Benha University
Faculty of Engineering–Benha

Department : Electrical Engineering	**Date : Wednesday 9-6-2021**
3rd year : Power and Control	**Time : 3.0 hrs.**
Exam : Final Solution	**Code : E1338**
Subject : Electrical Machines II	**Examiner: Dr. Abdelnasser Nafeh**

Answer the Following Questions

Question 1: [20 Marks]

1. A 6-pole, 230-V, 60-Hz, Y-connected, three-phase induction motor has the following parameters on a per-phase basis: $R_1 = 0.5\text{-}\Omega$, $R_2 = 0.25\text{-}\Omega$, $X_1 = 0.75\text{-}\Omega$, $X_2 = 0.5\text{-}\Omega$, $X_M = 100\text{-}\Omega$, and R_{fe}, $= 500\text{-}\Omega$. The friction and windage loss are 150-W. **Determine** the efficiency and shaft torque of the motor at its rated slip of 2.5%.

2. A 10-hp, 4-pole, 25-Hz, three-phase, wound rotor induction motor is taking 9100 W from the line. Core loss is 290 W, stator copper loss is 568 W, rotor copper loss in 445 W, friction and windage losses are 100 W. ***Determine*** **(a)** power transferred across air gap; **(b)** mechanical power in watt developed by rotor; **(c)** mechanical power output in watt; **(d)** efficiency; **(e)** slip.

Question 2: [20 Marks]

3. The following data were obtained from no-load, and DC tests of a three phase, wye-connected, 40-hp, 60-Hz, 460-V, design **B** induction motor whose full load current is 57.8-A. the blocked rotor test was made at 15-Hz.

Blocked Rotor Test	No-Load Test	DC-Test
$V_L = 36.2$ V	$V_L = 460$ V	$V_{DC} = 12$ V
$I_L = 58$ A	$I_L = 32.7$ A	$I_{DC} = 59$ A
$P_{3\text{-Phase}} = 2573.4$ W	$P_{3\text{-Phase}} = 4664.4$ W	

Determine (a) the machine parameters in ohms/phase, and the combined core, friction, and windage loss.

(b) Express the no-load current as a percent of rated current.

4. The rotor of a 3-phase, 60-Hz, 4-pole induction motor takes 120 kW at 3 Hz. **Determine (a)** the rotor speed and **(b)** the rotor copper losses. **(c)** If this motor has a stator copper loss of 3 kW, a mechanical loss of 2 kW, and a stator core loss of 1.7 kW. **Calculate** the motor output at the shaft and the efficiency. Neglect rotor core loss.

Question 3: [20 Marks]

5. A 100-hp, three-phase, wye-connected, 60-Hz, 460-V, four-pole, cylindrical-rotor synchronous motor is operating at rated conditions and 80 percent power-factor leading. The efficiency, excluding field and stator losses, is 96 percent, and the synchronous reactance is 2.72 Ω/phase. ***Determine*** **(a)** developed torque; **(b)** armature current; **(c)** excitation voltage; **(d)** power angle; **(e)** maximum torque.

6. A 400-V, 10 hp (7.46 kW), 3-phase synchronous motor has negligible armature resistance and a synchronous reactance of 10 Ω/phase. ***Determine*** the minimum current and the corresponding induced emf for full-load conditions. Assume an efficiency of 85%.

