Model Answers

Winter – 2019 Examinations

Subject & Code: Industrial A.C Machines (22523)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Model Answers

Winter – 2019 Examinations

Subject & Code: Industrial A.C Machines (22523)

1 Attempt any FIVE of the following: **10**

1 a) State the function of following parts in Induction motor.
(i) Stator
(ii) ~~Seiprings~~ Slip rings

Ans:

Sr. No.	Name of part	Function
1	**Stator**	1) Stator frame supports the core, terminal box and protects the inner parts. 2) Stator core houses stator winding. 3) Stator winding produces rotating magnetic field.
2	**Slip ring**	1) The rotor winding terminals are permanently connected to the slip rings. 2) Provides facility to connect external resistance to rotor circuit through brushes for starting and control.

1 Mark for one function of each part = 2 Marks

1 b) State suitable single phase motor for following applications:
(i) Table fan (ii) Mixers and Grinders

Ans:

Sr. No.	Application	Suitable Single Phase Motor
1	**Table Fan**	1) Capacitor split phase motor 2) Capacitor start capacitor run motor
2	**Mixers and Grinders**	1) Universal motor 2) A.C. Series motor

1 Mark for each application =2 Marks

1 c) State advantages of short pitch winding over full pitch winding in alternators.

Ans:

Advantages of Short Pitch Winding over Full Pitch Winding in Alternators:

1) Short pitching reduces the amount of copper needed for end connection when compared with full pitched coil.
2) They improve the waveform of generated EMF i.e. generated EMF can be made approximately to sine wave more easily and the distorting harmonics can be reduced.
3) Due to the elimination of high frequency harmonics, eddy current and hysteresis losses are reduced, thereby increasing the efficiency.
4) The power quality of generated emf is improved.

1 Mark for each of any two advantages = 2 Marks

1 d) List different torques in synchronous motor.

Ans:

Different Torques in Synchronous Motor:

1) Starting torque
2) Running torque
3) Pull-in torque
4) Pull-out torque

½ Mark each = 2 Marks

1 e) State advantages of rotating field type alternators. (any four)

Ans:

Advantages of Rotating Field Type Alternator:

1) For high-voltage alternator, large space is required to accommodate conductors with insulation, as high voltage is induced in them. If field poles are placed on rotor and armature winding is placed on stator, large space can be provided to accommodate large number of conductors and the required high level of insulation.
2) It is always better to protect high voltage winding from the centrifugal forces caused due to the rotation. So high voltage armature is kept stationary and field winding is kept rotating. This avoids the interaction of mechanical and electrical stresses.
3) It is easier to collect larger currents at very high voltage from a stationary member than from the slip ring and brush assembly. The voltage required to be supplied to the field is very low (110 V to 220 V d.c.) and hence can be easily supplied with the help of slip ring and brush assembly by keeping it on rotor.
4) Due to low voltage level on the field side, the insulation required is less and hence field system has very low inertia. It is always better to rotate low inertia system than high inertia, as efforts required to rotate low inertia system are always less.
5) Rotating field makes the overall construction very simple. With simple but robust mechanical construction and low inertia of rotor, it can be driven at high speeds. So greater output can be obtained from an alternator of given size.
6) If field is rotating, to excite it from external dc supply, two slip rings are enough. One each for positive and negative terminals. As against this, in three phase rotating armature, the minimum number of slip rings required is three and cannot be easily insulated due to high voltage levels.
7) The ventilation arrangement for high voltage side can be improved if it is kept stationary and field winding is kept rotating.
8) Rotating field is comparatively light and can run with high speed.

½ Mark for each of any four advantages = 2 Marks

1 f) List applications of stepper motor.

Ans:

Applications of Stepper Motor:

1) Computer controlled systems
2) Numerical control of machine tools
3) Tape drives
4) Floppy disc drives
5) Computer printers
6) X-Y plotters
7) Robotics
8) Textile industries
9) Integrated circuit fabrication
10) Electric watches
11) CNC system

½ Mark for each of any four applications = 2 Marks

12) Milling machines
13) X-Ray table positing system
14) Cameras
15) Wall Clocks
16) Scanners
17) Respirators
18) Digital Dental Photograph
19) Laser cutters
20) Extruders
21) Engravers
22) Analytical and Medical instruments
23) Embroidery Machines
24) Packaging Machines

1 g) List applications of servomotor.

Ans:

Applications of Servomotor:

1) Computers
2) Robotics and toys
3) CD/DVD players
4) Textile industries
5) Instrument servos
6) Tracking and guidance system
7) Self-balancing recorders
8) Remote positioning devices
9) Process controllers
10) Electromechanical actuators
11) Air-craft control system
12) Programming device

½ Mark for each of any four applications = 2 Marks

2 Attempt any THREE of the following: 12

2 a) Derive the condition for maximum torque under running condition of a 3 phase induction motor.

Ans:

Condition for Maximum Torque Under Running Conditions:

Torque produced by three-phase induction motor is given by,

$$T = \left(\frac{3\times60}{2\pi N_S}\right)\frac{sE_2^2R_2}{(R_2^2+s^2X_2^2)} \text{ N-m}$$ 1 Mark

Since synchronous speed N_S is constant and the rotor standstill emf E_2, rotor standstill resistance R_2 & reactance X_2 are constants, the only variable on which torque depends will be the slip 's'.

