UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2004/2005

October 2004

EEE 542 – INDUSTRIAL POWER ELECTRONICS

Time : 3 Hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **SEVEN (7)** printed pages and **SIX (6)** questions before answering.

This question paper has two sections, **Section A** and **Section B**.

Answer **FIVE (5)** questions.

Use two answer booklets which is provided where the answer for questions in **Section A** are in one answer booklet and for **Section B** in another answer booklet.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

Section A

1. A three-phase SCR bridge converter (6-pulse) is connected to a 3-phase source with a line voltage rms value 230 *V* and 50 *Hz* (sinusoidal), and supplies a dc load. The load current is 10 *A* and maintained constant by a large inductance.

Case 1: Source inductance, $L_s = 0$

(i) Draw the circuit diagram. Make a sketch of three voltages and currents i_a, i_b, and i_c. Indicate in the sketch when the SCRs are conducing.

(10%)

(ii) List the conditions needed for a SCR to start conducting. What are the conditions for it to stop conducting.

(5%)

(iii) Sketch load voltage, v_d for the firing angle, $\alpha = 60°$.

(10%)

(iv) Derive the equation for the average value of the dc voltage v_d, where the firing angle α is a variable.

(10%)

(v) Calculate the ac power passing through the rectifier when the firing angle is 60°

(5%)

Case 2: Source inductance, $L_s = 5\ mH$

(vi) Sketch load voltage v_d, when $\alpha = 60°$.

(10%)

(vii) Find the equation for the average value of the dc voltage v_d, where the firing angle α is a variable, taking the influence of the line inductance L_s into consideration.

(15%)

(viii) Calculate the firing angle α that provides the same power as in (v).

(10%)

(ix) Find the commutation angle u in this case.

(25%)

2. (a) A step-down converter is to be operated with constant input voltage, V_d.

[i] Draw the circuit with ideal components of L, C and R.

(10%)

[ii] Obtain the equation for average inductor current at the edge of continuous conduction mode and draw the waveform.

(20%)

[iii] Show that the voltage ratio at the discontinuous mode,

$$\frac{V_o}{V_d} = \frac{D^2}{D^2 + \frac{1}{4}\left[\frac{I_o}{I_{LB,\max}}\right]}$$

where V_o = Output voltage

D = Duty ratio

I_o = Average output current

$I_{LB,max}$ = Maximum inductor current

(40%)

[iv] If V_d = 12.6 V, V_o = 5 V, f_s = 20 kHz, L = 1 mH, determine the inductor current for the condition in (ii).

(5%)

(b) A step-up converter has a source voltage of 10 V and a load voltage of 50 V. The switching frequency is 25 kHz, the inductance and load resistance are 100 μH and 500 ohms respectively. Show that the current is discontinuous.

(25%)

3. (a) A three-phase diode bridge rectifier is connected to a sinusoidal ac source and supplies a load with constant ripple free current.

[i] Draw the source current waveform and determine its rms value in terms of the load current.

(20%)

[ii] Derive the expression for fundamental harmonic component rms value of the source current.

(20%)

(b) The speed of a separately excited dc motor is controlled by a single-phase full-wave SCR bridge converter from an ac source. The field winding is also controlled by a full converter and the field current is set to the maximum possible value. The ac supply voltage to the armature and field converters is 400 V, 50 Hz. The armature resistance is 0.25 ohm, the field circuit resistance of 200 ohms, the motor voltage constant is 1.4 V/A-rad/sec. The armature current corresponding to the load demand is 50 A. The current is ripple free. If the firing delay angle of the armature converter is 45°, determine (a) the torque developed by the motor, (b) the speed and (c) the effective rms input current.

(60%)

Section B

4. In the full-bridge inverter circuit such as shown in Figure 4, input voltage $V_d = \sqrt{2}$ 240 Volt, the amplitude modulation ratio $m_a = 0.8$, the frequency modulation ratio $m_f = 39$ and the fundamental frequency is 50 Hz. Calculate the rms values of the fundamental-frequency voltage and some of the dominant harmonics in the output voltage v_o if a PWM bipolar voltage-switching scheme is used (see Table 1).