***Question 4*: [20 Marks] ……. Short Answer Required.**

1. How does the name of an induction motors is derived?
2. Classify 3-phase induction motors on the basis of their construction. Which one is generally preferred and why?
3. Usually, semi-closed slots are preferred is small motors, why?
4. Why the rotor slots of an induction motor are skewed?
5. Why the rotor conductors of the squirrel cage rotor are short-circuited in the case of slip-ring induction motors, the rotor circuit is closed through resistors?
6. What is slip in an induction motor?
7. What is the value of slip at start in an induction motor?
8. If the full load speed of a 3-phase, 50 Hz induction motor is 1460 rpm, what will be its synchronous speed?
9. How does the supply voltage affect the torque developed by an induction motor?
10. What is the effect on the slip when the load on an induction motor increases?
11. Why the rotor conductors are placed at the outermost periphery of the rotor?
12. Why the synchronous motor is not self-starting? Or why can't a synchronous motor start by itself?
13. What is the speed regulation of a synchronous motor?
14. What is pull-out torque?
15. Why a synchronous motor runs only at synchronous speed?
16. Compare between three-phase induction motors and synchronous motors.
17. How a synchronous motor can be used as a synchronous condenser?
18. Why dampers are used in a synchronous motor?
19. How is a synchronous motor started? Or how a synchronous motor is made self-starting?
20. Define the term over-excitation and under-excitation with reference to synchronous machines.

Question 5*: [10 Marks] ……*Chose the correct answer, and please, Draw Answer Table only for this Part.

[1] A synchronous machine is called as doubly excited machine because
A. It can be over excited ***B***. It has two sets of rotor poles ***C***. Both its rotor and stator are excited ***D***. It needs twice the normal exciting current

[2] If the field of a synchronous motor is under excited, the power factor will be
A. Lagging ***B.*** Leading ***C.*** Unity ***D.*** More than unity

[3] A synchronous motor connected to infinite bus-bars has at constant full-load, 100 % excitation and unity pf. On changing the excitation only, the armature current will have
A. Leading pf with under-excitation ***B.*** Leading pf with over excitation ***C.*** Lagging pf with over excitation ***D.*** No change of pf

[4] The maximum value of torque angle in a synchronous motor is.......degrees electrical
A. 45 ***B.*** 90 ***C.*** Between 45 and 90 ***D.*** Below 60.

[5] The angle between the synchronous rotating stator flux and rotor poles of a synchronous motor is
A. Synchronizing angle ***B.*** Torque angle ***C.*** Power factor angle ***D.*** Slip angle

[6] In a synchronous machine when the rotor speed becomes more than the synchronous speed during hunting, the damping bars develop
A. Synchronous motor torque ***B.*** DC motor torque ***C.*** Induction motor torque ***D.*** Induction generator torque

[7] When load on a synchronous motor is increased its armature current is increased provided it is
A. Normally excited ***B.*** Over excited ***C.*** Under-excited ***D.*** All of the above

[8] Which of the following statements about a three-phase induction motor are false?
(A) The speed of rotation of the magnetic field is called the synchronous speed (B) A three-phase supply connected to the rotor produces a rotating magnetic field (C) The rotating magnetic field has a constant speed and constant magnitude (D) It is essentially a constant speed type machine
(1) C only ***(2)*** B only ***(3)*** A only ***(4)*** All of the above ***(5)*** A and C only.

[9] Which of the following statements is false when referring to a three-phase induction motor?
(A) The synchronous speed is half the supply frequency when it has four poles (B) In a 2-pole machine, the synchronous speed is equal to the supply frequency (C) If the number of poles is increased, the synchronous speed is reduced (D) The synchronous speed is inversely proportional to the number of poles
(1) All of the above ***(2)*** D only ***(3)*** B only ***(4)*** None of the above ***(5)*** A and C only.

[10] In a three-phase induction motor. Which of the following statements are false?
(A) If the rotor is running at synchronous speed, there is no torque on the rotor (B) If the number of poles on the stator is doubled, the synchronous speed is halved (C) At no-load, the rotor speed is very nearly equal to the synchronous speed (D) The direction of rotation of the rotor is opposite to the direction of rotation of the magnetic field to give maximum current induced in the rotor bars.
(1) A, B, C ***(2)*** C only ***(3)*** B only ***(4)*** A and C only ***(5)*** D only.

Best wishes,

***Question 1*: [20 Marks]**

1. A 6-pole, 230-V, 60-Hz, Y-connected, three-phase induction motor has the following parameters on a per-phase basis: R_1 = 0.5-Ω, R_2 = 0.25-Ω, X_1 = 0.75-Ω, X_2 = 0.5-Ω, X_M = 100-Ω, and R_{fe}, = 500-Ω. The friction and windage loss is 150-W. **Determine** the efficiency and shaft torque of the motor at its rated slip of 2.5%.