For maximum torque,

$$\frac{dT}{ds} = \frac{d}{ds}\left[\left(\frac{3\times60}{2\pi N_S}\right)\frac{sE_2^2R_2}{(R_2^2+s^2X_2^2)}\right] = 0$$

$$\therefore \left(\frac{3\times60}{2\pi N_S}\right)\frac{d}{ds}\left[\frac{sE_2^2R_2}{(R_2^2+s^2X_2^2)}\right] = 0$$ 1 Mark

$$\therefore \frac{(R_2^2+s^2X_2^2)E_2^2R_2-sE_2^2R_2(0+2sX_2^2)}{(R_2^2+s^2X_2^2)^2}=0$$ 1 Mark

$$(R_2^3E_2^2+s^2X_2^2E_2^2R_2)-2s^2R_2X_2^2E_2^2=0$$
$$(R_2^2E_2^2+s^2X_2^2E_2^2)-2s^2X_2^2E_2^2=0$$
$$(R_2^2E_2^2-s^2X_2^2E_2^2)=0$$
$$(R_2^2-s^2X_2^2)=0$$
$$R_2^2=s^2X_2^2$$ 1 Mark
$$R_2=sX_2$$

Thus the motor under running condition produces maximum torque at speed or slip when rotor resistance is equal to the rotor reactance under running condition. The maximum torque under running conditions is produced at a speed that corresponds to the slip value given by the ratio of the rotor resistance to the standstill rotor reactance ($s = R_2/X_2$).

OR Equivalent Derivation

2 b) A 16 pole, 3 phase star connected alternator armature has 12 slots with 24 conductors per slot and flux per pole is 0.1 wb. Sinusoidally distributed. Calculate line emf generated at 50 Hz

Ans:

Data Given:

Star connected alternator
No. of Poles P = 16
Total no. of slots = 12
Conductors per slot = 24
Flux per pole ϕ = 0.1 Wb
Frequency f = 50Hz

As data of winding about short or full pitch is not given, Assuming Full-pitched coils, Pitch factor = K_p = 1 1 Mark

A) Distribution-factor (K_d):

Slots/pole/phase: m = 12/16/3 = 0.25
Slots/pole: n = 12/16 = 0.75
Slot angle: $\beta=\frac{180°}{n}=\frac{180°}{0.75}=240°$

$\therefore$ Distribution factor, $K_d=\frac{sin(\frac{m\beta}{2})}{m\times sin(\frac{\beta}{2})}=\frac{sin(\frac{0.25\times240°}{2})}{0.25\times sin(\frac{240°}{2})}=\frac{sin(30°)}{0.25\times sin(120°)}=2.3$ 1 Mark

(NOTE- As K_d has maximum value of 1, student assuming K_d = 1 to be awarded appropriate marks)

B) Phase value of Emf (E_{ph}):

Total no. of conductors Z = 12×24 = 288
No. of conductors/phase = 288/3 = 96
No. of turns/phase T = 96/2 = 48
The rms value of emf induced in each phase winding is given by,
$E_{ph}=4.44\,K_pK_df\emptyset T$ volt
$=4.44\,(1)(2.3)(50)(0.1)(48)$

$= 2450.88\ volt$ 1 Mark

OR

$= 4.44\,(1)(1)(50)(0.1)(48)$

$= 1066\ volt$

For star connected alternator,

Line emf $E_L = \sqrt{3}E_{ph} = \sqrt{3}(2450.88) = 4245.048$ volts 1 Mark

OR $E_L = \sqrt{3}E_{ph} = \sqrt{3}\ X\ 1066\ volts = 1846$ volts

2 c) Explain the effect of variable excitation on the behavior of synchronous motor under constant load condition.

Ans:

Effect of Variable Excitation on the Behavior of Synchronous Motor Under Constant Load Condition:

Consider a synchronous motor having a fixed supply voltage V and driving a constant mechanical load. Since the mechanical load is constant, the load angle δ remains constant. Now when excitation is changed, the back emf E_b changes but there is hardly any change in the losses of the motor. Therefore, constant load demands constant output power and consequently the input power of motor (=3 $V_{ph}I_a$ cosϕ) remains same. Since the applied voltage V to the motor is constant, the constant input demands constant ($I_a$cosϕ). This means that the in-phase component ($I_a$cosϕ) drawn from the supply will remain constant. In synchronous motor, the stator current (I_a) is determined by dividing resultant voltage-phasor (E_R) by the synchronous impedance Z_s. If the field excitation is changed, back e.m.f E_b also changes. This results in the change of phase position of resultant voltage E_R and current I_a w.r.t. V for different values of field excitation.

Normal Excitation:

When the excitation is adjusted in such a way that the magnitude of induced e.m.f. is equal to the applied voltage (E_b = V), the excitation is called normal excitation. The motor draws certain current I_a from the supply and the power factor is usually lagging, as shown in Fig.(a).

2 Marks for explanation

Under Excitation:

When the excitation is adjusted in such a way that the magnitude of induced e.m.f. is less than the applied voltage (E_b < V), the excitation is called under excitation.

Due to this, E_R increases in magnitude. This means for constant Z_s, current drawn by the motor increases. But E_R phase shifts in such a way that, phasor I_a also shifts to keep (I_a cosϕ) component constant. This is shown in the Fig.(b). So in under excited condition, current drawn by the motor increases. The p.f. cosϕ decreases and becomes more and more lagging in nature.

Over Excitation:

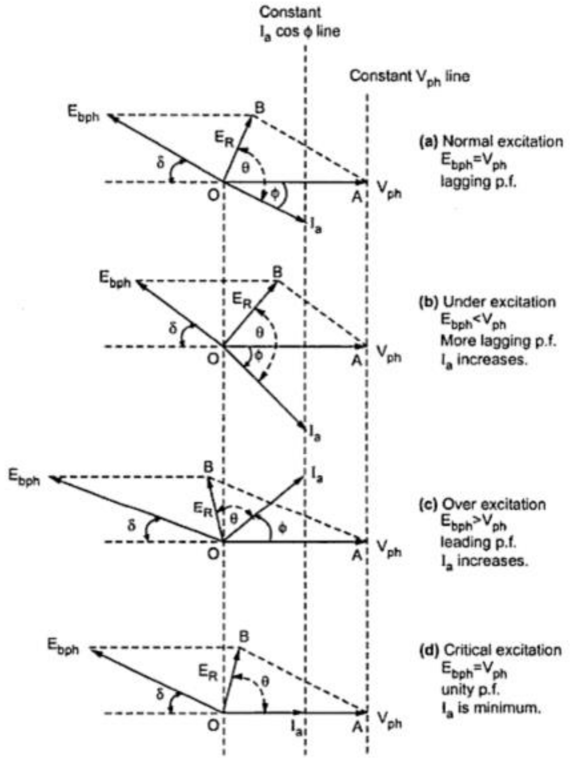
The excitation to the field winding for which the induced e.m.f. becomes greater than applied voltage (E_b > V), is called over excitation.

