SEMESTER 2 EXAMINATION 2013 - 2014

POWER ELECTRONICS AND DRIVES

DURATION 120 MINS (2 Hours)

This paper contains 6 questions

Answer
TWO questions out of **THREE** from **SECTION A**
and
TWO questions out of **THREE** from **SECTION B**

An outline marking scheme is shown in brackets to the right of each question.

This examination paper provides 80% of the module's marks, the remainder being from the coursework and laboratory work.
All numerical answers should be given to 5 significant figures.

A data sheet will be provided.

University approved calculators MAY be used.

A foreign language translation dictionary (paper version) is permitted provided it contains no notes, additions or annotations.

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Section A

Question A1.

(a) Describe and discuss the operation and features of the ac to ac power transmission system shown in the Figure 1.

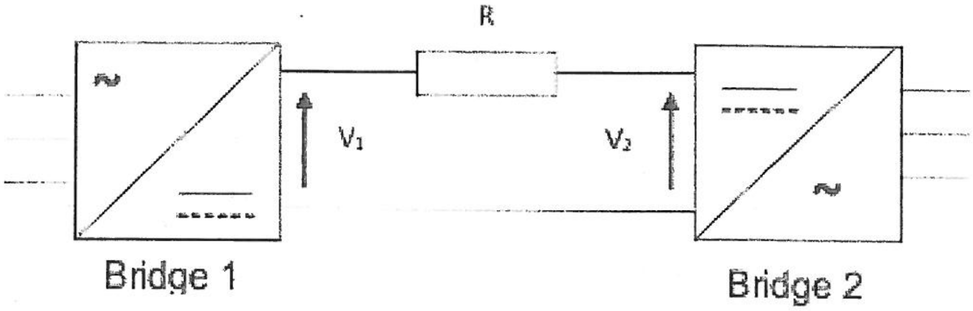


FIGURE 1

[4 marks]

(b) Calculate the voltages V_1 and V_2 for the transmission circuit shown in the figure together with the firing advance angle of the inverter and the firing angle of the rectifier. Calculate the system efficiency, ignoring any power loss in the two converters. The system specification is given below.

	Bridge Converter 1	Bridge Converter 2
Type	6-pulse fully controlled	6-pulse fully controlled
Supply voltage	208V	415V
Frequency	60Hz	50Hz
Source inductance per phase	0.019444mH	0.016667mH
Mode	Rectifier	Inverter
Power		775kW
dc current		5,000A
The resistance, R is 0.002Ω		

The mean output voltage of a p pulse converter, including overlap is given by: -

$$V_{mean} = p\frac{V_m}{\pi}sin\frac{\pi}{p}cos\alpha - \frac{pXI_L}{2\pi}$$

[10 marks]

(c) In the circuit shown in Figure 2, the thyristor is turned on at time $t = 0$, where the supply voltage, v, is given by

$$v = V_m sin(\omega t + \varphi)$$

where V_m is the peak voltage, ω is the supply frequency and φ is a constant phase angle.

Draw waveforms for the voltage across the inductor, V_L, and the current, i, when the phase angle, $\varphi = 120°$ (2.0944 rads). Label the horizontal axis from $\omega t = 0$ to $\omega t = 360°$ (2π rads) in $30°$ increments.

Calculate the average current over a supply cycle if the supply voltage is 70.711V, the supply frequency is 50Hz and the inductance is 5mH.

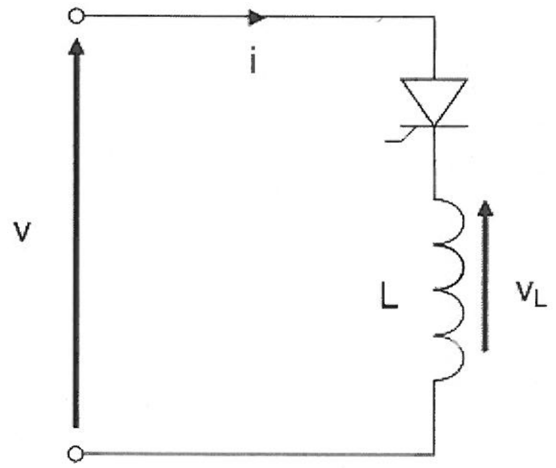


FIGURE 2

[6 marks]

TURN OVER

Question A2.

(a) (i) Draw and label a circuit diagram of a single phase to single phase cycloconverter. Identify each power electronic device in your circuit by numbering them in order. The supply and output frequencies are 60Hz and 15Hz respectively. The delay angles of the converter are all equal at $\pi/4$ rad.

(ii) Draw voltage waveforms for the supply and output for three supply cycles. Also show which devices are conducting using the device numbers shown in your circuit diagram.

