NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
DEPARTMENT OF ELECTONIC ENGINEERING
BACHELOR OF ENGINEERING (HONS) DEGREE

Final Examination May 2013

TEE 2202 ELECTRONIC DRIVES

Duration of Examination – 3 Hours

INSTRUCTIONS TO CANDIDATES

1. Answer **any TWO**questions from section **A** and **any THREE** questions from section **B.**
2. Each question in section **A** carries 15 marks and each question in section **B**carries 24 marks.
3. Show all your steps clearly in any calculations.
4. Start each new question on a fresh page.

SECTION A

Question A1

a) In a factory, the following loads are operated:
800 000kW induction motors at an average power factor of 0.7
100kW lighting and heating loads at unity power factor.
A three phase synchronous motor is to be installed to provide 220 000kW to a new process.
i. Determine the kVA rating of the synchronous motor if the overall factory power factor is to be raised to 0.95. [7 marks]
ii. Calculate the power factor of the synchronous motor. [2 marks]

b) Draw the equivalent circuit of a single phase induction motor. State what each component in the circuit represents. [6 marks]

Question A2

a) A three-phase, 200kW, 2300V, 60Hz, 4 – pole star connected synchronous motor has a synchronous reactance of 11Ω per phase. When it draws 165.8kW, the power angle is 15°. Neglect ohmic losses.

i. Determine the excitation voltage per phase [2 marks]
ii. Determine the supply line current [3 marks]
iii. Determine the supply power factor [2 marks]
iv. Calculate the speed of the motor [2 marks]

b) Why is it necessary to have a starting method in a single phase induction motor? Describe and explain one method that can be used to start a single phase induction motor. [6 marks]

Question A3

a) A three phase, 14kV, 10MVA, 60 Hz 2-pole, 0.85 power factor lagging, star-connected, synchronous generator has a synchronous impedance of 20Ω per phase and a synchronous resistance of 2Ω per phase. The generator is connected to an infinite bus.

i. What is an infinite bus? [1 mark]
ii. Determine the excitation voltage at the rated condition [5 marks]
iii. What is the torque angle? [1 mark]
iv. Determine the maximum power that the generator can supply. [2 marks]

b) What is a universal motor? How does it operate? [3 marks]

c) Using the double revolving field theory, explain how a single phase induction motor operates. [3 marks]

SECTION B

Question B1

a) What is commutation and why is it required in thyristor switches? Describe and explain the operation of one commutation circuit that can be used with inverters? [6 marks]

b) The speed of an 8kW, 200V, 1200rpm separately excited dc motor is controlled by a single-phase full converter. The rated armature current is 40A. The armature resistance is R_a = 0.25Ω and armature inductance is 10mH. The ac supply voltage is 265V. The motor voltage constant is $K_a\Phi$ = 0.18V/rpm. Assume that motor current is continuous and ripple-free.

i. For a firing angle of 30°, calculate the motor speed. [5 marks]
ii. The polarity of the back emf is reversed for regenerative braking of the motor. Determine the firing angle to maintain an armature current of 40A at the speed value calculated in Question B1 (b) i. [4 marks]

c) An electric furnace uses electric heater elements that are controlled using a three phase voltage controller. The heater elements are divided into three groups, which are in turn connected in delta to a 380V, 50Hz three phase supply. The elements are purely resistive,

and each group can be modeled as a resistance of 12Ω. The total power required at some operating point is 18kW.

i. Determine the firing angle and corresponding conduction angle. [6 marks]

ii. Calculate the current rating foreach power semiconductor switch in the voltage controller for this power level. [3 marks]

Question B2

a) Semiconductors are used in power electronic applications. Such semiconductors are referred to as power semiconductors. In their operations they may need heat sinks.

i. Explain why power semiconductors are used in the switching mode. [3 marks]

ii. What are heat sinks and why are they used in power semiconductors. [3 marks]

b) A three phase semi converter is used in an electrolysis process for purification of some metal. The converter is required to maintain a constant current of 5A through the electrolytic cell. The electrolyte is a solution of the impure metal. The pure metal is deposited on one of the two electrodes dipped into the electrolyte during the process. The converter outputs are connected to the electrodes through a large inductance to make the current ripple-free. The electrolytic cell can be modeled as battery in series with a 48Ω resistor. At the start of the process the battery voltage is 480V and it drops to 360V when almost all the metal in the electrolyte has been absorbed (end of the process). Determine the range of firing angles to maintain a current of 5A throughout the process. [9 marks]