● SOLUTION

The synchronous speed of the motor is

$$N_s = \frac{(120 \times 60)}{6} = 1200 \text{ rpm} \quad \text{or} \quad \omega_s = 125.66 \text{ rad/s}$$

The per-phase applied voltage is

$$V_1 = \frac{230}{\sqrt{3}} = 132.791 \text{ V}$$

The effective rotor impedance as referred to the stator is

$$\hat{Z}_2 = \frac{R_2}{s} + jX_2 = \frac{0.25}{0.025} + j0.5 = 10 + j0.5 \ \Omega$$

The stator winding impedance is

$$\hat{Z}_1 = R_1 + jX_1 = 0.5 + j0.75 \ \Omega$$

Since R_c, jX_m, and $\hat{Z}_2$ are in parallel, we can compute the equivalent impedance $\hat{Z}_e$ as

$$\frac{1}{\hat{Z}_e} = \frac{1}{500} + \frac{1}{j100} + \frac{1}{10 + j0.5}$$
$$= 0.102 - j0.015 \text{ S}$$

or

$$\hat{Z}_e = 9.619 + j1.417 \ \Omega$$

Hence, the total input impedance is

$$\hat{Z}_{in} = \hat{Z}_1 + \hat{Z}_e = 10.119 + j2.167 \ \Omega$$

The stator current: $\tilde{I}_1 = \frac{\tilde{V}_1}{\hat{Z}_{in}} = 12.832\angle -12.09° \text{ A}$

The power factor: pf = cos (12.09°) = 0.978 lagging

Power input: $P_{in} = 3V_1I_1 \cos\theta = 4998.54$ W

Stator copper loss: $P_{scl} = 3I_1^2R_1 = 246.99$ W

$$\hat{E}_1 = \tilde{V}_1 - \tilde{I}_1\hat{Z}_1 = 124.763\angle -3.71° \text{ V}$$

Core-loss current: $\tilde{I}_c = \frac{\tilde{E}_1}{R_c} = 0.25\angle -3.71°$ A

Magnetization current: $\tilde{I}_m = \frac{\tilde{E}_1}{jX_m} = 1.248\angle -93.71°$ A

Excitation current: $\tilde{I}_\phi = \tilde{I}_c + \tilde{I}_m = 1.273\angle -82.38°$ A

Hence, the rotor current: $\tilde{I}_2 = \tilde{I}_1 - \tilde{I}_\phi = 12.461\angle -6.59°$ A

Core loss: $P_m = 3I_c^2 R_c = 93.75$ W

Air-gap power: $P_{ag} = P_{in} - P_{sc\ell} - P_m = 4657.8$ W

Rotor copper loss: $P_{rc\ell} = 3I_2^2 R_2 = 116.46$ W

Power developed: $P_d = P_{ag} - P_{rc\ell} = 4541.34$ W

Power output: $P_o = P_d - 150 = 4391.34$ W

Efficiency: $\eta = \frac{P_o}{P_{in}} = 0.879$ or 87.9%

Shaft torque: $T_s = \frac{P_o}{\omega_m} = \frac{P_o}{(1 - s)\omega_s}$

$$= \frac{4391.34}{(1 - 0.025) \times 125.66} = 35.84 \text{ N·m}$$

2.

A 10 H.P., 4 pole, 25 Hz, 3-phase, wound rotor induction motor is taking 9100 watt from the line. Core loss is 290 watt, stator copper loss is 568 watt, rotor copper loss in 445 watt, friction and windage losses are 100 watt. Determine; (a) power transferred across air gap; (b) mechanical power in watt developed by rotor; (c) mechanical power output in watt; (d) efficiency; (e) slip.

