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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical & Computer Engineering

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX5453 Power Electronics**
Academic Year	: 2023/2024
Date	: 08th February 2025
Time	: 0930 – 1230 hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Five (5)** questions in **Three (3)** pages.
3. Answer all the **Five (5)** questions.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (CBT).
6. Answers should be in clear handwriting.
7. Do not use Red colour pen.

Question 01

Figure Q1 shows a half-wave, controlled rectifier circuit with a pure resistive load equal to R.

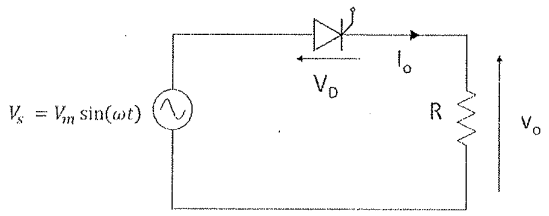


Figure Q1

i. If the supply voltage $V_s = V_m \sin(\omega t)$ and conduction angle $\alpha < 90°$, sketch the waveforms of the output voltage (V_o) and the voltage across the diode (V_d) in a common time scale. Indicate all the voltage levels and phase angles. *(4 marks)*

ii. Starting from the first principles, prove the following expressions for the average voltage of the output voltage (V_o) and rms of the current flowing through the load resistor (I_o) are true when the conduction angle $\alpha < 90°$:

a. $V_{avg} = \frac{V_m}{\pi}[1 + \cos\alpha]$ *(2 marks)*

b. $I_{rms} = \frac{V_m}{2R}\sqrt{\frac{1}{\pi}\left(\pi - \alpha + \frac{\sin 2\alpha}{2}\right)}$ *(2 marks)*

iii. The half-wave, controlled rectifier is connected to 240 V_{rms}, 50 Hz supply and a load resistor of $R = 15\ \Omega$. Calculate the following when the conduction angle, $\alpha = \pi/6$:

a. Average (DC) current flowing through the load. *(3 marks)*
b. rms of the output voltage. *(3 marks)*
c. Power absorbed by the load. *(3 marks)*
d. Input power factor. *(3 marks)*

Question 02

The converter shown in Figure Q2 operates as a phase controller and drives a resistive load of 15 Ω. The supply voltage is 230 V, 50 Hz. The delay angle of thyristors T_1 and T_2 are equal to $2\pi/5\ rad$.

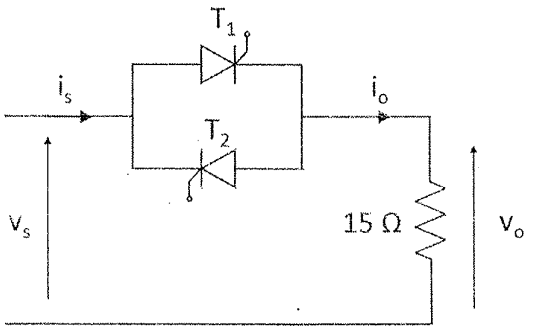


Figure Q2

i. Sketch the input voltage and the output voltage waveforms on a common time scale. *(4 marks)*

ii. Derive an expression for the rms value of the output voltage (V_o) in terms of input voltage (V_S) and delay angle (α) and, thereby, calculate the rms voltage. *(4 marks)*

iii. Calculate the input power factor *(4 marks)*

iv. Calculate the average and rms values of the current flowing through a thyristor *(4 marks)*

v. If this controller is used for on-off controller with 10-17 on-off cycles, calculate the rms value of the output voltage. *(4 marks)*

Question 03

i. A chopper circuit is charging a 65 Ah battery from a 120 V DC supply in continuous conduction mode. An ideal inductor with 0.5 mH inductance is connected in series to the battery. Assume that the battery voltage is constant during the operation and has zero internal resistance.

