UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2011/2012

January 2012

EEE 542 – INDUSTRIAL POWER ELECTRONICS

Time : 3 hours

INSTRUCTION TO CANDIDATE:

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

Answer **FIVE** questions.

Answer to any question must start on a new page.

Distribution of marks for each question is given accordingly.

All questions must be answered in English.

1. (a) Sketch the circuit diagram of a single-phase full-wave half-controlled rectifier with RL load and describe its operation with the aid of relevant steady state waveforms.

    (6 marks)

    (b) A single-phase diode-bridge rectifier is supplying power to an inductive load. Sketch the circuit diagram and describe its operation with reference to the input and output current and voltage waveforms.

    (8 marks)

    (c) Find the average output current and voltage supplied to load, if the rectifier in part (a) is used to supply an inductive load of $200\,\mathrm{mH}$ with a resistive component of $30\,\Omega$ from a sinusoidal $240\,\mathrm{V_{rms}}$, $50\,\mathrm{Hz}$ supply. The supply line inductance is $12\,\mathrm{mH}$ and the diodes are ideal. Assume continuous current operation.

    (6 marks)

    (d) Find the total power loss of the diodes in the circuit with the same input/output conditions as in part (b), if the threshold voltage of the diodes is $0.7\,\mathrm{V}$ and on-state resistance is $0.02\,\Omega$.

    (5 marks)

2. (a) Briefly describe the principle of operation of ON-OFF ac controller with the aid of circuit diagram and steady state waveforms.

    (5 marks)

(b) A single phase half-wave ac voltage controller has a load resistance $R = 60\Omega$, input ac supply voltage is 240V RMS at 50Hz. The input supply transformer has a turns ratio of 1:1. If the thyristor T_1 is triggered at $\alpha = 60^0$. Calculate

    (i) RMS output voltage and load current,   (5 marks)

    (ii) Output power,   (1 marks)

    (iii) Input power factor,   (2 marks)

    (iv) Average output voltage and load current,   (5 marks)

    (v) Average and RMS thyristor current.   (7 marks)

3. (a) Sketch the circuit diagram of push-pull inverter and briefly describe its operation.

                                                                   (6 marks)

(b) A single-phase full-bridge PWM inverter with an inductive load consisting of 15Ω resistance and $25\,mH$ inductance as shown in Figure Q3(b), has an input dc supply voltage $V_d = 280\,V$. The inverter operates at a frequency of $50\,Hz$ and duty cycle 55%.

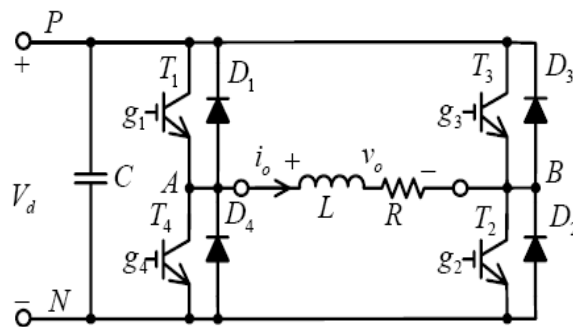Figure Q3(b)

    (i)   Determine the r.m.s. value of total ac output voltage,   (1 marks)

    (ii)   Determine the r.m.s. value of the fundamental and two lowest-order harmonics (3rd and 5th),

                                                            (8 marks)

    (iii)   Determine the r.m.s. value of total harmonic component of the output voltage,

                                                            (1 marks)

    (iv)   Determine the value of output current at each discontinuity in its waveform,

                                                            (7 marks)

    (v)   Sketch the output current and voltage waveforms. Indicate the instants at which discontinuity occur in the current waveform.

                                                            (2 marks)

4.   (a)   With the aid of circuit diagrams, describe the basic action of boost converter leading to derivation of an expression which relates output voltage (V_o) to the input voltage (V_{in}).