Due to increased magnitude of E_b, E_R also increases in magnitude. But the phase of E_R and I_a also changes. The I_a increases to keep (I_a cosϕ) constant as shown in

Fig.(c). The phase of E_R changes so that I_a becomes leading with respect to V in over excited condition. So power factor of the motor becomes leading in nature.

Critical Excitation:

When the excitation is adjusted in such a way that the power factor of the motor becomes unity, the excitation is called critical excitation. The motor draws minimum current I_a from the supply and the power factor is unity, as shown in Fig.(d).



2 Marks for diagram

2 d) Prove that for a 3Ø induction motor.
Rotor copper loss = s × Rotor input.

Ans:

The mechanical power P available from any electric motor can be expressed as:

$$P = \frac{2\pi\, N\, T}{60} \text{ watts}$$ 1 Mark

where

N = Speed of motor in r.p.m
T = Torque developed in N-m

$\therefore$ Induction Motor Torque (T) $= \frac{60}{2\pi}\frac{P}{N} = 9.55\,\frac{P}{N}$ N-m

If the gross output of the rotor of an induction motor is P_m and its speed is N r.p.m., then gross torque T_g developed is given by:

$$T_g = 9.55\,\frac{P_m}{N} \text{ N-m}$$ 1 Mark

Now,

Gross rotor output = $\frac{2\pi\, N\, T_g}{60}$ watts

If there were no copper losses in the rotor, the output would equal to rotor input and the rotor would run at synchronous speed N_s

Hence,

Rotor input = $\frac{2\pi\, N_s\, T_g}{60}$ watts — 1 Mark

Rotor Cu loss = Rotor input – Rotor output

$= \frac{2\pi\ T_g}{60}(N_s - N)$

$\frac{Rotor\ Cu\ Loss}{Rotor\ input} = \frac{(N_s - N)}{N_s}$ = s = Slip

∴ **Rotor Cu loss = s × Rotor input** — 1 Mark

3 Attempt any THREE of the following: 12

3 a) The power input to a 500V 50Hz 6Pole 3Ø induction motor running at 975 rpm is 40 kW. The stator losses are 1 kW and friction and windage losses are 2 kW. Calculate :

(i) ~~Seip~~ Slip
(ii) Rotor copper loss
(iii) Shaft power
(iv) Efficiency

Ans:

Synchronous speed N_S = 120f/P = 1000 RPM.

Slip 's' = $(N_S - N_R)/N_S$ = (1000-975)/1000

= **0.025 or 2.5%.** — 1 Mark

Rotor input power P_i = Motor input power – stator losses

= 40 kW – 1 kW

= 39 kW.

Rotor copper losses = slip x rotor input power = $s.P_i$

= 0.025 x 39 = 0.975 kW

= **975 W.** — 1 Mark

Shaft power = (mechanical power in rotor – friction & windage losses)

= $P_i(1\text{-}s)$ – friction and windage losses

= 39(1 – 0.025) – 2

= **36.025** kW — 1 Mark

Efficiency η = [(output power)/(input power)] x100

The output power is same as the shaft power.

% Efficiency η = (36.025/40) x 100 — 1 Mark

= **90.06 %**

3 b) Prove that $K_d = \frac{Sin\,(m\frac{\beta}{2})}{m\,\sin(\frac{\beta}{2})}$ in an alternator.

Ans:

Distribution Factor of a Winding:

Distribution factor is defined as;

$$K_d = \frac{Emf\ with\ distribured\ winding}{Emf\ with\ concentrated\ winding}$$ **OR**

$$K_d = \frac{Phasor\ sum\ of\ coil\ emf\ /phase}{Arithmetic\ sum\ of\ coil\ emf\ /phase}$$

Consider the following figure,

Let β be the value of the angular displacement between the slots. Its value is

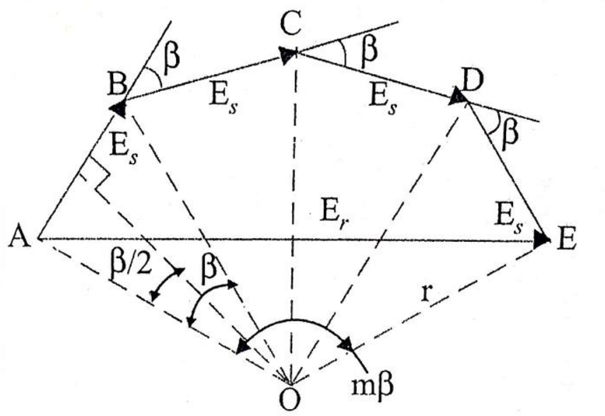
$$\beta = \frac{180°}{\text{No. of slots/pole}} = \frac{180°}{n}$$ 1 Mark

m = No. of slots/pole/phase.

m β = Phase spread angle.

Then the resultant voltage induced in one polar group would be m E_S.

Where Es is the voltage induced in one coil side. The following figure illustrates the method for finding the vector sum of 'm' voltages each of value Es and having a mutual phase difference of β (if m is large, then the curve ABCDE will become part of a circle of radius r). 1 Mark



1 Mark

AB = Es = 2r sin(β/2)

The arithmetic sum = m E_S = m× 2r sin(β/2)

The vector sum AE= E_r = 2r sin(mβ/2)

∴ The distribution factor (Kd) is proved as,

$$K_d = \frac{Vector\ or\ phasor\ sum\ of\ coil\ emfs}{Arithmetic\ sum\ of coil\ emfs} = \frac{2rsin(\frac{m\beta}{2})}{m\times 2rsin(\frac{\beta}{2})}$$

$$\therefore K_d = \frac{sin(\frac{m\beta}{2})}{m\times sin(\frac{\beta}{2})}$$ 1 Mark

3 c) Explain working of resistance split phase single phase induction motor with vector diagram.

