UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, SECOND SEMESTER MAY 2017

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 EIGHT (8) PAGES INCLUDING THIS PAGE

QUESTION ONE *(25 marks)*

(a) In an application, a set of three thyristors in series is used to work with a dc supply of $500V$. Assume that the usable forward break over voltage of each device is $200V$ and the leakage currents are $15mA, 22mA$ and $27mA$.

(i) Find the maximum value of equal resistances to parallel with each device for safe operation. (8 marks)

(ii) Calculate the voltages across each device under steady state and forward blocking. (3 marks)

(iii) Find the power dissipation in each of the devices and each of the resistors under forward blocking. (4 marks)

(b) Consider the circuit shown in Figure-Q1.

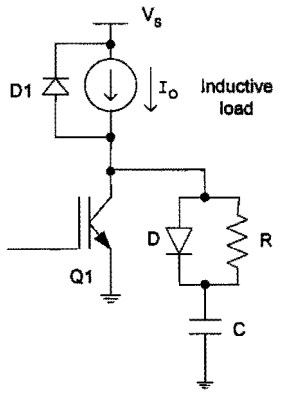

FIGURE-Q1

The IGBT shown is used to switch the inductive load at a 50% duty cycle. You may consider the following data assuming usual notation.

$V_S = 150V$ $I_o = 10A$ $f_S = 50kHz$ $t_{fi} = 200ns$

Considering the optimum conditions at turn-off and deriving any formula you use,

(i) Calculate the value of capacitor C. (6 marks)

(ii) Calculate the value of resistor R. (4 marks)

QUESTION TWO *(25 marks)*

A single phase fully controlled rectifier bridge circuit is connected to a dc source, inductor and a resistor as shown in Figure-Q2.

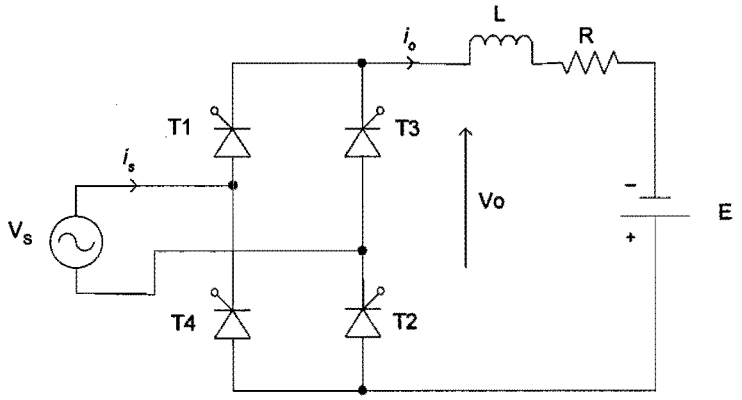

Figure-Q2

You may assume that the L is large and $V_s = 230V_{rms}$ at $50Hz$, $R = 0.6\Omega$ and $E = 140V$. The thyristors and the inductor can be considered as ideal.

(a) Draw the following waveforms on a common time scale with reference to V_S assuming a delay angle which will result $V_o(dc) < 0$.

(i) Load voltage v_o.

(ii) Current in the thyristor T_3.

(iii) Current in the thyristor T_2.

(iv) Current from the supply i_S.

(7 marks)

(b) Calculate the power transferred between the sources and any power losses if the delay angle is 130^0, deriving any formula you use.

(7 marks)

(c) (i) If the dc source to be charged with a current of $8A$, indicate clearly and fully the necessary settings of the circuit with supportive calculations. (5 marks)

(ii) For the above case (c) (i), find the power handled by each component of the load and the power factor seen by the ac source.

(6 marks)

QUESTION THREE *(25 marks)*

(a) A dc chopper converter circuit is shown in Figure-Q3.

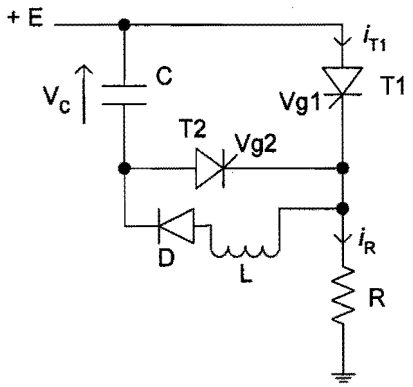

Figure-Q3

(i) Assume that $E = 36V$, $R = 8\Omega$ and $t_{OFF} = 150\mu s$, where t_{OFF} is the turn off time of thyristors. Calculate the minimum values of C and L deriving any formula you use. Also find the peak current value in T_1. (8 marks)

(b) A dc chopper operating on a supply voltage of $60Vdc$, feeds a separately exited dc motor. The field flux of the motor is kept constant and the losses in the chopper can be neglected. You may assume the following data.

