UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2015

Module Number: EE6303 **Module Name: Electrical Machines and Drives**

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

Q1 a) Discuss the effect of speed-power characteristics of the prime movers on the load sharing of two alternators connected in parallel.

[1 Mark]

b) Suppose that you are an engineer planning a new electric cogeneration facility for a plant with excess process steam. You have a choice of either two 10 MW turbo generators or a single 20 MW turbo generator. Explain the advantages and disadvantages of each choice.

[2 Marks]

c) Two alternators working in parallel supply a lighting load of 3000 kW and a motor load aggregating to 5000 kW at a power factor 0.72. One alternator is loaded up to 5000 kW at 0.8 power factor lagging. What is the load and the power factor of the other machine?

[2 Marks]

d) A 480 V, 100 kW, two pole, three phase, 60 Hz synchronous generator has a no-load speed of 3630 rpm and a full-load speed of 3570 rpm. It is operating in parallel with a 480 V, 75 kW, four pole, 60 Hz synchronous generator with a no-load speed of 1800 rpm and a full load speed of 1785 rpm. The two generators supply a total load of 100 kW at 0.85 power factor lagging.

i) Calculate the speed droops of the two generators.

ii) Determine the operating frequency of the power system.

iii) Determine the power supplied by each generator.

iv) If the terminal voltage is 460 V, explain how the low terminal voltage can be corrected.

[5 Marks]

Q2 a) i) List the types of single phase induction motors.

ii) Draw and explain the nature of the torque-speed characteristics of a single phase induction motor based on the double revolving field theory.

iii) Explain the construction, working principle and torque-speed characteristics of split phase motors.

iv) A 230 V, 50 Hz split phase induction motor has the main winding resistance of 5 Ω and inductive reactance of 12 Ω. The auxiliary winding of the motor has a resistance of 12 Ω and inductive reactance of 5 Ω. Determine the value of capacitance to be connected in series with the auxiliary winding to obtain maximum starting torque.

[6 Marks]

b) i) What are the applications of universal motors?

ii) List the problems usually encountered when a DC series motor is operated on AC power.

iii) What are the design modifications to be incorporated for satisfactory operation of DC series motors on AC power?

[1.5 Marks]

c) i) Discuss the stepper motor control scheme using a block diagram.

ii) A stepper motor has a step angle of 1.8^0 and is driven at 4000 pulses per second. Determine the following.

I) Speed.

II) Resolution (in steps/ revolution).

III) Number of pulses needed to rotate the shaft by 54^0.

[2.5 Marks]

Q3 a) State five situations where the motor nameplate data becomes useful.

[1 Mark]

b) Consider the motor nameplate shown in Figure Q3.

i) What is the motor nameplate standard used for the motor? Justify your answer.

ii) Calculate the number of stator poles in the motor.

iii) Illustrate why the rated voltage for the motor is indicated as 230/460 V.

iv) Comment on the starting torque and the starting current of the motor.

v) Compare the enclosure type used in the motor with the Open Drip Proof (ODP) enclosure.

vi) Briefly explain the two efficiency values given for the motor.

vii) Estimate the maximum starting current of the motor using Table Q3.

viii) Determine the maximum power output of the motor that can be delivered under temporary overload conditions.

[4 Marks]

c) The motor in b) is to be operated on 50 Hz. Calculate the revised rated voltage, rated speed and rated output power for the motor. State the assumptions you made.

[2 Marks]

d) i) Briefly explain the operation of a modern electric motor drive system with the aid of a general block diagram.

ii) State three advantages of the drive system in d) i) over other drive systems.

[2 Marks]

e) Classify electric motor drives into two categories based on the expected performance and explain the difference using suitable examples.

[1 Mark]

Q4 a) Show that the speed-torque characteristics of a separately exited DC motor can be expressed in the form of y = -mx+c. Clearly state m and c.

[1.5 Marks]

b) i) According to the expression derived in a), what are the parameters that can be used for DC motor controlling?

ii) Illustrate how speed-torque characteristics of the motor changes with each of the parameter in b) i).

[1.5 Marks]

c) Following details are given for a DC motor drive system. All the notations have their usual meaning.

Permanent magnet DC Motor

$R_a = 0.75\ \Omega$, $L_a = 5.0$ mH, $K_{E\phi} = 0.15$ Vs, $J_m = 1.5 \times 10^{-4}$ kgm^2

DC-DC converter

$V_d = 240$ V, $f_S = 30$ kHz, V_{tri} (peak) = 5 V

A closed loop control system needs to be designed having current, speed and position control loops. The crossover frequency of the current controller should be 1 kHz and the phase margin for the speed controller should be 30^0. Determine the controller parameters. State any assumption you made.

