UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: November 2016

Module Number: EE6320 **Module Name: Electrical Machines and Drives (O/C)**

[Three Hours]

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

Q1. a) i) State the problems associated with Y-Y three phase transformer connection.

ii) A three phase, 1200 kVA, 6.6 / 1.1 kV transformer has a delta connected primary and a star connected secondary. The per phase value of the primary and secondary resistances are 2 Ω and 0.03 Ω respectively. The iron loss is 20 kW. Calculate the efficiency of the transformer on full load at 0.9 power factor lagging.

[3.5 Marks]

b) A $\Delta - \Delta$ bank consisting of three 20 kVA, 2300/230 V single phase transformers supplies a load of 40 kVA. If one transformer is removed due to a faulty condition, calculate

i) the kVA load carried by each transformer.

ii) the total kVA of the resulted V-V bank.

iii) the ratio of the V-V bank transformer rating to the $\Delta - \Delta$ bank transformer rating.

[2.5 Marks]

c) i) What precautions must be taken when connecting three phase transformers in parallel?

ii) A 500 kVA , 6600/ 400 V, three phase transformer with an equivalent per phase impedance of $0.2 + 1.8\,j\ \Omega$ referred to the primary is sharing a load of 750 kVA at 0.8 power factor lagging with a 250 kVA, 6600/ 400 V three phase transformer with an equivalent per phase impedance of $0.35 + 3.3\,j\ \Omega$ referred to the primary. Calculate the load shared by each transformer.

[4.0 Marks]

Q2. a) Explain how the apparent power and power factor ratings are set for a synchronous generator.

[3.0 Marks]

b) A 13.8 kV, 50 MVA, 0.9 power factor lagging, 50 Hz, four-pole Y connected synchronous generator has a synchronous reactance of 2.5 Ω and an armature resistance of 0.2 Ω. Assume that this generator is connected to a steam turbine capable of supplying up to 45 MW. At 50 Hz, its friction and windage losses are 1 MW and its core losses are 1.5 MW.

i) Construct a capability curve for this generator.

ii) Can this generator supply a line current of 2000 A at 0.75 power factor lagging? Justify your answer.

iii) What is the maximum amount of reactive power that can be produced by this generator?

[7.0 Marks]

Q3. a) A 50 Hz, 14 pole, Y connected, three phase water turbine driven generator is rated at 120 MVA, 13.2 kV, 0.8 power factor lagging. Its direct-axis reactance(X_d) is 0.62 Ω and its quadrature axis reactance(X_q) is 0.40 Ω. All rotational losses may be neglected.

i) Calculate the internal generated voltage of the generator at full load, assuming that it has a cylindrical rotor of reactance X_d.

ii) Calculate the internal generated voltage of the generator at full load, assuming that it has a salient pole rotor.

[5.0 Marks]

b) i) Briefly explain the reason behind transformer humming.

ii) State four differences between ONAN and KDWF transformer cooling systems.

iii) A 60 Hz, 30 hp, 460 V, 35 A three phase induction motor has a rated speed of 1765 rpm. Calculate the revised motor ratings if the motor needs to be operated on a 50 Hz three phase supply. Clearly state the assumptions you made.

[5.0 Marks]

Q4. a) Briefly discuss on following parameters mentioned in a NEMA standard motor nameplate.

i) Service factor

ii) Letter code

iii) Design letter

iv) Insulation class

v) Time rating

[2.5 Marks]

b) i) State two methods used to vary the speed of an AC motor by changing the number of stator poles.

ii) Explain the principle of V/f controlling of an induction motor.

[2.5 Marks]

c) A 50 Hz, 20 hp, 460 V, Y-connected three phase induction motor is used to drive a centrifugal pump. The V/f controlling method is used to control the motor. Under rated voltage and frequency, motor runs at 965 rpm.

i) Determine the motor speed, frequency and voltage of the stator supply and the slip if the motor is operated at 75% of its rated power.

ii) Draw the torque-speed characteristic curves of the motor under rated voltage and rated frequency, and conditions in part (i). Draw the torque-speed characteristic curve of the pump in the same plot and indicate the operating points of the motor for the both operations. State the assumptions you made.

Hint: In centrifugal pumps, load torque is proportional to the quadratic value of the rotational speed.

[5.0 Marks]

Q5. a) i) State two advantages of DC motor drives over AC induction motor drives.

ii) What are the characteristics and applications of a high performance electric motor drive?

iii) Explain the four quadratic operation of a motor in an electric vehicle.

[3.0 Marks]

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

<u>Permanent magnet DC Motor</u>

$R_a = 0.82\ \Omega$, $L_a = 3.5$ mH, $K_{E\phi} = 0.12$ Vs, $J_m = 2.2 \times 10^{-4}$ kgm^2

<u>DC-DC converter</u>

$V_d = 120$ V, $f_S = 20$ kHz, V_{tri}(peak) = 5 V

A closed loop control system needs to be designed having current, speed and position control loops. Crossover frequency of the current controller should be 10% of the switching frequency and the phase margin for the speed controller should be 50^0. Determine the controller parameters. State any assumption you made.

[3.0 Marks]

c) A separately excited DC motor is powered through a three phase full bridge rectifier working on a 460 V, 50 Hz supply. Under rated conditions motor draws an armature current of 80 A at 230 V and runs at 1800 rpm. The voltage constant of the motor is 0.14 Vs. The load torque is proportional to the quadratic value of the motor speed. Calculate the required firing angle range if the motor speed needs to be controlled in the range of 400 rpm to 1200 rpm. Assume that the field current is maintained at its rated value.

[4.0 Marks]