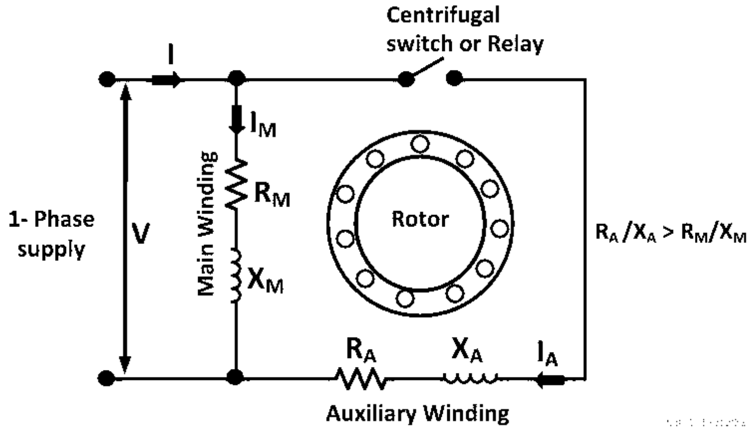
Ans:

Working of Resistance Split Phase Single Phase Induction Motor:

This motor consists of two windings in stator, first is main winding which is more inductive and less resistive, hence current drawn by this winding I_M is much more lagging behind the applied voltage V as shown in vector diagram. Second is the starting or auxiliary winding connected in series with resistor and centrifugal switch which is in ON position at the time of starting, so draws lagging current I_A by small angle with V as shown in phasor diagram. The main winding and starting winding are connected in parallel with each other. So splitting of the current is achieved here and the starting torque, $T \alpha k. I_A . I_M . \sin\varphi$ obtained is very much sufficient to accelerate the motor and motor starts rotating. After acquiring 75% of rated speed the starting or auxiliary winding is cut out of circuit with opening of centrifugal switch. Then motor continues to run with only main winding in the circuit.

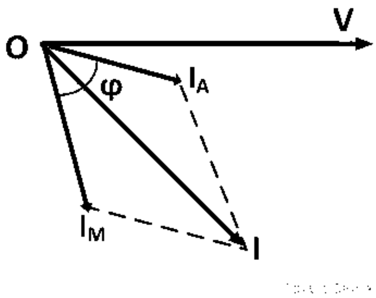
2 Marks for explanation

Circuit Diagram:



1 Mark for circuit diagram

Vector Diagram:



1 Mark for phasor diagram

3 d) A 400V, 50Hz ~~seipring~~ slip ring type three phase induction motor is star connected and has per phase rotor resistance and standstill reactance of 0.5 and 1.5 ohm respectively. Calculate resistance to be added per phase to achieve maximum torque at starting.

Ans:

$$\frac{T_s}{T_m} = \frac{2a}{a^2+1}$$

1 Mark

where,

T_s = Starting torque
T_m = Maximum torque
a = ratio of rotor resistance per phase to rotor reactance per phase
= R_2 / X_2

Since, $T_s = T_m$, $\frac{T_s}{T_m} = 1$ Hence, $1 = \frac{2a}{a^2+1}$ 1 Mark

$\therefore a = 1$

Now $a = \frac{R_2 + R_x}{X_2}$

where R_x = External resistance / phase added to the rotor circuit to achieve maximum torque at starting 1 Mark

$1 = \frac{0.5 + R_x}{1.5}$

$R_x + 0.5 = 1.5$

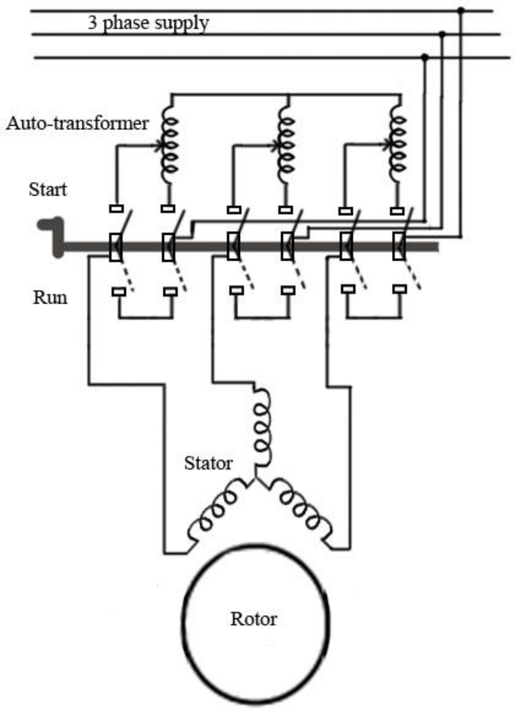
$\mathbf{R_x = 1\ \Omega}$ 1 Mark

4 Attempt any THREE of the following: 12

4 a) Explain working of autotramsformer starter for a 3 phase induction motor with neat diagram.

