Model Question Paper-1 with effect from 2019-20 (CBCS Scheme)

USN | | | | | | | | | | |

Fourth Semester B.E. Degree Examination

Electric Motors

TIME: 03 Hours **Max. Marks: 100**

Note: 01. Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE**.

Module -1

Q.01	a	What is meant by back EMF.? Explain the significance of Back EMF.	(06 Marks)
	b	State the applications of various types of DC motor	(06 Marks)
	c	A DC shunt motor runs at 1000 rpm on 200V supply its armature resistance is 0.8 Ω and the armature current drawn is 40 amps. What resistance must be connected in series with the armature to reduce the speed to 600 rpm, the armature current remaining same ? Neglect armature reaction	(08 Marks)

OR

Q.02	a	Derive the torque equation of a D.C. Motor	(04 Marks)
	b	What is the necessity of a starter for a D.C. Motor? Explain, with a neat sketch, the working of a 3- point D.C. Shunt motor starter, bringing out the protective features incorporated in it.	(09 Marks)
	c	A 220 V shunt motor with an armature resistance of 0.5 ohm is excited to give constant main field. At full load the motor runs at 500rpm and takes an armature current of 30A. If a resistance of 1.0 ohm is placed in the armature circuit, find the speed at (a) full-load torque (b) double full-load torque.	(07 Marks)

Module-2

Q. 03 a With a neat circuit diagram, explain the importance and procedure of conducting Swinburn test on DC motor. List the advantages of this test. Show how the efficiency as (10 Marks)

i. Motor
ii. Generator can be predetermined

b Two identical dc machine, when tested by Hopkinson's method gave the following data: (10 Marks)

i. Line voltage:230V & Line current excluding the field current:30 A
ii. Motor armature current:230A
iii. Field current 5A and 4A. The armature resistance of each machine is 0.025Ω calculate the efficiency of both the machines.

OR

Module-2

Q. 04 a Derive the torque equation for a three phase IM and obtain

i. $\frac{T_{st}}{T_m}$

ii. $\frac{T_{F.L}}{T_m}$ (10 Marks)

b. A 3-phase, 50 Hz, 400 V inductions motor has 4 poles star connected stator winding. Rotor resistance & reactance per phase are 0.15 Ω & 1Ω respectively. Full load slip is 5%. Calculate (i) total torque developed (ii) maximum torque (iii) speed at maximum torque. Assume stator to rotor torque ratio 2:1. (10 Marks)

Module-3

Q. 05 a In a 3 phase IM, show that rotor input: rotor cu loss: mechanical power developed is 1:s:1-s. (07 Marks)

b. Draw and explain the phasor diagram of 3 phase IM. Write the steps involved in drawing it. (06 Marks)

c. Explain the grid connected operation of induction Generator (07 Marks)

OR

Q. 06 a. Draw the circle diagram from no load and short circuit test of a 50 KW, 6 pole, 50 Hz, 450 V 3- phase slip ring induction motor furnished the following test data. (10 Marks)

No load: 450V, 20A, 0.15 p.f

S.C test: 200V, 150 A, 0.3 p.f

b. Explain the phenomenon of cogging and crawling in a 3 phase IM. (05 Marks)

c. Explain the construction and working of deep bar rotor type of Induction Motor. (05 Marks)

Module-4

Q. 07 a. Justify the necessity of starter for 3 phase induction motor. Explain star delta starter with neat sketch (08 Marks)

b. Explain any three methods of speed control of 3 phase induction motor (12 Marks)

OR

Q. 08 a. Explain double field revolving theory as applied to a single-phase induction motor and prove that it cannot produce any starting torque. (10 Marks)

b. Explain construction and working principle of a shaded pole motors. (10 Marks)

Module-5

Q. 09 a List the different methods of starting synchronous motor. Explain any one in detail. (08 Marks)

b. Describe a phenomenon of hunting in synchronous machine, what are the methods to overcome this. (06 Marks)

c. What is synchronous condenser? What is its application. (06 Marks)

OR

Q. 10 a. Explain the construction and working principle of universal motor. (10 Marks)

b. With a neat diagram explain the operation of two phase Ac servo motor. (10 Marks)

Solution of VTU Model Question Paper

Electric Motors [18EE44]

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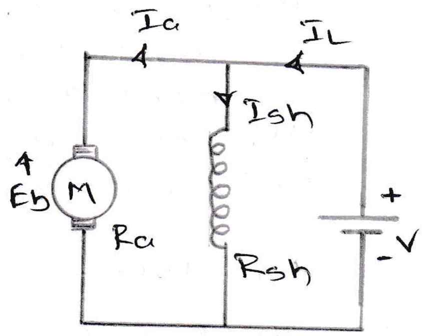
01 a **What is meant by back EMF? Explain the significance of back EMF. (6 marks)**

When armature of a DC motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence emf is induced in them as in the generator. The induced emf opposes the applied voltage (according to Lenz's law) and it is know as back EMF or counter EMF.

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



Net voltage across armature circuit $= V - E_b$

If R_a is armature resistance then $I_a = \frac{V - E_b}{R_a}$.

Significance of Back EMF.

→ When motor is running on no load, small torque is required to overcome friction and windage losses. Therefore armature current is very small and back emf will be nearly equal to applied voltage.

→ If motor is suddenly loaded then speed reduces. So Eb reduces, it increases Ia, hence increase in driving torque. So motor will stop slowing down, when armature current is sufficient to produce the increased torque required by the load.

→ If load is removed from motor, it increases speed of the motor, hence Eb increases. it reduces the armature current.

Hence Back EMF regulates the flow of armature current in a DC motor.

01.b State the applications of various types of DC motors [6 marks]

DC shunt motor → These are constant flux and constant speed motors. These provide low starting torque. So for application where we don't need high starting torque we can use DC shunt motor. Like. fan's, blowers, lathe machine,

DC series motor → These provide very high starting torque but these motor must not be run no noload condition. Due to this DC series motors are used in Electric traction, crane, conveyor etc.

DC compound motor → The characteristics of compound motor are similar to DC shunt motor. So where we use shunt motor there we can also use compound motor.

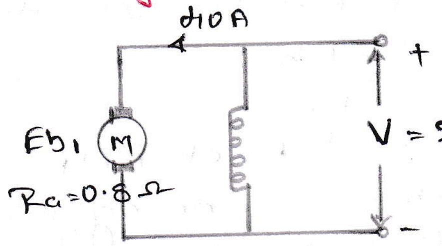
01.c. A DC shunt motor runs at 1000 rpm on 200V supply. its armature resistance is 0.8Ω and the armature current drawn is 40A. What resistance must be connected in series with the armature to reduce the speed to 600 rpm, the armature current remaining same? Neglect armature reaction [8 marks]

$N_1 = 1000$ rpm

$V = 200$ V

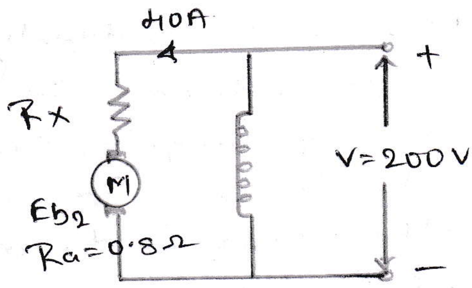
$I_a = 40$ A

$R_a = 0.8\Omega$.



$N_1 = 1000$ rpm

$$E_{b1} = V - I_a R_a$$
$$= 200 - [40 \times 0.8]$$
$$= 168 \text{ V}$$



$N_2 = 600$ rpm.