   a. Find the chopping frequency of the circuit to limit the charging current to C/10 with 10% ripple, when the duty cycle is kept at 20%. *(5 marks)*

   b. If another battery of 65 Ah (same voltage) is required to be charged at same rate with 5% ripple from this converter, determine the duty cycle, pulse on-time and the frequency of operation. *(5 marks)*

ii. A step-up (boost) converter is supplied by a 36 V DC supply delivers DC power and connected to a load at 48 V DC. The converter operates in constant frequency operation.

   a. The switch-on time of the converter is 120 µs. Find the time (T_{out}) of which the DC supply is connected to the output through the inductor. *(5 marks)*

   b. The time T_{out} is reduced to 50% of the previous case. Find the output DC voltage. *(5 marks)*

Question 04

Figure Q4 shows the circuit diagram of a buck-boost converter.

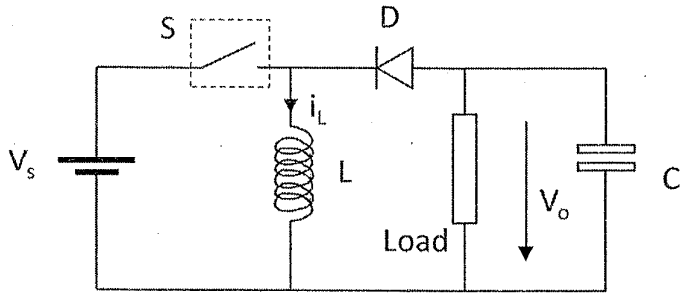


Figure Q4

i. Sketch the waveforms of the inductor current and the output voltage according to the switching pulses of S. *(3 marks)*

ii. Derive an expression for the output voltage of the buck-boost converter in terms of the duty cycle of the converter. *(3 marks)*

iii. If the converter needs to produce 24 V and 36 V at the output from a 30 V constant DC source, calculate the,

a. Pulse on-times for two cases when operating in 2 kHz constant frequency. *(2 marks)*

b. Frequencies for two cases when operating in 150 µs constant pulse on-time. *(2 marks)*

iv. Describe the function of a snubber circuit in the context of thyristor switching applications. You must include a circuit diagram together with waveform sketches in your answer. *(5 marks)*

v. Redraw the circuit diagram shown in Figure Q4 with a snubber circuit and state how it functions during the operation. *(5 marks)*

Question 05

Figure Q5 shows a square-wave bridge inverter with phase delay (displacement) control which delivers power to a resistive load which has 150 Ω resistance. The DC source connected to the inverter fluctuates its voltage between 28 V to 36 V. The inverter output voltage is required to be kept at 24 V_{RMS} 50 Hz.

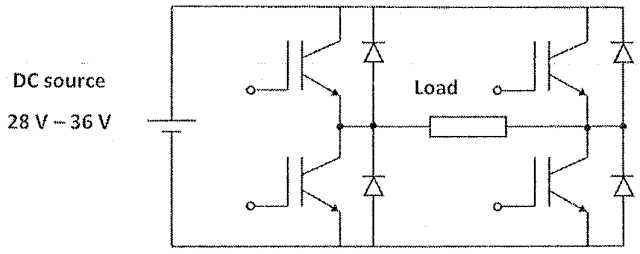


Figure Q5

i. Draw the output voltage and gate pulses of each switch for the inverter shown in Figure Q5 in a common time scale. *(4 marks)*

ii. Determine the range of phase angle (in degrees) to be maintained to obtain the required voltage at the inverter output. *(4 marks)*

iii. Calculate the average power delivered to the load. *(2 marks)*

iv. Calculate the range of pulse width to be maintained to obtain the same RMS voltage at the inverter output when uniform pulse width modulation (UPWM) is used. Assume that the career frequency is 16 times the frequency of output. *(4 marks)*

v. If the maximum controllable angle of a pulse is 20° in the UPWM, determine the minimum allowable DC voltage at the input. *(4 marks)*

vi. State the possible reason why the pulse width cannot be increased beyond 20°. *(2 marks)*