Electrical Engineering Department
Indian Institute of Technology Delhi

Major Exam. Part-II (08-05-2007)
Time: 90 minutes
Maximum Marks = 70

Name: ..... *Entry No*..... *Group*.....

EEL 203 - Electromechanics

Note:- (i) **Four questions out of Question Numbers 1 to 5 and three questions out of Question Numbers 6 to 9 should be answered.**
(i) **Make proper assumptions incase of insufficient data.**
(ii) **No clarifications on questions except for printing mistakes, if any.**
(iii) **No negative marks.**

1) A permanent magnet dc motor is known to have an armature resistance of 0.93 Ω. When operated at no load from a dc source of 48 V, it is observed to operate at a speed of 2000 rpm and to draw a current of 1.2 A. Find:

(a) The speed-voltage constant K_m (b) The no-load rotational losses of the motor
(c) The power output of the motor, when it is operating at 1600 rpm from a 46 V source
[10 marks]

2) A 3-phase, 100 kVA, 460 V, 60 Hz. 8 pole, induction machine has the following equivalent circuit parameters referred to the stator side:

$R_1 = 0.07\ \Omega$, $X_1 = 0.2\ \Omega$, $R_2 = 0.05\ \Omega$, $X_2 = 0.2\ \Omega$, $X_m = 6.5\ \Omega$

(a) If the machine is connected to a 3-phase, 460 V, 60 Hz supply, determine the starting torque, the maximum torque the machine can develop, and the speed at which the maximum torque is developed.
(b) If the maximum torque is to occur at start, determine the external resistance required in each rotor phase. Assume a turns ratio (stator to rotor) of 1.2. **[10 marks]**

3) A dc series motor has a rated input power of 20 kW at 550 V and 2000 rpm. To limit the inrush starting current to 150% of the rated value, a starter resistance is needed which may be switched out of the circuit when the current is low enough. The motor armature resistance is 0.5 ohms and the series field resistance is 0.5 ohms. Determine the value of the starting resistor and the starting torque. Neglect any rotational losses and brush voltage drop. **[10 marks]**

4) A 208 V, 60 Hz, three-phase, star-connected, salient pole, synchronous motor operates at full load and draws a current of 40 A at 0.8 pf lagging. The *d* and *q* axis reactances are 2.7 Ω/phase and 1.7 Ω/phase, respectively. The armature-winding resistance is negligible, and the rotational loss is 5 % of the power developed by the motor. Determine:

(1) the excitation voltage
(2) the power developed due to the field excitation
(3) the power developed due to saliency of the motor, and
(4) the efficiency of the motor **[10 marks]**

5) **(a)** A 230 V, 60 Hz, 4-pole, delta-connected, three-phase induction motor operates at a full-load speed of 1710 rpm. The power developed at this speed is 2 hp. If the supply voltage fluctuates ± 10 %, determine the torque range. **[5 marks]**

(b) A 120 V, 60 Hz, 6-pole, delta-connected, three-phase induction motor has a stator

impedance of 0.1 + j 0.15 Ω/phase and an equivalent rotor impedance of 0.2 + j 0.25 Ω/phase at standstill. Find the maximum power developed by the motor and the slip at which it occurs. What is the corresponding value of the torque developed by the motor? **[5 marks]**

6) (a) Sketch the connection diagram of a star-delta three-phase transformer with a Vector Symbol Y_d11. Show the cloak numbers on both sides of all the six windings and also at the terminal ends of the transformer to justify the vector symbol. **[5 marks]**

(b) A delta-star transformer bank is supplying a balanced three-phase, 500 kVA, 0.8 lagging power factor load. The input voltage to the high side (delta) is 2400 V at 50 Hz. The turns ratio of each transformer is 6.9. Sketch the circuit and determine the line voltage, phase voltage, line current, phase current for both the high voltage side and low voltage side. **[5 marks]**

7) (a) A three-stack stepper motor is used to produce a step size of 2^0. Determine the steps per revolution and the number of rotor teeth. **[3 marks]**

(b) A two-pole, permanent magnet, stepper motor requires six steps per revolution.

(1) Determine the number of stator phases. **[1 mark]**

(2) Sketch the cross-sectional view of the stepper motor with the phase windings connected (to get the appropriate field polarity). **[4 marks]**

(3) Write down the sequence of excitation for CW and CCW movements. **[2 marks]**

8) (a) Explain the principle of operation of as PM Brushless DC motor drive with the help of a neat simple schematic diagram indicating the position, current, and speed feedbacks. **[7 marks]**

(b) Separately give the merits and demerits of the PM BLDC motors over the conventional (i) dc motors, (ii) induction motors, and (iii) synchronous motors. **[3 marks]**

9) In a 3-phase switched reluctance motor having 6 stator poles and 4 rotor poles, the pole widths for the stator and rotor poles are the same, 40 degrees.

(a) Sketch the motor stator and rotor poles with the windings drawn and connected to correct polarities) and show an appropriate drive circuit (Unipolar or bipolar) and indicate the switching sequence for CW and CCW rotations of the motor. **[6 marks]**

(b) Sketch the inductance profile, current pulses, and the torque pulses of a phase for the ripple free-operation of the motor. **[4 marks]**