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MANIPAL INSTITUTE OF TECHNOLOGY
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VI SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER EXAMINATIONS, MAY 2023

POWER ELECTRONICS [ELE 3251]
REVISED CREDIT SYSTEM

Time:180 Minutes **Date: 25 May 2023** **Max. Marks: 50**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. In the DC-DC converter shown in the figure 1A, a fast recovery diode **D** has a lead inductance of 1μH and a reverse recovery charge of 10μC at a forward current i_F =5A. The switch **S** is switched at frequency $\mathbf{f_s}$. Analyse the circuit and determine the following parameters of the diode with the sketch of reverse recovery characteristics.
(i). The reverse recovery time.
(ii). The peak reverse recovery current.
(iii). The maximum reverse DC blocking voltage of the diode.
(iv). Assess the effect of increasing the switching frequency on the efficiency of the circuit.

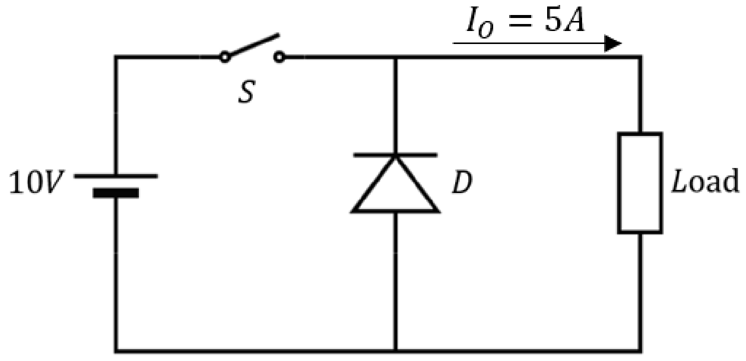

Figure 1A

(03)

1B. Compare the operational differences between Power MOSFET and IGBT with the plot of ideal I-V characteristics. Suggest which among the two devices is employed in any of the digital products. Give reasoning. **(02)**

1C. A half-wave diode rectifier with a capacitor filter has C=1000 μF and a load resistance R =1kΩ. The supply voltage is 230 V rms, 50Hz. With a neat circuit diagram,

(i). Determine the percentage output voltage ripple using the approximate formula (Assuming $V_o \approx V_m$, where V_o is the average load voltage and V_m is the peak of supply voltage).

(ii). Determine the peak-to-peak output ripple voltage using the exact equations.

(iii). Sketch the load voltage, load current, supply voltage, supply current clearly marking all the instants.

(iv). Determine the ratio of the RC time constant to the period of the input sine wave. Comment on the significance of this ratio. ***(05)***

2A. A single-phase full wave-controlled bridge rectifier feeding an RL load operates from a 230 V, 50 Hz AC supply. The converter provides an average load current of 10 A at a delay angle of 60°. The ripple content of the load current is negligible as the load inductance is very high. With a neat circuit diagram

(i). Determine the average load voltage and the load resistance.

(ii). Determine power consumed by the load.

(iii). If a freewheeling diode is now connected across the output for the same load resistance and the same firing angle, assess the percentage increase in the dc output voltage and the power consumed by the load. ***(04)***

2B. A single-phase full wave-controlled bridge rectifier is connected to a separately excited DC motor. The DC motor is represented by an equivalent RLE load. The AC source is 230 V rms, 50Hz and the average load current is 10 A. Consider E = 100 V, R = 0.5 Ω and L is very high resulting in continuous load current. Analyse the circuit and evaluate the following.

(i). Compute the firing angle when the power flows from AC source to the DC motor. Sketch the load voltage and load current up to 2 cycles.

(ii). Compute the firing angle if the power has to flow from the DC load to the AC source. Sketch the load voltage and load current up to 2 cycles. ***(03)***

2C. An inductor used for storing energy can be modeled as a 100 mH inductance in series with a 5Ω resistance. The controlled six-pulse three-phase bridge rectifier is used for the energy storage process. Assume the inductor to be large enough to maintain a constant output dc current. With a neat circuit diagram, estimate the required delay angle such that 12.5 kW is transferred to the inductor. Consider an AC source of 415V, 50Hz. ***(03)***

3A. Design a light-dimmer for a 230 V, 100 W lightbulb. The source is 230 V rms, 50 Hz. With a neat circuit diagram, specify the delay angle for the TRIAC to produce an output power of 70 W. Assume that the bulb is a load of constant resistance. ***(3)***

3B An employee of a company was asked to design a power converter for the specifications shown in Table 1. The employee selects a buck topology as the power converter with the assumptions shown in Table 2. For the specifications and assumptions, the designed values as calculated by the employee is shown in Table 3.

