UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, SECOND SEMESTER MAY 2014

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)***

An inductive load with a constant load current I_L is switched by a BJT as shown in Figure-Q1.

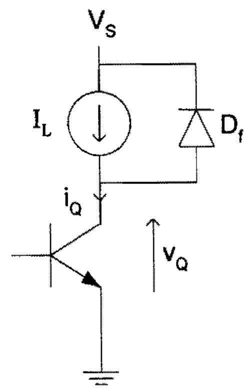


Figure - Q1

(a) Draw the circuit of a turn off snubber suitable for Figure-Q1 and assuming optimum conditions, draw the voltage and current waveforms modified by the snubber.

(4 marks)

(b) Derive an expression for the turn-off power loss of the transistor.

(8 marks)

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

$t_{fi} = 0.5\mu s$ $\quad t_{d(on)} = t_{d(off)} = negligible$

$V_S = 125V$ $\quad I_L = 10A$ $\quad Duty\ ratio = 50\%$

$Switching\ frequency = 100kHz$

(8 marks)

(d) Calculate the turn-off power loss in the transistor when the snubber circuit is designed for optimum conditions. What is the power loss in the snubber circuit? You may use the data given in (c) above.

(5 marks)

QUESTION TWO *(25 marks)*

A three phase fully controlled full wave rectifier is shown in Figure-Q2.

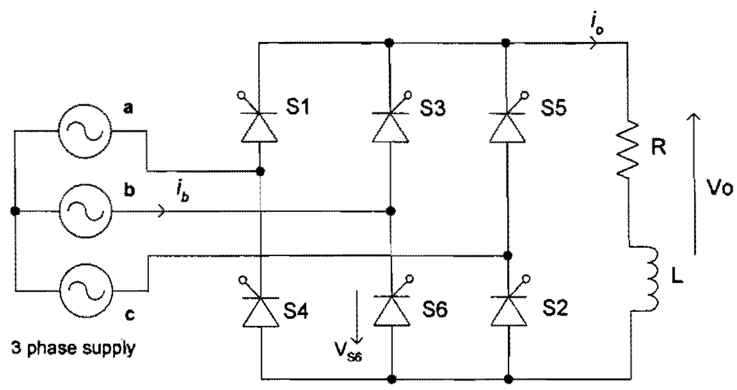


Figure-Q2

The rectifier is connected to a $400V_{rms,L-L}$, $50Hz$ three phase supply and the load is $R = 10\Omega$ in series with $L = 50mH$. Assume that the phase sequence as , b , c .

(a) Draw the following waveforms on the sheets provided at the end of the paper. Assume a delay angle greater than 30^0.

   (i) Output voltage v_o and the output current i_o .

   (ii) Currents in the thyristors S_3 and S_6 .

   (iii) Phase current and the phase voltage of phase b.

   (iv) Voltage v_{S6}, across the thyristor S_6 .

(14 marks)

(b) Find the delay angle for an average load current of $40A$ proving any formula you use.

(4 marks)

(c) Calculate the rms value of the current in a thyristor and in a phase.

(3 marks)

(d) If the normalized harmonic amplitudes $\frac{V_6}{V_m}$ and $\frac{V_{12}}{V_m}$ are 0.2 and 0.1 respectively, calculate the amplitude of the respective harmonic currents. Assume usual notation.

(4 marks)

QUESTION THREE *(25 marks)*

A fully controlled single phase bridge circuit is connected to a dc source as shown in Figure-Q3.

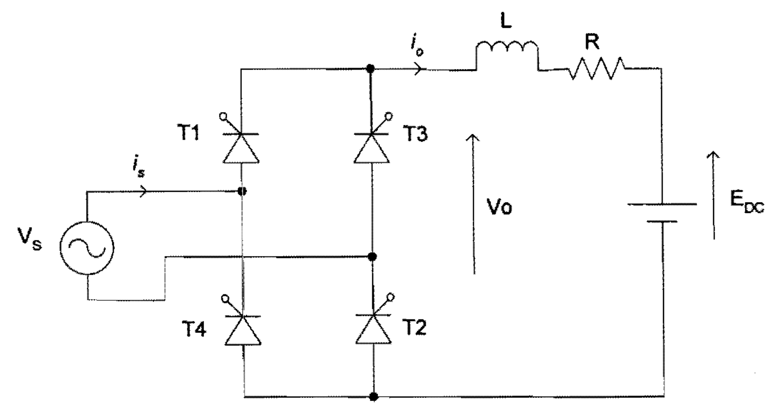


Figure-Q3

The ac supply voltage $V_s = 220V_{rms}$ at $50Hz$, $R = 0.5\Omega$ and $E_{DC} = 120V$. You may assume that the L is large.