Solution:

Power input to motor or stator = 9100 watt

Power transferred across air gap = Stator input – Stator core loss – Stator copper loss

= 9100 – 290 – 568 = **8242 W** (*Ans*)

Mechanical power developed in rotor = rotor input – Rotor copper loss = 8242 – 445 = **7797**

Rotor output = Mechanical power developed – Mechanical loss

= 7797 – 100 = **7697 W** (*Ans.*)

Motor efficiency = $\frac{\text{Output}}{\text{input}} \times 100 = \frac{7697}{9100} \times 100 =$ **84·58 %** (*Ans*)

Slip, $S = \frac{\text{Rotor copper loss}}{\text{Rotor input}} = \frac{445}{8242} =$ **0·05399** (*Ans*)

Question 2: [20 Marks]

3.

The following data were obtained from no-load, blocked-rotor, and DC tests of a three-phase, wye-connected, 40-hp, 60-Hz, 460-V, design B induction motor whose rated current is 57.8 A. The blocked-rotor test was made at 15 Hz.

Blocked Rotor	No-Load	DC
$V_{line} = 36.2$ V	$V_{line} = 460.0$ V	$V_{DC} = 12.0$ V
$I_{line} = 58.0$ A	$I_{line} = 32.7$ A	$I_{DC} = 59.0$ A
$P_{3\ phase} = 2573.4$ W	$P_{3\ phase} = 4664.4$ W	

(a) Determine R_1, X_1, R_2, X_2, X_M, and the combined core, friction, and windage loss.

(b) Express the no-load current as a percent of rated current.

Solution

(a) Converting the AC test data to corresponding phase values for a wye-connected motor,

$$P_{BR,15} = \frac{2573.4}{3} = 857.80 \text{ W}$$
$$V_{BR,15} = \frac{36.2}{\sqrt{3}} = 20.90 \text{ V}$$
$$I_{BR,15} = 58.0 \text{ A}$$
$$P_{NL} = \frac{4664.4}{3} = 1554.80 \text{ W}$$
$$V_{NL} = \frac{460}{\sqrt{3}} = 265.581 \text{ V}$$
$$I_{NL} = 32.7 \text{ A}$$

Determination of R_1:

$$R_{DC} = \frac{V_{DC}}{I_{DC}} = \frac{12.0}{59.0} = 0.2034\ \Omega$$
$$R_{1,wye} = \frac{R_{DC}}{2} = \frac{0.2034}{2} = \underline{0.102\ \Omega/\text{phase}}$$

Determination of R_2:

$$Z_{BR,15} = \frac{V_{BR,15}}{I_{BR,15}} = \frac{20.90}{58.0} = 0.3603\ \Omega$$
$$R_{BR,15} = \frac{P_{BR,15}}{I^2_{BR,15}} = \frac{857.8}{(58)^2} = 0.2550\ \Omega/\text{phase}$$
$$R_2 = R_{BR,15} - R_{1,wye} = 0.2550 - 0.102 = \underline{0.153\ \Omega/\text{phase}}$$

Determination of X_1 and X_2:

$$X_{BR,15} = \sqrt{Z^2_{BR,15} - R^2_{BR,15}} = \sqrt{(0.3603)^2 - (0.255)^2} = 0.2545\ \Omega$$
$$X_{BR,60} = \frac{60}{15} X_{BR,15} = \frac{60}{15}(0.2545) = 1.0182\ \Omega$$

From Table 5.10, for a design B machine,

$$X_1 = 0.4X_{BR,60} = 0.4(1.0182) = \underline{0.4073\ \Omega/\text{phase}}$$
$$X_2 = 0.6X_{BR,60} = 0.6(1.0182) = \underline{0.6109\ \Omega/\text{phase}}$$

Determination of X_M:

$$S_{NL} = V_{NL}I_{NL} = 265.581(32.7) = 8684.50 \text{ VA}$$
$$Q_{NL} = \sqrt{S^2_{NL} - P^2_{NL}} = \sqrt{(8684.50)^2 - (1554.8)^2} = 8544.19 \text{ var}$$
$$X_{NL} = \frac{Q_{NL}}{I^2_{NL}} = \frac{8544.19}{(32.7)^2} = 7.99\ \Omega$$
$$X_{NL} = X_1 + X_M \quad \Rightarrow \quad 7.99 = 0.4073 + X_M$$
$$X_M = \underline{7.58\ \Omega/\text{phase}}$$