$N_2 = 600$ rpm

we have $\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$

$$E_{b2} = \frac{N_2}{N_1} \times E_{b1}$$
$$= \frac{600}{1000} \times 168 = 100.8 \text{ V}$$

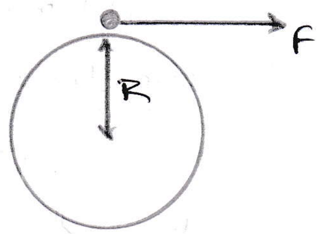
$$E_{b2} = V - (I_a (R_a + R_x))$$
$$100.8 = 200 - (40 (0.8 + R_x))$$
$$R_x = 1.68\,\Omega$$

02.a. Derive the torque equation of a D.C. motor (4 marks)

Torque is the turning moment of a force about an axis.

Consider a wheel of radius R meter acted upon by a circumferential force F Newton as shown in figure. Wheel is rotating at a speed of N rpm then angular speed of the wheel is

$$\omega = \frac{2\pi N}{60} \text{ rad/sec}$$



So workdone in one revolution is

W = F × distance travelled in one revolution

$= F \times 2\pi R$ joules

Power developed = work done / time for one revolution

$$P = F \times 2\pi R / 60/N$$

$$= FR\left[\frac{2\pi N}{60}\right]$$

$$= \frac{2\pi N T}{60} \text{ watts}$$

where T = torque in N-m

Let T_a = torque developed by the armature.

Power in armature = armature torque × ω

$$E_b I_a = T_a \frac{2\pi N}{60}$$

$$\frac{P\phi Z N}{60 A} I_a = T_a \frac{2\pi N}{60}$$

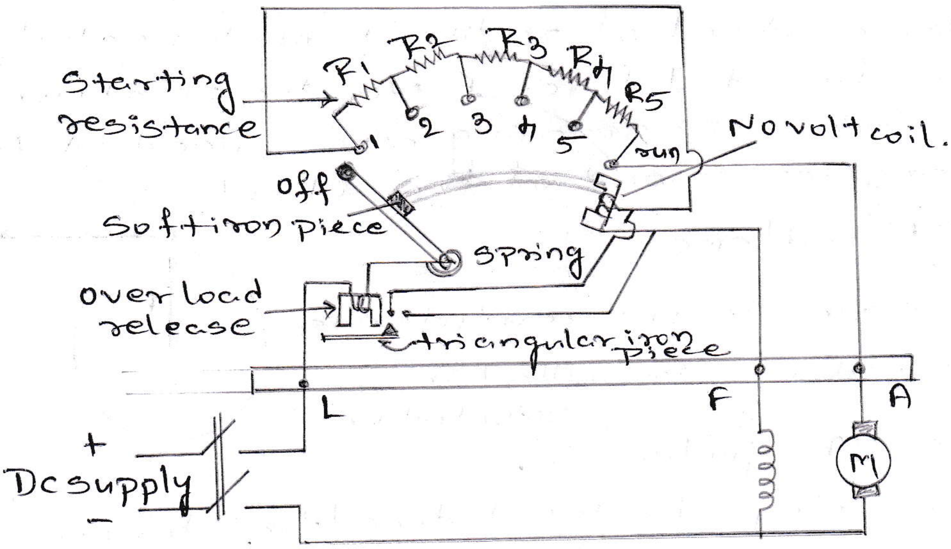
$$T_a = 0.159\, \phi Z I_a \frac{P}{A} \text{ N-m}.$$

02.b What is the necessity of a starter for a DC motor? Explain with a neat sketch, the working of a 3-point DC shunt motor starter, bringing out the protective features incorporated in it (9 marks)

During starting motor will be at stand still and back EMF will be zero. So if motor is directly switched on then it will draw a large amount of current during starting as $I_a = V/R_a$ and R_a is very small. This large current may damage the motor and also causes large voltage drop in line. To avoid this condition we need to use starter for DC shunt motor.

3 point starter

The connection diagram of a 3 point starter is as shown in the fig. below.



Operation

01. To start the motor DC supply is switched on with handel at off position.
02. The handel is now moved to first stud. Shunt field winding is directly connected across the supply while the whole starting resistance is inserted in series with the armature winding.
03. As the handel is gradually moved towards final stud, the starting resistance is cut out of armature circuit and inserted in field circuit. The handel is held in place with the help of no volt release coil, which is energised by shunt field current

protective features

01. If the supply voltage is suddenly interoupted or if field winding is accidentally cut. The no voltage release coil is demagnetised and handel goes back to off position due to pull of spring.
02. If motor is overloaded. Over load current will energise over load release coil. It will short circuit no volt coil and handel will be pull back to off position.

Q2.c A 220V shunt motor with an armature resistance of 0.5 ohm is excited to give constant main field. At full load the motor runs at 500 rpm and takes an armature current of 30A. If a resistance of 1.0 ohm is placed in the armature circuit, find the speed at (a) full-load torque (b) double full-load torque. (7 marks)

Given $V = 220V$, $R_a = 0.5\Omega$ $N_1 = 500 rpm$

$I_{a1} = 30A$ $R_{ex} = 1.0\Omega$

$E_{b1} = V - I_{a1}R_a = 220 - (30 \times 0.5) = 205 V$

Now 1Ω is inserted in armature circuit

$\therefore R_a = 0.5 + 1 = 1.5\Omega$

$E_{b2} = 220 - (30 \times 1.5) = 175 V$

we have $\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}$ or $N_2 = \frac{E_{b2}}{E_{b1}} N_1$

i.e $N_2 = \frac{175}{205} \times 500 = 426.829 rpm$ at full load torque

we have $T \propto I_a$ so if torque is doubled I_a also doubles.

Now $I_a = 2 \times 30 = 60A$.

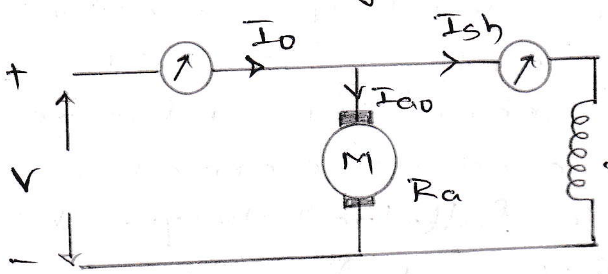
$E_{b3} = 220 - (60 \times 1.5) = 130V$.

$N_3 = \frac{E_{b3}}{E_{b1}} * N_1 = \frac{130}{205} * 500 = 317.073 rpm$.

Q3.a. With a neat circuit diagram explain the importance and procedure of conducting Swinburn's test on DC motor. List the advantages of this test. Show how the efficiency as (i) motor (ii) Generator can be predetermined (10 marks)

In Swinburn's test a DC machine is run as a motor at noload condition. As machine is on noload power drawn by the machine is utilized to over come iron and friction losses. Once the losses of machine are known its efficiency at any disered load can be predetermined.

The circuit diagram is as shown below.



The motor is brought to its rated speed by appling rated voltage and by adjusting the control rheostats.

Let

V = supply voltage

I_o = no load current

I_{sh} = shunt field current

∴ no-load armature current = $I_{ao} = (I_o - I_{sh})$

no-load input power to motor = $V I_o$ watts.

constant losses = $V I_o - [I_{ao}^2 R_a]$ watts = W_c

Armature current for motor = $I - I_{sh}$

armature current for generator = $I + I_{sh}$

→ Efficiency when running as motor.

input to motor = VI watts.

armature cu. loss = $I_a^2 R_a = (I - I_{sh})^2 R_a$ watts.

∴ total losses = $[I - I_{sh})^2 R_a + W_c$ watts.

Motor efficiency $\eta_m = \dfrac{\text{input} - \text{total loss}}{\text{input}}$

$$\eta_m = \frac{VI - (I - I_{sh})^2 R_a - W_c}{VI}$$

→ Efficiency when running as generator.

output of generator = VI watts

armature cu loss = $I_a^2 R_a = (I + I_{sh})^2 R_a$ watts.

