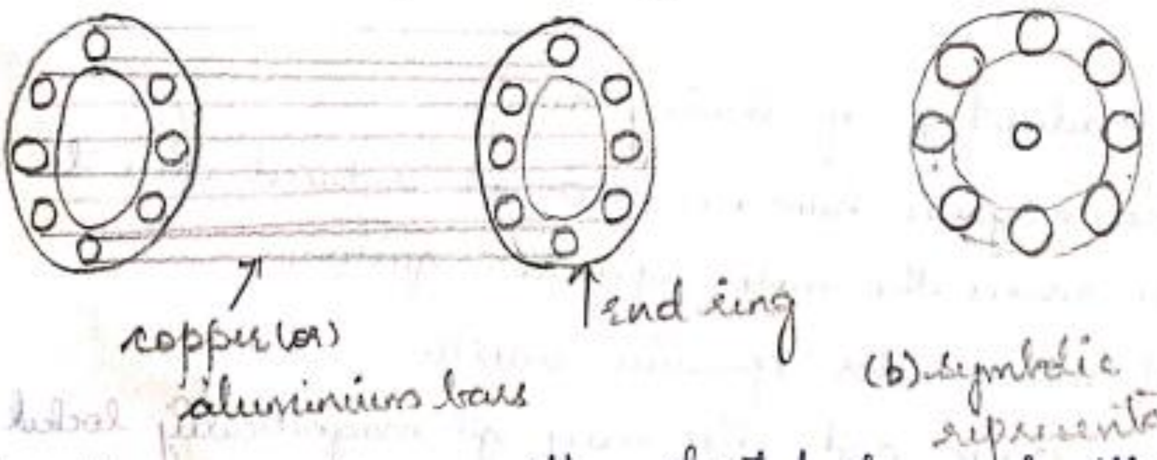
b. Squirrel cage Rotor :-

The rotor core is cylindrical and slotted on its pheriphery. The rotor consists of uninsulated copper or alluminium bars called rotor conductors. The bars are placed in the slots. These bars are permanently shorted at each end with the help of conducting copper ring called end ring.

The bars are usually brazed to the end rings to praide good mechanical strength.

The entire structure looks like a cage, forming a closed electrical circuit. So the rotor is called squirrel cage rotor.

Squirrel cage rotors.



WORKING PRINCIPLE OF AN INDUCTION MOTOR :-

Induction motor works on the principle of electromagnetic induction.

When a three phase supply is given to the three phase stator winding, a rotating magnetic field of constant magnitude is produced. The speed of this rotating magnetic field is synchronous speed N_s r.p.m.

$$N_s = \frac{120f}{P} = \text{speed of rotating magnetic field.}$$

where f = supply frequency

P = No. of poles for which stator winding is wound.

This rotating field produces an effect of rotating poles around a rotor. Let the direction of rotation of this rotating magnetic field is clockwise as shown in fig (a)

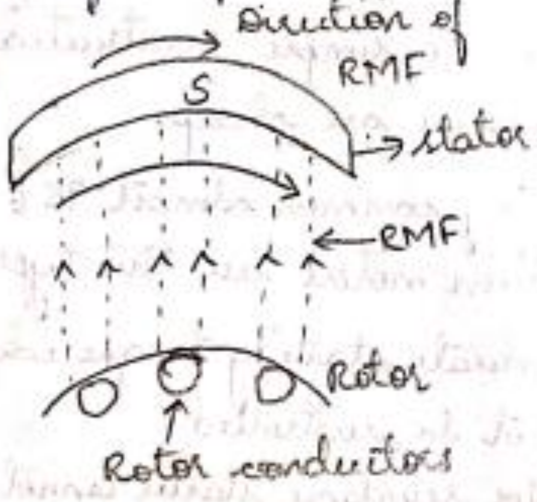


fig (a)