Determination of combined friction, windage, and core loss:

$$P_{NL} = I^2_{NL}R_{1,wye} + P_{core} + P_{f,w}$$
$$1554.8 = (32.7)^2(0.102) + P_{core} + P_{f,w}$$
$$P_{core} + P_{f,w} = \underline{1446 \text{ W/phase}}$$

(b)

$$\%I_{NL} = \frac{I_{NL}}{I_{rated}} \times 100 = \frac{32.7}{57.8} = \underline{56.6\%}$$

Note: The no-load current (exciting current) of a three-phase induction motor is large, generally 40% or higher in terms of rated current.

4. The rotor of a 3-phase, 60-Hz, 4-pole induction motor takes 120 kW at 3 Hz. **Determine (a)** the rotor speed and **(b)** the rotor copper losses. **(c)** If this motor has a stator copper loss of 3 kW, a mechanical loss of 2 kW, and a stator core loss of 1.7 kW. **Calculate** the motor output at the shaft and the efficiency. Neglect rotor core loss.

The rotor of a 3-phase, 60-Hz, 4-pole induction motor takes 120 kW at 3 Hz. Determine (*a*) the rotor speed and (*b*) the rotor copper losses.

(*a*) $$s = \frac{f_2}{f_1} = \frac{3}{60} + 0.05 \qquad n_s = \frac{120 f_1}{p} = \frac{120(60)}{4} = 1800 \text{ rpm}$$

$$n = (1 - s)n_s = (1 - 0.05)(1800) = 1710 \text{ rpm}$$

(*b*) By (*5.15*),

$$\text{rotor copper loss} = s \times (\text{rotor input}) = (0.05)(120) = 6 \text{ kW}$$

The motor of Problem 5.8 has a stator copper loss of 3 kW, a mechanical loss of 2 kW, and a stator core loss of 1.7 kW. Calculate (*a*) the motor output at the shaft and (*b*) the efficiency. Neglect rotor core loss.

From Problem 5.8, the rotor input is 120 kW and the rotor copper loss is 6 kW.

(*a*) $$\text{motor output} = 120 - 6 - 2 = 112 \text{ kW}$$

(*b*) $$\text{motor input} = 120 + 3 + 1.7 = 124.7 \text{ kW}$$

$$\text{efficiency} = \frac{\text{output}}{\text{input}} = \frac{112}{124.7} = 89.8\%$$

<u>Question 3</u>: [20 Marks]

5.

A 100-hp, three-phase, wye-connected, 60-Hz, 460-V, four-pole, cylindrical-rotor synchronous motor is operating at rated conditions and 80 percent power-factor leading. The efficiency, excluding field and stator losses, is 96 percent, and the synchronous reactance is 2.72 Ω/phase. Determine (a) developed torque; (b) armature current; (c) excitation voltage; (d) power angle; (e) maximum torque (also called pull-out torque).

Solution

(a) $$n_s = \frac{120f}{P} = \frac{120 \times 60}{4} = 1800 \text{ r/min}$$

$$P_{mech} = \frac{Tn}{5252} = \quad \Rightarrow \quad T_{dev} = \frac{5252 \cdot P_{mech}}{n}$$

$$T_{dev} = \frac{5252 \times 100/0.96}{1800} = \underline{304 \text{ lb-ft}}$$

(b) $$S = \frac{P_{shaft} \times 746}{\eta \times F_P} = \frac{100 \times 746}{0.96 \times 0.80} = 97{,}135 \text{ VA}$$

