The Open University of Sri Lanka

Faculty of Engineering Technology

Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX5313/ DMX5570 Power Electronics and Motor Drives**
Academic Year	: 2020/2021
Date	: 22nd January 2020
Time	: 1400-1700 hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions
2. This question paper consists of **Seven (7)** questions in Six (7) pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (**CBT**).
6. The symbols used in this paper have their usual meanings.
7. Clearly state any assumptions that you may make.
8. Answers should be in clear handwriting.
9. Do not use red color pen.

Question 1 **[20 marks]**

a) Explain the following in brief

i. Distinguish between DIAC and TRIAC in reference to power electronics [4 marks]

ii. How these components (mentioned above) differ from a SCR [4 marks]

b) The single-phase ac voltage controller has a $230V_{rms}$, 60Hz AC source. The normalized plot of $V_{0,\,rms}$ as a function of firing delay angle α is shown in figure Fig.Q1_a. If the load resistance is 25Ω, determine the following:

i. The delay angle required to deliver 650W to the load [2 marks]

ii. The rms source current [2 marks]

iii. The rms and average current in the SCRs [2 marks]

iv. The power factor. [2 marks]

v. The Total harmonic Distortion -THD of the source current (use Fig.Q1_b) [2 marks]

vi. Roughly sketch the waveforms (source voltage, output voltage and output current) of single-phase AC voltage controller with R-L load if the delay angle α is 45^0 [2 marks]

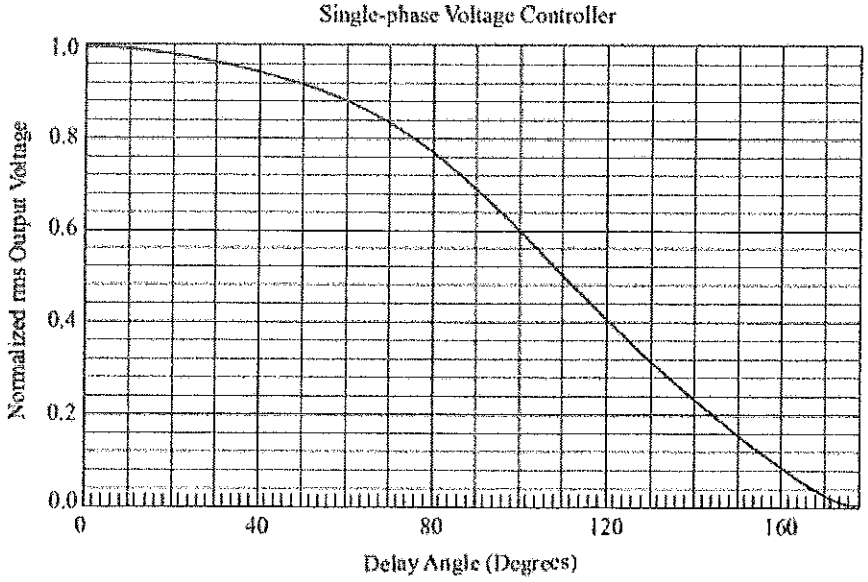

Fig Q1_a Normalized rms load voltage vs. delay angle for a single -phase ac voltage controller with a resistive load.

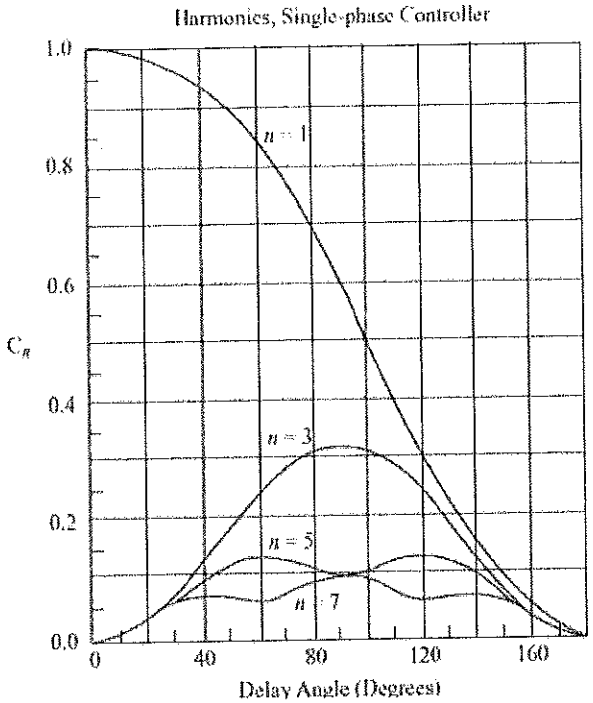

Fig.Q1_b Normalized harmonic content vs. delay angle for a single-phase ac voltage controller with a resistive load; Cn is the normalized amplitude

