UNIVERSITI SAINS MALAYSIA

Semester I Examination
Academic Session 2005/2006

November 2005

EEE 542 – INDUSTRIAL POWER ELECTRONICS

Time : 3 hours

INSTRUCTION TO CANDIDATE:

Please ensure that this examination paper contains **SEVEN (7)** printed pages and **FIVE (5)** questions before answering.

Answer **FIVE (5)** questions.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

...2/-

1. (a) A three-phase diode bridge rectifier connected to a 3-phase sinusoidal ac source supplies a constant dc load current of 15 A.

(i) Draw a sketch of the source voltage and input current.

(10%)

(ii) Derive an expression for the fundamental harmonic component rms source current and determine its value.

(15%)

(b) A single-phase SCR bridge converter is connected to a dc load. A load current of 10 A at 100 V is maintained constant by a large inductance on the load side.

(i) If the firing angle of the converter is 45°, determine the input ac voltage (50 Hz) to the converter, neglecting the source inductance.

(10%)

(ii) Considering the source inductance, L_s = 5 mH, for the same input and load conditions, calculate the firing and commutation angles.

(25%)

Prove that $V_{d\alpha} = \frac{2\sqrt{2}}{\pi} V_s \cos\alpha - \frac{2\,\omega L_s}{\pi} I_d$ (20%)

(iii) Sketch without and with source inductance, the output voltage of the converter $V_{d\alpha}(t)$, source current, $i_s(t)$. Indicate the firing angle and commutation angle in the sketch.

(20%)

...3/-

2. A step-up(boost) dc-dc converter is operated with a constant input voltage, V_d and duty ratio, D.

(i) Draw the circuit of the converter with ideal components L, C, R, a switching device and a diode.

(10%)

(ii) From the waveforms shown in Figure 1(a), determine the average inductor current and output current at the boundary in terms of the duty ratio.

(30%)

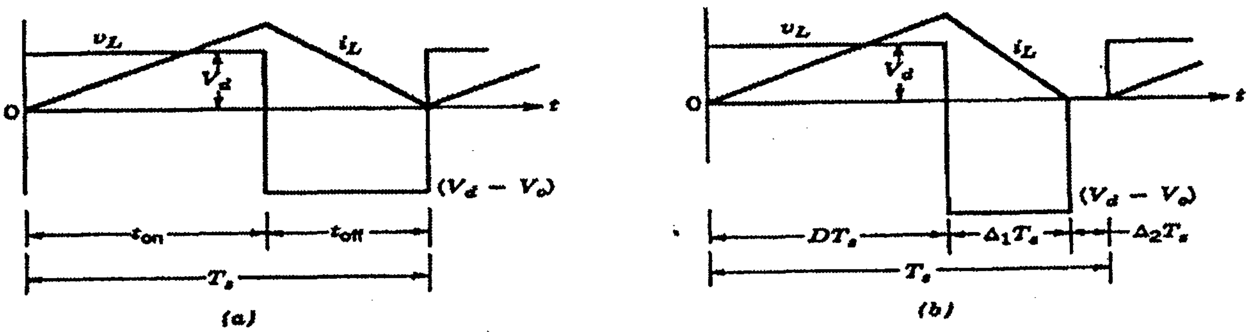

Figure 1 Step-up converter waveforms: (*a*) at the boundary of continuous–discontinuous conduction; (*b*) at discontinuous conduction.

(iii) The waveforms at discontinuous conduction are shown In Fig. 1(b). From the Figure prove that the duty ratio:

$$D = \left[\frac{4}{27} \frac{V_0}{V_d} \left(\frac{V_0}{V_d} - 1 \right) \frac{I_0}{I_{0B,\max}} \right]^{1/2}$$

where $V_0 = output\ voltage$

$I_0 = Average\ output\ current$

$I_{0B,\max} = Maximum\ output\ current$ (60%)

...4/-

3. (a) A buck-boost converter with an input voltage of 20 V and inductance 0.06 mH operates at 25 kHz. The output capacitor is sufficiently large. The output voltage is to be regulated at 10 V when the converter is supplying 1 A. Determine the maximum output current.

(20%)

Is current continuous? (5%)

(b) A full-bridge dc-dc converter connected to a dc motor load is shown in Figure 2.

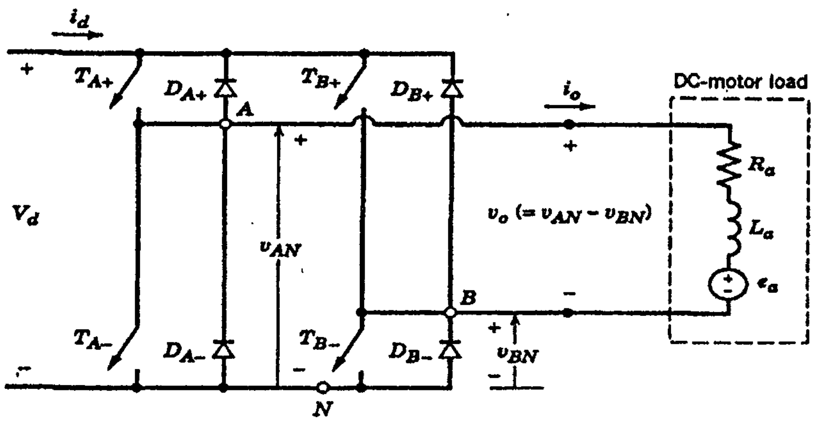

Figure 2 Full-bridge dc–dc converter.