(iii) Explain the operation of this cycloconverter, with a load consisting of an inductor and resistor in series, over an output cycle.

[7 marks]

(b) (i) The supply to a single phase to single phase cycloconverter is 100V and 50Hz. During an output half cycle the delay angles are 143, 98, 50, 42.447, 42.447, 50, 98 and 143 degrees.

(ii) Calculate the average voltage over the positive half cycle of the output voltage.

Also calculate the average power dissipated in a resistive load of 0.1Ω.

[7 marks]

(c) In a different converter, the voltage, v, across a load, over the time $-\pi < t < \pi$, is given by:

$$v = 0 \qquad \text{for} \qquad -\pi < t < \left(\alpha - \frac{5\pi}{6}\right)$$

$$v = 0 \qquad \text{for} \qquad \frac{-\pi}{2} < t < \left(\frac{\pi}{6} + \alpha\right)$$

$$v = 0 \qquad \text{for} \qquad \frac{\pi}{2} < t < \pi$$

$$v = 1 \qquad \text{for} \qquad \left(\alpha - \frac{5\pi}{6}\right) \leq t \leq -\frac{\pi}{2}$$

$$v = -1 \qquad \text{for} \qquad \left(\frac{\pi}{6} + \alpha\right) \leq t \leq \frac{\pi}{2}$$

where, α, is a delay angle with the following range.

$$0 \leq \alpha \leq \frac{\pi}{3}$$

Determine the Fourier series expansion for this voltage. Express the series in terms of the n^{th} harmonic.

[6 marks]

TURN OVER

Question A3.

(a) Draw and label a circuit diagram for a dc-dc switch-mode and step-down converter using a power MOSFET as the main semiconductor switching device. Describe the operation of this circuit, when continuous current flows in the inductor. Include in your answer, voltage and current waveforms for the inductor and circuit diagrams.

[7 marks]

(b) (i) Calculate the average output (load) current if the supply voltage is 600V, the output power is 960W and the duty cycle is 0.08.

(ii) Calculate the output current at the boundary of continuous and discontinuous current for a switching frequency of 50kHz. The inductor has a value of 100 μH. Also calculate the peak current.

(iii) Calculate the peak inductor current and the time during the off-period when the inductor current is zero for a duty cycle of 0.02.

[7 marks]

(c) The drain current, i, and the voltage drain to source voltage, v, of a power MOSFET are given by the following equations. Determine an equation for the energy dissipated in the transistor as a function of the time, t.

$$i = I(1 - t)$$
$$v = V tanh^{-1} t$$

where I and V are constants.

[6 marks]

Section B

Question B1.

A linear positioning system incorporates a high performance ballscrew with a lead of 0.02m, and is required to position the load, to a resolution of 10^{-5}m.

(a) Determine the required minimum pulses per revolution (PPR) of the incremental rotary position transducer that is used in this system, the encoder is directly coupled to the ballscrew. [4 marks]

(b) Discuss the operation of the optical rotary encoder suitable for this application, and highlight its advantages and disadvantages when used in this type of application. [6 marks]

(c) If the maximum linear speed of the load is 4m $\sec^{-1}$, determine the encoder's maximum speed and maximum output frequency. [4 marks]

(d) Comment on the precautions required when connecting the lead-screw to the encoder, and how can any problems be minimised. [6 marks]

TURN OVER

Question B2.

To test the component shown in Figure 3, it is spun at $1\ 000$ rev min^{-1} around the Z–Z axis using a directly coupled permanent magnet brushed d.c. motor. Assuming that the component has a uniform density of 1 500 kg m^{-3}, determine:

(a) The component's moment of inertia, around the axis of rotation, and hence the torque required to accelerate the component to 1 000 rev min^{-1} in 10 seconds.

[6 marks]

(b) The stored energy in the rotating system at 1 000 rev min^{-1}.

[2 marks]

(c) The regenerative current required to reduce the rotational speed from $1\ 000$ rev min^{-1} to zero in 5 seconds, and the energy returned to the supply.

[12 marks]

The motor's constants are $K_e = 0.6$ Volt sec Rad^{-1} and $K_t = 0.6$ Nm Amp^{-1}. The motor's rotor resistance is 1.5Ω and its inertia is 0.15 kg m^2.