The power-factor angle is negative for a leading power factor.[5]

$$\theta = -\cos^{-1}0.80 = -36.87°$$

$$V_{1\phi} = \frac{460}{\sqrt{3}} = 265.581 \text{ V}$$

$$\mathbf{S}_{1\phi} = \mathbf{V}_T\mathbf{I}_a^* \quad \Rightarrow \quad \frac{97{,}135}{3}\angle -36.87° = 265.581\angle 0° \times \mathbf{I}_a^*$$

$$\mathbf{I}_a^* = 121.92\angle -36.87° \quad \Rightarrow \quad \underline{\mathbf{I}_a = 121.92\angle 36.87° \text{ A}}$$

(c) $$\mathbf{E}_f = \mathbf{V}_T - \mathbf{I}_a jX_s = 265.581\angle 0° - (121.92\angle 36.87°)(2.72\angle 90°)$$

$$\mathbf{E}_f = 265.58 - 331.62\angle 126.87°$$

$$\mathbf{E}_f = 534.96\angle -29.73° \quad \Rightarrow \quad \underline{535\angle -29.7° \text{ V}}$$

(d) $$\delta = \underline{-29.7°}$$

(e) Pull-out torque occurs at $\delta = -90°$.

$$P_{in} = 3 \cdot \frac{-V_T E_f}{X_s} \cdot \sin\delta = 3 \cdot \frac{-265.581 \times 534.96}{2.72} \cdot \sin(-90°)$$

$$P_{in} = 156{,}700 \text{ W}$$

$$P = \frac{Tn}{5252} \quad \Rightarrow \quad T_{pull\text{-}out} = \frac{5252 \cdot P}{n}$$

$$T_{pull\text{-}out} = \frac{5252 \times 156{,}700}{746 \times 1800} = \underline{613 \text{ lb-ft}}$$

6.

A 400-V, 10 h.p. (7.46 kW), 3-phase synchronous motor has negligible armature resistance and a synchronous reactance of 10 Ω/phase. ***Determine*** the minimum current and the corresponding induced e.m.f. for full-load conditions. Assume an efficiency of 85%.

Solution. The current is minimum when the power factor is unity *i.e.*, when cos ϕ = 1. The vector diagram is as shown in Fig. 38.42.

Motor input = 7460 / 0.85 = 8,775 W

Motor line current = $8{,}775 / \sqrt{3} \times 400 \times 1$ = **12.67 A**

Impedance drop = $I_a X_S = 10 \times 12.67 = 126.7$ V

Voltage / phase = $400 / \sqrt{3}$ = 231 V

$E_b = \sqrt{231^2 + 126.7^2}$ = **263.4 V**

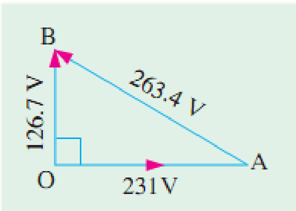

Fig. 38.42

<u>Question 4</u>: [20 Marks]

<u>(see text book and lecture notes)</u>

Q.1. How does the name of an induction motors is derived? **(PTU)**

Ans. The name of an induction motor is derived from the fact that it work on the basic principle of mutual induction. The current in the rotor conductions is induced by the motion of rotor conductor relative to the magnetic field produced by the stator currents.

Q.2. Classify 3-phase induction motors on the basis of their construction. Which one is generally preferred and why?

Ans. Three-phase induction motors may be classified as (*i*) squirrel cage induction motors and (*ii*) phase wound or slip-ring induction motor.

Squirrel cage induction motor is generally preferred due to its low construction cost, low maintenance, high pf, high efficiency, robust construction etc.

Q.3. Usually semi-closed slots are preferred is small motors, why?

Ans. In case of semi-closed slots, the reluctance becomes more uniform and improves the power factor of the motor.

Q.4. Why the rotor slots of an induction motor are skewed?

Ans. The rotor slots of an induction motor are skewed to reduce humming noise and ensuring quiet running, reduce magnetic locking and for smooth and uniform torque.

Q.5. Why the rotor conductors of the squirrel cage rotor are short-circuited in the case of slip-ring induction motors, the rotor circuit is closed through resistors?

