

**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

- Draw the possible connections of primary and secondary windings of three phase transformer.
- 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 $0.02 \angle 55^\circ \Omega$.
 - Determine the transformer winding connection and draw the per phase equivalent circuit.
 - Calculate the currents through the windings of the transformer unit.
 - If voltage at load is maintained at its rated value determine the supply voltage.
 - Calculate the voltage regulation.

Question 2

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

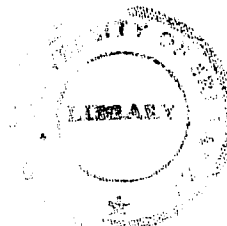
$$P = 3 \frac{E_f V_{phase}}{X_s} \sin \delta$$

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

$$V_{nom} = 20 \text{ kV}; S_{nom} = 300 \text{ MVA}; \cos \phi = 0.85$$

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 (field current remain unchanged)

- Calculate the synchronous reactance of the machine (resistance of the stator windings can be neglected)
- If the open circuit characteristic of the machine is linear determine the required field current at rated load.
- 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 starting 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 0.25Ω and field resistance of 115Ω . 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 145Ω 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:
 $S=4 \text{ MVA}$, $V_{\text{phase}} = 3.81 \text{ kV}$, $\cos\phi = 0.8$
Direct axis, quadratic axis and leakage reactances are as follows:
 $X_{ad} = 9.9 \Omega$, $X_{aq} = 6 \Omega$, $X_\sigma = 1.81 \Omega$

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

$I_f \text{ (pu)}$	0.0	0.1	0.25	0.5	0.75	1.0	1.5	2.0	2.5	3.0
$E_f \text{ (pu)}$	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 8Ω 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?