Motor speed $= 85\frac{rad}{s}$ Load torque $= 6Nm$ Armature inductance $= 0.06H$

Armature resistance $= 0.4\Omega$ motor torque constant $= 0.5\frac{Nm}{A}$

Motor voltage constant $= 0.5\frac{V}{rad/s}$ chopper frequency $= 200Hz$

(i) Sketch the motor terminal voltage and the armature current waveforms. (3 marks)

(ii) Calculate the maximum and minimum values of the armature current deriving any formula you use. (10 marks)

(iii) Derive equations for the armature current during ON and OFF periods. (4 marks)

QUESTION FOUR (*25 marks*)

Consider the fully controlled three phase rectifier shown in Figure-Q4.

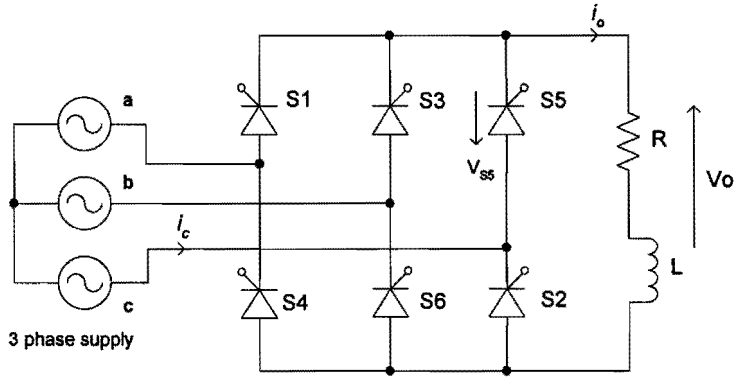

Figure-Q4

The rectifier is supplied with a $410V_{rms,L-L}$, $50Hz$ three phase supply. The load is inductive and having $R = 8\Omega$ and $L = 40mH$. Assume that the phase sequence as a, b, c.

(a) If the delay angle is 60^0, draw the following waveforms on the sheets provided.

(i) Output voltage v_o and output current i_o.

(ii) Currents in the thyristors S_5 and S_2.

(iii) Current of phase c.

(iv) Voltage v_{S5}, across the thyristor S_5.

(13 marks)

(b) Assuming a delay angle of 60^0,

(i) Find the dc load current deriving any formula you use.

(4 marks)

(ii) Calculate the rms values of currents in a phase and in a thyristor neglecting ripple.

(3 marks)

(iii) If the amplitude of the lowest harmonic normalized to $V_{m\,L-L}$ is 0.15, find the harmonic power dissipation in the load, neglecting other higher order harmonics.

(5 marks)

QUESTION FIVE (25 *marks*)

A full bridge converter circuit using IGBTs is shown in Figure-Q5. The load is inductive and consists with R and L in series.

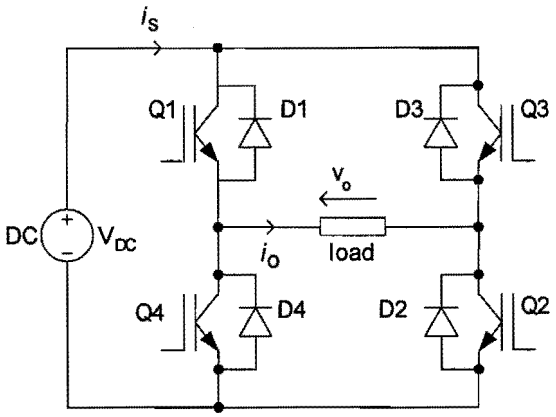

Figure-Q5

You may assume that,

V_{DC} =250V R= 8Ω L=20mH

(a) The bridge outputs a low frequency square wave of *50Hz*. Considering the fundamental and the next two higher harmonics,

(i) Find the power dissipation in the load. (5 marks)

(ii) Calculate the total harmonic distortion (THD) in the load voltage and load current. (6 marks)

You may use, $V_n = \frac{4V_{DC}}{n\pi} sin(n\omega_0 t)$ where n is odd.