Ans. In induction motors, torque develops by the interaction of stator and rotor fields. The rotor field is developed only if current flows through the rotor conductors which is only possible if rotor circuit is closed or short-circuited.

Q.6. What is slip in an induction motor?

Ans. The difference between the synchronous speed of stator revolving field and the rotor speed expressed as a fraction of synchronous speed is known as a slip in an induction motor.

Q.7. What is the value of slip at start in an induction motor?

Ans. 1

Q.8. If the full load speed of a 3-phase, 50 Hz induction motor is 1460 rpm, what will be its synchronous speed?

Ans. 1500 rpm.

Q.5. How does the supply voltage affect the torque developed by an induction motor?

Ans. $T \alpha V^2$ i.e., torque developed varies as the square of the supply voltage.

Q.6. What is the effect on the slip when the load on an induction motor increases?

Ans. When load increases, slip also increases.

Q.7. Why the rotor conductors are placed at the outermost periphery of the rotor?

Ans. This arrangement minimise the rotor reactance X_{2s} and increases the maximum torque produced by the motor, because T $\alpha \frac{1}{X_{2s}}$

Q.1. Why the synchronous motor is not self-starting?

Or

Why can't a synchronous motor start by itself?

Ans. When 3-phase supply is given to the stator of a 3-phase wound synchronous motor, a revolving field is set-up in the stator. Simultaneously, DC supply is given to the rotor which excites the poles. The stator revolving field tries to drag the rotor poles (or field) along with it but fails to do so due to rotor inertia.

Thus, a synchronous motor is not self-starting or in other words, a synchronous motor can't start by itself.

Q.2. What is the speed regulation of a synchronous motor?

Ans. Speed regulation of a synchronous motor is zero, because

$$\text{Speed regulation} = \frac{\text{No load speed-full load speed}}{\text{No-load speed}} = \frac{N_s - N_s}{N_s} = \text{zero}$$

Q.3. What is pull-out torque?

Ans. ***Pull-out* torque:** The maximum value to torque which a synchronous motor can develop at rated voltage and frequency without losing synchronism is called pull-out torque.

Q.4. Why a synchronous motor runs only at synchronous speed?

Ans. Synchronous motor can run only at synchronous speed because rotor poles are magnetically locked with the stator revolving field and the these rotor poles are dragged by the stator revolving field.

8.19 Comparison between Three-phase Synchronous and Induction Motors

Se. No.	Particulars	Synchronous motor	Induction motor
1.	Magnetic excitation	A synchronous motor is a doubly *excited* machine. Its armature winding is energised from an AC source, whereas, its field winding is excited from a DC source	An induction motor is a *singly-excited* machine. Its stator winding is energised from an AC source and rotor is excited due to induction.
2.	Speed	It always runs at *synchronous speed* and its speed is independent of load.	Its speed falls with the increase in load and is always *less than the synchronous speed.*
3.	Starting	It is *not self-starting*. It has to be run upto synchronous speed by some means before it can be synchronised to AC supply.	An induction motor has got *self-starting* torque.
4.	Power factor	A synchronous motor can be operated under *wide range of power factors, both lagging and leading* by changing its excitation.	An induction motor operates at only *lagging power factor,* which becomes very poor at light loads.
5.	Major application	It is usually used for *power factor correction* in addition to supplying torque to drive mechanical loads.	An induction motor is used for *driving mechanical loads* only.
6.	Efficiency	It is *more efficient* than induction motor of the same output and voltage rating.	Its *efficiency is lesser* than that of a synchronous motor of the same output and voltage rating.
7.	Cost	A synchronous motor is *costlier* than an induction motor of the same output and voltage rating.	The cost of an induction motor is *less* than a synchronous motor of the same output and voltage rating.

Q.2. How a synchronous motor can be used as a synchronous condenser?

Ans. An over-excited synchronous motor draws power at leading power factor, under this condition it can be used as a synchronous condenser.

Q.3. Why dampers are used in a synchronous motor?

