FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY-LEVEL 5
FINAL EXAMINATION – 2008/2009
MEX5270 – POWER ELECTRONICS AND MOTOR DRIVES

037

DATE : 26TH MARCH 2009
TIME : 1400HRS – 1700 HRS
DURATION : THREE (03) HOURS

Answer any five (05) questions. All questions carry equal marks.

Q1. (a) In an non-ideal static switching device, the current and voltage values during the switching transitions follow parabolic laws as stated by the following equations:

$$i = I\left(\frac{t}{t_{on}}\right)^2, v = V\left(\frac{t_{on}-t}{t_{on}}\right)^2 \text{ for ON transition}$$

$$i = I\left(\frac{t_{off}-t}{t_{off}}\right)^2, v = V\left(\frac{t}{t_{off}}\right)^2 \text{ for OFF transition}$$

Assume that the static performance of the switch is ideal. Derive an expression for the switching power loss at a frequency of f in Hz.

(b) During turn-on and turn-off of a power transistor the current and voltage relationships are as shown in Fig.Q1. Determine the energy loss during both turn-on as well as turn-off periods and the average switching power loss if the transistor is being switched at a frequency of 10kHz. Also determine the maximum instantaneous power dissipation.

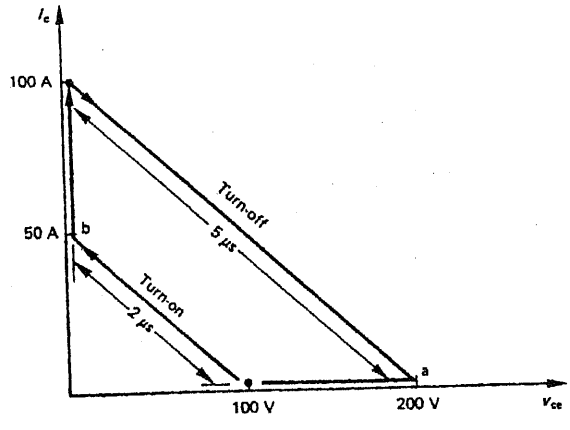


Fig.Q1

Q2. (a) Assume that the current and voltage variations in the power semiconductor switch, S as shown in Fig.Q2, are linear during switching transitions. The on-state voltage drop across the switch is V_D.

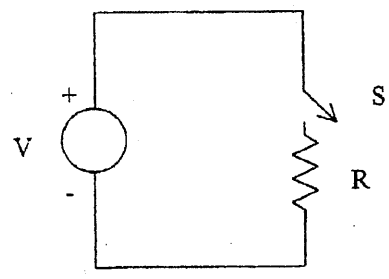


Fig. Q2

Derive an expression for the average switching power loss across the switch and show that

$$P_{SW} = \left(\frac{VI}{6} + \frac{V_D I}{3}\right)\left(t_{sw(on)} + t_{sw(off)}\right) f_s$$

Where, V is the off state voltage across the switch, I is the on state current through the switch, $t_{sw(on)}$ and $t_{sw(off)}$ are the switching transition times and f_s is the switching frequency.

(b) For the circuit as shown in Fig. Q2 the following data are given:

V = 100 V, R = 5 Ω, $t_{sw(on)}$ = 2 μs, $t_{sw(off)}$ = 3 μs, D (duty cycle) = 0.3 and f_s = 20 kHz.

(i) The switch is assumed to be non-ideal with a forward characteristics given by

$$V_D = 1.5 + 0.05i$$

where, i is the instantaneous current through the switch. Determine the on-state current, I, through the switch.

(ii) Determine the average switching power loss and also the average on-state loss of the switch. The off-state loss is assumed to be negligible.

(iii) With no heat sink used, the power semiconductor device exhibits a thermal resistance, $R_{\theta(ja)}$ = 4.5° C/W. Determine whether it is feasible for the power semiconductor switch to operate reliably and dissipate the total power loss as obtained in part (b) (ii).

It may be assumed that the ambient temperature is 50° C and the maximum junction temperature allowed for the switch is 150°C.

Q3. (a) In a single-phase diode bridge rectifier circuit as shown in Fig. Q3, V_s = 200 V square-wave at 60 Hz, L_s = 1mH, and I_d = 10A. Calculate the commutation overlap interval u, the average DC output voltage V_d and the power delivered to the load P_d. Also calculate the percentage voltage drop in V_d due to L_s.

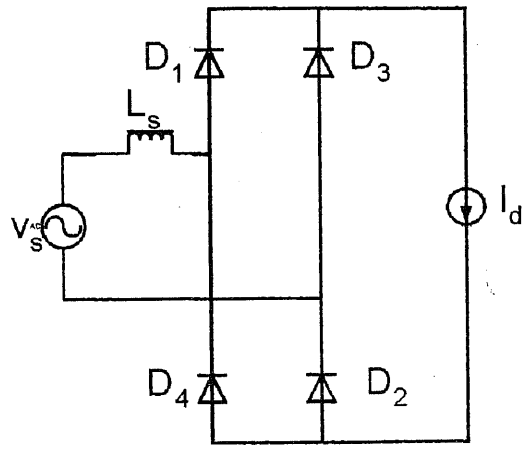


Fig. Q3.