∴ total losses = $(I + I_{sh})^2 R_a + W_c$ watts.

Generator efficiency = $\dfrac{\text{output}}{\text{output} + \text{total losses}}$

$$\eta_g = \frac{VI}{VI + (I + I_{sh})^2 R_a + W_c}$$

→ Advantages.

01. Economical, as power required to perform a test is low

02. Simple and convenient

03. Efficiency at any load can be predetermined.

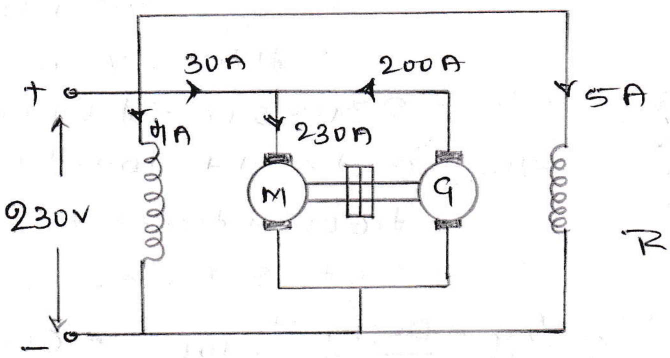
03.b. Two identical dc machine, when tested by Hopkinson's method gave the following data:

(i) Line voltage : 230 V and Line current excluding the field current : 30 A

(ii) Motor armature current : 230 A

(iii) Field current 5 A and 4 A, The armature resistance of each machine is 0.025 Ω

Calculate the efficiency of both the machines. [10 marks]



$R_a = 0.025\,\Omega$

Determination of constant loss.

Armature cu loss Motor $= I_{am}^2 R_a = 230^2 \times 0.025$

$= 1322.5\,W$

Armature cu loss Generator $= I_{ag}^2 R_a = 200^2 \times 0.025$

$= 1000\,W.$

Total iron, friction and windage loss in M-G set

$=$ Input to set − cu loss

$= (230 \times 30) - 1322.5 - 1000$

$= 4577.5\,W$

Iron, friction and windage loss in each machine

$W_c = 4577.5/2 = 2288.75\,W$

Motor efficiency

Motor armature cu loss $= 1322.5\,W$

Motor field cu loss $= I_{shm} V = 4 \times 230 = 920\,W$

total loss in motor $= W_c + [$armature and field cu loss$]$

$= 2288.75 + 1322.5 + 920$

$= 4531.25\,W.$

input to motor = 230 × (230 + 4) = 53820 W.

output of motor = input − total loss

= 53820 − 4531.25

= 49288.75 W.

efficiency $\eta_m = \frac{\text{output}}{\text{input}} \times 100 = \frac{49288.75}{53820} \times 100$

= 91.58 %.

Generator efficiency

Generator armature cu loss = 1000 W

Generator field cu loss = 230 × 5 = 1150 W.

total loss in generator = Wc + total cu loss

= 2288.75 + 1000 + 1150

= 4438.75 W.

output of generator = 230 × 200 = 46000 W

input to generator = output + total loss

= 46000 + 4438.75

= 50438.75 W

efficiency $\eta_g = \frac{\text{output}}{\text{input}} \times 100 = \frac{46000}{50438.75} \times 100$

= 91.19 %.

04.a. Derive the torque equation for a three phase IM and obtain (i) T_{st}/T_m (ii) T_{FL}/T_m [10 marks]

Torque developed by rotor is directly proportional to (i) rotor current
(ii) rotor emf
(iii) rotor power factor.

During starting

rotor current $I_2 = E_2/Z_2 = E_2/\sqrt{R_2^2 + X_2^2}$

rotor power factor $\cos\phi_2 = R_2/\sqrt{R_2^2 + X_2^2}$

∴ Starting torque $T_{st} \propto E_2 I_2 \cos\phi_2$

or $T_{st} = K E_2 I_2 \cos\phi_2$

$$= \frac{K E_2^2 R_2}{\sqrt{R_2^2+X_2^2}\,\sqrt{R_2^2+X_2^2}} = \frac{K E_2^2 R_2}{R_2^2 + X_2^2}$$

$K = 3/2\pi n_s$ where n_s = synchronous speed in rps

$\therefore T_{st} = \frac{3}{2\pi n_s} \frac{E_2^2 R_2}{R_2^2 + X_2^2}$ N-m

Maximum torque occurs when $R_2 = X_2$

$\therefore T_m = \frac{3}{2\pi n_s} \frac{E_2^2}{2X_2}$ N-m

$$\frac{T_{st}}{T_m} = \frac{3/2\pi n_s \; E_2^2 R_2 / R_2^2 + X_2^2}{3/2\pi n_s \; \frac{E_2^2}{2X_2}} = \frac{R_2 / R_2^2 + X_2^2}{1/2X_2}$$

$$\therefore \frac{T_{st}}{T_m} = \frac{2 R_2 X_2}{R_2^2 + X_2^2}$$

* We have $T \propto s E_2^2 R_2 / R_2^2 + (sX_2)^2$.

let S_f = full load slip

$\therefore T_{fL} = S_f E_2^2 R_2 / R_2^2 + (S_f X_2)^2$

and S_m = slip at maximum torque

$\therefore T_m = S_m E_2^2 R_2 / R_2^2 + (S_m X_2)^2$

$$\frac{T_{fL}}{T_m} = \frac{S_f E_2^2 R_2}{R_2^2 + (S_f X_2)^2} * \frac{R_2^2 + (S_m X_2)^2}{S_m E_2^2 R_2}$$

$$= \frac{S_f}{S_m} * \frac{R_2^2 + (S_m X_2)^2}{R_2^2 + (S_f X_2)^2}$$

Divide by X_2^2

$$= \frac{S_f}{S_m} \frac{(R_2/X_2)^2 + S_m^2}{(R_2/X_2)^2 + S_f^2}$$

but $R_2/X_2 = S_m$

$$\therefore \frac{T_{fL}}{T_m} = \frac{S_f}{S_m} \cdot \frac{S_m^2 + S_m^2}{S_m^2 + S_f^2} = \frac{2 S_f S_m}{S_m^2 + S_f^2}.$$

04.b. A 3-phase, 50 Hz, 400V induction motor has 4 pole, star connected stator winding. Rotor resistance and reactance per phase are 0.15 Ω and 1 Ω respectively. Full load slip is 5%. Calculate (i) total torque developed (ii) Maximum torque (iii) speed at maximum torque. Assume stator to rotor turns ratio 2:1 [10 marks]

Given $f = 50\ Hz$, $V_L = 400\ V$, $P = 4$, $R_2 = 0.15\ \Omega$

$X_2 = 1\ \Omega$, $s_{fl} = 0.05$, $E_1/E_2 = 2$

$$E_{1ph} = \frac{E_{1line}}{\sqrt{3}} = 400/\sqrt{3} = 230.94\ V$$

$$E_2 = E_1/2 = \frac{230.94}{2} = 115.47\ V$$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500\ rpm$$

$$n_s = 1500/60 = 25\ rps$$

(i) total torque

$$T = \frac{3}{2\pi n_s} \frac{s E_2^2 R_2}{R_2^2 + (sX_2)^2}$$

$$= \frac{3}{2\pi \times 25} \left[\frac{0.05 \times 115.47^2 \times 0.15}{0.15^2 + (0.05 \times 1)^2}\right]$$

$$= 76.43\ N\text{-}m$$

(ii) maximum torque

$$T_m = \frac{3}{2\pi n_s} \frac{E_2^2}{2X_2}$$

$$= \frac{3}{2\pi \times 25} \left[\frac{115.47^2}{2 \times 1}\right]$$

$$= 127.38\ N\text{-}m$$

(iii) slip at maximum torque

$$S_m = R_2/X_2 = 0.15$$

Speed at maximum torque $N = (1 - S_m) N_s$

$$= (1 - 0.15) \times 1500$$

$$= 1275\ rpm$$

05. a. In a 3-phase IM, show that rotor input : rotor cu loss : mechanical power developed is 1 : S : (1-S) (7 marks)