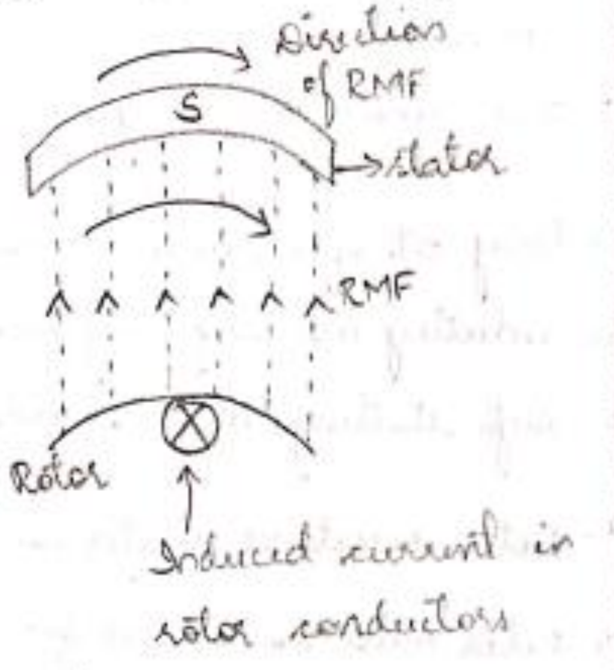
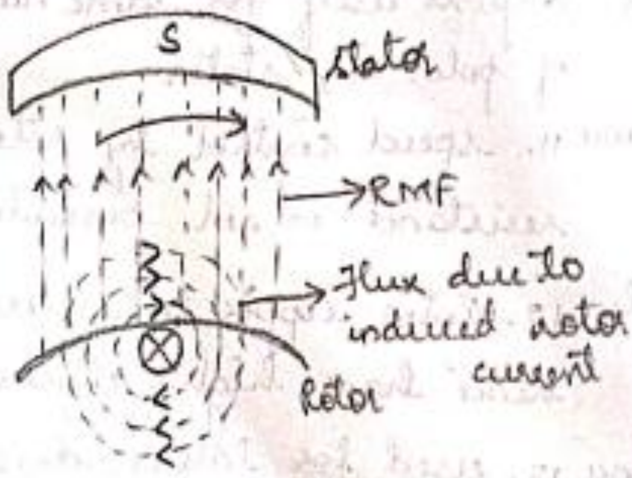
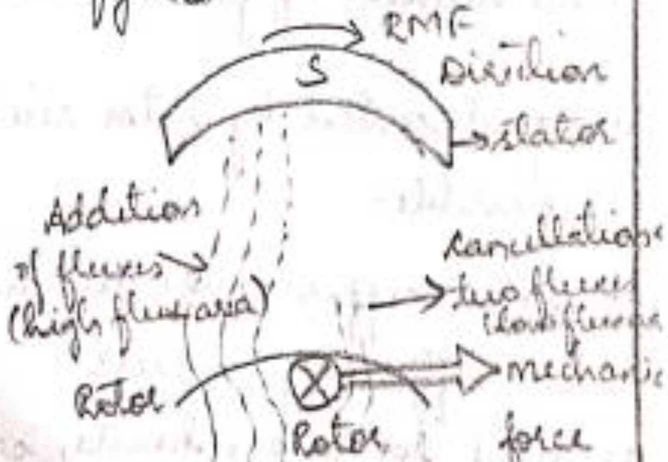


fig. (b)





- At this instant rotor is stationary and stator flux RMF is rotating. ∴ There exits a relative motion between the RMF and rotor conductors. This RMF gets cut by rotor conductors as R.MF sweeps over rotor conductors.
- Whenever conductors cut the flux, emf gets induced in it. The emf induced in the rotor conductors is called rotor induced emf. (Electromagnetic induction)
- As rotor forms closed circuit, induced emf circulates current through rotor called rotor current as shown in fig (b). Let direction of this current is going into the paper denoted by a cross as shown in fig (b).
- Any current carrying conductor produces its own flux. So rotor produces its flux called rotor flux. For assumed direction of rotor current, the direction of rotor flux is clockwise as shown in fig (c). This direction can be easily determined by using right hand thumb rule. There are two fluxes, one RMF and other rotor flux. Both fluxes interact with each other as shown in fig(d). On the left of rotor conductors, two fluxes are in same direction hence add up to high flux area. On the right side, two fluxes cancel each other to produce low flux area.
As flux lines act as streched rubber band, high flux density area exerts a push on rotor conductor towards low flux density area. So rotor conductor experiences a force from left to right in this case as shown in fig(d), due to interaction of the two fluxes.