(b) Show that the controlled full-wave bridge rectifier with a resistive load has a power-factor of

$$pf = \sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}}$$

Q4. (a) Sketch the power circuit of a buck DC-DC converter feeding a resistive load.

(b) Show that the minimum inductance required to keep the converter in continuous mode of conduction is

$$L_{min} = \frac{(1-D)R}{2f}$$

where D-duty cycle of the switch, R – resistive load and f –switching frequency of the converter.

(c) A buck converter has an input voltage that varies over the range of 40 V to 60 V. The converter is used to feed a resistive load and the load power varies over a range of 70Wto 120W at an output voltage of 20 V. The converter is operated at a switching frequency of 20 kHz. It is desired that the converter should operate in continuous conduction mode (CCM) for every operating condition. Determine the corresponding value of the minimum inductance required.

Q5. (a) A single phase ac voltage controller as shown in Fig. Q5 is operated with unequal firing angles for the two thyristors (firing angles α_1 for thyristor S_1 and α_2 for thyristor S_2 respectively).

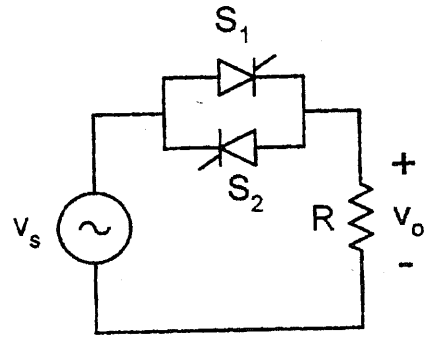


Fig. Q5

Show that the rms load voltage is

$$v_{o,rms} = \frac{V_m}{\sqrt{2}}\sqrt{1 - \frac{\alpha_1 + \alpha_2}{2\pi} + \frac{\sin 2\alpha_1 + \sin 2\alpha_2}{4\pi}}$$

where V_m is the peak ac input voltage

(b) Assume that the thyristor S_2 of the ac voltage controller shown in Fig. Q5. is replaced with a diode and the thyristor S_1 is operated with a firing angle of α.

(i) Show that the rms load voltage is given by

$$v_{o,rms} = \frac{V_m}{\sqrt{2}}\sqrt{1 - \frac{\alpha}{2\pi} + \frac{\sin 2\alpha}{4\pi}}$$

(ii) Determine the range of rms voltage across the load.

Q6. An inverter which produces an output voltage as shown in Fig.Q6 is used to supply an R-L series load with R = 10 Ω and L = 35mH. The dc input voltage is 250 V and the output frequency is 60 Hz.

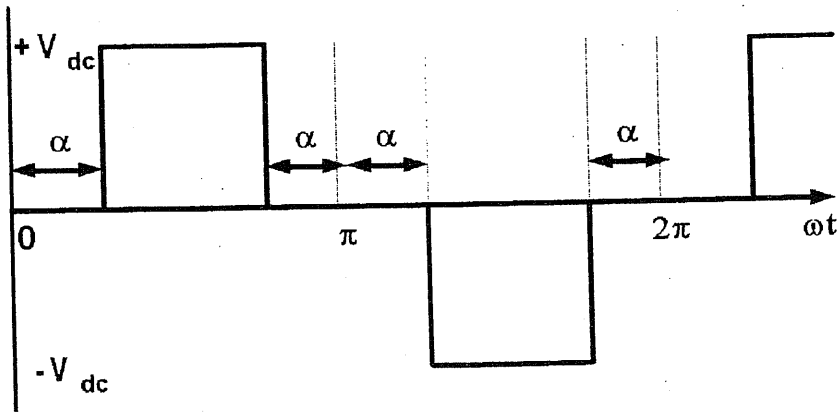


Fig. Q6

(a) Determine the rms value of the fundamental frequency of the load current when $\alpha = 0$.

(b) If the output fundamental frequency is lowered to 30 Hz, determine the value of α required to keep the rms current at the fundamental frequency at the same value as in part (a).

Q7. (a) For variable frequency control of induction motor explain:

(i) why the voltage/frequency (v/f) ratio is maintained constant for operating speeds below the base speed and

(ii) why the terminal voltage is made constant for operating speeds above the base speed.

(b) A 440V, 50 Hz, 6-pole, star-connected squirrel-cage induction motor has the following per-phase parameters referred to the stator:

Stator resistance, $R_s = 0.6\Omega$
Stator leakage reactance, $X_s = 1.0\ \Omega$
Rotor resistance, $R_r = 0.3\ \Omega$
Rotor leakage reactance, $X_r = 1.0\ \Omega$
Full-load slip, $s = 0.05$

The motor is fed from a voltage-source inverter which maintains a constant voltage/frequency ratio.

Determine the breakdown torque for an operating frequency of 10 Hz and hence express the breakdown torque as a ratio of its value at rated frequency.

Determine the v/f ratio at 10 Hz which would produce the same amount of torque as that at rated frequency.

Compare this v/f ratio to that at rated frequency and hence comment.

Q8. (a) What are the three types of dc drives based on the input supply ?

(b) What is a speed regulation of dc drives ?

(c) What is a four-quadrant dc drive ?

(d) Discuss the principle of regenerative braking of dc-dc converter-fed dc motor drives ?

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