Question 2 **[20 marks]**

Fig.Q2_a shows a full-bridge single-phase inverter. The inverter is controlled to give an output V_o with the waveform as shown in Fig.Q2_b. The Fourier expansion of the output voltage V_O is given by $Vo = \sum_n b_n \sin(n\omega t)$, where $b_n = \frac{4V_{dc}}{n\pi} \sin(n\beta)$ *and* $n = 1,3,5,7, \ldots$.

a) Sketch the gate signals to be given to devices Q_1 -Q_4. [5 marks]

b) Calculate the angle β required to eliminate the most dominant harmonic component of the output. [2 marks]

c) Calculate percentage of Total Harmonic Distortion (%THD) of the output for the case b) above. [3 marks]

d) The calculated angle β for the case(ii) above is used with the inverter to supply a fundamental rms voltage of 280V at the output. Calculate the voltage - V_{dc} required. [5 marks]

e) Briefly explain the use of inverters in industrial applications. What is meant by the term blanking time as applied to an inverter? Why is it required? [5 marks]

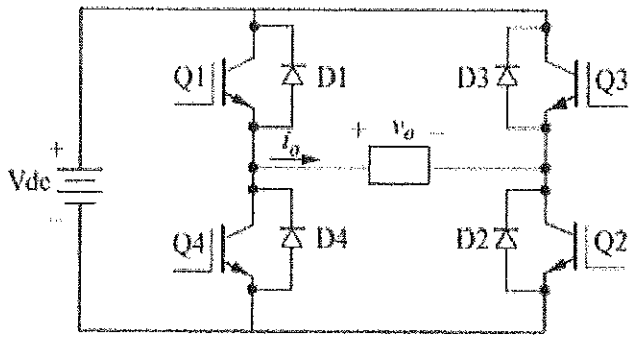

Fig.Q2_a

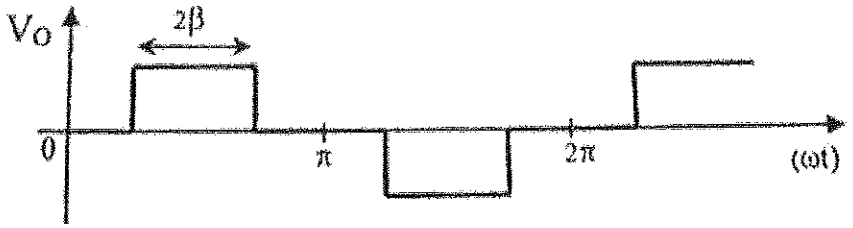

Fig.Q2_b

Question 3 **[20 marks]**

Fig.Q3 shows a three-phase, full wave, uncontrolled rectifier. The input three-phase supply is given by the following equations;

$$V_a = V_m * Sin(\omega t + 0), V_b = V_m * Sin\left(\omega t - \frac{2\pi}{3}\right), V_c = V_m * Sin\left(\omega t + \frac{2\pi}{3}\right),$$

a) Sketch the output voltage waveform – V_o to the same time scale as the three-phase supply. [5 marks]

b) Draw the phase current waveform - I_s (i_a) to the time scale as in (i). Clearly indicated $60^0(\pi/3)$ conducting periods of diode pairs. [5 marks]

c) Derive an equation for the rms current of I_s given in (ii) above. [10 marks]

Note that the line-to-line voltage equations for the above three-phase systems are,

$$V_{ab} = \sqrt{3}V_m * Sin\left(\omega t + \frac{\pi}{6}\right), V_{bc} = \sqrt{3}V_m * Sin\left(\omega t - \frac{\pi}{2}\right), V_{ca} = \sqrt{3}V_m * Sin\left(\omega t + \frac{5\pi}{6}\right),$$

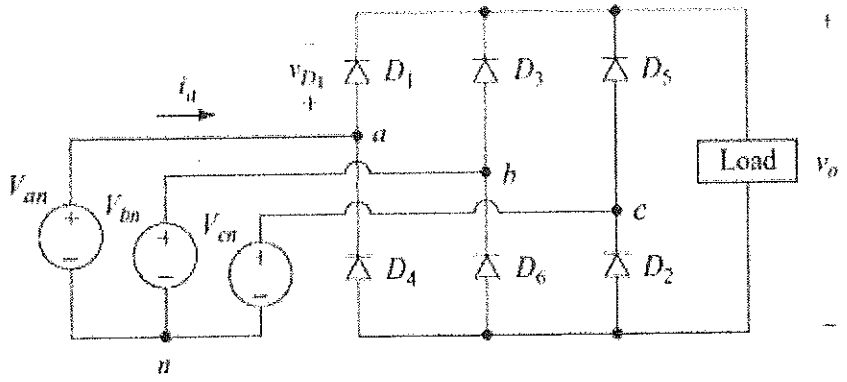

Fig.Q3

Question 4 **[20 marks]**

a) Explain the following as applied to a thyristor

i. Holding current [2 marks]