(a) Draw the following waveforms with reference to V_S assuming that the delay angle is set for rectification.

(i) Load voltage v_o.

(ii) Current in the thyristor T_1.

(iii) Current in the thyristor T_4.

(iv) Current from the supply i_S.

(7 marks)

(b) (i) Find the delay angle to obtain a dc load voltage of $V_o = 125V$ deriving any formula you use.

(5 marks)

(ii) Determine the power absorbed by each component of the load and find the power factor seen by the ac supply. Assume $V_o\,dc = 125V$.

(6 marks)

(c) If the delay angle is 126^0 with E_{DC} reversed, find and comment on the power transferred between the sources while calculating the losses.

(7 marks)

QUESTION FOUR *(25 marks)*

A fly back dc to dc convertor circuit is shown in Figure-Q4.

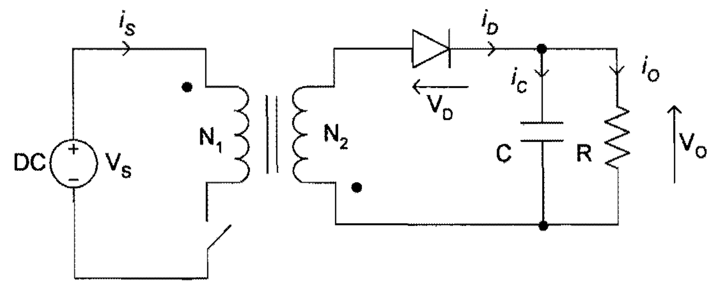


Figure-Q4

(a) Assuming that the C is large, draw the equivalent circuit showing the magnetic components and sketch the following waveforms.

(i) Current in the magnetizing inductance.

(ii) Current delivered from the source.

(iii) Current through the diode.

(iv) Current through the capacitor.

(7 marks)

(b) Derive the following expressions assuming usual notation.

(i) $V_O = \left(\frac{V_S D}{1-D}\right)\left(\frac{N_1}{N_2}\right)$

(4 marks)

(ii) Average current in the magnetizing inductance ,

$I_{LM} = \left(\frac{V_O}{(1-D)R}\right)\left(\frac{N_2}{N_1}\right)$

(4 marks)

(c) Following data is available for the converter shown in Figure-Q4.

$V_S = 25V$ $\quad \frac{N_1}{N_2} = 3$ $\quad L_M = 550\mu H$ $\quad R = 5\Omega$ $\quad C = 220\mu F$

$f_S = 50kHz$ $\quad V_o = 5V$

Calculate the following for the converter.

(i) Duty ratio of operation.

(ii) Average current flowing through the magnetizing inductance.

(iii) Maximum and minimum currents through the magnetizing inductance.

(iv) Peak to peak value of the output ripple voltage.

(v) Current from the input source if the efficiency of the system is 90%.

(10 marks)

QUESTION FIVE (25 *marks*)

A full bridge square wave inverter implemented with IGBTs is shown in Figure-Q5. The load consists of R and L in series.

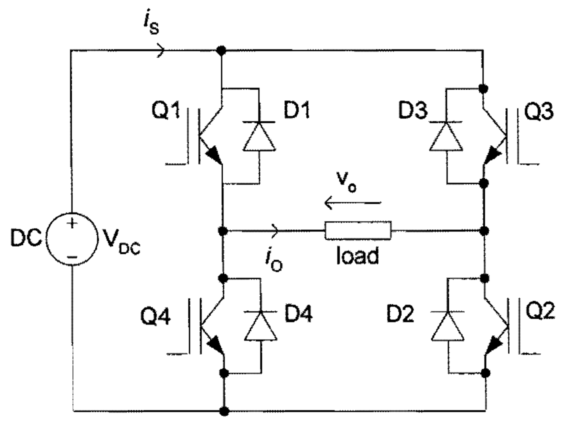


Figure-Q5

Assume the following data for the inverter.

