UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2023/2024

COURSE NAME	:	POWER ELECTRONICS
COURSE CODE	:	BEV30203
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	JANUARY/FEBRUARY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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Q1 (a) State **FOUR (4)** basic topologies of non-isolated DC-DC converters and their differences.

(6 marks)

(b) Explain briefly the operation of the converter in Continuous Current Mode (CCM) and Discontinuous Current Mode (DCM).

(4 marks)

(c) Design a buck-boost DC-DC converter with the parameters listed below,

Input Voltage, V_{in} = 12V
Duty Cycle = 0.25
Average Load Current, Ia = 1.25A
Inductance, L = 150uH
Capacitor, C = 220uF
Switching frequency, f_{sw} = 25 kHz

Assume the converter is lossless. Determine

(i) The output voltage (3 marks)

(ii) The peak-to-peak output voltage ripple (3 marks)

(iii) The peak-to-peak ripple current of inductor (3 marks)

(iv) The peak current of the transistor (3 marks)

(v) The critical values of L and C (3 marks)

Q2 A single-phase full-bridge square-wave voltage source inverter is connected in parallel with an R and L load of 25 Ω and 15 mH, respectively. The inverter operates at an output frequency of 50 Hz, assuming the fundamental output voltage to be 240 V.

(i) Define an expression of the RMS output voltage at the fundamental frequency (2 marks)

(ii) If the fundamental AC output voltage is 240 V, determine the required DC input voltage for the inverter (3 marks)

(iii) Calculate and express the instantaneous load current by considering until the 7^{th} harmonics components. (12 marks)

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(iv) Sketch the harmonic spectrum for output current up to 7^{th} harmonic components. (4 marks)

(v) Calculate the total harmonic distortion (THD) of the load current (4 marks)

Q3 (a) List **THREE (3)** advantages of full-wave rectifiers as compared to half-wave rectifiers. (3 marks)

(b) **Figure Q3(b)** shows the circuit diagram of a single-phase half-wave rectifier with an R-L load. The average voltage and current can be increased by making, which is possible by adding a freewheeling diode D_m. Explain briefly **THREE (3)** effects of a freewheeling diode in the circuit. (3 marks)

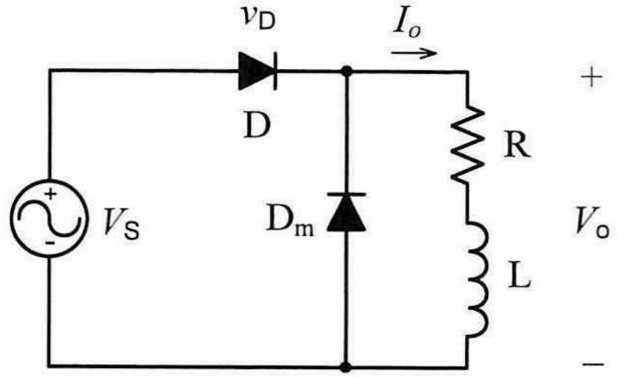

Figure Q3(b)

(c) **Figure Q3(c)** shows a single-phase half-wave controlled rectifier that has a resistive load of R = 10 Ω, the voltage at the secondary transformer is 230 V, and the firing angle of the thyristor is 60°.

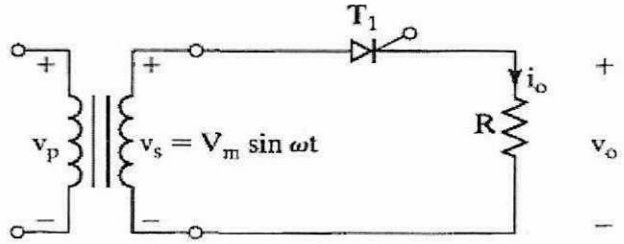

Figure Q3(c)

(i) Calculate the value of the average and rms load voltage. (4 marks)

(ii) Find the average and rms load current (4 marks)

(iii) Determine the average output power. (2 marks)

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(iv) Determine the new firing angle, α if the rectifier is connected to the load which consumes 25% of the maximum possible average output voltage.
(3 marks)

(v) Sketch the input voltage, output voltage and output current waveforms for the new firing angle, α in **Q3(c)(iv).**
(6 marks)

Q4 (a) An AC voltage converter is used to convert the fix AC input source to the variable AC rms output voltage. It is used for heating, lighting, transformer tap changing and many more. It is also known as a power transfer converter to transfer from one AC source to another AC source.

(i) List **TWO (2)** types of control that can be used for the AC converter.
(2 marks)

(ii) State **TWO (2)** differences between the half wave AC converter with the full wave AC converter.
(2 marks)

(iii) Sketch the output voltage and current with the help of diagram of the single phase full wave controller that consits of RL load.
(3 marks)

(b) A single phase full wave AC voltage converter is shown in **Figure Q4(b)**. With the thyristor as the switching devices, the output voltage is in the range of 0 V_o to V_o. If the resisitive load is connected to the converter is 20 Ω with the AC input source of 120Vrms, 50Hz,

