UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, SECOND SEMESTER MAY 2016

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	POWER ELECTRONICS
COURSE CODE:	EE422
TIME ALLOWED:	THREE HOURS

INSTRUCTIONS:

1. **There are five questions in this paper. Answer any FOUR questions. Each question carries 25 marks.**
2. **If you think not enough data has been given in any question you may assume any reasonable values.**

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THIS PAPER CONTAINS SIX (6) PAGES INCLUDING THIS PAGE

QUESTION ONE ***(25 marks)***

A power transistor used in a convertor switches a load current of $45A$ with a supply voltage of $250Vdc$. The load can be assumed as inductive with a clamping diode. The transistor is driven by a $25kHz$ square wave signal having a duty cycle of 50%. Assume the following device parameters which are given using usual notation.

$t_{d(on)} = t_{d(off)} = 120ns$ $t_{ri} = t_{fi} = 200ns$ $t_{rv} = t_{fv} = 150ns$

$V_{CE(sat)} = 1.2V$ $\theta_{jc} = 0.5^0 \frac{C}{W}$ $T_{j(max)} = 150^0C$

(i) Draw the collector emitter-voltage and collector current wave forms for one switching cycle marked with relevant parameters.

(5 marks)

(ii) Calculate the energy dissipated in the transistor during one switching cycle and hence the device power loss.

(10 marks)

(iii) If the transistor is mounted on a heat sink, find its required thermal specifications. Assume that the maximum ambient temperature is 40^0C and the thermal resistance of the mounting accessories is $0.2^0 \frac{C}{W}$.

(6 marks)

(iv) Calculate the temperature of the transistor case and the heat sink under steady state of operation for the conditions stated in (iii) above.

(4 marks)

QUESTION TWO *(25 marks)*

(a) An *IGBT* is used to switch an inductive load as shown in Figure-Q2. You may assume that the load current is fairly constant.

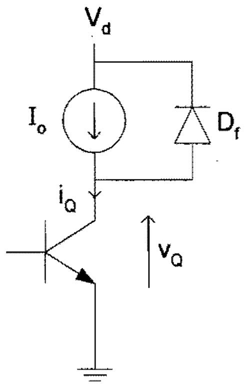

Figure - Q2

(a) Show the circuit of a turn off snubber which can be used with this *IGBT* switch. Draw the voltage and current waveforms modified by the snubber if optimum conditions are applied.

(4 marks)

(b) With respect to the circuit in (a) above, derive expressions for the turn-off power loss in the *IGBT* and in any other components.

(8 marks)

(c) Design the snubber circuit assuming optimum conditions, for the following data.

$t_{d(on)} = t_{d(off)} = negligible$ $t_{fi} = 500ns$

$V_d = 150V$ $I_o = 15A$ $Duty\ ratio = 50\%$

$Switching\ frequency = 100kHz$

(7 marks)

(d) Using the data given in (c) above, calculate the turn-off power loss in the *IGBT* and in the snubber circuit. What is the turn-off $\frac{dv}{dt}$ value?

(6 marks)

QUESTION THREE *(25 marks)*

A fully controlled single phase bridge circuit is connected to a separately excited dc motor as shown in Figure-Q3. Assume that the motor is operating in the inverting mode for regeneration.

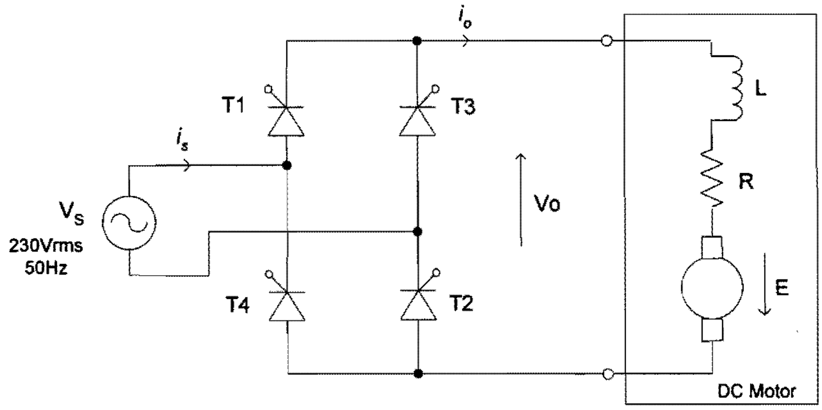

Figure-Q3

The speed of the motor is $150\frac{rad}{s}$ and the torque applied is $12Nm$. Some parameters related to the armature are,

$L = 0.05H$ $\quad R = 2\Omega$ $\quad$ torque constant $= 1\frac{Nm}{A}$ $\quad$ voltage constant $= 1\frac{V}{rad/_s}$.

While operating in the inverter mode and assuming that the armature current is continuous,

(a) Draw the following waveforms with reference to V_S.

(i) Motor terminal voltage v_O.