Let T = gross torque developed by motor in N-m

we know that power $P = \frac{2\pi NT}{60}$

P_2 is input to rotor from stator through rotating magnetic field which rotates at synchronous speed

So $P_2 = \frac{2\pi N_s T}{60}$ → (1)

Rotor output is gross mechanical power P_m and rotor rotates at N rpm

∴ $P_m = \frac{2\pi NT}{60}$ → (2)

Difference between P_2 and P_m is rotor cu loss P_c

∴ $P_c = P_2 - P_m = \frac{2\pi N_s T}{60} - \frac{2\pi NT}{60}$

$P_c = \frac{2\pi T}{60}(N_s - N)$ → (3)

Divide equation (3) by (1)

$$\frac{P_c}{P_2} = \frac{\frac{2\pi T}{60}(N_s - N)}{\frac{2\pi T}{60} N} = \frac{N_s - N}{N_s} = S$$

∴ $P_c = S P_2$

$P_m = P_2 - P_c = P_2 - S P_2 = (1-S) P_2$

So we can write

$P_2 : P_c : P_m = 1 : S : (1-S)$

05. b Draw and explain the phasor diagram of 3 phase IM. write the steps involved in drawing it (6 marks)

Let ϕ = magnetic flux linking with both stator and rotor.

Because of this there is self induced emf in stator (E_1) and mutually induced emf in rotor (E_2)

Let R_1 = Stator resistance/ph

X_1 = Stator reactance/ph

Stator voltage/ph V_1 can be written as

$$\overline{V_1} = -\overline{E_1} + \overline{I_1}(R_1 + jx_1) = -\overline{E_1} + \overline{I_1}\,\overline{Z_1}$$

Rotor induced voltage has to supply the drop across rotor impedance

$$\overline{E_{2r}} = \overline{I_{2r}}\,(R_2 + jx_2) = \overline{I_{2r}}\,\overline{Z_2}$$

Value of $\overline{E_{2r}}$ depends on turns ratio

Rotor current $\overline{I_{2r}}$ lag $\overline{E_{2r}}$ by rotor power factor angle $\cos\phi_{2r}$.

I_{2r} is reflected on stator side as

$$I_{2r}' = K\,I_{2r}.$$

Motor draws no load current

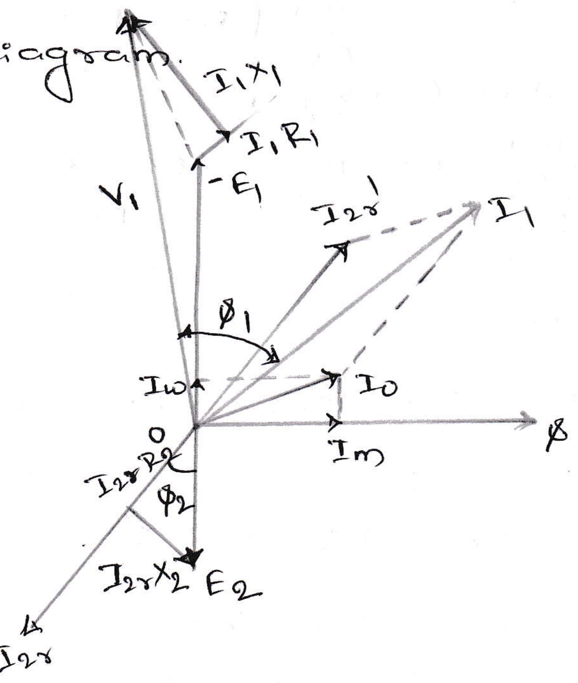
$$\overline{I_0} = \overline{I_w} + \overline{I_m}$$

total stator current

$$\overline{I_1} = \overline{I_0} + \overline{I_{2r}'}$$

The angle ϕ_1 is angle between V_1 and I_1 and $\cos\phi_1$ gives power factor of the induction motor.

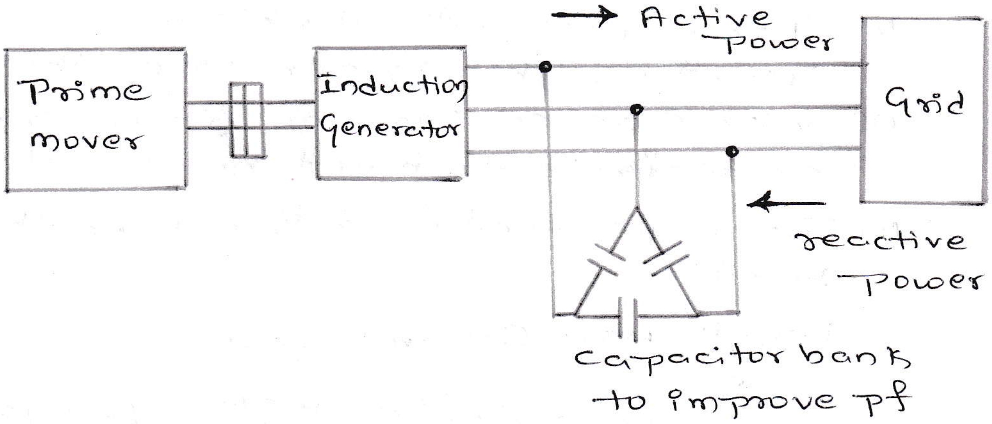
Phasor diagram.



Q5.c Explain the grid connected operation of induction generator. (7 marks)

Induction motor running above synchronous speed will act as induction generator. It draws reactive power and supplies active power.

In case of grid connected induction generator the magnetising current required for production of rotating magnetic field is supplied by the grid. Generator produces active power and supplies it to grid by consuming reactive power from the grid. During generating mode power factor is very low, to improve power factor capacitor banks are used. Voltage and frequency are governed by the grid.



06. a. Draw the circle diagram from noload and short circuit test of a 50 kW, 6 pole, 50 Hz, 450 V 3-phase slipring induction motor furnished the following test data.

No load : 450 V, 20 A, 0.15 pf.

Sc test : 200 V, 150 A, 0.3 pf. [10 marks]

From noload test

$I_0 = 20\,A \quad V_L = 450\,V$

$\cos\phi_0 = 0.15 \quad \therefore \phi_0 = \cos^{-1}(0.15) = 81.37^\circ$

From blocked rotor test

$I_{sc} = 150\,A, \quad V_{sc} = 200\,V$

$\cos\phi_{sc} = 0.3 \quad \therefore \phi_{sc} = \cos^{-1}(0.3) = 72.54^\circ$

$W_{sc} = \sqrt{3}\, V_{sc}\, I_{sc} \cos\phi_{sc}$

$= \sqrt{3} * 200 * 150 * 0.3$

$= 15.588\,kW$

$I_{SN} = \left(\frac{V_L}{V_{sc}}\right) I_{sc} = \frac{450}{200} * 150 = 337.5\,A$

$W_{SN} = \left[\frac{I_{SN}}{I_{sc}}\right]^2 W_{sc} = \left[\frac{337.5}{150}\right]^2 \times 15.58 \times 10^3 = 78.873\,kW$

Let current scale be 1 cm = 15 A

Steps to draw circle diagram.