                                                            (12 marks)

    (b)   The buck-boost converter shown in Figure Q4(b) has an input voltage $30\,\text{V}$ and load resistance of $35\,\Omega$. The converter is operating at switching frequency of $17\,\text{kHz}$. The value of the inductor and output capacitor are $5\,\text{mH}$ and $170\,\mu\text{F}$, respectively. If the output voltage is required to be twice that of the input voltage, determine;

(i)   duty ratio D,   (2 marks)

(ii)   peak-to-peak output ripple voltage,   (3 marks)

(iii)   magnitude of the average input current,   (3 marks)

(iv)   magnitude of the average inductor current, and   (2 marks)
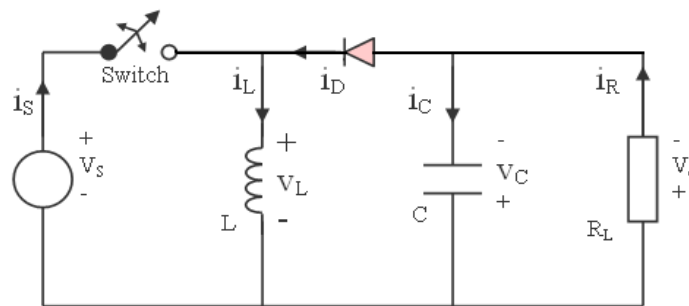
(v)   peak inductor current.   (3 marks)

Figure Q4(b)

5.   (a)   Briefly describe the function an LC-resonant circuit in resonant inverters.

(2 marks)

(b)   A series resonant full-bridge inverter with a transformer connected load is shown in the Figure Q5b. The inverter is operating at a switching frequency of $f_o = 5\ kHz$, and has $C_r = 5\mu F$, $L_r = 40\mu H$, $L_r = 3\Omega$, and $V_{dc} = 120$ V.

(i)   Draw an equivalent circuit having direct connected load resistance R_L

.   (3 marks)

(ii)   Determine the resonant frequency ω_r and f_r, the damping factor α and the off period of load current,

(5 marks)

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(iii)   Determine the peak supply current I_P and,   (7 marks)

(iv)   Determine the average switch current I_A.   (8 marks)

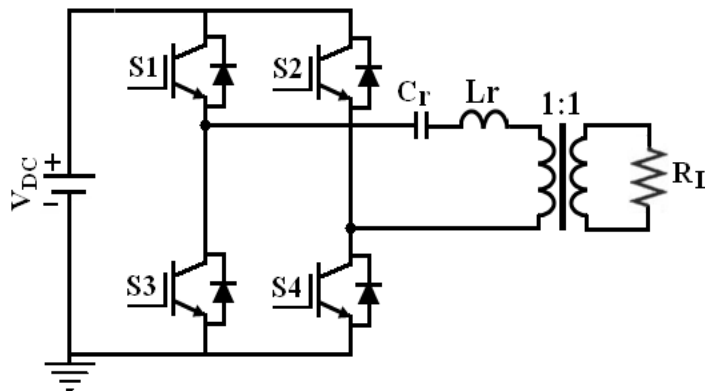[Note: Suppose the transformer is ideal and it has $1:2$ turn ratio.]

Figure Q5(b)

6.   (a)   A single-phase controlled rectifier is used to charge a battery as shown in Figure Q6(a). The input voltage to the rectifier circuit is 240 V RMS. Find the charging current for a firing angle of 55°. If any one of the thyristor is open circuited, what is the charging current?
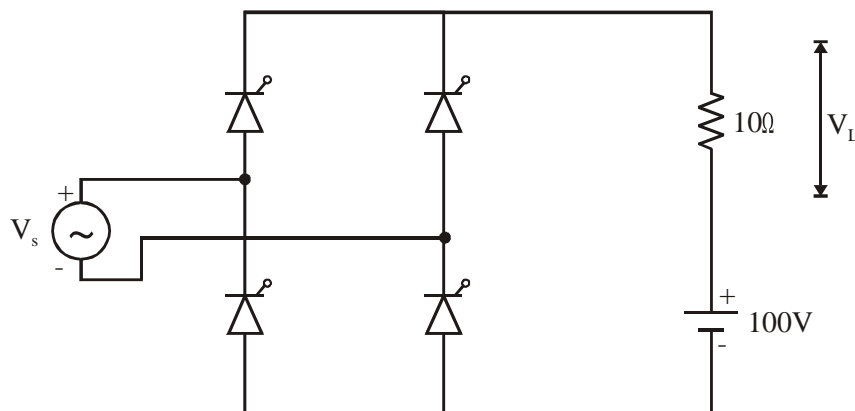
(9 marks)

Figure Q6(a)

(b)   Sketch the circuit diagram of a full-bridge dc-dc converter and describe its operation with the aid of relevant steady state waveforms. Derive an expression that relates its output voltage with the input voltage through the duty cycle D.

(12 marks)

(c)   Sketch the schematic block diagram of an uninterruptable power supply (UPS) with load normally connected to ac main supply and briefly describe its operation.

(4 marks)

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