Department of Electrical Engineering, IIT Delhi
EEL 203 ELECTROMECHANICS
Session 2008-09, II Semester
Major Test, Duration: 2 Hr. Max. Marks:120

NOTE: This has TWO Parts. Part-I is with "Closed Book" and Part-II is with "OPEN BOOK" (Including Laptop)

PART-I (CLOSED BOOK): Max. Marks: 60
Part-A (To be answered in the Answer Book)

1. From Maxwell's Equations obtain Faraday's law, Ampere's Law and Ohm's Law. (6)
2. A closed Ferromagnetic Core of relative permeability μ_r, cross section A and mean magnetic length l is wound with two coils (1,2) of turns N_1 and N_2 carrying currents i_1,i_2 respectively such that each aids the flux produced by the other.
    a. From basic principles derive expressions for self inductance of each coil and the mutual inductance between them in terms of the above parameters. (4)
    b. A voltage E_1 (rms) at a frequency f is applied across coil 1 with coil 2 open. Derive expressions for the peak core flux, current drawn from the source and the voltage (rms) across coil 2. Neglect resistances, leakage flux and core loss. (4)
3. With proper derivations, obtain the load condition under which a transformer will have maximum efficiency. (5)
4. Show that in a rotating machine with three phase stator windings excited by three phase currents, a rotating magnetic filed is produced in the air-gap. Derive an expression for the speed of this field in terms of supply frequency and no. of poles. (8)
5. A P- pole, synchronous generator has three phase stator winding with N_{se} series turns per phase. The rotor (field), rotated at N rpm, is excited by dc to cause a sinusoidal air-gap flux density distribution with a flux per pole = Φ. Derive an expression for the generated stator voltage per phase if the stator has
    a. concentrated full pitch winding
    b. short- pitched winding by a chording angle β (derive pitch factor)
    c. distributed full pitch winding with m slots/pole/phase (derive distribution factor)
    d. both (b) &(c) above

    From the above, obtain a relation for generated frequency in terms of P and N (13)

Name : RM No.

Part-B (To be answered on the Question paper)

1. Indicate the Electric machine(s) suitable for the following
   a. Nuclear Power Generation
   b. Hydro Power Generation
   c. Wind Power Generation
   d. Irrigation pump sets
   e. Electric trains
   f. Refrigerator
   g. Food Mixer
   h. Ceiling fan
   i. Robots
   j. Municipal Water Supply (5)
2. Write TEN (distinctive) sentences pertaining to Industrial Visit to ABB (Only the technical points learnt must be included) (10)

2.1

2.2

2.3

2.4

2.5

2.6

2.7

2.8

2.9

2.10

3. Identify and label the items shown in the Pictures relating to Electrical Machines and Transformers given in Annexure-I [redacted] (5)

PART-II: This part is an OPEN BOOK Exam.

Duration: 1 Hr. Max. Marks: 60

1. A Substation receives 3- phase, 50 Hz. power at 11 kV (line to line) and delivers to LV consumers at 415V (line-to line) through a distribution transformer connected in Dy mode . It supplies power to three student hostels, each hostel connected to one line of the LV side of the transformer. (Three lines a,b,c supply to three hostels respectively). Each hostel has 400 rooms and the load in each room is 100W (resistive).
   a. Calculate the current drawn in each line on the HV side of the transformer, if all the hostel rooms are fully energized. (3)
   b. Due to an accident, supply to one of the hostel is disconnected. Calculate the current drawn in each line on the HV side of the transformer. (5)
2. Two coils, one mounted on a stator and the other on a rotor, have self and mutul inductances of

   L_{11}=3 mH. L_{22}= 1.5 mH L_{12}=1.8 cos θ mH,

   where θ is the angle between the axes of the coils. The coils are connected in series and carry a current i= $\sqrt{2}$ I sin ωt.

   a) Derive an expression for the time average torque T on the rotor as a function of I and θ. (5)

   b) Sketch the curves of T Vs θ for I= 5 and 10 A. (3)

   c) A helical restraining spring which tends to hold the rotor at θ =90° is now attached to the rotor. The spring provides an opposing torque which linearly varies from zero at 90° to T_0 at 0°. Find T_0 to hold the system in equilibrium when I = 10 A and θ=30°. Find the equilibrium position of θ when current is changed to I =5A. (6)
3. A 30 kVA, 50 Hz, 2200V: 220 V ,1- phase transformer has the following resistances and leakage reactances of primary (1) and secondary(2) ref. to respective sides in ohms as follows:

   R_1= 0.65, R_2=0.0065, X_{l1}= 7.2, X_{l2}= 0.072

   a) Calculate the primary voltage when it is delivering rated current at 1.0 PF at rated secondary voltage. (5)

   b) Simulate the above procedure by writing a MATLAB script to obtain primary voltage variation from no load to full load to keep the secondary voltage constant at rated value for a load PF of (i) 1.0, (ii) 0.8 lag (8)
4. A 415 V, 4- pole, 50 Hz. 3- phase squirrel cage induction motor has delta connected stator winding housed in 36 slots in single layer mode. Each coil is short-pitched by one slot. Peak of the resultant air-gap flux density (assumed sinusoidally distributed in space) is 0.6 T. It has mean air-gap dia. of 15 cm., effective core length of 20 cm, and air-gap length of 0.35 mm.
   a. With suitable assumptions, calculate the number of conductors in each slot. (6)
   b. Under the condition of (a), calculate the current drawn from the supply per phase to produce the above air-gap flux density wave. (7)
   c. It is found that each phase current of (b) produce , in addition to fundamental, 5^{th} and 7^{th} harmonic mmf of peak amplitude respectively equal to 1/5 and 1/7 of fundamental. Determine the nature of air-gap field and the flux per pole due to these harmonic fields. (7)

5. The concept of linear induction motor is used to develop a magnetically levitated high speed train. The Engine car carries a three phase 10-pole winding placed in a linear configuration. Dimensions of the winding configuration of the car is of 10 m length (in the direction of movement of the train) and 4 m wide excluding end windings. This winding is facing the track which is a linearly dispossessed squirrel cage winding The air-gap is sandwiched between the above two. Determine the supply frequency to run the train near 400 kmph. (5)