(ii) Armature current i_o. (4 marks)

(b) Derive an expression for i_o. (5 marks)

(c) Derive an expression for the average value of v_O. Hence find the required delay angle for the given operating point. (8 marks)

(d) Justify the initial assumption of 'continuous current'. (4 marks)

(e) Find the power transferred to the ac supply and the power losses in the system if the thyristors are ideal. (4 marks)

Note: $i = \frac{V_m}{Z}[\sin(\omega t - \theta)] + \frac{E}{R} + Ae^{-\frac{t}{\tau}}$ where,

$Z = \sqrt{R^2 + (\omega L)^2}$ $\quad \theta = tan^{-1}\left(\frac{\omega L}{R}\right)$ $\quad \tau = \frac{L}{R}$ $\quad A = constant$

QUESTION FOUR ***(25 marks)***

A three phase fully controlled full wave rectifier connected to an R-L load is shown in FigureQ4.

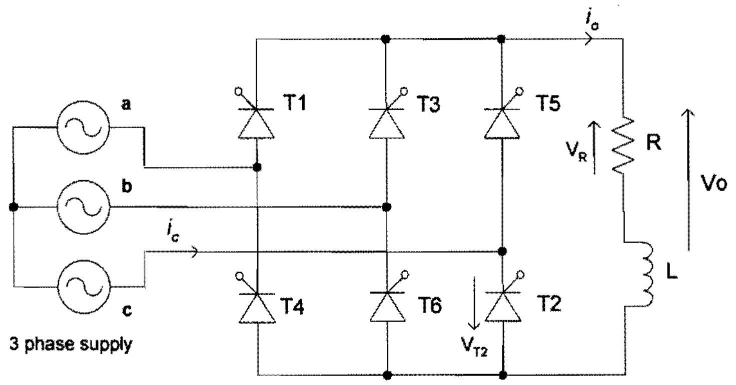

Figure-Q4

The three phase supply is $410V_{rms,L-L}$, $50Hz$ and the load is $R = 8\Omega$ in series with $L = 75mH$. Assume that the phase sequence is $a\ b\ c$ and the output current is ripple free.

(a) Derive an expression for the average load voltage if the delay angle is $'\alpha'$. (3 marks)

(b) What is the positive peak value of the output voltage? Calculate the delay angle for an average output voltage of $350V$. (3 marks)

(c) Draw the following waveforms on the sheets provided at the end of the paper. You may assume that the operating conditions are, as in (b) above.

- (i) Output voltage v_o and the voltage v_R . (3 marks)
- (ii) Currents in the thyristors T_2 and T_5 . (4 marks)
- (iii) Phase current and the phase voltage of 'phase c'. (3 mark)
- (iv) Voltage v_{T2}, across the thyristor T_2 . (4 marks)

(d) Find the values of the following with respect to this convertor assuming the conditions given in (b).

- (i) Value of the rms current in the thyristor T_5 and in 'phase c'. (3 marks)
- (ii) Power dissipated in the load. (2 marks)

QUESTION FIVE (25 *marks*)

A dc to dc buck converter is shown in Figure-Q5. It is operating at a switching frequency of f_s with a duty ratio of D.

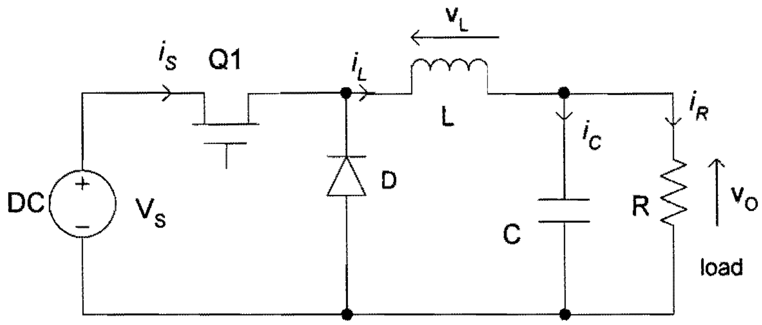

Figure-Q5

(a) Assuming that C is large, draw the waveforms of v_L and i_L.

(2 marks)

(b) If V_O can be assumed as constant show that the duty factor D is given by $\left[1 - \frac{|\Delta i_L| L f_S}{V_O}\right]$, where Δi_L is the peak to peak variation of the inductor current.

(5 marks)

(c) Derive an expression for the amplitude of the ripple voltage at the output.

(5 marks)

(d) Some of the data related to this convertor are given below.

$V_S = 60V \quad V_o = 48V \quad f_s = 50KHz \quad R = 15\Omega$

Using these values, calculate the following.

(i) The Duty factor. (2 marks)

(ii) Value of L, to have a peak to peak variation of i_L a 10% of the average load current. What is the maximum value of the current in the inductor?

(4 marks)

(iii) Value of C, to have a peak to peak variation of v_O a 5% of the average load voltage.

(2 marks)

(e) Calculate the value of the average source current.

(5 marks)

Question Four

Reg No: . ...