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

074

Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX5453 Power Electronics**
Academic Year	: 2022/2023
Date	: 01st February 2024
Time	: 1330 – 1630 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 an ideal half-wave rectifier circuit with a pure resistive load equal to R.

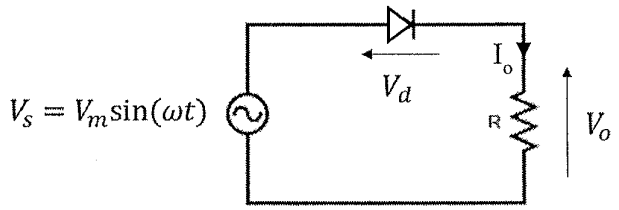


Figure Q1

i. If the supply voltage $V_s = V_m \sin(\omega t)$, 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:

a. $V_{avg} = \frac{V_m}{\pi}$ *(2 marks)*

b. $I_{rms} = \frac{V_m}{2R}$ *(2 marks)*

iii. If the rectifier is supplied with a 240 Vrms, 50 Hz supply and connected to a load resistor of $R = 15\ \Omega$, calculate the following:

a. Average 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 controller shown in Figure Q2 is operating 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 60^0.

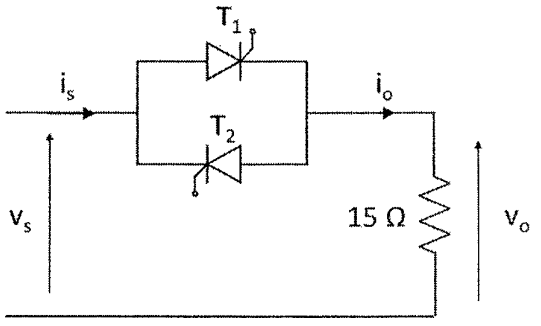


Figure Q2

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) and, thereby, calculate the rms voltage. *(4 marks)*

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

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

v. If this controller is used as an on-off controller with 15-17 on-off cycles, calculate the output voltage (rms) *(4 marks)*

Question 03

i. A chopper circuit is charging a 65 Ah battery from a 100 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 15%. *(5 marks)*

   b. If another battery of 65 Ah (same voltage) is required to be charged at C/2 rate 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 32 V DC supply delivers DC power and connected to a load at 52 V DC. The converter operates in constant frequency operation.

   a. If 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. If 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.

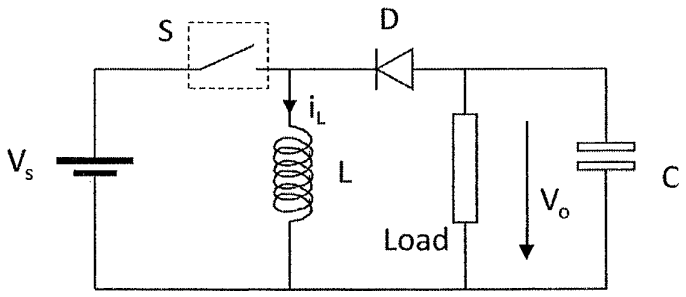


Figure Q4

i. Sketch the waveform 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 20 V and 30 V at the output from a 24 V constant DC source, calculate,

   a. The pulse on-times for two cases when operating in 1.5 kHz constant frequency. *(2 marks)*

   b. The frequencies for two cases when operating in 100 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 Q3 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 120 Ω resistance. The DC source connected to the inverter fluctuates its voltage between 24 V to 30 V. The inverter output voltage is required to be kept at 20 V_{RMS} 50 Hz.

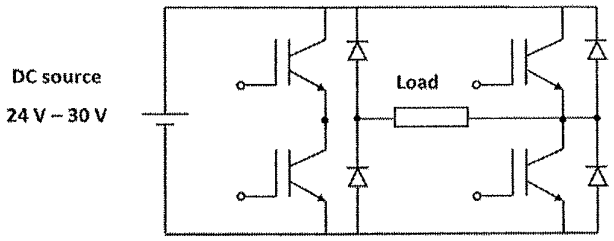


Figure Q5

i. Draw sketches of output voltage and gate pulses of each switch of above inverter in a common time scale. *(4 marks)*

ii. Determine the range of phase angle to be maintained to obtain 20 V_{RMS} 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, if this bridge is used with uniform pulse width modulation (UPWM). 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)*