The bridge is controlled by the use of bipolar PWM voltage switching.

(i) Draw the sketch of switching frequency and control waveforms.

(10%)

(ii) Draw the voltage waveforms v_{AN}, v_{BN} and v_o. Indicate the period of operation of the switch pairs in the waveforms.

(25%)

...5/-

(iii) Draw the waveform of current, i_0 supplied to the load. Indicate the devices conducting over a switching period.

(20%)

(iv) If the input voltage, V_d = 220 V, average output voltage, V_0 = 180 V, find the duty ratios D_1 and D_2 of the switch pairs. The switching frequency is 25 kHz.

(20%)

4. A single-phase full-bridge inverter circuit shown in Figure 3 is operated with PWM bipolar switching scheme. The input voltage to the bridge is 230 V. The amplitude modulation ratio is 0.6. The switching frequency is 1450 Hz and the output voltage fundamental frequency is 50 Hz.

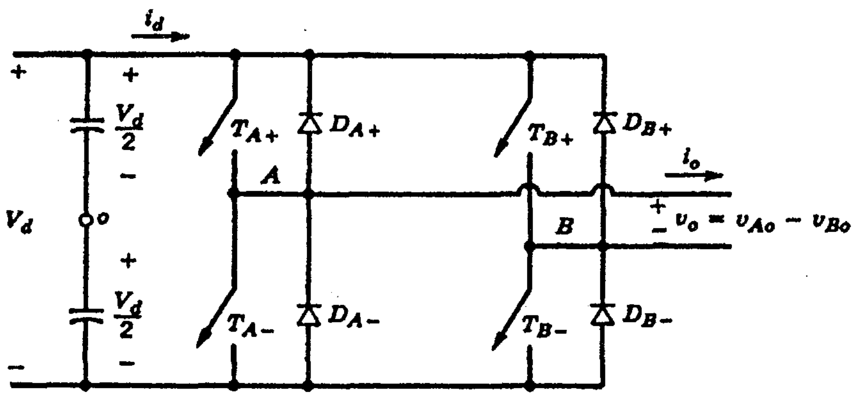

Figure 3 Single-phase full-bridge inverter.

(i) Explain PWM bipolar voltage switching scheme. (25%)

(ii) Find the frequency modulation ratio. (5%)

(iii) Determine the rms value of fundamental frequency voltage.

(20%)

...6/-

(iv) Compute the rms values of the dominant harmonics in the output voltage using Table 1. (50%)

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*
1 *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

Note: $(\hat{V}_{Ao})_h / \frac{1}{2}V_d$ [$= (\hat{V}_{AN})_h / \frac{1}{2}V_d$] is tabulated as a function of m_a.

...7/-

5. (a) A three-phase square wave inverter shown in Figure 4 is connected to a balanced resistive load at the output terminals. The load neutral point is 'n'.

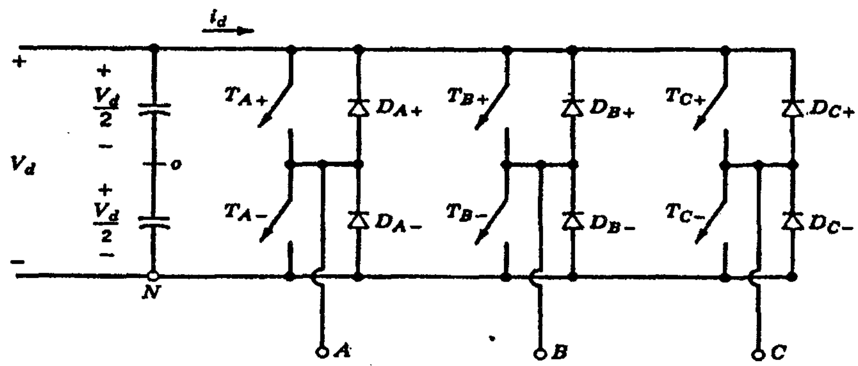

Figure 4 **Three-phase inverter.**

(i) Explain how square-wave operation is obtained. (10%)

(ii) Draw the steady-state waveforms V_{An}, i_A and i_d. (30%)

(iii) Determine the fundamental frequency line-to-line rms output voltage in terms of the input voltage, V_d

(15%)

(b) Draw the circuit of a parallel-resonant current source inverter for induction heating.

(15%)

(i) Draw the output voltage and current waveforms. (25%)

(ii) What are the techniques to control the power output of the inverter.

(5%)

oooOooo