[2 Marks]

d) A 15 hp separately excited DC motor is powered through a single phase full bridge rectifier working on a 240 V, 50 Hz supply. Under rated conditions, the motor draws an armature current of 110 A at 200 V and runs at 1800 rpm. The voltage constant of the motor is 0.13 Vs.

i) The motor speed needs to be controlled in the range of 600 rpm to 1800 rpm. Calculate the required range of firing angle, if the field current is maintained at its rated value.

ii) Calculate the no-load speed in rpm and the stall torque of the motor, if it is operated with a firing angle of 40^0.

iii) The field circuit is powered through a single switch DC-DC converter connected to a 30 V DC battery. Under rated conditions, duty of the converter is 1. Calculate the required duty of the converter if the motor speed needs to be increased up to 2500 rpm at its rated power and rated voltage. Assume the field flux is proportional to the field voltage.

[5 Marks]

Q5 a) Briefly discuss the advantages and disadvantages of AC motor drives compared to DC motor drives.

[1 Mark]

b) Show that the developed torque of an induction motor is proportional to the slip speed for a given supply voltage, frequency and air gap flux when the slip is very small.

[1 Mark]

c) State three parameters which can be used for induction motor controlling with their limitations.

[1 Mark]

d) Explain the principle of V/f controlling of an induction motor in detail and draw the corresponding voltage-frequency characteristic for the speed range from 0 to twice the rated speed.

[3 Marks]

e) V/f controlling is used in a three phase induction motor drive with the following parameters.

Rated voltage	= 400 V
Rated frequency	= 50 Hz
Rated speed	= 1470 rpm
Rated output power	= 10 hp

The stator resistance can be assumed as zero and leakage inductances can be ignored. Assume that the air gap flux of the machine is kept constant at its rated value through the actions of the controller and the power processor.

i) Draw the torque-speed characteristics of the motor for supply frequencies of 50 Hz and 30 Hz in the same diagram for the low slip region.

ii) Calculate the operational motor speeds for above frequencies, if the load torque is constant at rated motor torque. Neglect the frictional losses.

iii) Determine the phase voltage values of the power processor for supply frequencies of 50 Hz, 30 Hz and 70 Hz.

iv) The torque increases as a quadratic function of speed, i.e. $T_L = k\, n_m^2$ where T_L is the load torque, k is a constant and n_m is the motor speed in rpm. What is the maximum possible value for k to operate the motor at 2000 rpm?

[4 Marks]

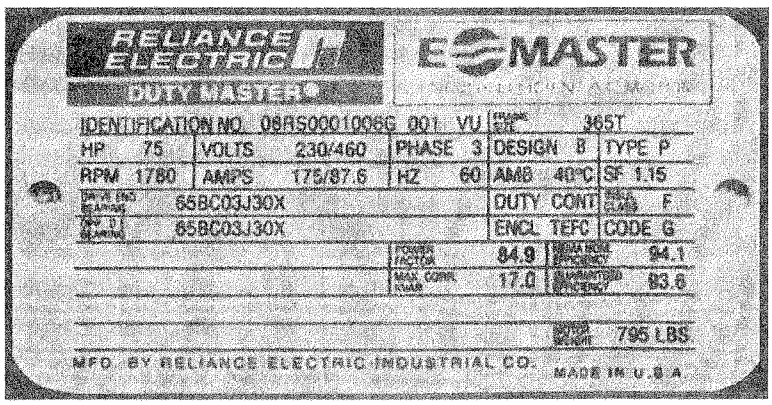

Figure Q3

Table Q3

NEMA Code Letter	KVA/HP with locked rotor	Approximate Mid-Range Value
A	0-3.14	1.6
B	3.15-3.55	3.3
C	3.55-3.99	3.8
D	4.0-4.49	4.3
E	4.5-4.99	4.7
F	5.0-5.59	5.3
G	5.6-6.29	5.9
H	6.3-7.09	6.7
J	7.1-7.99	7.5
K	8.0-8.99	8.5
L	9.0-9.99	9.5
M	10.0-11.19	10.6
N	11.2-12.49	11.8
P	12.5-13.99	13.2
R	14.0-15.99	15.0
S	16.0-17.99	-
T	18.0-19.99	-
U	20.0-22.39	-
V	22.4-and up	-