01. Draw vector $OO' = I_o = 20A = 20/15 = 1.33$ cm at an angle 81.37° w.r.t voltage axis.

02. Draw horizontal line from O' parallel to x-axis.

03. Draw vector $OA = I_{SN} = 337.5A = \frac{337.5}{15} = 22.5A$ at an angle 72.57° w.r.t voltage axis.

04 Join O'A this is output line.

05. Draw perpendicular bisector of OA' and mark point C. This is center of the circle.

06. With C as center and O'C as radius draw a semicircle to meet horizontal line from O' at B

07. Draw perpendicular from A on the x-axis meeting it at D

Length AD = 6.9 cm = WSN

$\therefore$ Power scale $= \frac{WSN}{L(AD)} = \frac{78.873 \times 10^3}{6.9} = 11.43$ kw/cm

Circle diagram is on graph sheet.

06. b. Explain the phenomenon of cogging and crawling in a 3-phase IM (5 marks)

A squirrel-cage rotor may exhibit a peculiar behaviour in starting for certain relationship between number of poles and stator and rotor slots. If $S_1 = NS_2$ the variation in relactance as a function of space will be quite pronounced, resulting in strong aligment forces at the instant of starting. These forces may create an aligning torque stornger than accelerating torque with consequent failure of motor to start. This phenomenon is known as cogging. It can be avoided by proper selection of S_1 and S_2

Certain combination of S_1 and S_2 cause accentuation of certain space harmonics of the mmf wave. for example 5th and 7th harmonics which correspond to pole, five and seven times that of the fundamental. 5th harmonic rotates

8

SCALE X Y

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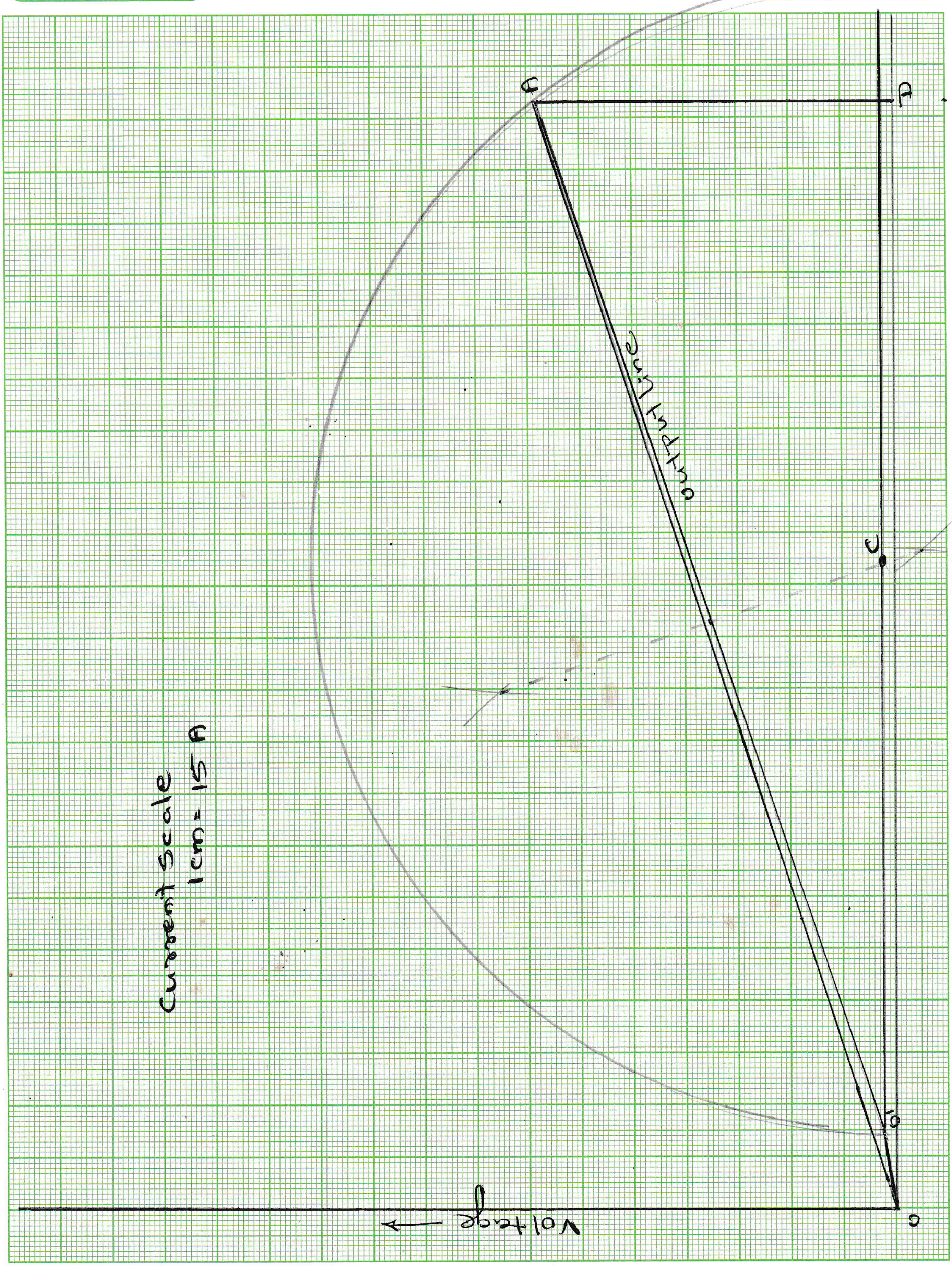
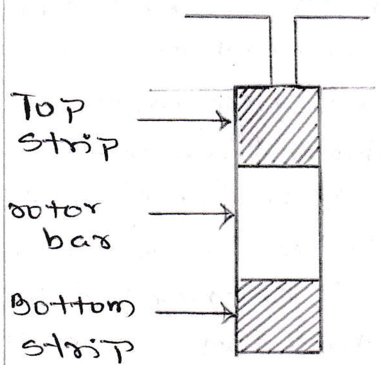
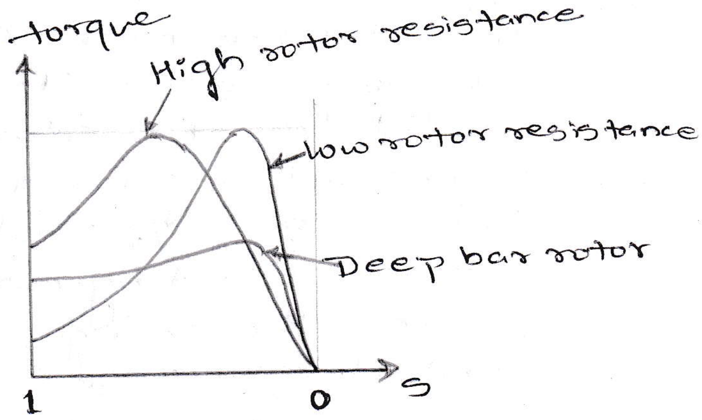


backwards with synchronous speed of ns/5 and the 7th harmonic pole rotate forward at ns/7. These harmonics mmf produces their own asynchronous torque. Due to this motor speed reduces under normal operation. This phenomenon is known as crawling

06.c Explain the construction and working of deep bar rotor type of induction motor [5 marks]

In deep bar rotor type of rotor construction bars of narrow width are laid down in deep semi enclosed slots. More magnetic flux links with the top strip as compared to bottom strip. Due to this the leakage reactance of top strip is very small and that of bottom strip will be significantly large. During starting $f_2 = f_1$, so reluctance of top strip will be small and bottom strip will be large. Hence effective impedance will be more. It reduces the starting current and increases starting torque. When motor runs at normal speed $f_2 = sf_1$ due to this reluctance of bottom strip reduces and motor performance improves.