V_{DC} =220V   R=25Ω   L=50mH   f=50Hz

(a) Draw the following waveforms assuming ideal components. The waveforms should be marked with identified critical points.

(i) Load voltage v_O.

(ii) Load current i_O.

(iii) Current flowing from the supply i_S.

(5 marks)

(b) The load current for the period $0 < t < \frac{T}{2}$ where T is the cycle time, given by

$$i_o(t) = \frac{V_{DC}}{R} + \left(I_{min} - \frac{V_{DC}}{R}\right) e^{-\frac{t}{\tau}} \quad ; \qquad \tau = \frac{L}{R}.$$

Find the maximum and minimum values of the current through the load.

(5 marks)

(c) If the output voltage is given by

$$v_O = \sum_n^{\infty} \frac{4V_{DC}}{n\pi} \sin(n\omega_0 t)$$ where n is odd, find the following quantities.

(i) Power absorbed by the load.

(ii) Average current delivered by the source.

(iii) Total harmonic distortion of the output voltage.

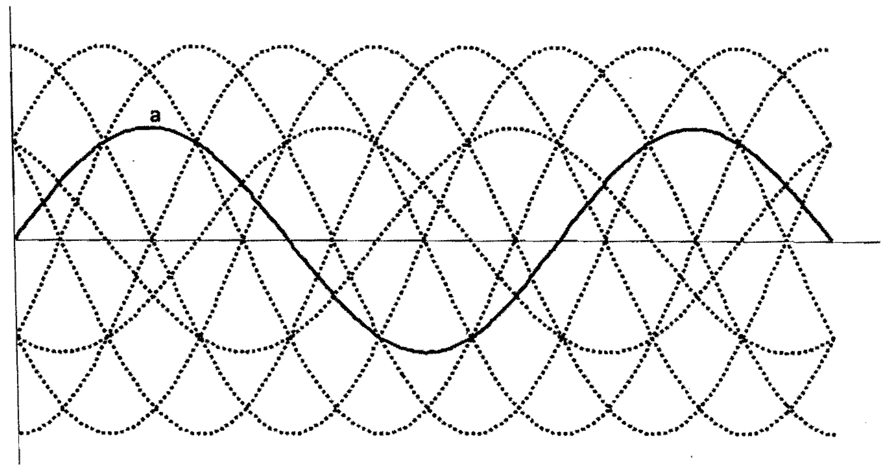
(iv) Total harmonic distortion on the output current.

(15 marks)

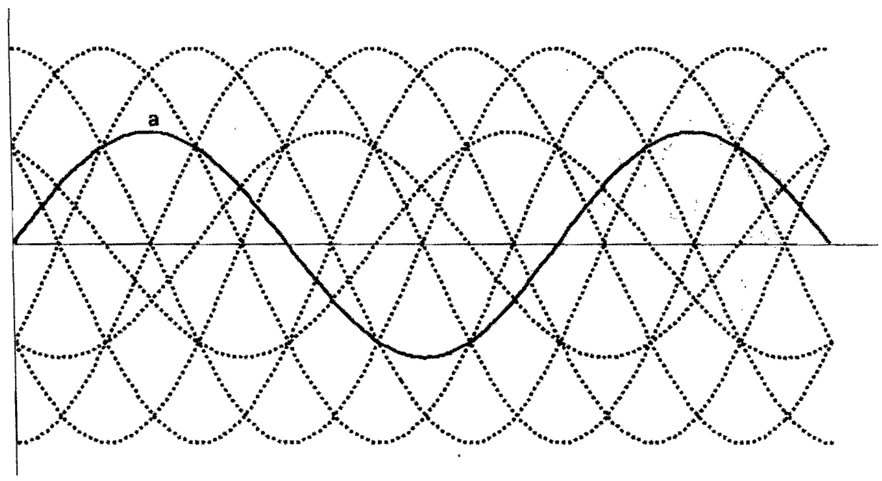
Question Two

Reg No:

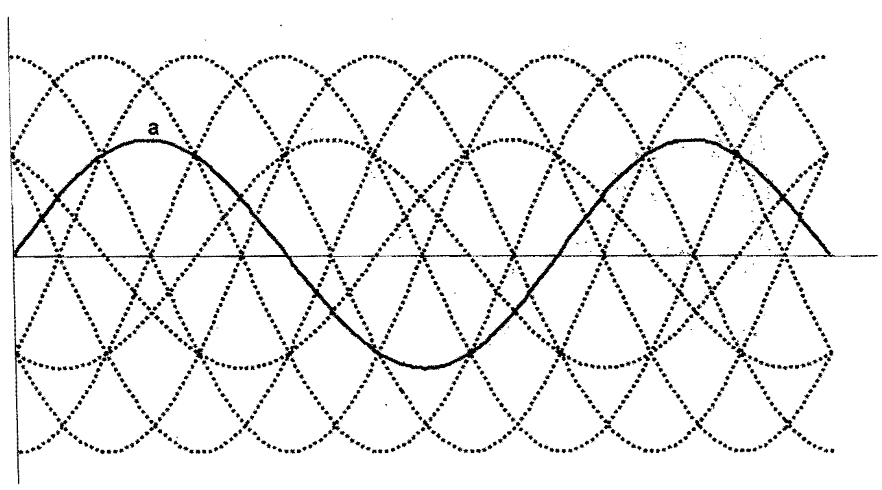
v_0



i_0



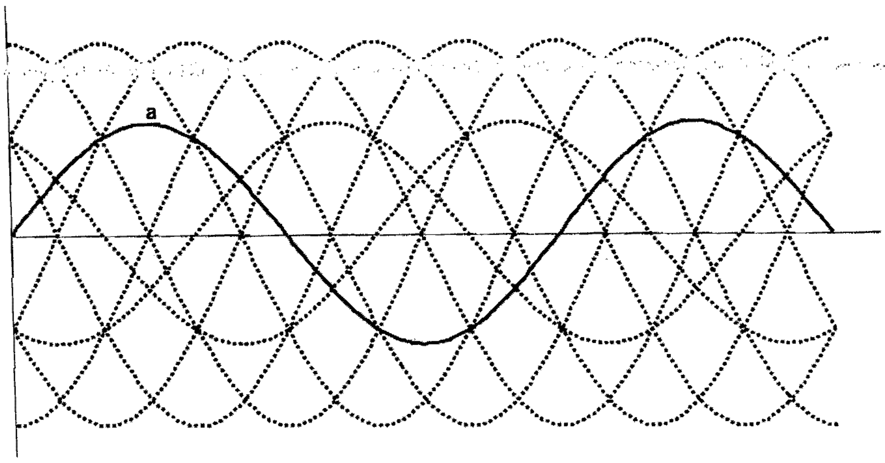
i_3



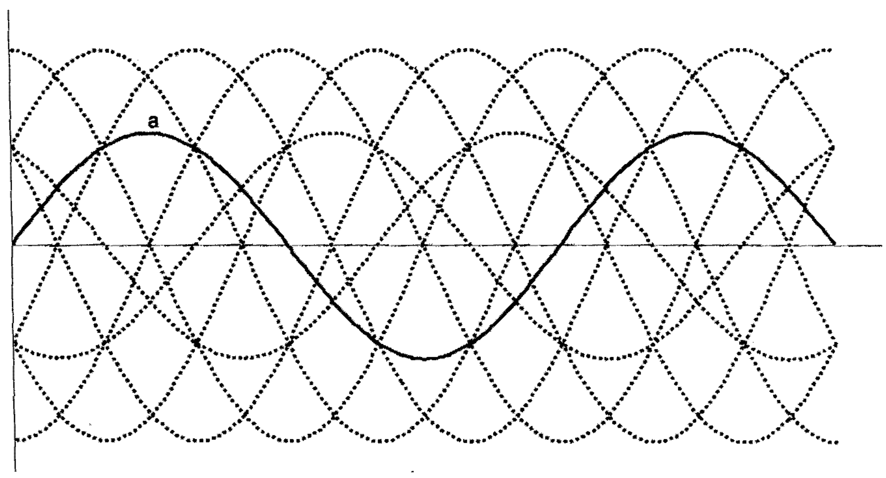
Question Two

Reg No:

i_6



v_b
i_b



v_{S6}