Vsupply
600V
60Hz
3-ϕ

c) The speed of a single phase 1kW, 120V, 60Hz, 1750rpm induction motor is controlled by a single phase ac voltage controller connected to a single phase, 120V, 60Hz supply. At $\alpha=90^0$, the conduction angle is 135° and speed is 1200rpm.

i. Draw qualitative waveforms of the motor terminal voltage and motor current. [5 marks]

ii. Determine the rms voltage across the motor terminals. [4 marks]

Question B3

a) During turning off of a thyristor, current rises to 100A and voltage falls to 0V in 2μs, and during turn off, voltage rises to 200V and current falls to 0A in 5μs. When the thyristor is conducting, it has a voltage drop of 2V across its terminals. Calculate the energy loss per switching cycle and hence the mean power loss if the thyristor is being switched at a frequency of 10kHz and the conduction time is 70μs. [6 marks]

b) Using a diagram and for a typical application, describe and explain how a dual three phase converter works. Distinctly show current directions in the motoring and regenerative modes. In your explanations, show how the application is accomplished by the converter. [9 marks]

c) In a single-phase half bridge inverter, the load current is:

$$\mathbf{I_o = 540 \sin(\omega t - 45^\circ)}$$

The dc supply is 300V.

i. Sketch the waveforms for output voltage, output current and supply current and indicate the conducting devices in the various intervals. [6 marks]

ii. Determine the average value of the supply current from the dc supply [3 marks]

Question B4

a) A transistor used in an *ac* to *dc* converter dissipates 11mJ per switching cycle. The switching frequency is 1.2 kHz. The maximum junction temperature is 200°C and the ambient temperature is 30°C. The thermal resistance from the thyristor junction to the case is 1.3°C/W. The thermal resistance from the case to the heat sink is 0.8°C/W.

i. Design a suitable heat sink for the thyristor (obtain thermal resistance from the heat sink to ambient environment). [4 marks]

ii. What is the case temperature for the value of the calculated thermal resistance? [2 marks]

b) A buck converter is used to charge a battery bank from a *dc* voltage with a supply voltage of 160V. Assume an ideal switch, no loss operation, and neglect ripple of the output voltage. The battery bank consists of 40 identical batteries. Each battery has an internal resistance of 0.1Ω. At the beginning of the charging process, each battery voltage is 2.5V. When the battery is charged up to 3.2V, the charging process is completed. The average charging current is kept constant at 0.5A.

i. Draw a circuit diagram for the charging system indicating how the batteries are connected to the chopper. [3 marks]

ii. Determine the range of the chopper on time during the charging process if the chopper operating frequency is 250Hz. [6 marks]

c)

i. Using diagrams and waveforms describe and explain how a controlled rectifier can be used to construct a cycloconverter (explain using a single phase to single phase cycloconverter). [6 marks]

ii. Explain how a three phase to three phase cycloconverter can be used to start a synchronous motor. [3 marks]

Question B5

a)

i. Show the characteristic of a thyristor. [2 marks]

ii. Describe how a thyristor switch can be turned on and off. [4 marks]

b) A subway car uses a step up chopper for regenerative braking. The *dc* motor voltage constant is 0.3V/rpm and the *dc* bus voltage is 600V. The armature resistance is 0.1Ω. At a motor speed of 800rpm and motor current of 300A

i. Determine the duty ratio [4 marks]

ii. Determine the power fed back to the *dc* bus as a fraction of the power regenerated by the motor. [5 marks]

c) For a three phase bridge inverter, the dc supply voltage is 380V.

i. Sketch the waveforms of voltages of two of the phases and, hence of the load line voltage. [6 marks]

ii. Determine the angle by which firing of the thyristors has to be shifted to get an rms line voltage of 280V [3 marks]

END OF PAPER