Ans:

Working of Autotramsformer Starter for a 3 Phase Induction Motor:



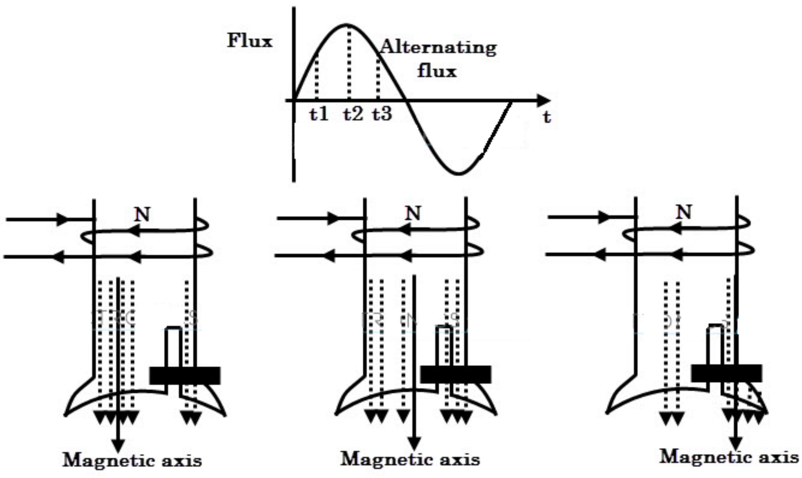
2 Marks for diagram

A three phase star connected autotransformer along with suitable change over switch forms an autotransformer starter.When the switch is in the starting position, the stator of an induction motor is supplied with reduced voltage through the autotransformer using suitable tap.This limits the starting current to a safe value.Usually 3 tappings per phase are provided to give 50,65 or 80% of the normal line voltage across the motor terminals.When the motor attains about 80% of its normal speed, the switch is thrown to 'RUN' position which connects the motor directly across the supply and cuts out the autotransformer from the circuit.These actions may be carried out automatically by time-delay operated magnetic contactors. The provision of required taps on the autotransformer makes the adjustment possible to suit the local conditions. Hence the motor is started safely by reducing heavy starting inrush current. 2 Marks for working

4 b) Explain phase shifting (production of rotating magnetic field) in shaded pole induction motor with neat diagram.

Ans:

Phase Shifting (Production of Rotating Magnetic Field) in Shaded Pole Induction Motor:



(a) t= t1 (b) t= t2 (c) t= t3

2 Marks for diagram

When single phase supply is applied across the stator winding, an alternating field is created. The flux distribution is non-uniform due to shading bands on the poles. The shading band acts as a single turn coil and when links with alternating flux, emf is induced in it. The emf circulates current as it is simply a short circuit. The current produces the magnetic flux in the shaded part of pole to oppose the cause of its production which is the change in the alternating flux produced by the winding of motor. Now consider three different instants of time t_1, t_2, t_3 of the flux wave to examine the effect of shading band as shown in the figure.

- At instant t_1: The flux is positive and rising; hence the shading band current produces its own flux to oppose the rising main flux. Due to this opposition, the net flux in shaded portion of pole is lesser than that in unshaded portion. Thus the magnetic axis lies in the unshaded portion and away from shaded portion.
- At instant t_2: The flux is maximum; the rate of change of flux is zero. So the shading band emf and current are zero. Thus the flux distribution among shaded and unshaded portion is equal. The magnetic axis lies in the center of the pole.

2 Marks for explanation

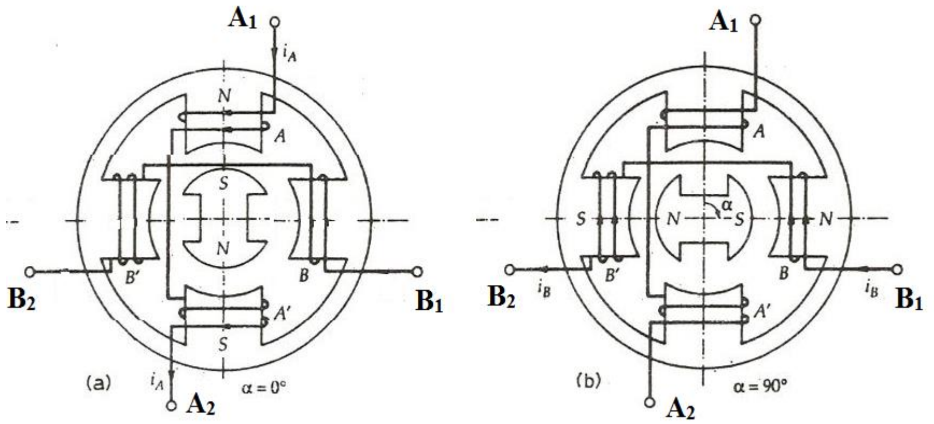
- At instant t_3: The flux is positive but decreasing, hence according to Lenz's rule, the shading band emf and current try to oppose the fall in the main flux. So the shading band current produces its own flux which aids the main flux. Since shading band produces aiding flux in shaded portion, the strength of flux in shaded portion increases and the magnetic axis lies in the shaded portion.

Thus it is seen that as time passes, the magnetic neutral axis shifts from left to right in every half cycle, from non-shaded area of pole to the shaded area of the pole. This gives a rotating field effect which is sufficient to provide starting torque to squirrel cage rotor and rotor rotates.

4 c) Explain the construction and working of permanent magnet stepper motor.

Ans:

Permanent Magnet Stepper Motor:



2 Marks for diagrams

OR any other equivalent figure

The constructional sketch of Permanent Magnet Stepper Motor is shown in the figure. The rotor consists of permanent magnet poles of high retentivity steel and is cylindrical in shape. The concentrating windings on diametrically opposite poles are connected in series to form a two phase winding on the stator. The rotor poles align with the stator teeth depending on the excitation of the winding. The two coils AA' connected in series to form a winding of Phase A with terminals A_1 and A_2. Similarly the two coil BB' is connected in series forming a phase B windings with terminals B_1 and B_2.

In figure (a) the phase A is excited, causing current i_A flowing from A_1 to A_2 of phase A, whereas phase B is not excited. Due to the current i_A the poles are created on stator as shown. The south pole of the rotor is attracted by the north pole of stator phase A. Thus, the magnetic axis of the stator and rotor coincide and $\alpha = 0^o$.

