THE OPEN UNIVERSITY OF SRI LANKA
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
DIPLOMA IN TECHNOLOGY

ECX4238 - ELECTRICAL MACHINES

FINAL EXAMINATION –2006/2007

064

Date: 18th April 2007 **Time: 0930 - 1230 hrs**

This paper contains seven questions and answer any **five (5)**. All questions carry equal marks.
Graph papers will be available on your request.

Question 1

a. Draw the possible connections of primary and secondary windings of three phase transformer.

b. A three phase, 230 V, 120 kVA at 0.85 power factor lagging load is to be connected to 4000 V three phase supply via transformer. The three phase transformer is formed by connecting three single phase 50 kVA, 2300/230 V transformers, per phase equivalent impedance (referred to the LV side) of $0.02\angle 55^0\ \Omega$.

I. Determine the transformer winding connection and draw the per phase equivalent circuit.
II. Calculate the currents through the windings of the transformer unit.
III. If voltage at load is maintained at its rated value determine the supply voltage.
IV. Calculate the voltage regulation.

Question 2

a. Prove that output power of a three phase round rotor synchronous machine can be expressed as

$$P = 3\frac{E_f V_{phase}}{X_s} Sin\delta$$

b. A certain three-phase, two pole 50 Hz, round rotor synchronous generator has following nominal parameters:

V_{nom}= 20 kV; S_{nom}= 300 MVA; Cosφ=0.85

A field current of 450 A produces nominal voltage at the output terminals when the generator is open circuited. The short circuit current is 10 kA (filed current remain unchanged)

I. Calculate the synchronous reactance of the machine (resistance of the stator windings can be neglected)
II. If the open circuit characteristic of the machine is linear determine the required field current at rated load.
III. Calculate the power angle and the voltage regulation.

Question 3

a. For an induction motor prove the torque – slip relation ship given below:

$$\frac{T}{T_{max}} = \frac{2}{\frac{s}{s_{max}} + \frac{s_{max}}{s}}$$

b. A three phase four pole star connected 415 V, 50 Hz induction motor has following T-equivalent parameters:

$R_1 = 0.4\,\Omega, \quad R_2' = 0.56\,\Omega, \quad X_1 = X_2' = 1.12\,\Omega \quad X_m = 48\,\Omega$

Core loss is equal to 650 W.

Calculate :

I. Starting current and staring torque.
II. Maximum torque and corresponding speed
III. Output power at the slip of 0.03

Question 4

a. Briefly explain the function of "commutator" in DC machines.

b. With the help of load characteristics explain the excitation process of DC shunt and series motors.

c. A certain 230 V DC shunt motor has armature resistance of 0.25 Ω and field resistance of 115 Ω. At full load machine speed is 1050 rev/min and supply current to the motor is 40 A.

I. Calculate electromagnetic torque at full load.
II. If the field resistance is adjusted to 145 Ω determine the new speed of the machine (assume that electromagnetic torque remains constant).
III. What is the efficiency of the machine in part (ii) if friction and windage losses are 500 W.

Question 5

a. Explain briefly how experimental values of X_d and X_q are determined?

b. A three phase hydro-generator has following nominal parameters:

S=4 MVA, $V_{phase} = 3.81$ kV, Cosφ =0.8

Direct axis, quadratic axis and leakage reactances are as follows:

$X_{ad} = 9.9\,\Omega, \quad X_{aq} = 6\,\Omega, \quad X_\sigma = 1.81\,\Omega$

The open circuit characteristic of the machine is given as follows:

I_f (pu)	0.0	0.1	0.25	0.5	0.75	1.0	1.5	2.0	2.5	3.0
E_f (pu)	0.0	0.116	0.29	0.58	0.83	1.0	1.2	1.33	1.4	1.46

Draw the phasor diagram under nominal condition and determine the excitation voltage and mmf (in pu) of the machine.

Question 6

a. Explain why induction motor cannot operate with zero slip.

b. Give reasons for conducting locked rotor test at low voltage and reduced frequency.

c. State whether direct starting (self starting) is applicable to the synchronous motors. What are the common methods of starting synchronous motors?

d. A three phase four pole 200 V, 60 Hz synchronous motor has reactance of 8 Ω per phase. The field current of the motor is adjusted so that it takes 3 kW from the supply at unity power factor.

I. Determine the excitation voltage and power angle.

II. While the field current remains at a constant value, the load on the shaft of the motor was increased up to its maximum limit. Calculate the maximum torque that machine can deliver.

Question 7

a. Draw the torque-speed curves and explain briefly methods for controlling the speed of following machines:

i. Separately excited DC motor

ii. Induction motor

iii. Synchronous motor

b. A common load is shared by two synchronous generators. Sketch the load frequency characteristics of both generators and graphically illustrate the load of each generator.

c. What are the factors that contribute iron losses in distribution transformers? Explain condition under which these losses vary.

d. Explain why many transformers are immersed in oil?