Ref. No. : Ex/PE/PC/B/T/226/2025

B.E. POWER ENGINEERING SECOND YEAR SECOND SEMESTER - 2025

Subject: ELECTRICAL MOTORS AND DRIVES **Time: 3 hrs** **Full Marks : 100**

Part-I (50 marks)

Use separate answer scripts for each Part

Q1. Answer any three questions: 3×2

(a) What are electrical drives? Draw the block diagram of an electrical drive system.
(b) Explain the reverse braking through the four quadrant operation of a motor driving a hoist load.
(c) What are the functions of the power modulators?
(d) Write down the fundamental torque equation of a motor load system and explain each component of the equation.
(e) Draw the circuit diagram of a DC-DC converter or chopper and write down its one of the functions.

Q2. Answer any three questions 4×3

(a) Derive the voltage phasor equation of salient pole synchronous motor operating at unity power factor. Also draw the corresponding phasor diagram.
(b) Derive the expression of the torque develop in a cylindrical rotor synchronous motor.
(c) Draw the rotor structures of different types of Permanent Magnet Synchronous motor (PMSM) and explain the operations.
(d) How does a Hysteresis synchronous motor work?
(e) What is hunting in synchronous motor operation? Suggest one method to avoid it.

Q3. Answer any two questions: 2×4

(a) How can we change the operation of a synchronous motor from motoring to regenerative braking? Explain with circuit diagram.Is it necessary to maintain the V/f ratio constant upto base speed and V constant above the based speed? If yes, explain why.
(b) What are the two different modes of operation of variable frequency drive (VFD)? Write down atleast three features of each mode. Draw the circuit diagram of a self-controlled synchronous motor drive with load commutated thyristor inverter.
(c) What is Brushless DC motor or trapezoidal PMAC Motor? How does it operate when supplied from a current regulated voltage source inverter (VSI). Draw the corresponding induced voltage, phase current and torque waveforms.
(d) Draw the block diagram of variable frequency control of multiple synchronous motors and explain the corresponding control operation.

Q4. Answer any three questions: 3×8

(a) A three phase star connected 6600 V synchronous motor has the synchronous reactance of 10Ω per phase. For a certain load, the power input is 900 kW and the induced emf is 8900 V. Determine the line current. Neglect resistance.
(b) A 3-phase salient pole synchronous motor has the direct axis synchronous reactance of 0.95 p.u. and a quadrature axis synchronous reactance of 0.6 p.u. Draw the phasor diagram for the motor operating on full load at 0.8 pf leading and calculate the load angle.

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(c) A 400V, 3 phase installation takes a current of 40 A at 0.8pf lagging. A synchronous motor improves the power factor to 0.95 pf lagging. This motor drives a 15 hp load at an efficiency of 85%. Determine (i) the pf of the synchronous motor, (ii) the leading kVAr supplied by the motor and (iii) the kVA rating of the motor.

(d) A 400 V, 6 pole, 3 phase, 50 Hz star connected synchronous motor has resistance and reactance of 0.4Ω and 10Ω respectively. It draws a current of 10 A at unity power factor when operating with a certain field current. Keeping the field current constant, the load torque is increased until the motor draws a current of 40A. Determine the torque developed and new power factor.

(e) A 1 MW, 3 phase, 6.6 kV, 50 Hz, 6 pole, unity power factor star connected synchronous motor has the synchronous reactance of 25 ohm. Its resistance is considered to be negligible. The motor is controlled by a line commutated inverter and load commutated converter in self-controlled mode. The load side commutated converter operates at a fixed firing angle of 0^0 when working as rectifier and 140^0 when working as an inverter. The DC link inductor resistance is 0.2 ohm. The drive operates in self-controlled mode with constant (V/f) ratio. Determine the source side firing angle when the synchronous motor is operating at rated torque and 750 rpm. Also find the same when the motor is regenerating at the rated torque andas 750 rpm.

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Bachelor in Power Engineering 2nd Year 2nd Semester Examination 2025

Sub: ELECTRICAL MOTORS AND DRIVES

Full Marks: 100 **Time: 3 hours**

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PART II (50 Marks)

Q1. Answer **any six** of the following (CO1) (6×1=6)

(a) What is Crawling of Induction Motor?
(b) What are the factors for determination of Motor Ratings?
(c) What is Cumulatively compounded DC motors?
(d) How speed variations can be realized by flux control in DC motor?
(e) Why chopper based DC drives give better performance than rectifier controlled drives?
(f) What is Deep Bar Rotor??
(g) Why MOSFET, IGBT, IGCT, GTO are preferred over thyristor for building chopper?
(h) What are the effects of harmonics in VSI fed induction motor drive?
(i) Where injected emf is provided for speed control of Induction Motor?
(j) What is split phasing for single phase Induction Motor?
(k) Write the relation between torque and current in case of DC motor.

