UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: May 2023

Module Number: EE7213 **Module Name: Power Electronic Applications(C-18)**

[Three Hours]

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

Q1 a) Uninterruptible Power Supplies (UPS) provides protection against power outages and voltage regulation during under-voltages and over-voltages.

i) Draw the power circuit of the single-phase UPS showing power electronic converters used in it. Explain the purpose of the converters in the power circuit you have drawn.

ii) Draw the block diagram of an on-line UPS and explain its operation.

[4.0 Marks]

b) A forward converter giving 24 V output voltage for an input voltage variation of 100 - 200 V needs to be designed. The power rating of the converter is 1.2 kW. A MOSFET switch and a diode with voltage ratings of 600 V each are available.

i) Calculate appropriate turns ratios for the primary to secondary winding and the primary to tertiary winding. Maintain at least 25% safety margin for the voltage stress on the switch and the diode.

ii) Calculate the size of the filter inductance needed to maintain continuous conduction of inductor current at its minimum load of 10% from the rated load. Consider switching frequency of 10 kHz.

iii) Draw the current waveform across the filter inductor when the forward converter is operating at its rated power with input voltage of 160 V. Calculate the peak value of the inductor current at this loading condition. Consider the inductance calculated in part ii).

[6.0 Marks]

Q2 a) i) What is a Flexible AC Transmission System (FACTS)?

ii) What are the transmission line parameters controlled by FACTS controllers to control the power flow in the line?

iii) Draw the circuit diagram of a Static Var Compensator (SVC) and identify its main components.

iv) Draw the circuit diagram of a Unified Power Flow Controller (UPFC) and identify its main components.

v) Briefly explain the advantages of a UPFC over SVC.

[6.0 Marks]

b) Figure Q2 illustrates a bipolar HVDC transmission link between two countries. Each pole in the figure is a standard 12 pulse thyristor converter. The parameter values indicated in the figure are as follows.

$V_{LL,R} = 120$ kV

$X_{S,R} = 8.0\ \Omega$

$V_{LL,I} = 121$ kV

$X_{S,I} = 6.0\ \Omega$

At a certain loading condition, the power delivered to country 2 is 500 MW. At this operating condition, per pole DC voltages at two countries are $V_{dR} = 300$ kV, $V_{dI} = 295$ kV respectively. The two converters at each side operate at the same firing angles.

i) State four advantages of HVDC transmission over AC transmission.

ii) Calculate the current in the DC transmission line and the power loss in the DC lines.

iii) Calculate the firing angle of the rectifier side.
Hint: The dc voltage of a 6-pulse phase-controlled rectifier with usual notations is given by

$$V_{dc} = \frac{3\sqrt{2}}{\pi} V_{LL} cos\alpha - \frac{3X_s}{\pi} I_{dc}.$$

iv) Calculate the amount of reactive power absorbed by the converters at the rectifier side.

[4.0 Marks]

Q3 a) Wide variety of power electronic converter topologies are used for solar inverters to integrate PV systems to the utility grid.

i) Discuss two advantages of modularized PV system architecture with DC-AC inverters over PV system architecture with a central inverter.

ii) Draw the circuit diagram of a grid connected PV inverter that includes low frequency isolation transformer and a front-end boost converter.

iii) What are the reasons of having an isolation transformer in the grid connected PV inverter you have drawn in part ii)?

iv) Draw the circuit diagram of a transformer less PV inverter topology that has higher efficiency than a basic full-bridge inverter topology.

v) Explain how the efficiency is increased in the inverter topology you have drawn in part iv)?

[5.0 Marks]

b) i) Can a wind turbine be connected to the grid via a permanent magnet synchronous generator (PMSG) as shown in Figure Q3b)i)? Explain your answer.

ii) Figure Q3b)ii) shows a wind energy conversion system that uses power electronic converters. Explain the type of power electronic converters that are used and the reasons for having them in this system.

iii) Draw the block diagram of a wind energy conversion system that uses a partially rated converter.

iv) What are the advantages and disadvantages of the system with partially rated converter that you have drawn in part iii) when compared with the system shown in Figure Q3b)ii).

[5.0 Marks]

Q4 a) i) Explain the adverse impacts of proliferation of power electronic based systems in the utility grid.

ii) Briefly explain the two types of conducted electromagnetic Interferences (EMI).

iii) State four measures that can be taken to minimize EMI during the design stage of the power electronic converters.