(b) A bipolar PWM signal is generated using a *50 Hz* sine wave reference having amplitude of *10V* and a triangular carrier of 1.45kHz with an amplitude 14.3V. If this PWM signal is used to switch the bridge shown in Figure-Q5 with the associated data,

(i) Find the rms voltage and rms current of the fundamental component at the load. (4 marks)

(ii) Calculate the power dissipation in the load due to fundamental component. (3 marks)

(iii) Analytically compare the harmonic distortion of the load current with the square wave switching scheme. (7 marks)

Normalized Fourier coefficients $\frac{V_n}{V_{DC}}$ for bipolar PWM:

$n=1$	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
$n=m_f$	0.60	0.71	0.82	0.92	1.01	1.08	1.15	1.20	1.24	1.27
$n=mf\pm2$	0.32	0.27	0.22	0.17	0.13	0.09	0.06	0.03	0.02	0.00

Question Four

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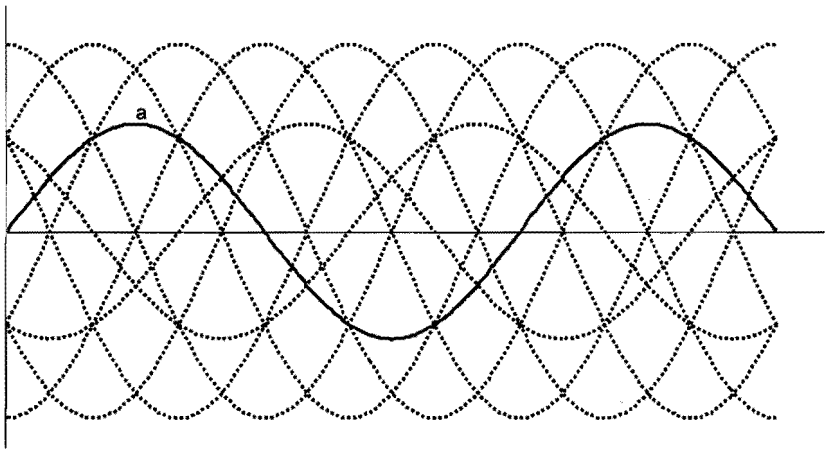

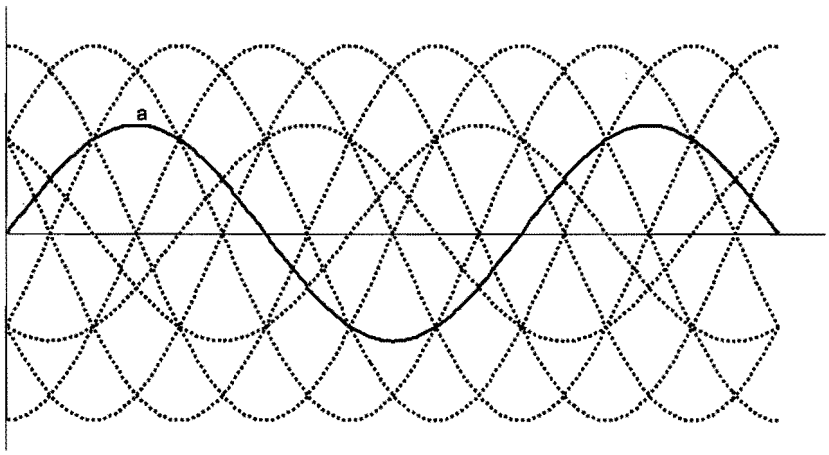

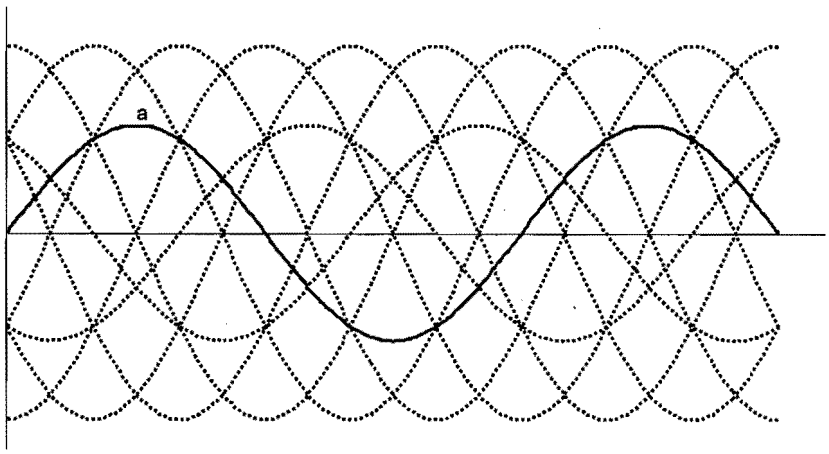

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