Table 1: Specifications

Input Voltage	12 V
Output Voltage	5 V
Output Current	5 A

Table 2: Assumptions

Switching frequency	25kHz
Inductor current ripple	<10%
Output Voltage ripple	<1%

Table 3: Designed L and C

Inductance (L)	235μH, 5A(RMS)
Capacitance (C)	100 uF, 24V

Hence evaluate the design and answer the following questions:

(i). Is the buck topology ideal for the design specifications mentioned in Table 1? If not, suggest a better topology.

(ii). Are the designed values in Table 3 meeting the specifications and Assumptions? Are they underrated or overrated? Justify with appropriate calculations. **(4)**

3C A DC voltage source of V_s is converted to AC supply with the help of a single phase-full bridge square wave inverter. The output of the inverter is fed to R-L series load with R=10Ω and L=50mH. The inverter output frequency is 50Hz. Determine

(i). DC voltage Vs of the source required to establish a load voltage which has a fundamental frequency component of 230V rms.

(ii). Amplitudes of the Fourier series terms for the square wave load voltage (consider up till the 5th harmonic).

(iii). THD of load voltage (consider up till the 5th harmonic). **(03)**

4A A full bridge inverter is connected to an RL load. A square wave switching scheme is employed to generate the required AC voltage across the load. With a neat circuit diagram, answer the following questions.

(i). Sketch the load voltage and load current (up to 2 cycles). Indicate the devices conducting during different intervals of one cycle.

(ii). With a neat sketch of the harmonic spectrum of the load voltage, comment on the THD and the effect of the harmonics.

(iii). Comment on the purpose of connecting diodes in antiparallel with the switches.

(iv). Specify the peak voltage and current rating of the switches. **(04)**

4B A three-phase bridge inverter delivers power to a resistive load from a 450V dc source. For a star connected load of 10 ohms per phase, the inverter is operated in 180° mode of conduction. The switch used in the circuit has a voltage rating of 600V and current rating of 20A. With a neat circuit diagram, evaluate the following,

(i). Compute RMS value of load phase voltage and the RMS value of the load current

(ii). Compute the power consumed by the three-phase load.

(iii). Verify if the switch rating will suit the design criteria of the circuit. Sketch the switch current up to 2 cycles. ***(04)***

4C Justify the statement with reasoning, "SVPWM technique provides greater overall performance and efficiency as compared to SPWM technique". ***(02)***

5A The harmonic spectrum of a bipolar PWM full bridge inverter is captured on a simulation tool as shown in figure. 5A. The spectrum shows the peak amplitudes of the voltages. The inverter is connected across a series R-L load with R=34 Ω and L=25mH. The available DC link voltage is 200V. The designer must consider only the first set of harmonics for analysis and assume linear modulation. Assess the harmonic spectrum and evaluate the following questions.

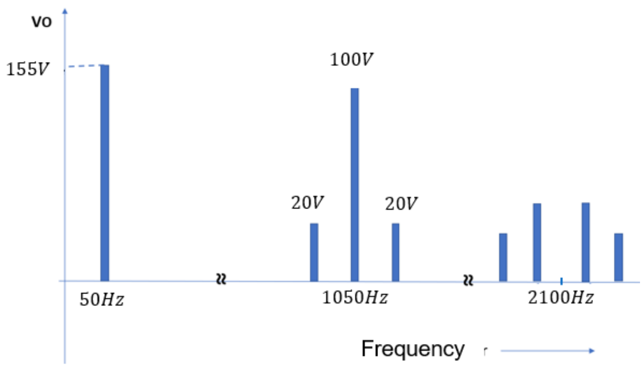

Figure. 5A

(i). Specify the amplitude modulation ratio m_a and frequency modulation ratio m_f.

(ii). Verify if the THD of the load current is less than 10%. ***(05)***

5B An installation team selects a two-stage conversion solar PV system to power home appliances. The PV system is configured with 2 parallel connected strings having 12 modules per string. The STC rated values of voltage and current of individual modules at Maximum Power Point (MPP) are $V_m = 18.75\text{V}$ and $I_m = 4\text{A}$. The PV system is connected to a boost DC-DC converter which forms the intermediate stage. The next stage is the single phase SPWM inverter whose input DC link voltage is 350V. The inverter is designed to produce an AC voltage of 230V rms at 50Hz. Consider linear modulation range for the design. With a neat block diagram, evaluate the set up and answer the following.

(i) Specify the amplitude modulation ratio m_a.

(ii) Specify the duty cycle of the boost converter.

(iii) Defend the choice made by the team in selecting the intermediate converters.

(iv) If the installation team now decides to employ a single stage system with the inverter alone, specify the modified value of amplitude modulation ratio. ***(03)***

5C Sketch the circuit of buck converter with ZCS and ZVS switch configuration. Suggest which among the two is more suited for the buck converter and justify. ***(02)***