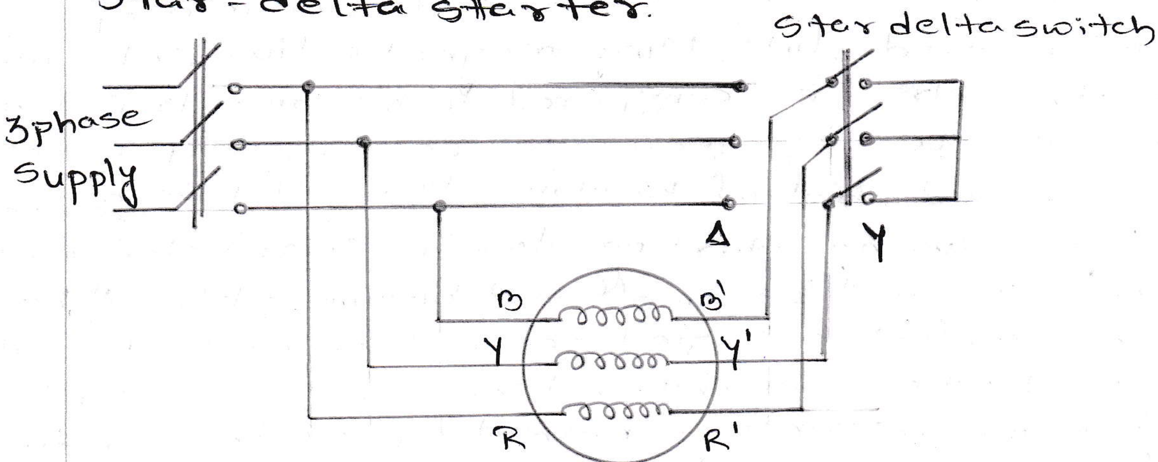
07.a. Justify the necessity of starter for 3 phase induction motor. Explain star delta starter with neat sketch. (8 marks)

At starting voltage induced in the rotor will be maximum as slip at stand still condition is 1. As rotor impedance is low, the rotor current is excessively large. The rotor current is given by the equation

$$I_{2r} = SE_2 \Big/ \sqrt{R_2^2 + (sx_2)^2}$$

This large rotor current is reflected in the stator because of transformer action. This results in high starting current generally 4 to 10 times the full load current in the stator. This high starting current may damage the motor winding and this high starting current will produce large line voltage drop and this adversely affect the operation of other electrical equipments connected to the same line. There fore we need a starter for 3-phase induction motor.

Star-delta starter.



The stator winding of the motor is designed for delta operation and is connected in star during the starting period. when machine speeds up the connections are changed to delta. The circuit connection is as shown in the fig. At starting the change over switch is connected to star position. Therefore each stator phase gets $V/\sqrt{3}$ volts where V is line voltage. This reduces starting current, when motor picks up the speed the changeover switch is connected to delta and line voltage is applied to stator winding.

$$\frac{I_{st}}{I_{fl}} = \left(\frac{1}{\sqrt{3}}\right)^2 \left(\frac{I_{sc}}{I_{fl}}\right)^2 s_{fl} = \frac{1}{3} s_{fl} \left[\frac{I_{sc}}{I_{fl}}\right]^2$$

07.b Explain any three methods of speed control of 3 phase induction motor. [12 marks]

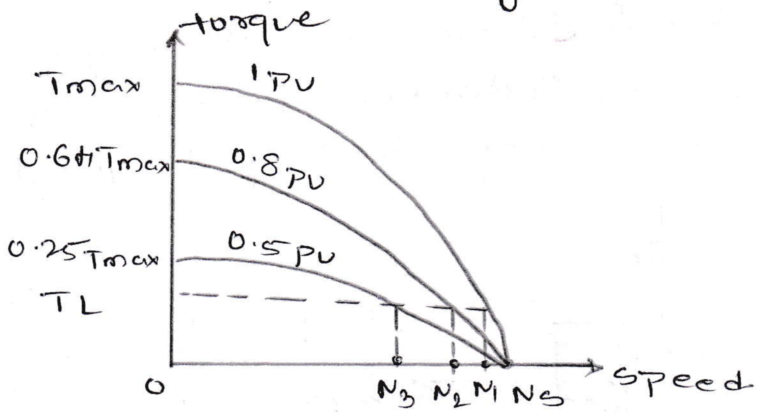
01. Speed control by change of stator voltage

The maximum torque of induction motor is proportional to the square of applied voltage

i.e $T_{max} \propto V^2$

If supply voltage drops to 80% of ratted voltage the maximum torque drops to 64% of its rated.

maximum value. This method is useful for changing speed of induction motor having soft torque speed characteristics. Change in supply voltage can be obtained using auto transformer or by using solid state AC voltage controller.



02. Speed control by changing the frequency (V/f)

Synchronous speed is given by

$$N_s = 120f/P$$

Thus by controlling the frequency, speed of the induction motor can be controlled.

We have air gap flux $\phi_g = \frac{1}{4.44 K_1 T_{ph1}} \left(\frac{V}{f}\right)$

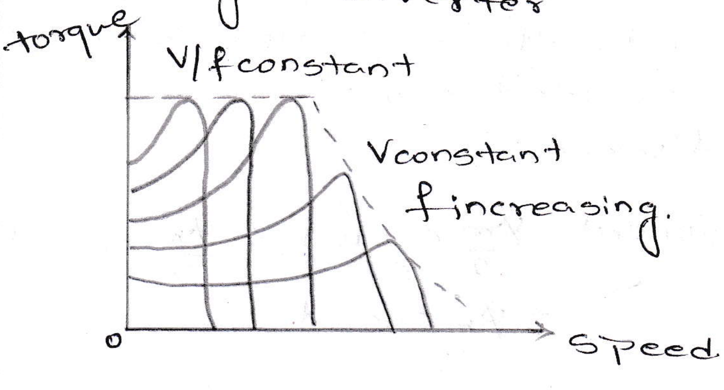
where K_1 = Stator winding constant

T_{ph1} = Stator turns/ph

V = Supply voltage

f = Supply frequency

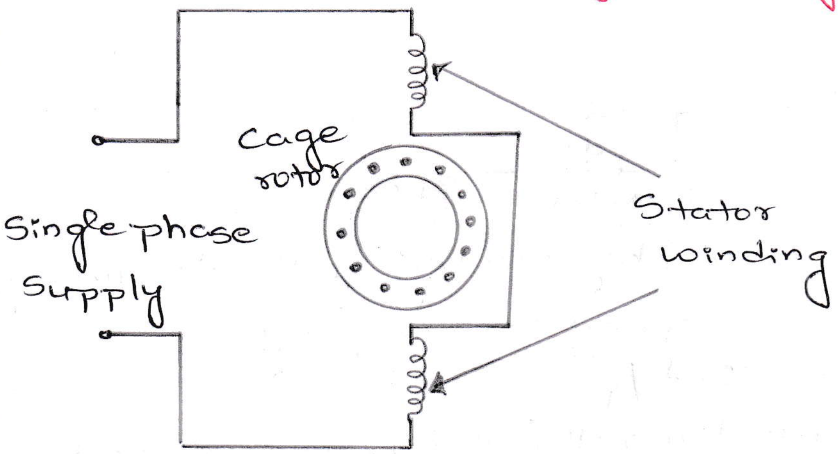
From the above equation it can be seen that air gap flux gets affected due to change in frequency. This may lead to saturation of the stator core and motor may take high magnetisation current and no load current. Thus to maintain airgap flux constant the ratio V/f is kept constant. Due to this, frequency control method is also called as V/f method. Variable frequency and voltage is obtained by a device called cycloconverter.



03. Speed control by changing number of poles.

We know that $N_s = 120f/P$, so by changing number of poles we can change the speed of induction motor. But in this method we need a special type of motor which allow change of number of poles.

