UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: July 2016

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

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

Q1 a) i) Compare the advantages and disadvantages of Bipolar Junction Transistor (BJT), MOSFETs and IGBTs.

ii) Explain the operation of a thyristor using i-v characteristic and relevant diagrams.

[3 Marks]

b) A simple thyristor converter circuit with RL load is shown in Figure Q1a. Firing angle of the thyristor is α ($0^\circ < \alpha < 180^\circ$). The ac source voltage, $V_s = \sqrt{2}\, V_s \sin \omega t$.

i) Sketch the waveforms of V_d, i, V_R, V_L, anode to cathode voltage (V_T) and i_G for two cycles of the ac source voltage for a predefined α ($0^\circ < \alpha < 90^\circ$). State any assumptions you made.

ii) Modify the circuit in Figure Q1a by replacing R with a dc voltage source, E_d.

iii) For two cycles of ac source voltage, sketch the waveforms of V_d, i, V_L, anode to cathode voltage (V_T) and i_G for above modified circuit. State any assumptions you made.

[4 Marks]

c) A circuit configuration for a single phase thyristor converter is shown in Figure Q1b. The ac source voltage, $V_s = \sqrt{2}\, V_s \sin \omega t$. Firing angle of the thyristor is α ($0^\circ < \alpha < 180^\circ$).

i) Sketch the waveforms of V_S , i_S, V_d for two cycles of ac source voltage and identify the devices conducting in each interval of V_d.

ii) Sketch the waveforms of voltage across the thyristor T_1 and T_3 for two cycles of ac source voltage.

iii) Derive the expressions for the average value and the rms value of the output voltage.

[3 Marks]

Q2 a) i) Sketch the complete circuit diagram of a three phase diode rectifier with three phase ac sources and a resistive load. Indicate all relevant parameters in your diagram.

ii) Redraw the circuit diagram drawn in i), by neglecting source inductances and replacing dc side by a current source.

iii) Draw the waveforms of input phase voltages, input line voltages and output voltage separately for one and half cycle of input phase voltage. Indicate the elements conducting in different intervals of output voltage V_d.

iv) Draw the waveforms of currents in each phase separately.

v) Derive an expression for average output voltage in terms of rms line to line voltage V_{LL}.

vi) Calculate percentage Total Harmonic Distortion (%THD), Displacement Power Factor, and Power Factor.

[6 Marks]

b) The speed of a 110 V, 7 hp dc motor is controlled by a single phase thyristor converter connected to the armature. The ac supply voltage is 120 V, 50 Hz and the voltage constant of the motor is 0.065 V/rpm. Consider all elements are ideal and lossless. Assume a very large inductor in series with the armature and the armature resistance is negligible. At a certain operating point, the speed of the motor is 1500 rpm and it draws rated motor current.

i) Draw the power circuit diagram of this system.

ii) Determine the firing angle of the converter.

iii) Determine the rms value of the supply ac current.

iv) Determine the supply power factor.

v) Sketch the waveforms of supply ac voltage, supply ac current, output voltage, and output current.

[4 Marks]

Q3 a) i) Draw the power circuit of the step–up (boost) dc-dc converter.

ii) Using necessary steady-state waveforms, obtain the input/output voltage and input/output current relationships, in terms of the switch duty ratio D for the continuous conduction mode of operation of the step-up dc-dc converter. State clearly the assumptions you made.

[4 Marks]

b) i) For a step-up dc-dc converter operating in discontinuous conduction mode, show that the average output current I_o can be expressed as,

$$I_o = \frac{D\,\Delta_1\,T_s\,V_d}{2L}$$

Note that all notations have their usual meaning.

ii) For a step-up dc-dc converter operating in discontinuous conduction mode, show that,

$$\frac{V_d}{V_o} + D^2 \frac{R}{2 L f_s} \left(\frac{V_d}{V_o} \right)^2 = 1$$

Note that all notations have their usual meaning.

iii) For a step-up dc-dc converter operating at the edge of the continuous conduction, show that,

$$\frac{2 L f_s}{R} \frac{V_o}{V_d} = D \left(1 - D\right)$$

Note that all notations have their usual meaning.

iv) In a step-up dc-dc converter which is fed from a 100 V input voltage, output voltage is maintained at 200 V. Switching frequency is 100 kHz and the output power is 1 kW. What is the minimum value of the inductance, for the converter to operate at the boundary condition?

[6 Marks]

Q4 a) i) Draw the power circuit of the Buck-Boost type dc-dc converter.

ii) Using necessary steady-state waveforms, obtain the input/output voltage and input /output current relationships, in terms of the switch duty ratio D for the continuous conduction mode of operation of the Buck-Boost type dc-dc converter. State clearly the assumptions you made.

iii) Show that at the edge of the continuous conduction, the average output current I_{oB} can be expressed as,

$$I_{oB} = \frac{T_s V_o}{2 L} \left(1 - D\right)^2$$

Note that all notations have their usual meaning.

[5 Marks]

b) i) State two types of control methods used in AC voltage controllers.

ii) Draw the waveforms of output voltage (V_o), voltages across each thyristor and out put current (i_o) of a single phase voltage controller with resistive load, if the phase controlled method is used with firing angle α.

iii) In the single phase voltage controller described in ii), show that the rms value of the output voltage is given by,

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

where V_s is the rms value of the source voltage.

[5 Marks]

Q5 a) i) What is the objective of switch mode inverters?

ii) Name three types of single phase voltage source dc-ac converters.

iii) Briefly explain the four quadrant operation of switch mode dc-ac converter.

