UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: July 2016

Module Number: EE7202 **Module Name: Power Electronic Applications**

[Three Hours]

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

Q1 a) i) What are the requirements to be considered when designing a DC power supply?

ii) Compare the merits and demerits of switch mode power supplies with linear power supplies.

[4 Marks]

b) i) A fly-back converter shown in Figure Q1 is operating in complete demagnetizing mode. Derive the voltage transfer ratio $\left({}^{V_o}\!/_{V_d}\right)$ for this converter in terms of the transformer turns ratio ($N_1 : N_2$) and switch duty ratio D.

ii) Show that the maximum current through the switch is given by,

$$\frac{V_d}{2\,L_m}DT_s + \frac{N_2}{N_1}\,\frac{I_o}{(1-D)}$$

Note that all notations have their usual meaning.

iii) The fly-back converter shown in Figure Q1 is connected to 230 V, 50 Hz utility via an idealized single phase diode rectifier. The output power of the fly-back converter is 160 W and the turns ratio of the transformer is 1:3. The dc output voltage of the fly back converter is 800 V and the switching frequency is 50 kHz. Calculate the maximum value of the magnetizing inductance that can be used if the converter is always required to be operated in complete demagnetization.

[8 Marks]

Q2 a) Power loss, switching stress and Electromagnetic Interference (EMI) can be avoided by using Zero Current Switching (ZCS) strategy in switch mode DC-DC converters.

i) State the problems associated with switch mode converters and explain how those are mitigated using ZCS.

ii) Derive the expressions for voltage across the capacitor ($V_{cr}(t)$) and current through the inductor ($i_{Lr}(t)$) of undamped parallel resonant circuit.

iii) Briefly explain the frequency characteristic of a parallel resonant circuit.

[4 Marks]

b) Figure Q2 shows the circuit diagram of a step down DC-DC converter which is fed from a 42 V DC source. The converter is connected to a load which draws 0.5 A current.

i) Modify the circuit shown in Figure Q2 using simple LC resonant in order to obtain Zero Current Switching (ZCS).

ii) Draw the voltage waveforms across the resonant capacitor and the current waveform through the resonant inductor in ZCS for one cycle by giving supportive reasons for the modified circuit in i). (Relevant calculations should be included).

Hint: The current through the resonant inductor and the voltage across the resonant capacitor for a parallel resonant circuit is given by the following equations with their usual notations.

$$V_{cr}(t) = Z_0(I_d - I_{L0})\sin\omega_0(t - t_0) + V_{co}\cos\omega_0(t - t_0)$$

$$I_{Lr}(t) = I_d + (I_{L0} - I_d)\cos\omega_0(t - t_0) + \frac{V_{co}}{Z_0}\sin\omega_0(t - t_0)$$

iii) Calculate the maximum current through the resonant inductor, if values of the resonant capacitance (C_r) and the resonant inductance (L_r) are 0.3 μF and 0.15 mH respectively.

iv) State the condition for natural turn-off of the switch in ZCS.

v) Calculate the maximum Lr and the minimum Cr values for natural turn-off of the switch at zero current for resonance frequency of 118 kHz.

[8 Marks]

Q3 a) i) State five different residential and industrial applications of power electronics.

ii) Explain the operating principal of a fluorescent lamp using relevant diagrams.

iii) Explain the problems associated with conventional ballasts and how they can be overcome using electronic ballasts.

[5 Marks]

b) Power electronics plays a vital role in saving electrical energy in air conditioning and space heating applications.

i) Briefly explain the importance of power electronics in air conditioning and space heating with relevant graphs and diagrams.

ii) Draw the circuit diagram of the power electronic converter used in part i).

[5 Marks]

c) Calculate the induced current due to skin effect of a conductor at a distance of 5 cm from the surface considering following details.

current at the surface is 14.8 A ,

conductivity of the metal is $3.5*10^7 S/m$,

frequency is 50 Hz,

permeability constant (μ_0) is $4\pi*10^{-7} H/m$,

Hint: Induced current due to skin effect and skin depth are given by following equations.

$$I(x) = I_0 e^{-\frac{x}{\delta}}$$

$$\delta = k\sqrt{\frac{\rho}{f}}$$

where $k = \sqrt{\frac{1}{\pi\mu_0}}$

Note that all notations have their usual meaning.

[2 Marks]

Q4 a) i) State the advantages and disadvantages of High Voltage DC (HVDC) transmission.

ii) HVDC transmission has more benefits than high voltage AC transmission. But HVDC is not using in Sri Lanka. Explain why?

iii) Draw the single line diagram of a typical HVDC transmission system and briefly explain functions of each block.

iv) What is the purpose of using 12 pulse converter topology for converting AC voltage into DC voltage in HVDC transmission?

v) Draw a circuit diagram for a 12 pulse converter.

[7 Marks]

b) Matrix converter is a direct 3-phase AC-AC converter topology used in modern power systems.

i) Draw the schematic diagram for a 3-phase matrix converter.

ii) Explain why there are only 27 acceptable switching strategies in a Matrix converter.

iii) What is a bi-directional switch and draw the 3 possible implementations of a bi-directional switch.