Q11 a) ***Explain the concept behind the generation of rotating field in a three phase induction motor.***

element and swap it

4

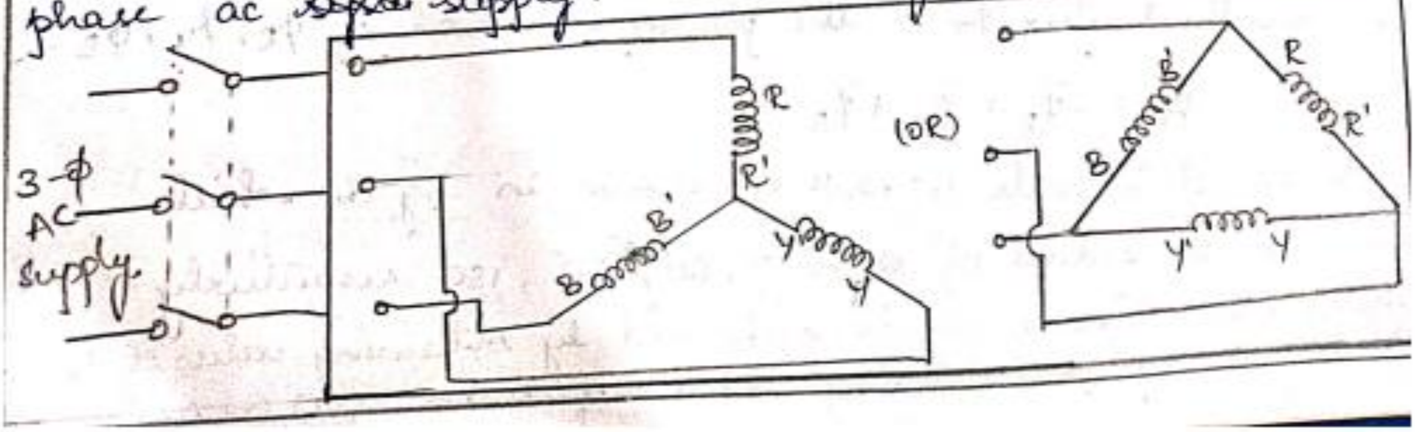
ROTATING MAGNETIC FIELD [RMF] :-

- The rotating magnetic field can be defined as the field or flux having constant amplitude but whose axis is continously rotating in a plane with a certain speed.
- If the arrangement is made to rotate a permanent magnet, then the resulting field is a rotating magnetic field. But in this method, it is necessary to rotate a magnet physically to produce rotating magnetic field.
- In three phase induction motors such a rotating magnetic field is produced by suppling currents to a set of stationary windings with the 3-ϕ a.c ~~sup~~ supply.

The current carrying windings produce the magnetic flux. Due to interaction of these fluxes produced due to 3-ϕ supply resultant flux has a constant magnitude and its axis rotating in space, without physically rotating the windings. This type of field is rotating magnetic field.

PRODUCTION OF RMF :-

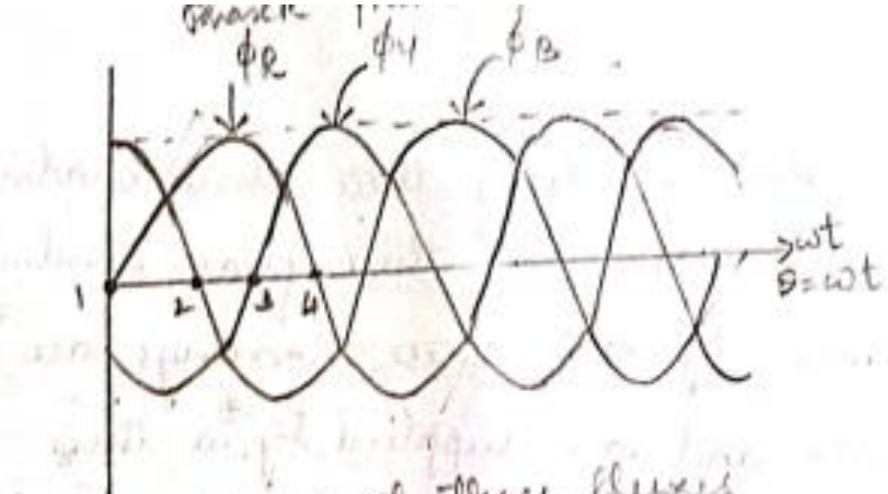
A three phase induction motor consists of three phase windings as its stationary part called stator. The three phase windings are are displaced from each other by 120°. These windings are connected in star (or) delta and are supplied by a three phase ac ~~supl~~ supply. These windings are denoted as RR', YY', BB'