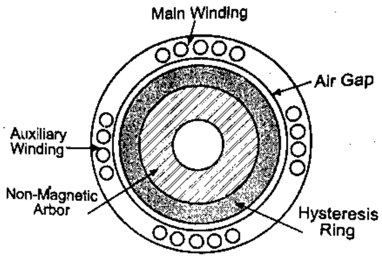
In figure (b) the phase B is excited, causing current i_B flowing from B_1 to B_2 of phase B, whereas phase A is not excited. Due to the current i_B the poles are created on stator as shown. The south pole of the rotor is attracted by the north pole of stator phase B and the rotor moves by 90° in the clockwise direction. Thus, the magnetic axis of the stator and rotor coincide and $\alpha = 90^o$.

2 Marks for explanation

Similarly, if phase A alone is excited with reversed current i_A, the rotor moves

further by 90° and when the magnetic axis of the stator and rotor coincide, we get $\alpha = 180^o$. Further if only B phase is excited with reversed current i_B, the rotor moves further by 90° and when the magnetic axis of the stator and rotor coincide, we get $\alpha = 270^o$.
In this way, the sequential excitation of phases A and B with forward and reverse current, the rotor movements in steps of 90° can be obtained. It is also possible to obtain steps of 45° by exciting both the phases simultaneously.

4 d) Describe with neat sketch working of hysteresis motor.
Ans:



2 Marks for diagram

Working:
When stator is energized with single phase ac supply, rotating magnetic field is produced because of starting (auxiliary) and main windings, which remain in circuit permanently. The rotor, which is hysteresis ring, cuts this flux, emf is induced and eddy currents start circulating in rotor as it is a shorted ring. Thus eddy current torque is developed along with the hysteresis torque in the rotor. Hysteresis torque in the rotor is developed because the rotor magnetic material has high hysteresis loss property and high retentivity. Now the rotor starts rotating initially as induction motor with speed somewhat less than synchronous speed and rotor pole axis lagging behind the axis of rotating stator field.
When the speed of the rotor reaches near about the synchronous speed, then rotor poles are locked with stator field poles and then rotor starts rotating with synchronous speed. At the condition of synchronism, the relative motion between stator field and rotor field vanishes, hence no eddy current & torque. In this condition the rotor continues to rotate because of hysteresis torque. This torque is constant at all speeds and motor runs with perfect synchronous speed. Due to the principle of magnetic locking this motor either rotates at synchronous speed or not at all.

2 Marks for working

4 e) Explain construction and working of AC servomotor.
Ans:
Construction of AC Servo Motor:
AC servo motor is mainly composed of a stator and a rotor. Laminated stator core is usually made of silicon steel. Two phase windings are placed in the stator slots at 90 degree electrically apart from each other. One phase winding is the field winding and the other is the control winding. Field winding and control winding are excited as shown in figure. The rotor is squirrel cage type or drag cup type rotor.

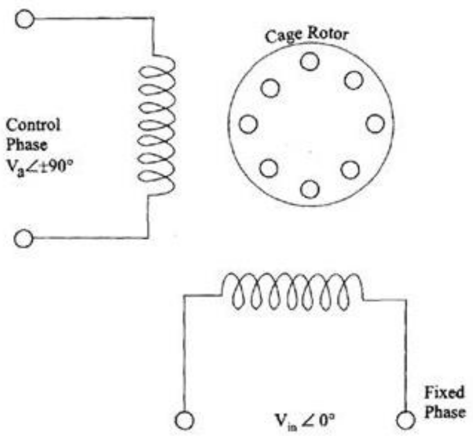
2 Marks for construction

Model Answers

Winter – 2019 Examinations

Subject & Code: Industrial A.C Machines (22523)

Working of AC Servo Motor:



These motors are used for position control or in servo mechanisms, hence are termed as servomotors. A voltage V_m is applied to the main or reference winding at zero angle, while V_a is the voltage applied to control winding which controls the torque-speed characteristics with 90° angle. The 90° space displacement of the two coils/windings and the 90° phase difference between the voltages applied to them result in production of rotating magnetic field in the air gap. This rotating magnetic field is cut by rotor conductors and emf is induced in them. Since rotor is short-circuited, the rotor currents flow. The interaction between rotor currents and rotating magnetic field results in force (or torque) acting on rotor. Due to the force or torque acting on the rotor, it is set in motion. 2 Marks for working

5 Attempt any TWO of the following: **12**

5 a) Explain the activities carried out during weekly maintenance of 3 ph. Induction motor.

Ans:

Activities Carried out During Weekly Maintenance of 3 ph. Induction Motor:

1) Check belt tension. In cases where this is excessive it should immediately be reduces and in the case of sleeve bearing machines the air gap between rotor and stator should be checked.
2) Blow out windings of protected type motors, situated in dusty locations. 6 Marks
3) Examine starting equipment for burnt contacts where motor is started and stopped frequently.
4) Examine oil in the case of oil ring lubricated bearings for contamination by dust, dirt, etc (This can be roughly ascertained on inspection by the colour of the oil)

OR

Preventive maintenance on a weekly basis includes remedial measures for the following;

1) Start each motor to determine if it comes up to speed within the normal time frame.
2) Measure line current and compare to previous records and if it is within the FLC of the motor's nameplate rating. Line currents should be balanced with in the tolerance limits.
3) Listen to each motor for any unusual noises.
4) Inspect switches, fuses, starter, and other control equipment.
5) Observe any excessive sparking of brushes.
6) Check lubricant levels of bearings and look for any leaks.

7) Look for corrosion on slip rings.
8) Check brushes for excessive sparking while the motor is running.
9) Check oil rings for rotation with the shaft for the motors that have this arrangement.
10) For motors lubricated and cooled by oil mist systems its important to check the oil mist flow paths/pressure components.

5 b) Define the voltage regulation of an alternator. Explain synchronous impedance method for finding regulation of alternator.

Ans:

Voltage Regulation of an Alternator:

The voltage regulation of an alternator is defined as the change in terminal voltage from no-load to full-load expressed as fraction or percentage of full-load voltage, keeping the speed and field excitation constant.