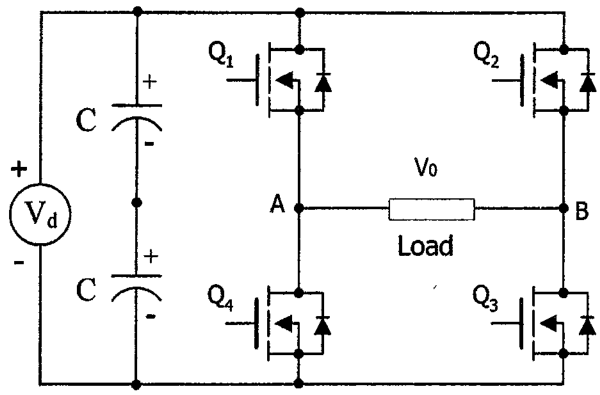

Figure 4

(100%)

Table 1

Generalized Harmonics of v_{Ao} for a Large m_f

h \ m_a	0.2	0.4	0.6	0.8	1.0
Fundamental	0.2	0.4	0.6	0.8	1.0
m_f	1.242	1.15	1.006	0.818	0.601
$m_f \pm 2$	0.016	0.061	0.131	0.220	0.318
$m_f \pm 4$					0.018
$2m_f \pm 1$	0.190	0.326	0.370	0.314	0.181
$2m_f \pm 3$		0.024	0.071	0.139	0.212
$2m_f \pm 5$				0.013	0.033
$3m_f$	0.335	0.123	0.083	0.171	0.113
$3m_f \pm 2$	0.044	0.139	0.203	0.176	0.062
$3m_f \pm 4$		0.012	0.047	0.104	0.157
$3m_f \pm 6$				0.016	0.044
$4m_f \pm 1$	0.163	0.157	0.008	0.105	0.068
$4m_f \pm 3$	0.012	0.070	0.132	0.115	0.009
$4m_f \pm 5$			0.034	0.084	0.119
$4m_f \pm 7$				0.017	0.050

5. Consider the problem of ripple in the output current of a three-phase square-wave inverter. Assume line to line voltage of the output voltage is V_{LL} = 200 Volt at a frequency of 50 Hz and the load is inductor L = 100 mH per-phase. Calculate the peak ripple current of the inverter output current. If the inverter is operating in a synchronous PWM mode with m_f = 39 and m_a=0.8, calculate the peak ripple current of the inverter output current.

(100%)

6. In the three-phase square wave inverter shown in Figure 6, the load to be balanced and purely resistive with a load-neutral n. Draw the steady-state wave-form of voltage v_{An}, current I_A, current I_{D+} and current I_d. If the load of inverter now is purely inductive, draw the steady-state wave-form of voltage v_{An}, current I_A, current I_{D+} and current I_d.

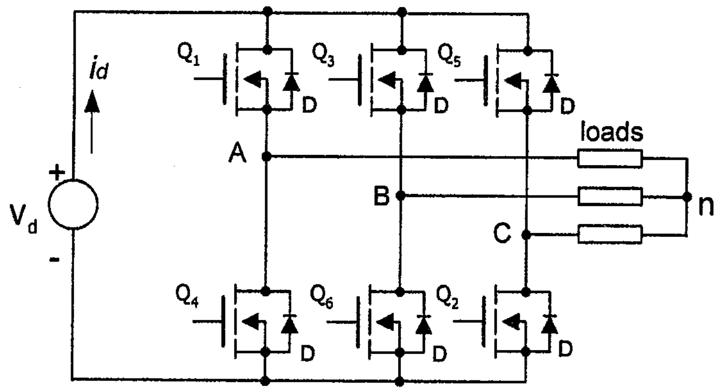

Figure 6

(100%)

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