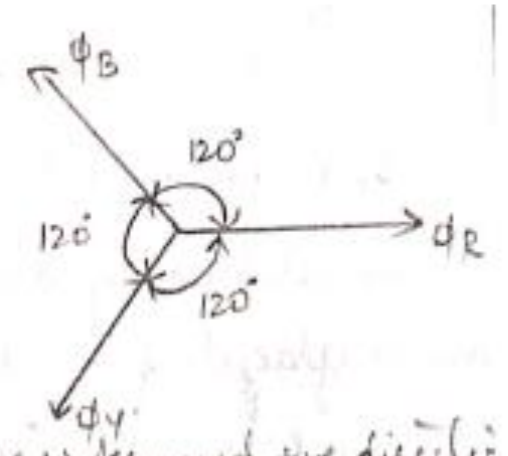
$$\phi_R = \phi_m \sin\omega t = \phi_m \sin\theta \quad \text{—— (1)}$$

$$\phi_Y = \phi_m \sin(\omega t - 120^\circ) = \phi_m \sin(\theta - 120^\circ) \quad \text{—— (2)}$$

$$\phi_B = \phi_m \sin(\omega t - 240) = \phi_m \sin(\theta - 240) \quad \text{—— (3)}$$



(a) waveforms of three fluxes



(b) Assumed +ve directio[n]

CASE 1 :- θ = 0°

$$\phi_R = \phi_m \sin 0 = 0$$

$$\phi_Y = \phi_m \sin(-120^\circ) = -0.866\,\phi_m$$

$$\phi_B = \phi_m \sin(-240^\circ) = +0.866\,\phi_m$$

The phasor addition is shown in fig. The +ve values are shown in ~~+ve~~ assumed +ve directions while negative values are shown in opposite direction to the +ve direction of assumed +ve directions of resp. fluxes. Refer to assumed positive directions shown in fig (b).

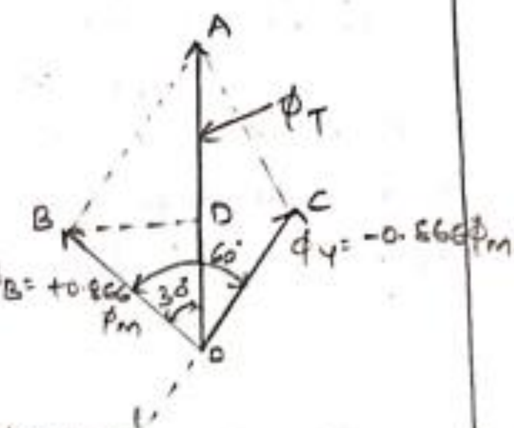


fig (c). Vector diagram for θ = 0°

BD is drawn perpendicular from B on ϕ_T. It bisects ϕ_T.

$$OD = DA = \frac{\phi_T}{2}$$

In ΔOBD,

$$\angle BOD = 30^\circ$$

$$\cos 30^\circ = \frac{OD}{OB} = \frac{\phi_T/2}{0.866\phi_m}$$

$$\phi_T = 2 \times 0.866\phi_m \times \cos 30^\circ$$

$$= 1.5\phi_m$$

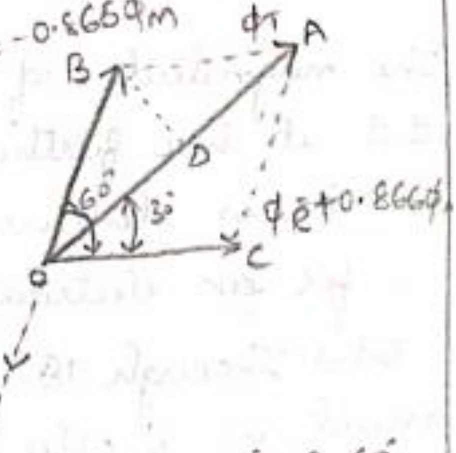
∴ magnitude of ϕ_T is $1.5\phi_m$ and its position is vertically upwards at $\theta = 0^\circ$.

