B.E. POWER ENGINEERING SECOND YEAR SECOND SEMESTER EXAMINATION 2021-22

Subject : ELECTRICAL MOTORS AND DRIVES

(Ex/PE/PC/B/T/226/2022)

Full Marks : 50

Part-I

Q1. Answer any three questions: 3×2

(a) What are electrical drives? Draw the block diagram of an electrical drive.
(b) Classify power modulators.
(c) Explain the fundamental torque equation of a motor load system,
(d) Explain the reverse motoring and forward braking through the four quadrant operation of a motor driving a hoist load.
(e) Explain the functions of inverters and Cycloconverters

Q2. Answer any four questions 4×3

(a) Discuss the effect of change of excitation on power factor of synchronous motor.
(b) Draw and explain the phasor diagram of synchronous motor operating at lagging power factor.
(c) Develop the torque expression of a cylindrical rotor wound field motor. Also draw its speed torque characteristics when supplied from a fixed frequency.
(d) Explain the operation of a synchronous condenser? Draw the phasor diagram.
(e) What is hunting? How can it be avoided?
(f) Why Permanent Magnet Synchronous Motors (PMSM) are preferred for industrial applications with large duty cycles?
(g) Why a synchronous motor does not have starting torque?

Q3. Answer any two questions: 2×4

(a) What is a Brushless DC or trapezoidal PMAC Motor? Explain its operation when supplied from a current regulated voltage source inverter. Write its torque expression.
(b) How can the dynamic braking be used to stop or decelerate a load driven by a synchronous motor? Draw the dynamic braking equivalent circuit and determine the expression of the braking torque.
(c) Explain the operation of the self-controlled synchronous motor drive with load commutated thyristor inverter for motoring operation.
(d) Enumerate the advantages of Cyclo-converter based self-controlled synchronous motor drives. Write down its applications with examples.

Q4. Answer any three questions: 3×8

(a) A 10MVA 3-phase star connected, 3-phase, 11 kV, 16 pole, 50 Hz, salient pole synchronous motor has $x_d = 6$ ohm and $x_q = 4$ ohm per phase. The motor is working at full load unity power factor and rated voltage. Find current, emf, and power angle. Draw the phasor diagram.
(b) An induction motor takes 2000 kW from a 3 phase 3300 V system at 0.75 pf lagging. Find the rating of a synchronous condenser to raise the power factor to 0.9 lagging. Also find the total kVA supplied at the new power factor.
(c) A 2000 hp, 2300 V, 20 pole, 50 Hz synchronous motor has a reactance of 1.85 ohm per phase. The motor is supplied from a constant voltage system at 2300 V. Its field

excitation is so adjusted that the power factor is unity at rated load. Calculate the maximum torque which the motor can develop. Neglect losses.

(d) A 3.3 kV, 50 Hz star connected synchronous motor has a synchronous impedance of (0.8 + j 55) ohm. It is synchronised with 3.3 kV supply main and draws 750 kW at an excitation of 4.27 kV (line value). Determine the armature current, power factor, power angle and the mechanical torque developed.

(e) A 1000 kW, 3 phase, 6.6 kV, 50 Hz, 6 pole, unity power factor, star connected synchronous motor is controlled by a load commutated inverter and line commutated converter. Load commutated inverter operates at 150° and rectifies at 0°. 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 for (i) the synchronous motor operating with rated current at 750 rpm and (ii) the regenerative braking operation with rated current at 750 rpm. The synchronous motor reactance is 2.5 ohm and its resistance is neglected.

REF: PE/PC/B/T/226/2022

Bachelor in Power Engineering 2nd Year 2nd Semester Examination 2022

Sub: ELECTRICAL MOTORS AND DRIVES

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

PART II

Q1. Answer <u>any six</u> of the following: (6×1=6)

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

Q2. Answer <u>any four</u> of the following: (4×2=8)

(a) What are the different classes of Motor Duty?
(b) Derive the expression for induction motor torque in terms of supply voltage from the equivalent circuit. Assume the parameters and mention them precisely.
(c) Explain the torque speed characteristics and show the Induction generator region
(d) Discuss Speed control of induction motor by Cycloconverter.
(e) Derive the expression $V_a = 2V_m/\Pi \cos\alpha$ for continuous conduction in case of single phase fully controlled rectifier control of dc separately excited motor.
(f) What are the different methods of speed control for a three phase induction motor a?
(g) Draw and explain the dynamic braking of separately excited DC motor with chopper control
(h) For three phase fully controlled rectifier control how the thyristor is fired? What is the phase difference and what is the gate pulse duration?

Q3. Answer <u>any three</u> of the following: (3×4=12)

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

Q4. Answer <u>any three</u> of the following: (3×8=24)

1. A 3-phase, star-connected, 440volts, 50Hz, 4-pole induction motor has the following per phase constants in ohms referred to stator: r_1=0.25, x_1=0.45, r_2=0.12, x_2=0.55, X_m=28. Stator to rotor effective turns ratio is 1.4. 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;
   (c) The external resistance to be inserted in the rotor circuit to produce maximum torque at starting;
   (d) The internal power developed for a slip of 0.05;

(2) A 220V, 900 rpm and 150A separately excited dc motor has an armature resistance of 0.05Ω. 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 800 rpm and braking torque of twice the rated value.

(3) 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?

(4) A 440V, 50Hz, 3-phase star connected squirrel cage induction motor gave the following test results:

No Load Test: 440V, 9A, 560W

Blocked Rotor Test: 110V, 36A, 4820W

The effective stator resistance is 0.75Ω per phase. Calculate the equivalent circuit parameters.

(5) A 4-pole, 50Hz, 3 phase induction motor develops a maximum torque at a speed of 1400 rpm and has per phase rotor resistance of 0.25Ω. Calculate the value of external resistance that must be inserted in series with each rotor phase to produce a starting torque equal to half of maximum torque. Neglect the stator impedance.

(6) A 3-phase, delta-connected, 6 pole, 50Hz, 440V, 925rpm, squirrel-cage induction motor has the following parameters:

$$R_S = 0.2\Omega,\ R_R` = 0.3\Omega,\ X_S = 0.5\Omega,\ X_R` = 1\Omega$$

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 100Hz as a ratio of its value at 50Hz.
(ii) Obtain the torque at the rated motor current and 75Hz as the ratio of rated full-load torque of the motor.

(7) 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.

(8) 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.

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

$$R_s = 0.55\ \Omega,\ R_r' = 0.45\ \Omega,\ X_s = X_r' = 1.2\ \Omega \text{ and } X_m = 60\ \Omega$$

Motor is controlled by injecting a voltage into its rotor.

(i) Calculate motor torque for a speed of 1250 rpm when a voltage $15\angle 0°$ (phase is measured with respect to the source voltage) is injected into the rotor. Ignore X_m.