Ans. In synchronous motors, dampers are used to suppress the oscillations of the rotor around its find position.

Q.4. How is a synchronous motor started.

Or

How a synchronous motor is made self-starting?

Ans. A synchronous motor is not self-starting. It can be started by using either of the following methods:

1. *By using an auxiliary motor:* This motor is coupled to the shaft of main motor and rotates it almost at synchronous speed. Then DC excitation is given to rotor poles of the main motor which are magnetically locked with the stator revolving field and motor starts rotating at synchronous speed.

2. *By using damper winding*: Due to damper winding the synchronous motor stars rotating as a squirrel cage induction motor. Once, it picks-up speed near to synchronous speed, DC excitation is given to the rotor poles. Thus, the rotor poles are magnetically locked with the stator revolving field and the motor starts rotating at synchronous speed.

Q.5. Define the term over-excitation and under-excitation with reference to synchronous machines.

Ans. *Over-excitation:* The excitation (field current) at which a synchronous motor operates at leading power factor is called over-excitation.

Under-excitation: The excitation (field current) at which a synchronous motor operates at lagging power factor is called under-excitation.

Question 5*: [10 Marks] ……. *Chose the correct answer.

[1] A synchronous machine is called as doubly excited machine because A. It can be over excited B. It has two sets of rotor poles C. Both its rotor and stator are excited D. It needs twice the normal exciting current

Ans: C

[2] If the field of a synchronous motor is under excited, the power factor will be
A. Lagging B. Leading C. Unity D. More than unity

Ans: A

[3] A synchronous motor connected to infinite bus-bars has at constant full-load, 100 % excitation and unity pf. On changing the excitation only, the armature current will have A. Leading pf with under-excitation B. Leading pf with over excitation C. Lagging pf with over excitation D. No change of pf

Ans: B

[4] The maximum value of torque angle in a synchronous motor is.......degrees electrical
A. 45 B. 90 C. Between 45 and 90 D. Below 60.

Ans: B

[5] The angle between the synchronous rotating stator flux and rotor poles of a synchronous motor is A. Synchronizing angle B. Torque angle C. Power factor angle D. Slip angle

Ans:B

[6] In a synchronous machine when the rotor speed becomes more than the synchronous speed during hunting, the damping bars develop
A. Synchronous motor torque B. DC motor torque C. Induction motor torque D. Induction generator torque

Ans: D

[7] When load on a synchronous motor is increased its armature current is increased provided it is A. Normally excited B. Over excited C. Under excited D. All of the above

Ans:D

[8] Which of the following statements about a three-phase induction motor are false?
(a) The speed of rotation of the magnetic field is called the synchronous speed (b) A three-phase supply connected to the rotor produces a rotating magnetic field (c) The rotating magnetic field has a constant speed and constant magnitude (d) It is essentially a constant speed type machine
(1) C only (2) B only (3) A only (4) All of the above (5) A and C only.

Ans: 2

[9] Which of the following statements is false when referring to a three-phase induction motor?
(a) The synchronous speed is half the supply frequency when it has four poles (b) In a 2-pole machine, the synchronous speed is equal to the supply frequency (c) If the number of poles is increased, the synchronous speed is reduced (d) The synchronous speed is inversely proportional to the number of poles
(1) All of the above (2) D only (3) B only (4) None of the above (5) A and C only.

Ans: 3

[10] In a three-phase induction motor. Which of the following statements are false?
(a) If the rotor is running at synchronous speed, there is no torque on the rotor (b) If the number of poles on the stator is doubled, the synchronous speed is halved (c) At no-load, the rotor speed is very nearly equal to the synchronous speed (d) The direction of rotation of the rotor is opposite to the direction of rotation of the magnetic field to give maximum current induced in the rotor bars.
(1) A, B , C (2) C only (3) B only (4) A and C only (5) D only.

Ans: 5

1-C	2-A	3-B	4-B	5-B
6-D	7-D	8-2	9-3	10-5

Best wishes,