UNIVERSITY OF RUHUNA

Faculty of Engineering

Mid-Semester 5 Examination in Engineering: June 2014

Module Number: EE5314 **Module Name: Power Electronics**

[Two Hours]

[Answer all questions, each question carries 7.5 marks]

Q1 a) i) State three applications of Power Electronics.

ii) Draw a block diagram to illustrate the structure of Power Electronics.

iii) Briefly explain the types of power converters used in Power Electronics.

iv) How do you trigger thyristors to start conducting? Illustrate with suitable diagrams and expressions.

[3 Marks]

b) i) A basic half-wave rectifier circuit with a pure resistive load does not conduct any current during the negative half cycle of an input sinusoidal signal. However, an industrial system may need to conduct current in the forward direction to some part of the negative half cycle.

(I) Draw the circuit of a half-wave rectifier that can do this.

(II) Sketch the following graphs on the same axes for the circuit in i)

(A) Source voltage vs time

(B) Output voltage vs time

(C) Current through the load vs time

(D) Voltage across diode vs time

ii) A half-wave uncontrolled rectifier is connected to a 230 V supply to drive a resistive load. From the three diodes given in Table Q1, find the most suitable diode for this application. Give the reasons for your answer.

Table Q1

Diode	Peak Inverse Voltage (V)
D1	300
D2	340
D3	235

[3.5 Marks]

c) The controlled rectifier circuit shown in Figure Q1a has a supply voltage $v_s = 20 \sin \omega t$ V and a DC voltage source $E_d = 10$ V. The variation of v_d and i are shown in Figure Q1b. Calculate the firing angle α of the thyristor. (Assume the thyristor is ideal.)

[1 Mark]

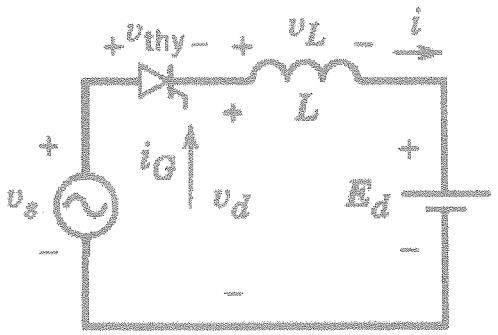

Figure Q1a: Controlled Rectifier Circuit

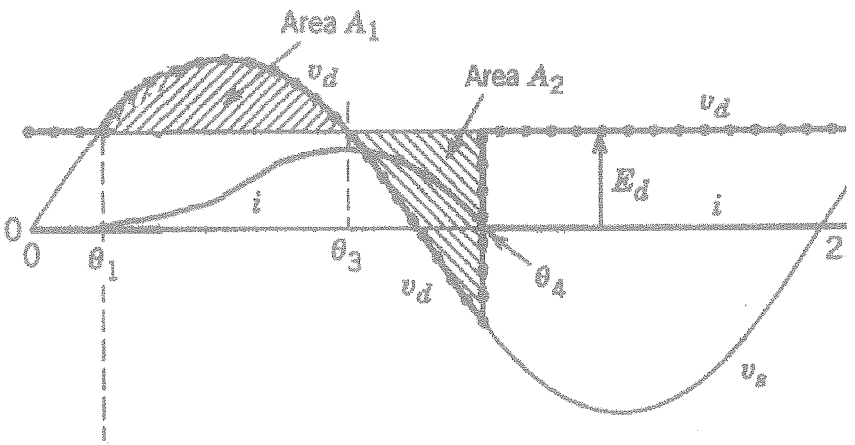

Figure Q1b: Variation of v_d and i

Q2 a) i) Why are Snubber Circuits required to be connected with Power Electronic Switching Transistors?

ii) Compare BJT and MOSFET in Power Electronics.

iii) What are the limits of the Safe Operating Area (SOA) of a BJT as a switching device?

[3 Marks]

b) In Magnetic Resonance Imaging (MRI) systems, a phase controlled converter shown in Figure Q2 is used to control the magnetic field of a large electromagnet. The converter is fed by a 60 Hz, AC source having a peak value of 2000 V and a negligible inductance. The required steady state magnetic current I_d is 400 A.

i) Plot the supply voltage $v_s(t)$ and output voltage v_d in the same time scale.

ii) Derive an expression for the average output voltage using firing angle α and supply voltage $v_s(t)$.

iii) Calculate α required for this application.

iv) Find the rms value of the fundamental and the 3rd harmonic components of the supply current.

v) If the Magnet model is replaced with a resistive load, plot the supply voltage $v_s(t)$ and output voltage v_d in the same time scale.

vi) Derive an expression for the average output voltage v_d in part v).

[4.5 Marks]

