UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: August 2015

Module Number: EE5304 **Module Name: Power Electronics**

[Three Hours]

[Answer **all questions**, each question carries **12 marks**]

Q1 a) A basic thyristor converter circuit with RL load is shown in Figure Q1a. The ac source voltage $v_s = \sqrt{2}\,V_s \sin\omega t$. The delay angle of the thyristor is α ($0^\circ < \alpha < 180^\circ$). Assume that the thyristor in the circuit has the ideal characteristics.

i) State the main difference between a thyristor and a diode.

ii) Illustrate the waveforms of v_d, i_d and the anode-cathode voltage v_T across the thyristor for one cycle of the ac source voltage for a predefined α ($0 < \alpha < 90^\circ$) value.

iii) Modify the circuit in Figure Q1a in order to remove the negative voltages appear across the load.

iv) For one cycle of ac source voltage, illustrate the waveforms of v_d and the anode-cathode voltage v_T across the thyristor in the modified circuit.

v) Derive an expression for the average output voltage of the circuit in a) iv).

[5 Marks]

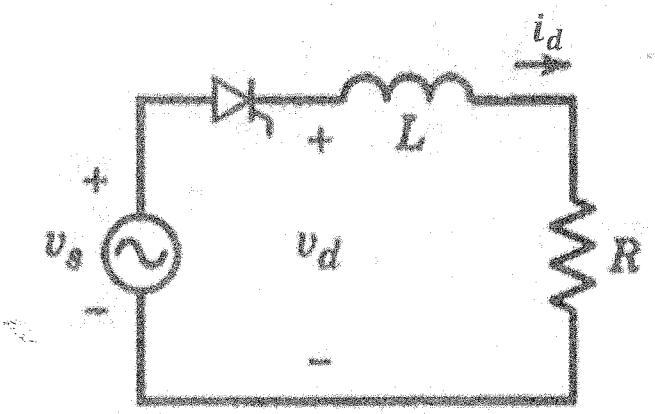

Figure Q1a

b) A circuit configuration for a single-phase, half-controlled converter is shown in Figure Q1b. The ac side voltage $v_s = \sqrt{2}\,V_s \sin\omega t$. It has a constant dc load current I_d in the dc side. The delay angle of the thyristors is α ($0^\circ < \alpha < 180^\circ$). Assume that the diodes and the thyristors in the circuit have ideal characteristics.

i) Sketch the waveforms of v_d and i_s for one cycle of ac source voltage and identify the devices conducting for each intervals of v_d.

ii) Sketch the waveforms of voltages across thyristor T_1 and diode D_1 for one cycle of ac source voltage.

iii) Find an expression for average output DC voltage V_d.

iv) Can this converter operate in inverter mode? Justify your answer.

v) Calculate the Displacement Power Factor, Power Factor and %THD (Total Harmonics Distortion) for $V_d = \frac{1}{2} V_{d0}$ where V_{d0} is dc output at $\alpha = 0$.

[7 Marks]

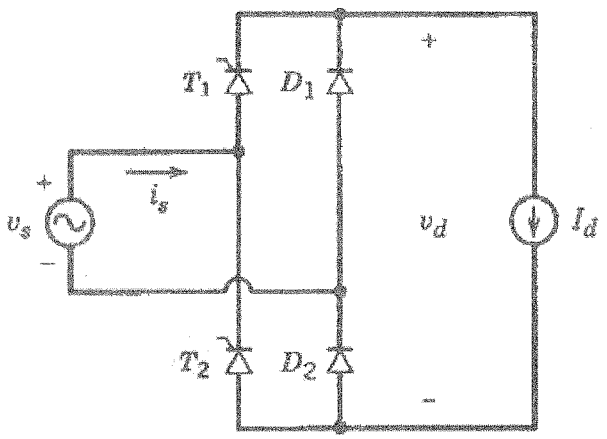

Figure Q1b

Q2 a) i) Write the purpose of using dc-dc switch mode converters.

ii) List two applications where dc-dc switch mode converters are used.

[2 Marks]

b) A circuit diagram of a simple step-down dc-dc converter is shown in Figure Q2a.

i) Identify the two main drawbacks in the circuit shown in Figure Q2.

ii) Sketch a power circuit diagram of the step-down dc-dc converter which eliminates the drawbacks mentioned in b) i).

iii) Explain briefly how the circuit in b) ii) overcomes the drawbacks.

iv) For the step-down dc-dc converter, show that at the edge of the continuous conduction, the average output current I_{oB} can be expressed as

$$I_{0B} = 4D\ (1 - D) I_{0B,min}$$

Note that all the notations have the usual meanings.

