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CS/M.Tech(EE-OLD)/SEM-1/PEM-101/2012-13

2012
POWER ELECTRONICS-I

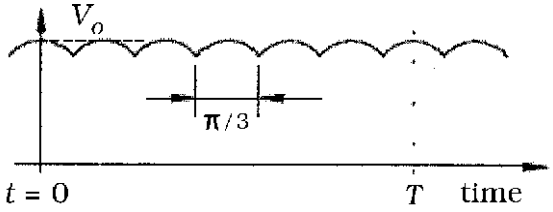
Time Allotted : 3 Hours *Full Marks :* 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Answer any *five* questions. 5 × 14 = 70

1. a) Find the *dc* and rms values of the fundamental and the first few harmonics of the waveform given below.



Output voltage waveform of a 3-phase bridge (6-pulse) *AC-DC* rectifier.

b) A 50 Hz non-sinusoidal periodic voltage is expressed in a Fourier series as $v(t) = 10 + 20\cos(2\pi ft - 25^\circ)$ volts. The voltage is applied to a load resistor of 5 Ω in series with an inductor of 15 mH. Calculate the power absorbed by the load.

c) A voltage source of $v(t) = 220\cos\omega t$ volts is applied to a converter. The input current is given by $i(t) = 6 + 13\cos(314t - 45^\circ) + 5\cos(3 * 314t + 45^\circ) + 2\cos(5 * 314t - 60^\circ)$.

Calculate :

(i) the power absorbed by the load, assuming that the converter absorbs no power

(ii) the distortion factor of the input current

(iii) the THD of the input current

(iv) the input power factor of the converter.

$5 + 3 + (1\frac{1}{2} + 1\frac{1}{2} + 1\frac{1}{2} + 1\frac{1}{2})$

2. a) Explain the dynamic characteristics of practical switch with switch voltage and current waveforms.

b) The output *dc* voltage V_o of a step-down (buck) converter is maintained at 5 V by controlling the duty cycle D .The input dc voltage V_d to the converter varies in the range of 10–40 V. The switching frequency f_s of the converter is 20 kHz. The minimum load current, I_0, of the converter is 1A. Assuming ideal devices and components (i) calculate the minimum inductance required for operation of the converter in continuous conduction mode (ii) The converter operates with a *dc* input voltage of $V_d = 12 \cdot 6$. Obtain the filter capacitance C required to keep the output voltage ripple factor $\Delta V_o / V_o \leq 1\%$ (iii) Calculate the RMS ripple current in the L and C (iv) Derive an expression for the output voltage ripple, ΔV_o, of a buck converter operating in discontinuous conduction mode. Hence calculate the output voltage ripple of the buck converter, when the load current is 0·4 A. $4 + (4 \times 2\frac{1}{2})$

3. Write explanatory notes on any two with necessary circuit and waveforms : 2×7

   (i) Multi-output Boost converter

   (ii) Single phase series converter

   (iii) State space analysis of regulators

   (iv) Protection and cooling of power devices

   (v) Designing of a transformer or an inductor for converter.

4. Draw the circuit and explain the operation of a buck-boost regulator with different waveforms. Deduce the expression ΔV_c and ΔI. Also find out the conditions for continuous inductor current.

5. a) Explain a practical driver circuit for MOSFET or IGBT.

   b) A dc-dc flyback converter has a turns ratio $N_2 / N_1 = 1 \cdot 8$. The dc supply voltage $V_d = 12$ V. The required output voltage V_o is 18 V. The switching frequency of the converter, f_s=100 kHz. The maximum load up to which the converter transformer core is required to demagnetise completely in each switching period is 120 W :

      (i) Find the duty cycle D for the maximum load power of 120 W

      (ii) Find the maximum leakage inductance L_m the transformer can have.

(iii) Find the capacitance C to keep the peak-peak output voltage ripple ΔV_o within 0·5% of V_o.

c) Deduce the expressions of R_S, C_S, snubber loss and power rating of R_S. $3 + (3 \times 2\frac{1}{2}) + 3\frac{1}{2}$

6. For a single-phase bridge rectifier, the supply voltage to the rectifier is 240 V (rms) at 50 Hz. The total source inductance to the rectifier is L_S= 2 mH. Assume the load current at all times is smooth and ripple free.

(i) Calculate the dc load voltage when the L_S is neglected

(ii) Calculate the overlap angles μ when the load current is 20 A and 40 A and L_S is not neglected.

(iii) Calculate the dc output voltage of the rectifier for the load current in (ii)

(iv) Sketch the output voltage waveforms for the loads in (ii)

(v) Sketch the input voltage waveforms to the rectifier for the loads in (ii). 2 + 3 + 3 + 3 + 3

7. a) Consider the fully-controlled full wave thyristor AC-DC converter. The converter is supplied from an AC source of 2000 V, line-line, at 50 Hz. The AC source inductance is L_s=0·5mH per line. The load consists of series connection of a resistance R = 0·12 Ω, and inductance L = 0·3 H and a DC voltage source of E volts. With a firing angle of α = 30°, the load current is found 1000 A which can be assumed to be continuous and ripple free.

(i) Find the *DC* output voltage V_d of the converter for the condition of operation described above

(ii) Find the commutation angle μ of the converter

(iii) Sketch one of line-line voltage and one of the line current waveforms at the input terminals of the converter

(iv) Sketch the commutation notch voltage waveform of one of the line-line *AC* input voltages to the converter

(v) Find the *DC* voltage E in the load

(vi) Find the Total Harmonic Distortion (THD) of the input current drawn from the *AC* source. For this calculation, consider only the first five harmonics of the input current.

OR

b) (i) A three phase bridge rectifier supplies a load at a *dc* voltage of 300 V and current of 30A from a 415 V three phase supply via a delta-star transformer. Determine the required diode and transformer specification. Assume all diode forward drops of 0·7 V and smooth ripple-free load current.

(ii) Explain the disturbances in commercial power supply and power conditioning in terms of Power Quality problems. 8 + 6

8. Develop a dynamic model of a current controlled boost converter or a voltage controlled buck converter feeding a purely resistive load from either a pure *DC* or a 1-phase, 230 V, 50 Hz. Plot the phase and bifurcation diagram.

9. Either for (a) or (b) design both power circuit and control circuit for the following specifications :

   a) Chopper with Input : 220 V DC, Load : Highly inductive load with rated current of 30 A at 220 V DC operating frequency of chopper : 25 kHz

   b) Converter with input of 230 volts, 50 Hz, Load : Highly Inductive load with rated current of 30 A at 220 V DC.

10. Explain 1-D piecewise smooth map and border collision bifurcation. Develop and explain the 1-D piecewise smooth map model and bifurcation diagram of a closed loop controlled buck or boost converter.