1 Mark for any definition or any formula

OR

$$\% \text{ Voltage regulation} = \frac{No-load\ volatge - Full-load\ voltage}{Full-load\ voltage} \times 100$$

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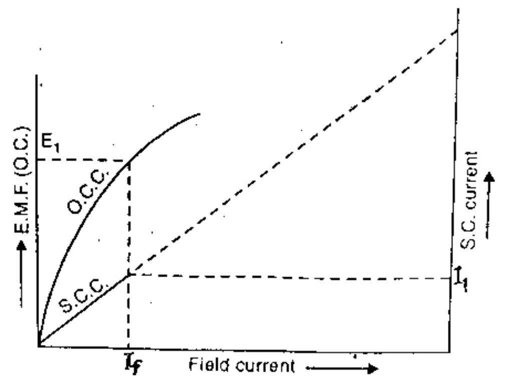
OR

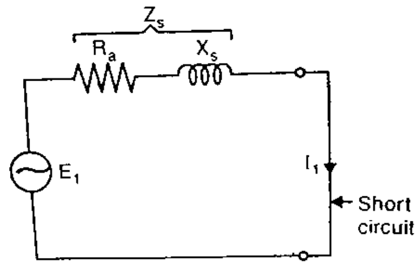
$$\% \text{ Voltage regulation} = \frac{No-load\ volatge - Full-load\ voltage}{No-load\ voltage} \times 100$$

Voltage Regulation of 3-phase Alternator by Synchronous Impedance Method:

1) Plot the OCC and SCC on the same field current base as shown in following figure:



2) Consider field current I_f. The open circuit voltage corresponding to this field current is E_1.The short circuit armature current corresponding to field current I_f is I_1.On the short circuit, voltage E_1 is being used to circulate short circuit armature current I_1 against the synchronous impedance Zs. This is illustrated in following figure:



1 Mark for each point

= 5 Marks

Now $E_1 = I_1 Z_S$

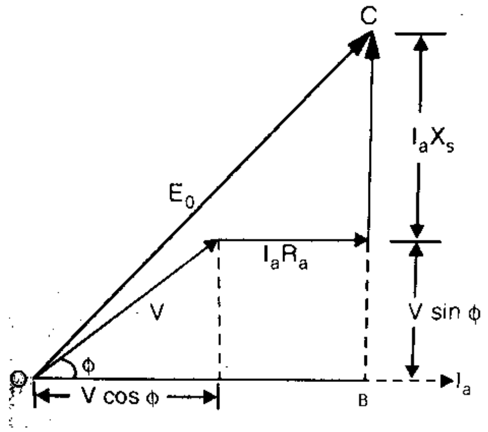
$$Zs = \frac{E_{1\ per\ phase(open\ circuit)}}{I_{1\ per\ phase(short\ circuit)}}$$

3) By performing resistance test the effective armature resistance R_a can be calculated.

4) The synchronous reactance can be calculated as

$$X_S = \sqrt{\left(Z_S^2 - {R_a}^2\right)}$$

5) Once we know Ra and Xs the phasor diagram can be drawn for any load and any p.f. Following figure shows the phasor diagram for usual case of inductive load. Here current Ia has been taken as reference phasor.



The E_0 can be found out as: $E_0 = \sqrt{(OB^2 + BC^2)}$

But, OB = $Vcos\emptyset + I_a R_a$ and BC = $Vsin\emptyset + I_a X_s$

$$E_0 = \sqrt{[(Vcos\emptyset + I_aR_a)^2 + (Vsin\emptyset + I_aX_s)^2]}$$

$$\%\ \text{Voltage Regulation} = \frac{E_0 - V}{V} \times 100$$

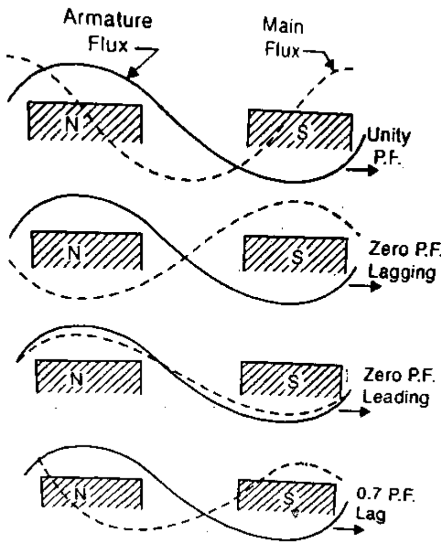
5 c) State the modification to be done in dc series motor to work satisfactorily as ac series motor. State applications of ac series motor.

Ans:

Modifications are necessary in a dc series motor so that it operates satisfactorily

1 Mark for

	on ac supply. The modifications are as follows: 1) AC series motor is built with a few field turns as possible in order to reduce series field impedance. 2) A.C series motor is provided with a large number of poles with less flux per pole. 3) The motor is provided with large number of armature conductors to compensate the reduced field and to develop the required torque. 4) The air gap is made very small because of weak field. 5) All parts of the magnetic circuit of an a.c series motor must be laminated to reduce the eddy current losses. 6) A.C series motors are designed to operate on low frequency, low voltage supply. 7) The armature coils are single turn coils and brushes of less width are used. 8) The compensating winding is provided in the pole faces of an a.c series motor to neutralize the armature reaction effect. 9) The motor is suitable for low voltage. It requires transformer to operate it. 10) Inter poles are provided for good commutation, high efficiency and high output. 11) Use of high resistance carbon brushes are made. 12) Width of brushes is kept small to avoid sparking.	each of any three points = 3 Marks
	Application of A.C Series Motor: 1) Electric traction 2) Stone crushing machine 3) Washing machine 4) Mixers and grinders 5) High speed vacuum cleaners 6) Sewing machines 7) Food processors 8) Drilling machine	1 Mark for each of any three applications = 3 Marks
6	**Attempt any TWO of the following.**	**12**
a)	Define armature reaction in an alternator. Explain the effect of armature reaction at various P.F. of loads of alternator. **Ans:** **Armature Reaction:** The effect of armature flux on main flux is called as armature reaction.	1 Mark
	Armature Reaction at Various Power Factors: When armature is loaded, the armature flux modifies the air gap flux & its angle (electrical) with respect to main flux depends on the load power factor. This is illustrated in waveform diagram as shown below :	