[5 Marks]

Q5 a) i) State the types of disturbances in power systems and briefly explain each of them.

ii) State the five different types of UPSs.

iii) Briefly explain the functions of two of them by using relevant circuit diagrams.

iv) List pros and cons of delta conversion online UPS.

v) Explain the importance of static bypass switch in online UPSs.

[6 Marks]

b) Due to a non-linear load, a system is having a maximum short circuit current of I_{sc} = 3 kA. The rms current drawn from the source (I_s) is 150 A and resulting harmonic currents are I_3 = 5 A, I_5 = 3 A, I_7 = 2 A, I_{13} = 0.4 A and I_{15} = 0.2 A.

i) Explain how non-linear loads inject current and voltage harmonics to the power systems.

ii) Check whether the system is following IEEE 519-1992 standards referring Table Q5.

iii) Why 3rd harmonic component is more significant in power systems?

iv) List the methods used for harmonic mitigation.

v) Briefly explain two types of electromagnetic interference and list the methods used to mitigate them.

[6 Marks]

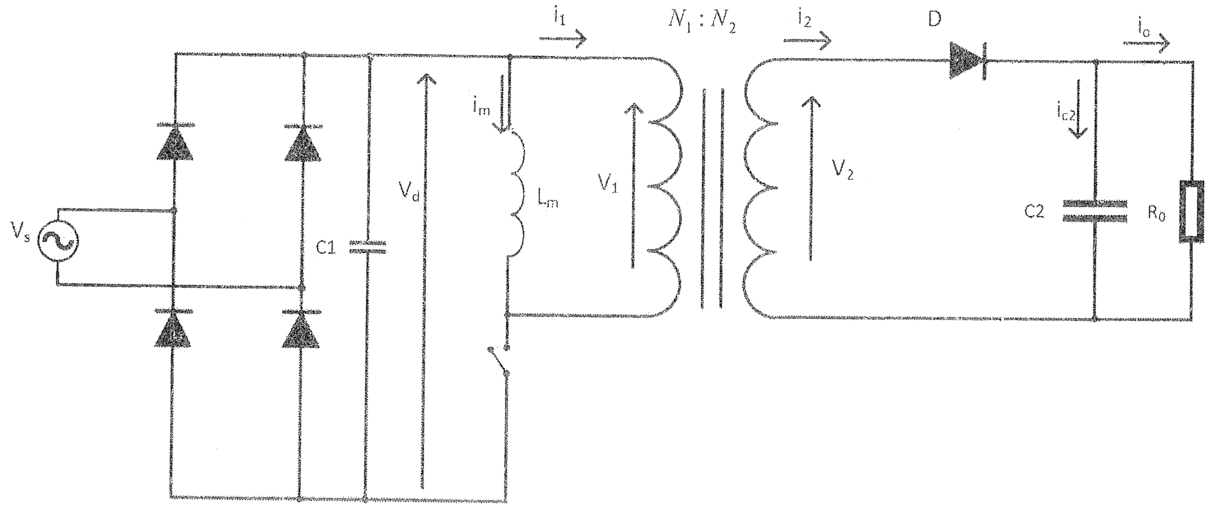

Figure Q1

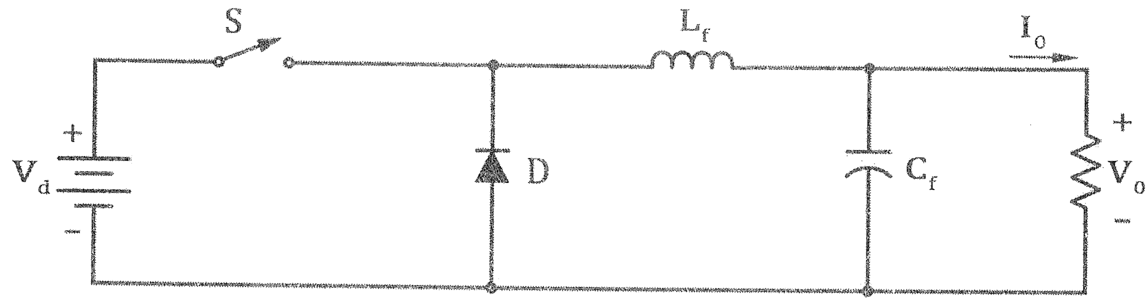

Figure Q2

Table Q5: Harmonic Current Distortion (I_h / I_1) Limits

I_{SC}/I_1	Odd Harmonic Order h (%)					Total Harmonic Distortion (%)
	$h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	
<20	4.0	2.0	1.5	0.6	0.3	5.0
20–50	7.0	3.5	2.5	1.0	0.5	8.0
50–100	10.0	4.5	4.0	1.5	0.7	12.0
100–1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Note: Harmonic current limits for nonlinear load connected to a public utility at the point of common coupling (PCC) with other loads at voltages of 2.4–69 kV. I_{sc} is the maximum short-circuit current at PCC. I_1 is the maximum fundamental-frequency load current at PCC. Even harmonics are limited to 25% of the odd harmonic limits above.