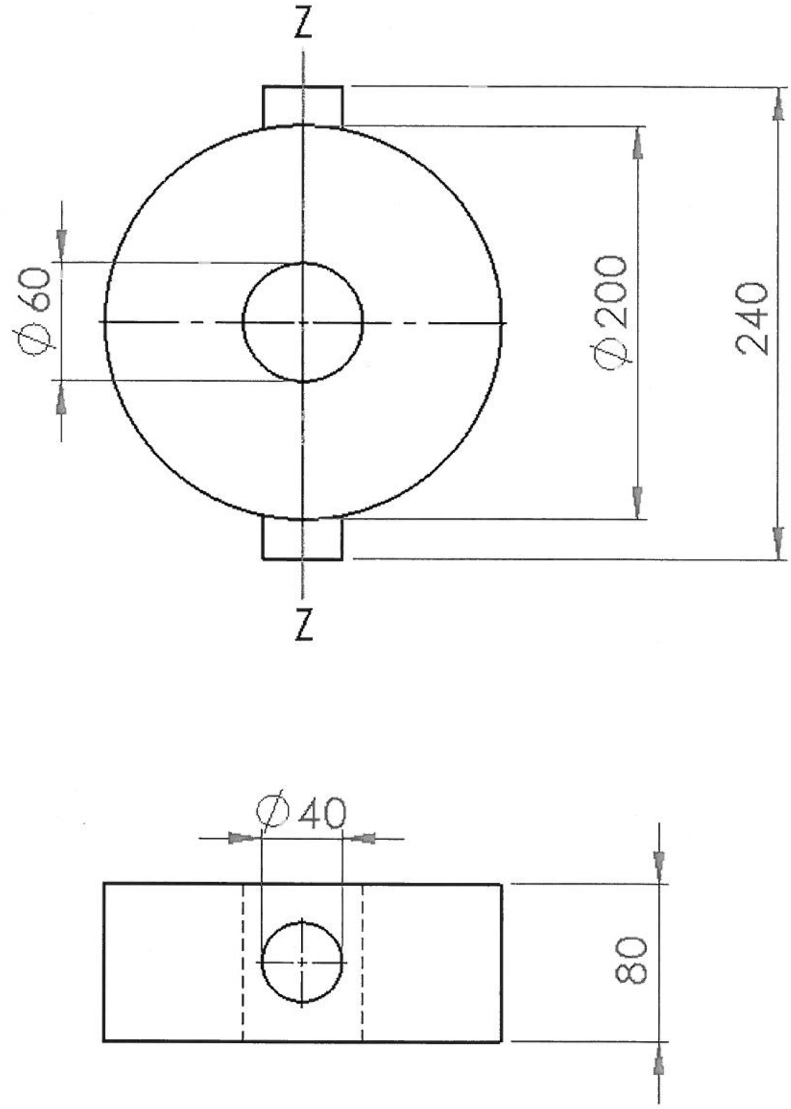


FIGURE 3: Component to be tested, all dimensions are in millimeters.

TURN OVER

Question B3.

Discuss the following aspects of the motor-drive selection process:

(a) The environmental cost savings from the use of a variable speed drive.

[6 marks]

(b) The rationale for the move from brushed motors to brushless motors.

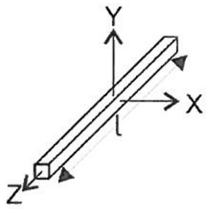
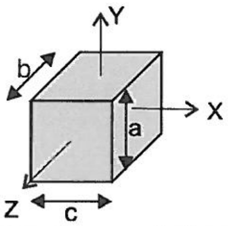
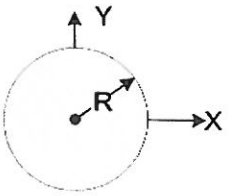
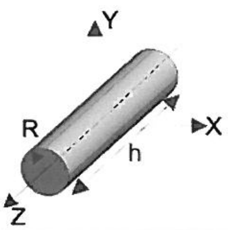
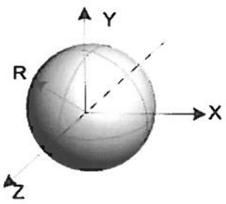
[6 marks]

(c) The benefits of using networked systems including, drives across a process line.

[8 marks]

END OF PAPER

Handout for Power Electronics and Drives

Body		I_{xx}	I_{yy}	I_{zz}
Slender bar		$\frac{ml^2}{12}$	$\frac{ml^2}{12}$	–
Cuboid		$\frac{m}{12}(a^2 + b^2)$	$\frac{m}{12}(b^2 + c^2)$	$\frac{m}{12}(a^2 + c^2)$
Thin disc*		$\frac{mR^2}{4}$	$\frac{mR^2}{4}$	$\frac{mR^2}{2}$
Cylinder		$\frac{m}{12}(3R^2 + h^2)$	$\frac{m}{12}(3R^2 + h^2)$	$\frac{mR^2}{2}$
Sphere		$\frac{2}{5}mR^2$	$\frac{2}{5}mR^2$	$\frac{2}{5}mR^2$

* A thin disc is considered a special case of a cylinder where h = 0.