CASE 2 :- $\theta = 60^\circ$

$\phi_R = \phi_m \sin 60^\circ = +0.866\phi_m$

$\phi_Y = \phi_m \sin(-60^\circ) = -0.866\phi_m$

$\phi_B = \phi_m \sin(-180^\circ) = 0$



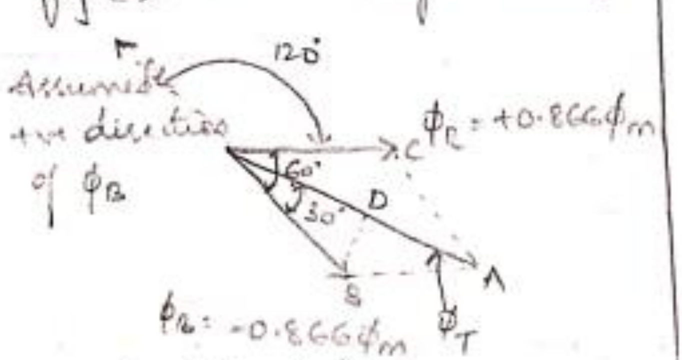
(d) Vector diagram for $\theta = 60^\circ$

- Doing the same construction, drawing perpendicular from B on ϕ_T we get the same result,

$$\phi_T = 1.5\phi_m$$

But it can be seen that though its magnitude is $1.5\phi_m$ it has rotated through 60° in space, in clockwise direction from its previous position.

fig (e) :- Vector diagram $\theta = 120^\circ$



CASE 3 :- $\theta = 120^\circ$

$\phi_R = \phi_m \sin 120 = +0.866\phi_m$

$\phi_Y = \phi_m \sin 0 = 0$

$\phi_B = \phi_m \sin(-120) = -0.866\phi_m$

Similarly drawing ⊥r from B on ϕ_T, we have

$\phi_T = 1.5\phi_m$

But the position of ϕ_T is such that it has further rotated through 60° from its previous position in clockwise direction.

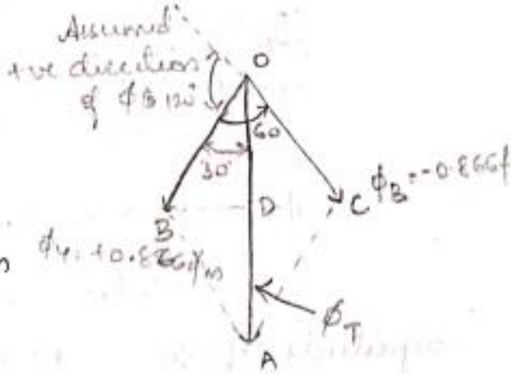
CASE 4:- $\theta = 180°$

$\phi_R = \phi_m \sin 180 = 0$

$\phi_Y = \phi_m \sin 60 = +0.866\phi_m$

$\phi_B = \phi_m \sin(-60) = -0.866\phi_m$

IIIly $\phi_T = 1.5\phi_m$



fig(c) Vector diagram for $\theta = 180°$

The magnitude of ϕ_T remains same. But it can be seen that it has further rotated through 60° from its previous position in clockwise direction.

So for an electrical half cycle of 180°, resultant ϕ_T has rotated through 180°. This is applicable for the windings wound for 2 poles.

11
6. The frequency of the EMF in the stator of a 4-pole induction motor is 50 Hz, and that in the rotor is 2 Hz. What is the slip and at what speed is the motor running?

Sol. Given:-

$P = 4, f = 50 Hz, f_r = 2 Hz$

$s = ?$ $N = ?$

(i) $s = ?$

$f_r = sf$

$$s = \frac{f_r}{f} = \frac{2}{50} = 0.04$$

$\%s = 4\%$

(ii) $N = ?$

$$\%s = \frac{N_s - N}{N_s} \times 100 \qquad N_s = \frac{120f}{P} = \frac{120 \times 50}{4}$$

$$4 = \frac{1500 - N}{1500} \times 100 \qquad N_s = 1500 rpm$$

$N = 1440 rpm$