[6.0 Marks]

b) Suppose you have made an AC to DC converter that generates 12 V regulated DC output voltage for an input voltage of 230 V, 50 Hz. The harmonic spectrum of the current at the AC side is listed in Table Q4. The rms value of the total current drawn from the grid is measured as 12.4 A.

i) Calculate the total harmonic distortion level (THD) of the current at the AC side.

ii) Calculate the rms value of the 50 Hz component of the current at the AC side.

iii) Explain two solutions that can be used to lower the THD level of the current drawn from the grid.

[4.0 Marks]

Q5 a) i) State two appliances that uses power electronics in a residential house and explain for which purposes the power electronic is used in those applications.

ii) State two design considerations of an electric welder and draw the block diagram of an electric welder that fulfills the above design considerations.

[4.0 Marks]

b) Figure Q5 shows a circuit diagram of a zero-voltage switching (ZVS) quasi resonant buck converter.

i) Why the converter shown in Figure Q5 is called as zero voltage switching converter and what are the reasons for using zero voltage switching?

ii) Draw the current waveform through the resonant inductor and the voltage waveform across resonant capacitor when the resonant switch is operating in half wave mode.

iii) A ZVS quasi resonant buck converter with power rating of 1.2 kW gives 12 V output voltage for an input voltage of 24 V. Calculate the appropriate sizes for the resonant switch inductor and capacitor to operate this converter in half-wave mode.

iv) Explain three disadvantages of resonant converters.

[6.0 Marks]

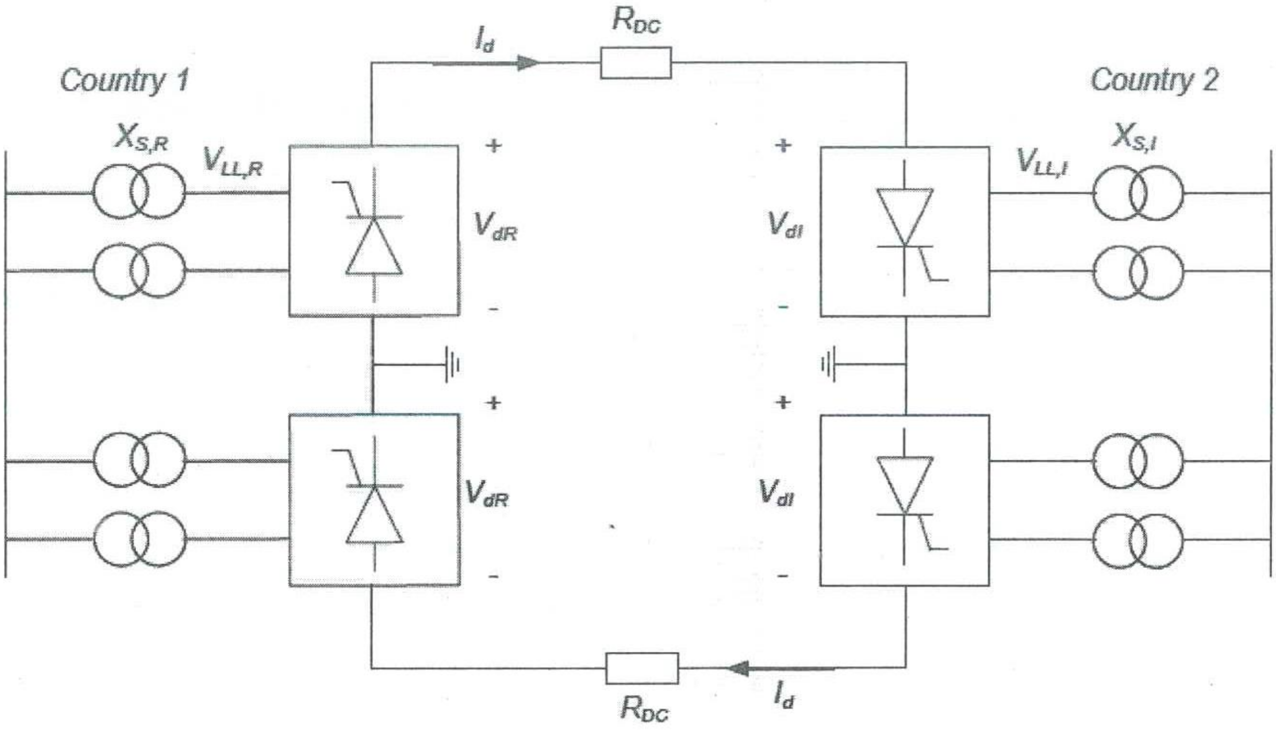

Figure Q2: HVDC transmission link between two countries.