[4 Marks]

b) Figure Q5 shows a full bridge inverter circuit operates in PWM with bipolar voltage switching. Fundamental frequency of the output voltage is 50 Hz.

i) If m_f= 8 and m_a<1 for this inverter, sketch the triangular waveform and control waveform for one cycle of the control waveform. Note that m_f is the frequency modulation index and m_a is the amplitude modulation index.

ii) Sketch the output voltage waveform, clearly indicating the elements conducting in each interval.

iii) Clearly stating the assumptions you have made, show that the peak amplitude of the fundamental frequency component $\left(\hat{V}_o\right)_1$ of the full bridge PWM inverter can be expressed as,

$$\left(\hat{V}_o\right)_1 = m_a V_d$$

where m_a is the amplitude modulation index.

iv) What are the advantages of PWM with unipolar switching compared to bipolar switching?

[6 Marks]

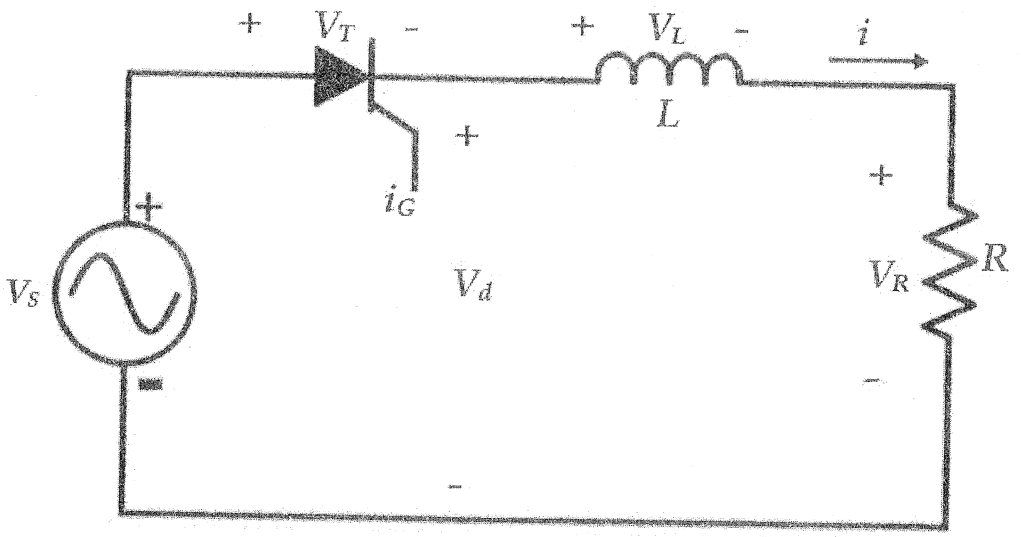

Figure Q1a

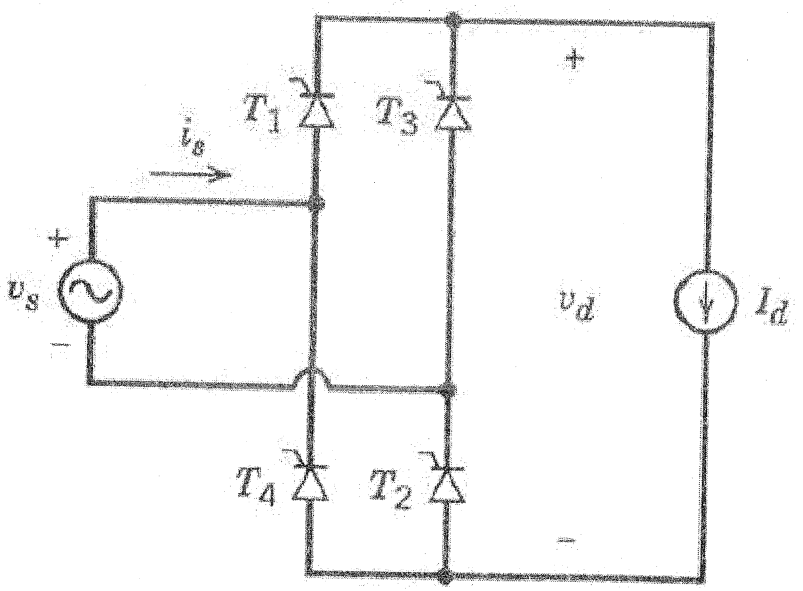

Figure Q1b

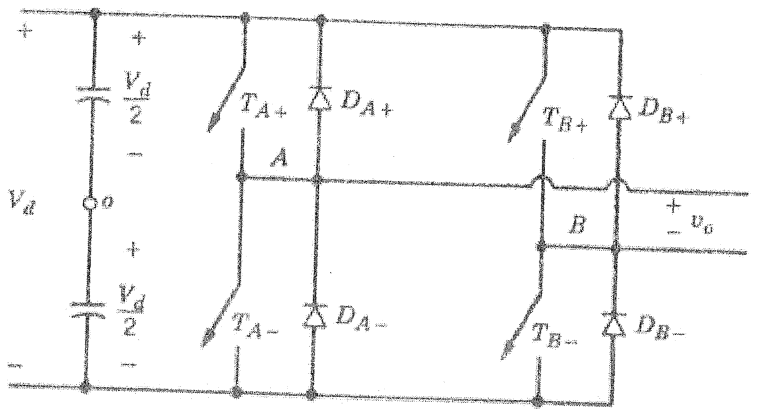

Figure Q5