The Open University of Sri Lanka

Department of Electrical and Computer Engineering

Diploma in Technology

ECX4238– Electrical Machines

Final Examination - 2012/2013

Duration: Three hours.

CLOSED BOOK

Date: 22nd August 2013

Time: 0930-1230 hrs

This paper contains eight (8) questions. Answer any five (5) questions. All questions carry equal marks. Graph papers will be available on your request.

Q1

a) In order to change the voltage level of a three phase system, three single-phase transformers or single three-phase transformer can be used. Discuss the advantages and disadvantages of above two possibilities. [4 marks]

b) What are the main types of three-phase winding connections of the three-phase transformer? Discuss their special characteristics and applications. [4 marks]

c) Consider three ideal single-phase, 50 Hz, 5kVA, 200V/100V transformers.

i. A three-phase transformer is formed by connecting LV side winding in star and HV side winding in delta. Calculate:

   a) Primary and secondary side voltage of three-phase transformer
   b) Line and phase currents of LV and HV sides
   c) kVA Rating of three-phase transformer [6 marks]

ii. Now, the LV side windings are connected in delta and HV side windings are connected in star. Determine voltages and currents in each LV and HV sides and kVA rating of three-phase transformer. [6 marks]

Q2

a) Certain three-phase transformer has been labeled as 32Yd1. Explain what information you can obtain from above labeling? [3 marks]

b) Sketch the winding connection and draw phasor diagram to show all votages and currents of the transformer mentioned in (a). [5 marks]

c) Figure Q2 shows the winding connections of a three phase transformer. Draw the phasor diagram to show the EMFs in windings and determine the phase shift between primary and secondary EMF [6 marks]

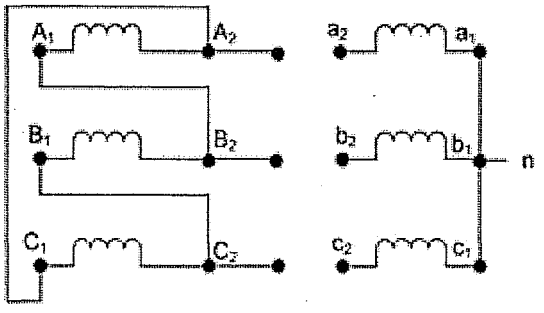

Figure Q2

d) A 50 Hz, Δ-Y connected, 11000/440 V three-phase transformer takes a line current of 6A. Determine each currents through both primary and secondary coils. What is the output power if the power factor equals to 0.85. [6 marks]

Q3

a) What are the conditions to be satisfied for parallel operation of generators? [5 marks]

b) Briefly explain a synchroscope method for synchronization of generator. [4 marks]

c) A 480 V, 100 kW, two poles, three-phase, 60 Hz synchronous generator's prime mover 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 poles, 60 Hz synchronous generator whose prime mover has a no-load speed of 1800 rpm and a full-load speed of 1785 rpm. Both generators share a common load of 100 kW at 0.85 PF lagging.

d)

i. Calculate the speed droops of each generator. [3 marks]

ii. Calculate the operating frequency when both generators share the load. [4 marks]

iii. Determine the power supplied by each of the generators. [4 marks]

Q4

a) What are the main constraints of the amount of power delivered by a synchronous generator? Draw a diagram (capability curve) indicating those limits and the safe operating area of a synchronous generator.(Assume $R_a <<< X_s$) [3 marks]

b) A 270 V, 50 Hz, Δ-connected. 6 poles, synchronous generator is rated at 50 kVA at 0.8 PF lagging. It has a synchronous reactance of 1Ω per-phase. Assume that this generator is connected to a steam turbine capable of supplying up-to 45kW. The rotational losses are 1.5 kW, and the core loss is 1.0 kW.

i. Sketch the capability curve for the generator, including the prime mover power limit. [5 marks]

ii. Can this generator supply a line current of 100 A at 0.7 p.f lagging? Justify your answer. [4 marks]

iii. What is the maximum amount of reactive power this generator can produce? [4 marks]

iv. If the generator supplies power of 30 kW, what is the maximum amount of reactive power that can be simultaneously supplied by the generator? [4 marks]

Q5

a)

i. What are the merits and the demerits of the permanent magnet DC machines compared to the conventional separately excited DC machine? [3 marks]

ii. Explain term armature reaction of the DC machine? Explain consequences of armature reaction in a DC machine. [3 marks]

b) Discuss the speed and torque characteristics of a DC shunt motor. [4 marks]

c) A DC shunt motor is supplied by a 250 V DC supply. It has an armature resistance of 0.25 Ω and a field resistance of 125 Ω. At a certain load the motor takes a current of 5 A while running at 1200 rpm. If the current at full load is 52A, determine the speed at full load? [10 marks]

Q6

a)

i. What are the methods for speed controlling of a DC shunt motor? [3 marks]

ii. Describe with a suitable sketch, one of the above methods of speed controlling of DC shunt motor. [4 marks]

b) A 250 V, DC shunt motor has an armature resistance of 0.5 Ω and a field resistance of 250 Ω. When driving a load of constant torque at 600 rpm, the armature current is 20A.If it is desired to raise the speed from 600 to 800 rpm, what additional resistance should be connected in series with the field resistance? Assume that the magnetic circuit is unsaturated. [13 marks]

Q7

a) Prove the following for a three-phase wound rotor induction motor *(Hint: you may use the approximate equivalent circuit)*

i. Slip at maximum torque is proportional to the rotor resistance [3 marks]

ii. Maximum torque is independent of the rotor resistance [3 marks]

b) A 400 V, 4 poles, 50 Hz, Y-connected, three-phase induction motor has per-phase rotor resistance and reactance of 0.01Ω and 0.1 Ω respectively. The ratio of stator to rotor turns is 4 and the maximum torque is twice the full-load torque. Determine:

i. Maximum torque and the corresponding slip [6 marks]

ii. Full load slip [4 marks]

iii. Output Power (Power developed by the motor) [4 marks]

Q8

a) Explain briefly why the large three-phase induction motors need special starting arrangements. [2 marks]

b) A three-phase, Y-connected, 460 V (line to line), 25 Hp, 60 Hz, 8 pole induction motor has the following per phase parameters referred to the stator:(1 Hp = 745.69 W)

$R_1 = 0.342\ \Omega$ $R_2 = 0.164\ \Omega$

$X_1 = 0.561\ \Omega$ $X_2 = 0.265\ \Omega$ $X_m = 14.75\ \Omega$

Friction, windage and stray load losses = 265 W

Using approximate equivalent circuit or otherwise, calculate the following for an operation at a slip of 0.02. The motor is operated at rated voltage and frequency.

i. Rotor speed [3 marks]

ii. Stator current and power factor [6 marks]

iii. Output torque and power [6 marks]

iv. Efficiency 3 marks]

(Clearly state any assumptions that you make)