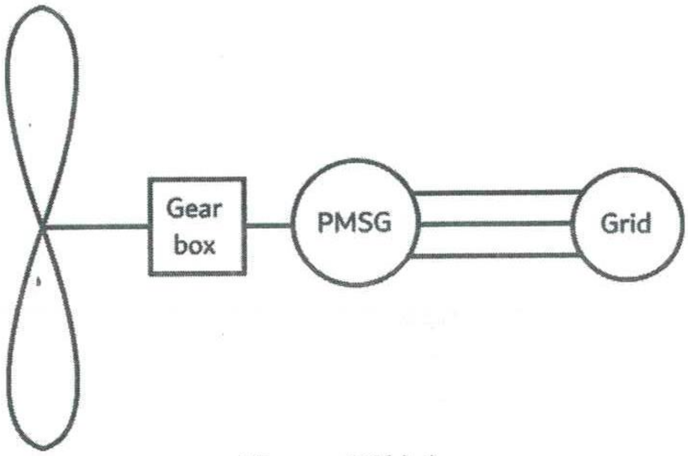

Figure Q3b).i).

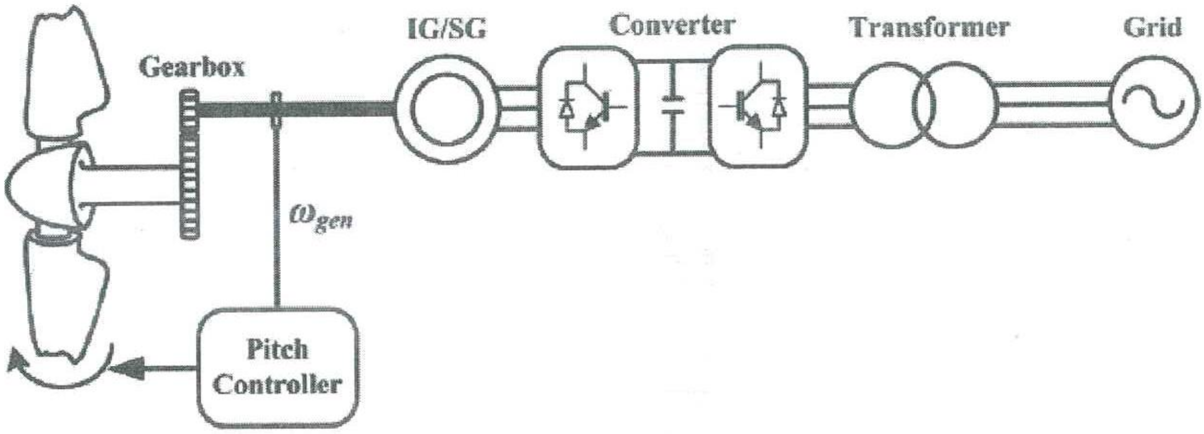

Figure Q3b)ii): Wind energy convertion system.

Table Q4.

h	3	5	7	9	11	13	15	$h > 15$
$\frac{I_h}{I_1}\%$	87.2	42.1	12.5	3.2	2.1	1.1	0.2	≈ 0

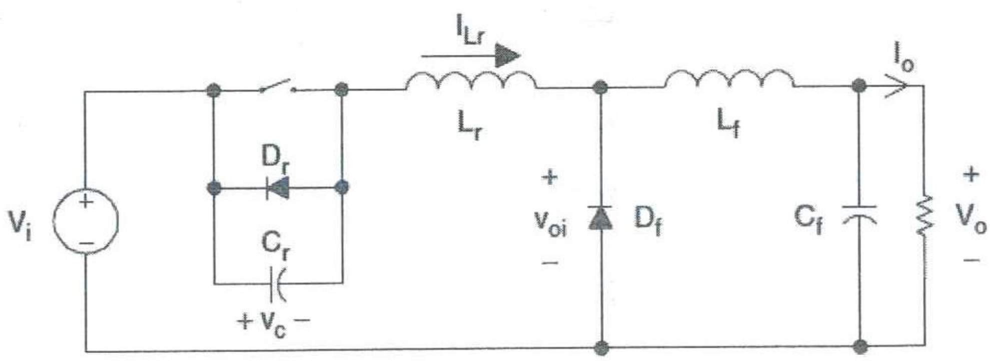

Figure Q5: Zero voltage switching quasi resonant buck converter.