ii. Latching current [2 marks]

iii. Why a thyristor needs a longer gate pulse at the gate to drive an inductive load, compared to a resistive load [3 marks]

b) The full-wave controlled bridge rectifier of Fig.Q4 has an ac input of 120 V rms at 60 Hz and 10Ω load resistor with a 100mH inductor load. The delay angle is 60°.

i. Verify the load current is continuous. [5 marks]

ii. Determine the DC component of the voltage [4 marks]

iii. Power absorbed by the load. [4 marks]

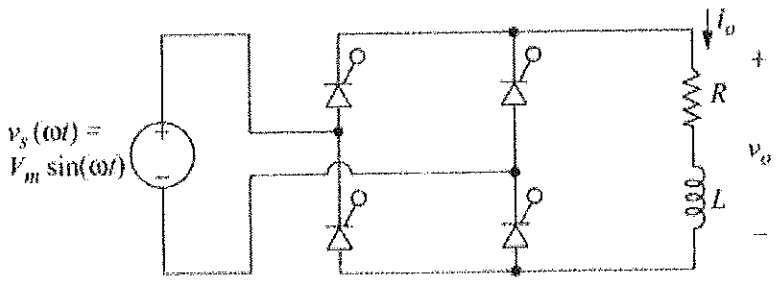

Fig.Q4

Question 5 **[20 marks]**

a) Briefly discuss

i. The application of a switching dc-dc voltage regulator. (SMPS – Switched Mode Power Supply). [3 marks]

ii. What is the most salient feature of SMPS over the conventional DC voltage regulator? [3 marks]

b) Fig.Q5 shown a circuit diagram of a buck converter.

i. Sketch the available mode circuits relevant to the switching conditions and the steady state waveforms of the inductor current I_L, source current I_S, inductor voltage V_L, inductor current I_L for discontinuous mode of conduction. Mark the important voltage levels, current levels, ON/OFF time periods, etc. [5 marks]

ii. A buck converter has an input of 6 V and an output of 1.5 V. The load resistor is 3Ω, the switching frequency is 400 kHz, L = 5mH, and C=10 μF.

1. Determine the duty ratio. [2 marks]
2. Determine the average, peak, and rms inductor currents. [3 marks]
3. Determine the average source current. [2 marks]
4. Determine the peak and average diode current. [2 marks]

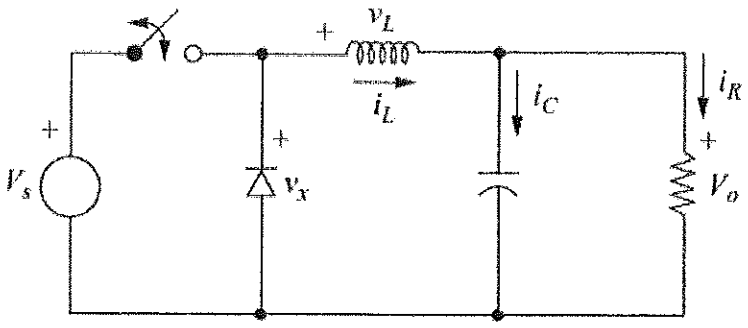

Fig.Q5

Question 6 **[20 marks]**

a) List down three capabilities of a power electronics convertor to supply a dc motor. [6 marks]

b) Variable speed drive is built with a separately excited DC motor, rated at 220 (max set voltage). The motor is coupled to pump that developed a torque proportional to the square of the speed at rated voltage conditions. Motor load system runs at 1200rpm in steady state. No load speed of the motor at rated voltage conditions is 1300 rpm. Calculate the combination of the armature and field voltages required to run the motor load systems at,

i. 250 rpm [7 marks]

ii. 1750 rpm [7 marks]

Question 7 **[20 marks]**

a) Briefly explain

i. The three broad classes of snubber circuits according to the circuit topology perspective. [3 marks]

ii. Heat sinks and thermal management [3 marks]

iii. Turn -off snubber [2 marks]

b) A MOSFET mounted on a heat sink absorbs a thermal power of 12W. The thermal resistances are 1.2^0C/W from the junction to the case, 0.9^0C/W for the case to the heat sink, and 2.5^0C/W for the heat sink to ambient. The ambient temperature is 42^0C. Determine the junction temperature. [12 marks]

End of the paper