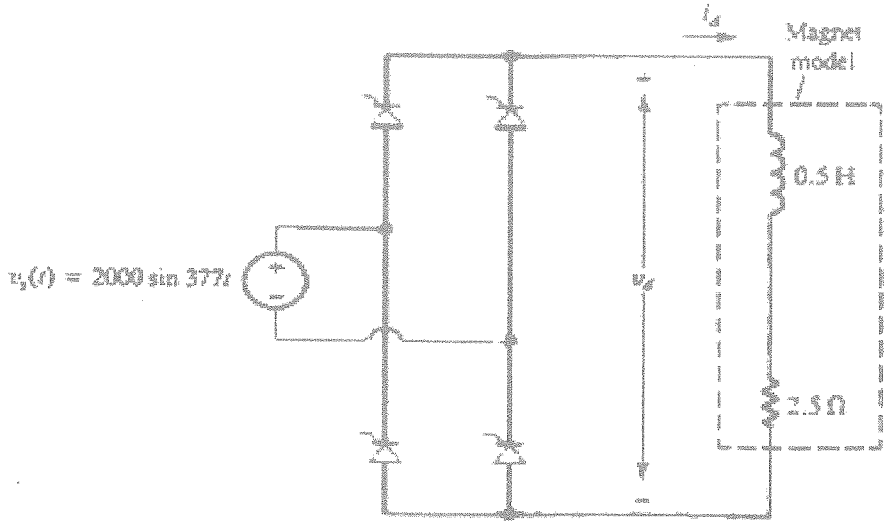

Figure Q2: Phase Controlled Converter of an MRI System

Q3 a) i) Plot the reverse recovery characteristic curve of a Diode.

ii) Explain the Secondary Breakdown limit of a BJT Transistor.

iii) Discuss the advantages of three phase full bridge rectifiers over single phase full bridge rectifiers.

[3 Marks]

b) The rectifier shown in Figure Q3 is operated from a 460 V 50 Hz 3 phase supply and the load resistance is R = 20 Ω. Consider the source inductance as negligible.

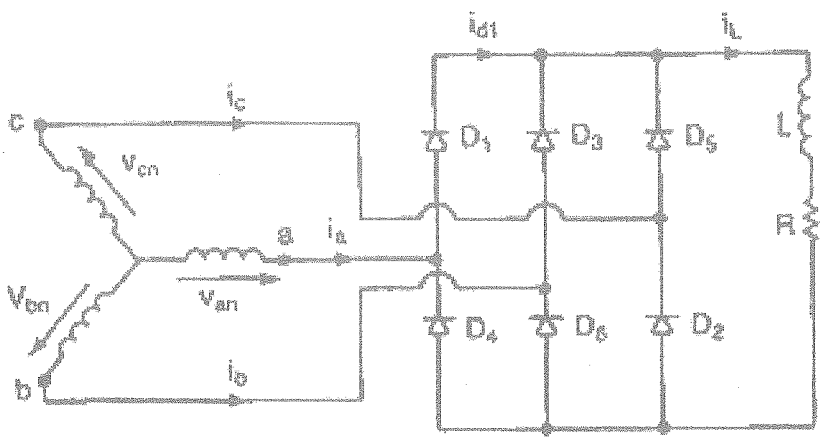

Figure Q3: Three Phase Rectifier Circuit

i) Plot the phase voltages, output voltages and phase currents in the same time scale.

ii) Show the diodes conducting in part i) in the same phase current plot.

iii) Derive expressions for average and rms output voltage.

iv) Determine the average DC output current.

v) Determine the rectification efficiency of the circuit.

vi) If all the Diodes D_1 to D_6 are replaced with thyristors triggered at a firing angle α of 90°, plot the output voltages in the same time scale.

vii) If only D_1, D_3 and D_5 are replaced by Thyristors T_1, T_3 and T_5 triggered at a firing angle α of 30°, plot the output voltages in the same time scale.

[4.5 Marks]

Q4 a) i) Name two types of Thyristors used in Power Electronics.

ii) Sketch the V-I characteristics of a Thyristor and show the important current and voltage limits.

iii) What is the importance of "holding current" and "Forward break over voltage" of a Thyristor?

[3 Marks]

b) The approximate model of the fully controlled rectifier converter shown in Figure Q4 has a supply of 230 V at 60 Hz with a supply inductance of 1.4 mH. If the converter delivers 3 kW of power at a firing angle α of 30°,

i) Find an expression for average output voltage.
[You may use the results obtained in Q2- part b) i)]

ii) Calculate the average output current.

iii) Calculate the average output voltage.

iv) Calculate the commutation angle.

v) Find the Displacement Power factor.

vi) If firing angle α is increased to 120°, plot the supply voltage and average output voltage variation in the same time scale.

v) Describe the mode of operation of the circuit and its importance.

[4.5 Marks]

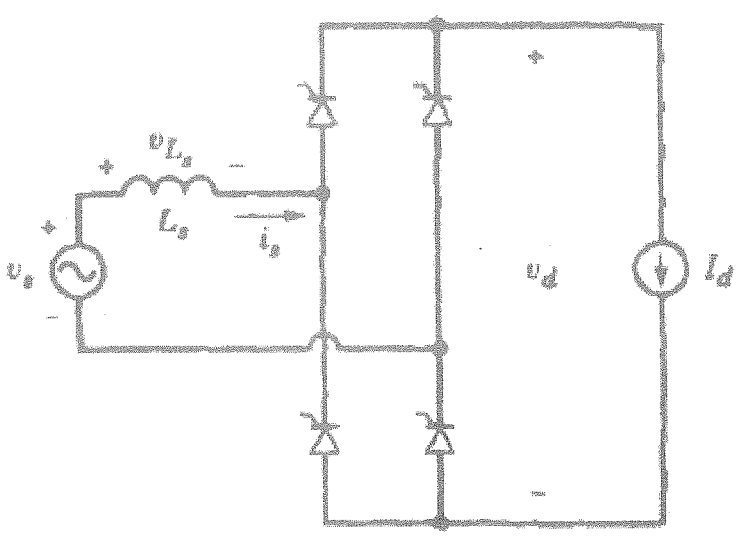

Figure Q4: Approximate model of a fully controlled rectifier converter