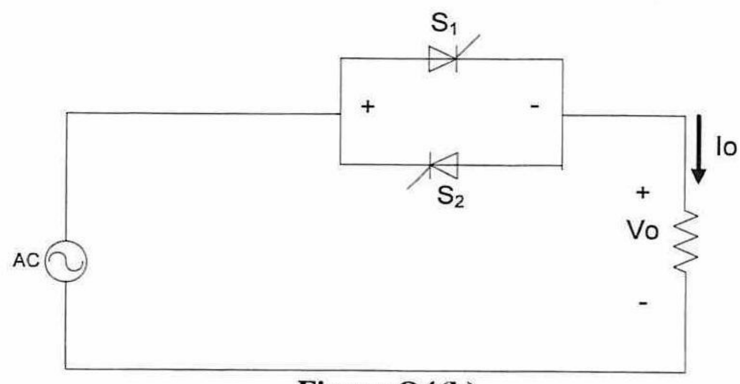

Figure Q4(b)

(i) Formulate the ***power factor (pf)*** equation for the output if the given rms output voltage is $V_{rms} = \frac{V_m}{\sqrt{2}}\sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin(2\alpha)}{2\pi}}$.
(6 marks)

(ii) Calculate the delay angle required to deliver 500 W to the load. (5 marks)

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(iii) Calculate the rms source current using the value in **Q4(b)(ii)**.

(4 marks)

(iv) Sketch and calculate the average thyristor current if the load power is 500 W

(3 marks)

- END OF QUESTIONS -

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APPENDIX A

FORMULAS

$$\sin(A \pm B) = \sin A\cos B \pm \cos A\sin B$$

$$\sin 2A = 2\sin A\cos A$$

$$\cos 2A = 1 - 2\sin^2 A$$

$$\int \sin nx \,\mathrm{dx} = -\frac{\cos \mathrm{nx}}{\mathrm{n}}$$

$$\int \sin^2 nx \,\mathrm{dx} = \frac{\mathrm{x}}{2} - \frac{\sin 2nx}{4n}$$

DC/DC Converter

$$I_{L,avg} = \frac{V_s D}{R(1-D)^2}$$

$$r = \frac{D}{RCf}$$

$$I_{\max} = I_L + \frac{\Delta i_L}{2} = \frac{V_S D}{R(1-D)^2} + \frac{V_S DT}{2L}$$

$$I_{\min} = I_L - \frac{\Delta i_L}{2} = \frac{V_S D}{R(1-D)^2} - \frac{V_S DT}{2L}$$

$$\frac{\Delta V_O}{V_O} = \frac{D}{RCf}$$

AC-DC Converter

Controlled full-wave rectifier

$$I_{rms} = \frac{V_m}{R}\sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$

Full Bridge Rectifier with R-L load

$$i_o(\omega t) = \frac{V_m}{Z}\left[\sin(\omega t - \theta) - \sin(\alpha - \theta)\, e^{-\frac{(\omega t - \alpha)}{\omega \tau}}\right]$$

$$V_{oavg} = \frac{1}{\pi}\int_{\alpha}^{\beta} V_m sin\omega t d\omega t$$

$$Z = \sqrt{R^2 + (X_L)^2}$$

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$$\theta = tan^{-1}\left(\frac{X_L}{R}\right)$$

$$\tau = \frac{L}{R}$$

DC-AC Converter

Single-phase full-bridge inverter

$$i_o = \sum_{n=1,3,5,...}^{\infty} \frac{4V_{dc}}{n\pi Z_n} \sin\left(n\omega t - \theta_n\right)$$

Three phase inverter (180⁰)

$$V_{ab} = \sum_{n=1,3,5}^{\infty} \frac{4V_s}{n\pi} \cos\frac{n\pi}{6} \sin n\left(\omega t + \frac{\pi}{6}\right)$$

$$V_L = \sqrt{\frac{2}{3}} V_i$$

$$V_{Ln} = \frac{4V_s}{\sqrt{2}\, n\pi} cos\frac{n\pi}{6}$$

Three phase inverter (120⁰)

$$V_{ab} = \sum_{n=1,3,5}^{\infty} \frac{2V_s}{n\pi} \cos\frac{n\pi}{6} \sin n\left(\omega t + \frac{\pi}{6}\right)$$

$pf = \frac{P_{out}}{S_{in}}$, $HF_n = \frac{V_n}{V_1}$, $THD = \frac{1}{V_1}\left(\sum_{n=2,3,..}^{\infty} V_n^2\right)^{1/2}$, $DF = \frac{1}{V_1}\left[\sum_{n=2,3,..}^{\infty} \left(\frac{V_n}{n^2}\right)^2\right]^{1/2}$

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AC-AC Controller

Phase Control

$$V_{o(rms)} = \left\{ \frac{1}{2\pi} \left[\int_{\alpha}^{\pi} 2V_s^2 \sin^2 \omega t \, d(\omega t) + \int_{\pi}^{2\pi} 2V_s^2 \sin^2 \omega t \, d(\omega t) \right] \right\}^{1/2}$$

$$V_{o(avg)} = \left\{ \frac{1}{2\pi} \left[\int_{\alpha}^{\pi} \sqrt{2} V_s \sin \omega t \, d(\omega t) + \int_{\pi}^{2\pi} \sqrt{2} V_s \sin \omega t \, d(\omega t) \right] \right\}$$

On-Off Control

$$V_{avg} = \left(\frac{n}{2\pi(n+m)} \right) \left[\int_0^{2\pi} Vm \sin(\omega t) \, d(\omega t) \right]$$

$$V_{rms} = \left[\left(\frac{n}{2\pi(n+m)} \right) \int_0^{2\pi} (Vm \sin(\omega t))^2 \, d(\omega t) \right]^{\frac{1}{2}}$$

$$I_A = \frac{n}{2\pi(m+n)} \int_0^{\pi} I_m \sin \omega t \, d(\omega t)$$

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