08.a Explain double field revolving theory as applied to a single phase induction motor and prove that it cannot produce any starting torque. (10 marks)

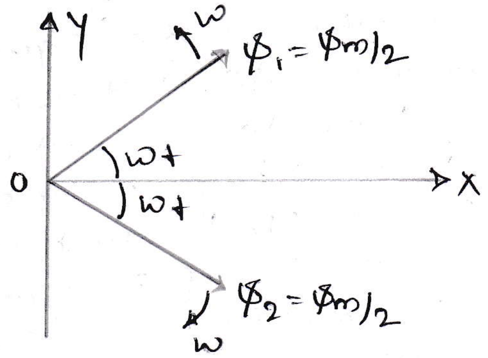


Double field revolving theory is based on the fact that an alternating sinusoidal flux ($\phi = \phi_m \cos\omega t$) can be represented by two revolving fluxes each equal to half of the maximum value of alternating flux (ie $\phi_m/2$) and each rotate at synchronous speed $N_s = 120f/P$, $\omega = 2\pi f$ in opposite direction.

Instantaneous value of flux

$\phi = \phi_m \cos\omega t$

Consider two fluxes ϕ_1 and ϕ_2 each of magnitude $\phi_m/2$ rotating in opposite direction with angular velocity ω



Let two fluxes start rotating from OX at $t=0$. After time t seconds the angle through which the flux vectors have rotated is ωt.

Resolving the fluxes.

$$\text{total X-component} = \frac{\phi_m}{2}\cos\omega t + \frac{\phi_m}{2}\cos\omega t$$

$$= \phi_m \cos\omega t.$$

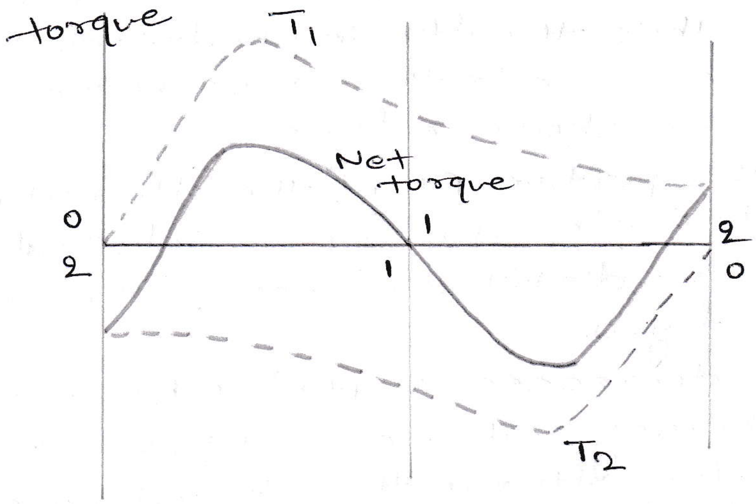
total Y-component = $\frac{\phi_m}{2} \sin\omega t - \frac{\phi_m}{2} \sin\omega t$

$= 0$

Resultant flux $\phi = \sqrt{(\phi_m \cos\omega t)^2 + 0^2}$

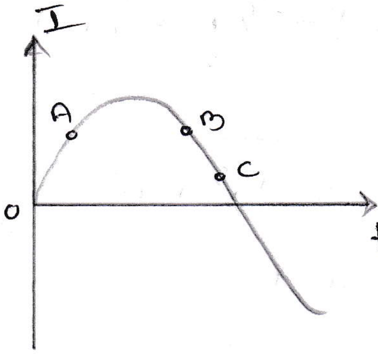
$\phi = \phi_m \cos\omega t$

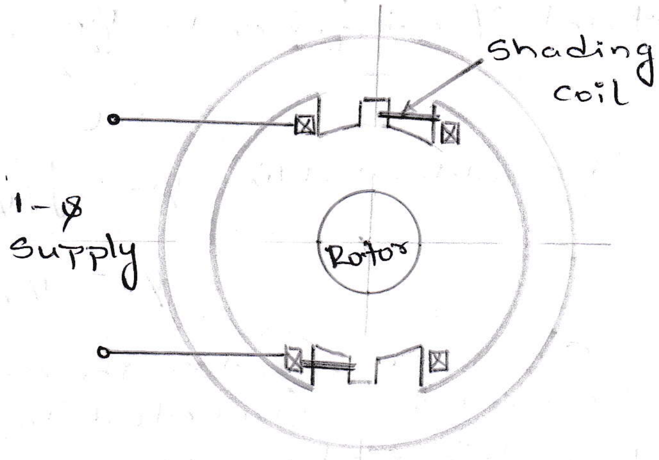
Consider a rotor is stationary and stator winding is connected to a single phase supply. The alternating flux produced by the stator winding can be represented as sum of two rotating fluxes ϕ_1 and ϕ_2 each equal to half of maximum flux, rotating at synchronous speed in opposite direction. The flux ϕ_1 will produce torque T_1 in anticlockwise direction and ϕ_2 will produce torque T_2 in clockwise direction. At stand still these two torques are equal and opposite and net torque developed is zero. Therefore single phase induction motor is not self starting.

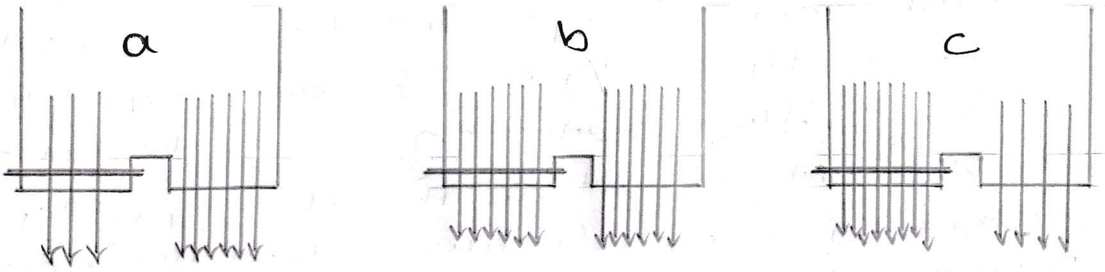


Q8.b **Explain construction and working principle of a shaded pole motor. (10 marks)**

Shaded pole motor has salient poles on stator excited by single phase supply and a squirrel cage rotor. A portion of each is surrounded by a short circuited turn of a copper strip called shading coil.







During portion OA of the alternating current cycle the flux begain to increase and an emf is induced in the shading coil. The resulting current in the shading coil will be in such a direction so as to oppose the change in flux. Thus the flux in shaded portion of the pole is weakened while that in unshaded portion is strengthned as shown in fig. a.

During the portion AB of the alternating current the flux reached almost maximum value and is not changing. So flux distribution across the pole is uniform as in fig. b.

As flux decreases in portion BC, current is induced in shading coil so as to oppose the decrease in current. Thus flux in the shaded portion increases while that in the unshaded portion is weakened as in fig. c.

This shifting flux is like a rotating field moving from unshaded portion to shaded portion. Due to this rotor starts to rotate.

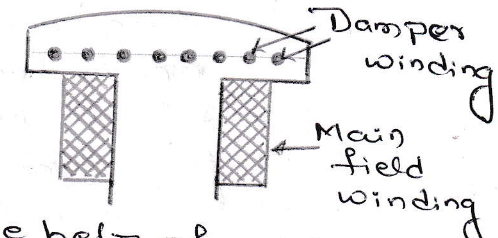
09.a. List the different methods of starting synchronous motor. Explain any one in detail. [8 marks]

As synchronous motors are not self starting any of the following method can be used to start a synchronous motor.

01. Using Pony motor
02. Using damper winding.
03. As a slipring induction motor
04. Using small DC machine coupled to it

Starting using damper winding

In a synchronous motor. in addition to the normal field winding, the addition winding consisting of copper bars placed in the slots in Pole faces. The bars are short circuited with the help of end rings.