Q2. Answer **any four** of the following (CO2) (4×2=8)

(l) For three phase fully controlled rectifier control how the thyristor is fired? What is the phase difference and what is the gate pulse duration?
(m) What are the different classes of Motor Duty?
(n) Draw the equivalent circuit of a Single Phase Induction Motor?
(o) Explain the torque speed characteristics of 3 Phase IM and show the Induction Generator region
(p) Discuss Speed control driver circuit of 3Phase induction motor by Cycloconverter.
(q) Derive the expression $\mathbf{V_a = 2V_m/\Pi\ Cos\alpha}$ for continuous conduction in case of single phase fully controlled rectifier-based DC separately excited motor.
(r) What are the different methods of starting for a three phase induction motor?
(s) Draw and explain the Dynamic Braking of separately excited DC motor with chopper control

Q3. Answer **any three** of the following: (CO3) (3×4=12)

(a) With a suitable block diagram, explain the closed loop control of current regulated voltage source inverter drive.
(b) Explain the operation of Star Delta Starter in case of 3-phase Induction motor.
(c) Explain in brief with a diagram the dual converter scheme for Multiquadrant Operation of DC Separately Excited motor fed from a fully controlled rectifier.
(d) Draw the drive circuit for regenerative braking control of chopper based separately excited DC motor drive and discuss its operation
(e) Draw the circuit diagrams for no load and block rotor test in case of an 3 Phase induction motor and mention the parameters calculated from each test. How the mechanical load is represented in Equivalent circuit
(f) Draw driver circuit for a Current Source Inverter Based speed Control of 3 phase Induction Motor

Q4. Answer **any three** of the following:(CO4) (3×8=24)

1. A 220V, 1000 rpm and 100A separately excited DC motor has an armature resistance of 0.055Ω. The motor is fed from a chopper which provides both motoring and braking operations. The source has a voltage of 220V. Assuming continuous conduction. Calculate the duty ratio of chopper for motor speed of 900 rpm and braking torque of 1.5times the rated value.
2. A 3-phase, star-connected, 440volts, 50Hz, 6 -pole induction motor has the following per phase constants in ohms referred to stator: r_1=0.20, x_1=0.50, r_2=0.12, x_2=0.55, X_m=30. Stator to rotor effective turns ratio is 2. Determine:
   (a) The slip at which maximum toque occurs, the maximum torque and the corresponding power output;
   (b) The rotor current and the torque at starting;
3. No load and short circuit tests conducted on 3φ, 5 HP, 220 volts, 60 Hz, 1800 rpminduction motor gave the following results. No load test: 220 volts, 4.35 amps, 244 watts Short circuit test: Voltage of 220 volts produces a current of 64.5 Amps; Resistance per phase = 0.545 ohms, Friction, windage and core loss = 213 watts. Obtain the equivalent circuit parameters.
4. A 220 V D.C shunt motor has an armature resistance of 0.5 ohm and a field resistance of 250 ohm. When driving a constant torque load at 600rpm, the motor draws 21 A. What will be the new speed of the motor if an additional 220 ohm resistance is inserted in the field?.
5. A 230 V, 4-pole, 50 Hz split phase induction motor has following impedance at standstill :

   Main Winding : r = 1.8 ohm , x= 4.0 ohm

   Starting Winding : r =2.2 ohm , x = 5.0 ohm

   Determine the value of capacitance to be inserted in series with the starting winding to get (i) maximum starting torque (ii) maximum torque per ampere at starting.
6. A 3-phase, delta-connected, 8 pole, 50Hz, 440V, 900rpm, squirrel-cage induction motor has the following parameters:

   $R_S = 0.25\Omega$, $R_R` = 0.38\Omega$, $X_S = 0.5\Omega$, $X_R` = 1.5\Omega$

The motor is fed from a voltage source inverter with a constant V/f ratio from 0 to 50Hz and constant voltage of 440V above 50Hz frequency.

(i) Determine the breakdown torque for a frequency of 150Hz as a ratio of its value at 50Hz.

(ii) Obtain the torque at the rated motor current and 100Hz as the ratio of rated full-load torque of the motor.

7. A 220V, 900rpm, 175A separately excited dc motor has an armature resistance of 0.08Ω. It is fed from a single phase fully controlled rectifier with an ac source voltage of 220V, 50Hz. If the armature circuit inductance of motor of the drive be 0.9mH, calculate the motor torque for $\alpha = 60^0$ and speed = 400 rpm.

8. A 440 V, 50 Hz, 6-pole, 1400 rpm, Y-connected wound rotor motor has the following parameters:

R_s= 0.58 Ω, R_r'= 0.45 Ω, X_s= X_r'= 1.2 Ω and X_m= 70 Ω

Motor is speed controlled by injecting a voltage into its rotor.

(i) Calculate motor torque for a speed of 1450 rpm when a voltage $20\angle 0°$ (phase is measured with respect to the source voltage) is injected into the rotor. Ignore X_m.

9. An 6 pole, 50 Hz slip ring induction motor runs at a slip of 2.67% on full load. The rotor resistance per phase of the winding is 0.24 ohm. What external resistance per phase must be added in the rotor circuit so that the motor now runs ate a slip of 17.33% such that the torque remains same in both the cases.