[6 Marks]

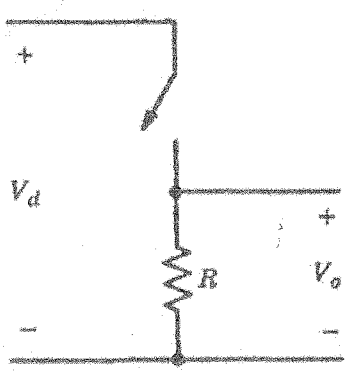

Figure Q2a

c) A circuit diagram of a boost converter is shown in Figure Q2b.

i) Show that a boost converter designed for continuous-current operation have an inductor value greater than L_{min}, which can be expressed as

$$L_{min} = \frac{D\,(1-D)^2 R}{2f_s}$$

Note that all the notations have the usual meanings.

ii) Find the inductor value of the boost converter for continuous-current operation to have an output of 30 V from a 12 V input voltage. The load is a 50 Ω resistor and switching period is 40 μs.

[4 Marks]

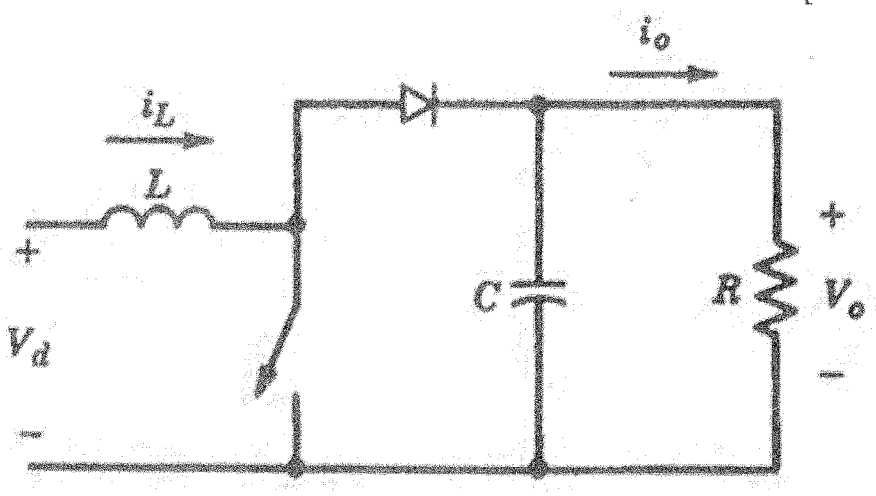

Figure Q2b

Q3 a) i) Sketch the power circuit of a Buck-Boost type dc-dc converter.

ii) Using suitable waveform diagrams, briefly explain what is meant by continuous conduction mode and discontinuous conduction mode for a Buck-Boost type dc-dc converter.

iii) Why is this converter defined as Buck-Boost type? Justify your answer.

iv) In a Buck-Boost converter, the duty ratio is adjusted to regulate the output voltage V_0 at 15 V. The input voltage varies in a wide range from 8 V to 40 V. The minimum power output from the converter is 2 W. The switching frequency is 20 kHz. It is required that the converter always operate in a continuous-conduction mode. Stating all the assumptions, calculate the minimum value of inductance L that can be used in the converter.

[6 Marks]

b) i) Distinguish the main difference between full-bridge dc-dc converter over single switch dc-dc converter.

ii) Recognize the purpose of connecting diodes in antiparallel with the controllable switches.

iii) Define the blanking time associated with the full-bridge dc-dc converter.

c) The output voltage is controlled by the thyristors with delay angles α $(0 < \alpha < \pi)$ and $\pi + \alpha$, for T_1 and T_2 respectively, in the single phase ac voltage controller shown in Figure Q5.

i) Sketch the output voltage v_0, output current i_0 and voltage across the thyristor T_1 and T_2.

ii) Show that the rms value of output voltage can be expressed as

$$V_{0(rms)} = V_s \sqrt{\frac{1}{\pi}\left[\pi - \alpha + \frac{\sin(2\alpha)}{2}\right]}$$

iii) Show that the supply Power Factor (PF) can be expressed as

$$PF = \sqrt{\frac{1}{\pi}\left[\pi - \alpha + \frac{\sin(2\alpha)}{2}\right]}$$

[5 Marks]

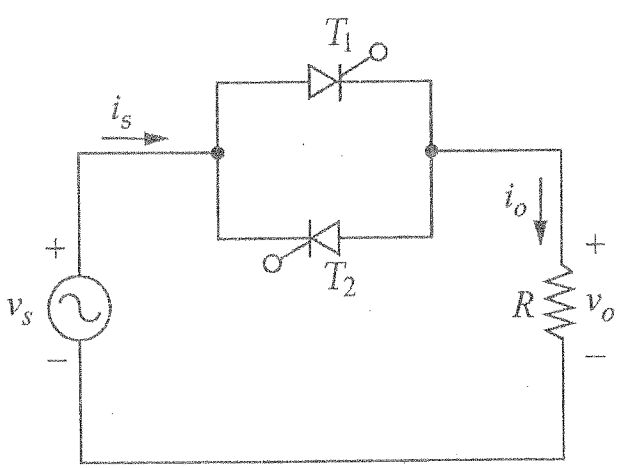

Figure Q5