This addition winding on the rotor is called damper winding. As these windings short circuited, act as a squirrel cage rotor winding of an induction motor. Once the motor stator winding is excited by 3 phase supply motor starts rotating as an induction motor. at sub synchronous speed. Then DC supply is given to the field winding. At a particular instant motor gets pulled into synchronous speed. Once motor start to rotate at synchronous speed. the relative motion between damperwinding and rotating magnetic field becomes zero and damper winding will not produce any torque. So damper winding will be active only during starting

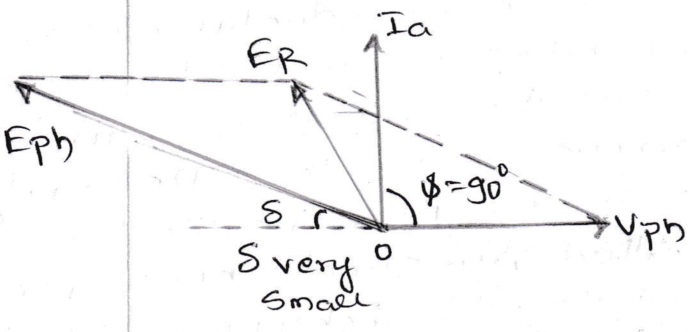
09.b. Describe a phenomenon of hunting in synchronous machines. What are the methods to overcome this. (6 marks)

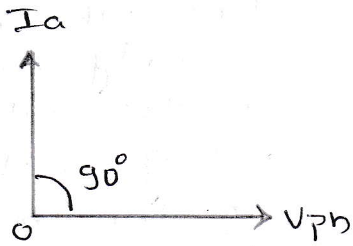
When synchronous motor is on no load, the stator and rotor pole axes almost coincide with each other when motor is loaded, the rotor pole axes falls back with respect to stator. The angle by which rotor retards is called load angle or angle of retardation 'δ'. If the load is suddenly changed by a large amount, then rotor tries to retard to take its new equilibrium position. But due to inertia of the rotor, it cannot achive its final position instantaneously. while achiving this rotor passes through equilibrium point back and fourth. And swings near the new equilibrium point. Such oscillation of rotor about its new equilibrium position due to sudden change in load is called swinging or hunting in synchronous motor.

Hunting can be reduced by using damper winding.

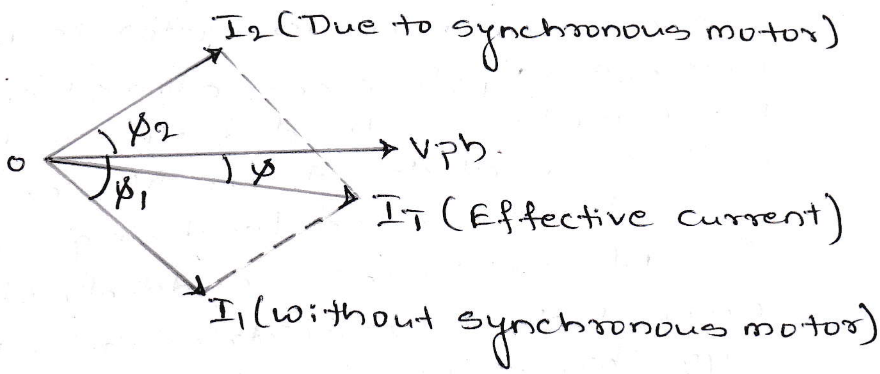
09.c. What is synchronous condenser? what is its application. (6 marks)

When synchronous motor is over excited it takes leading power factor current. If synchronous motor is on no load, where load angle δ is very small and it is over excited ($E_b > V$) then power factor angle increases almost upto 90°. And motor runs with almost zero leading power factor condition. This is shown in the phasor diagram as shown below.



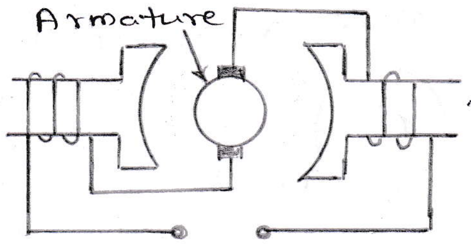


This characteristics is similar to a normal capacitor which always takes leading power factor current. Hence over excited synchronous motor operating on no load condition is called as synchronous condenser or synchronous capacitor. This is the property due to which synchronous motor is used as a phase advancer or as power factor improvement device.



10.a. Explain the construction and working principle of universal motor. (10 marks)

Universal motors are small capacity series motors which can be operated on DC supply or single phase alternating supply of same voltage with similar characteristics. Construction of universal motor is same as DC series motor. but some modifications are made to reduce losses on AC supply.



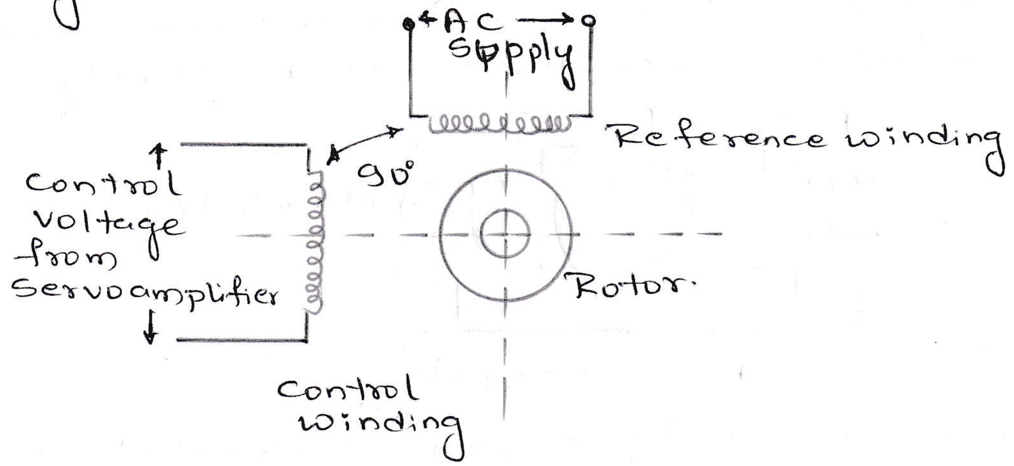
When DC supply is given, it opperates as a normal DC series motor and produces the rotating torque in single direction. But when AC supply is given to motor during positive half cycle motor rotates in one direction let us take clockwise. When supply take negative half cycle during this current in the field winding as well as armature both change the direction. Due to this the torque direction will remain same as positive half cycle and motor produces torque in unidirection irrespective of the half cycle of the supply wave-form.

Universal motors produce high starting torque and are capable of running at high rpm. So these are used in vacuum cleaners, food processors and mixers, hair driers, coffee grinders, drill machines etc.

10.b. With a neat sketch explain the operation of two phase AC servomotor. (10 marks]

AC Servomotor is basically a two phase induction motor. AC servomotor has a stator and rotor. The stator carries two windings, uniformly distributed and displaced by 90° in space, from each other. One winding is called as main winding or fixed winding or reference winding. The reference winding is excited by a constant voltage A.C. supply.

The other winding is called control winding. It is excited by variable control voltage, which is obtained from a servoamplifier. The windings are 90° away from each other and control voltage is 90° out of phase with respect to the voltage applied to the reference winding. This is necessary to produce rotating magnetic field.



Working.

The control voltage applied to the control winding and the voltage applied to the reference winding are 90° out of phase. There fore flux produced by these two winding are also 90° out of phase. The resulting flux in the air gap is hence rotating in nature. This rotating magnetic field sweeps over a stationary rotor and emf gets induced in rotor. This emf circulates the current in rotor. Now current carrying conductor kept in magnetic field experience force and rotor start to rotate. Direction of rotation, torque and speed depends on control voltage