2 Marks for diagram

a) When the load p.f. is unity, the effect of armature reaction is wholly distorting. In other words, flux in air gap is distorted but not weakened. As shown in figure, at unity p.f., armature flux is 90° electrically behind the main flux. The result is that the total flux is strengthened at trailing pole tips and weakened at leading pole tips. However the average flux in the air gap practically remains unaltered.

b) When the load p.f. is zero lagging, the effect of armature reaction is wholly demagnetizing. In other words the flux in air gap is weakened. As shown in figure, at zero p.f. lagging, the armature flux and main flux are in direct opposition with each other resulting in considerably reduction in air gap flux and hence generated emf.

c) When the load p.f. is zero leading, the effect of armature reaction is wholly magnetizing. In other words the flux in air gap is increased. As shown in figure at zero p.f. leading the armature flux and main flux are in phase with each other resulting in considerably increased in air gap flux.

d) For intermediate values of load p.f. the effect of armature reaction is partly distorting and partly weakening for inductive loads which is shown in figure for 0.7 lagging p.f. For capacitive loads the effect of flux is partly distorting and partly strengthening.

3 Marks for explanation

OR Equivalent Diagrams & Explanation

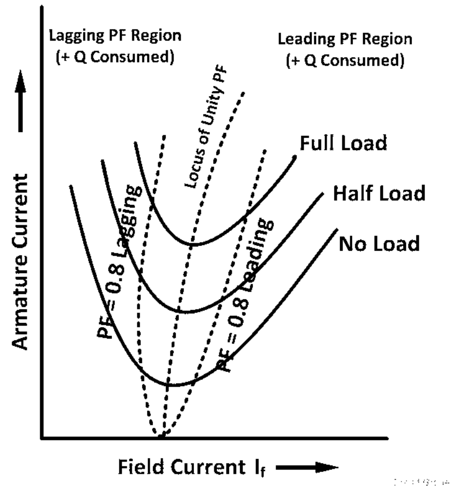
b) Draw and explain ‘V’ and ‘inverted V curves’ for synchronous motor.

Ans:

‘V curves’ and ‘inverted V curves’ for Synchronous Motor:

V curve:

V curve is a plot of the stator current versus field current for different constant loads. The graph is plotted between the armature current I_a and field current I_f at no load. This curve is known as V curve because the shape of this curve is similar to the letter “V”. For higher values of field current the power factor is leading whereas for lower values of field current the power factor is lagging. Similar curves are plotted for various constant loading conditions. When such number of V-curves are plotted, the unity power factor line is locus of minimum armature current. The family of curves for different loads are as shown below:

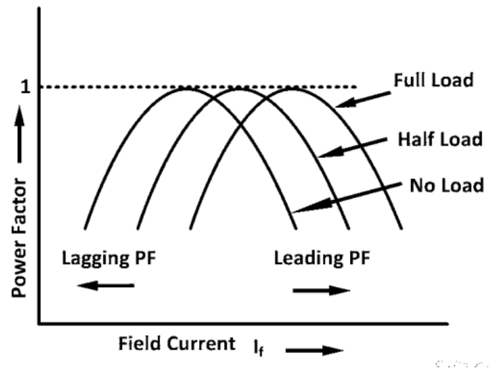


3 Marks for diagram and explanation of V curves

Inverted V Curve:

When the power factor is plotted against field current for any constant load, the shape of the graph looks like an inverted V. Such curves obtained by plotting p.f. against field current at various constant load conditions, are called Inverted V-curves of synchronous motor. The highest point on each of these curves indicates unity power factor.

3 Marks for diagram and explanation of inverted V curves



c) List different starting methods of three phase synchronous motor. Explain any one of them.

Ans:

Different Starting Methods of Three Phase Synchronous Motor:

As synchronous motor is not self starting, different methods of starting are as follows:

1) By using an Induction (Pony) motor
2) By using a DC Machine / Source
3) By using Damper windings

1 Mark for each = 3 Marks

1) By using an Induction (Pony) motor:

A small induction motor (pony motor) is directly coupled with the synchronous motor. The number of poles of the induction motor should be less than the synchronous motor. First supply is given to the pony motor, when it rotates the rotor of the synchronous motor near to the synchronous speed, the main switch and DC switch of synchronous motor are closed. The rotor poles of synchronous motor are pulled into synchronism. After that, supply to the pony motor is disconnected and it can be de-coupled from the synchronous motor shaft.

2) By using a DC Machine / Source:

A DC machine is coupled to the synchronous motor. The DC machine works like a DC motor initially and brings the synchronous motor near to synchronous speed. The main switch and DC switch of synchronous motor are closed. The rotor poles of synchronous motor are pulled into synchronism. Once it is achieved, the DC machine can be operated like a DC generator and DC power generated can be supplied to the rotor of the synchronous motor.

3 Marks for any one methods

3) By using Damper Windings:

In this method, the motor is first started as an induction motor and then starts running as a synchronous motor after achieving synchronous speed. For this, damper windings are used. Damper windings are additional windings consisting of copper bars placed in the slots in the pole faces. The ends of the copper bars are short-circuited. These windings behave as the rotor of an induction motor. When 3 phase power is supplied to the motor, the motor starts running as an induction motor at a speed below synchronous speed. After some time DC supply is given to the field winding. The rotor gets pulled into synchronism and starts running at constant speed as a synchronous motor.