UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

December 2015 / January 2016

EEE 542 – INDUSTRIAL POWER ELECTRONICS

Duration : 3 hours

Please check that this examination paper consists of **SIX (6)** pages printed material and **SEVEN (7)** pages of Appendixs before you begin the examination.

Instructions: This question paper consists of **SIX (6)** questions. Answer **FIVE (5)** questions. All questions carry the same marks.

You are not allowed to take this question paper out of the examination hall.

1. (a) A single-phase semi-converter is used to supply power from a 230 V_{rms} ac source to a 1 kW heater load. The firing angle of the thyristor is adjusted to 45°. Determine the power absorbed by the heater.

(20 marks)

(b) A single-phase full converter is operated from a 120 V, 60 Hz supply. The load current with an average value of $I_o = 1\,A$ is continuous with negligible ripple content. The turn ratio of transformer is unity. If the delay angle is, $\alpha = \pi/3$, calculate

(i) The average output voltage

(5 marks)

(ii) The harmonic factor of input current,

(15 marks)

(iii) The displacement factor

(5 marks)

(iv) The input power factor

(5 marks)

(c) A controlled full-wave rectifier has an ac source of 240 V rms at 60 Hz. The load is a series combination of resistor, inductor and dc source with R=10 Ω, and L = 0.8 H and V_{dc} = -100 V. The delay angle of converter is 105°. Determine the power supplied to the ac system from the dc source. Estimate the peak-peak ripple in the load current from the first ac term in the Fourier series.

(50 marks)

2. (a) Sketch the circuit diagram of a single-phase bidirectional controller with one thyrsitor and four diodes. Describe operation of the circuit with the aid of key steady state waveforms for the case of resistive load.

(20 marks)

(b) Design a single-phase full-wave ac voltage controller to supply power in the range of 750-1500 W to a 32 Ω resistor load from 230-V (rms), 60-Hz source. Specify the range of firing angle α, and voltage and current ratings of the thyristors.

(50 marks)

(c) The single-phase transformer tap changer as shown in Figure 2(c) has following parameters: $V_P = 240\,V\ (rms),\ 60\,Hz;\ V_1 = 120\,V;\ V_2 = 120\,V;\ R = 10\Omega,$ and $\alpha = 98°$. The tap change is operating in control range 3 ($V_1 \leq V_o \leq (V_1 + V_2)$). Determine the rms output voltage and rms currents of thyristors T_1 &T_3.

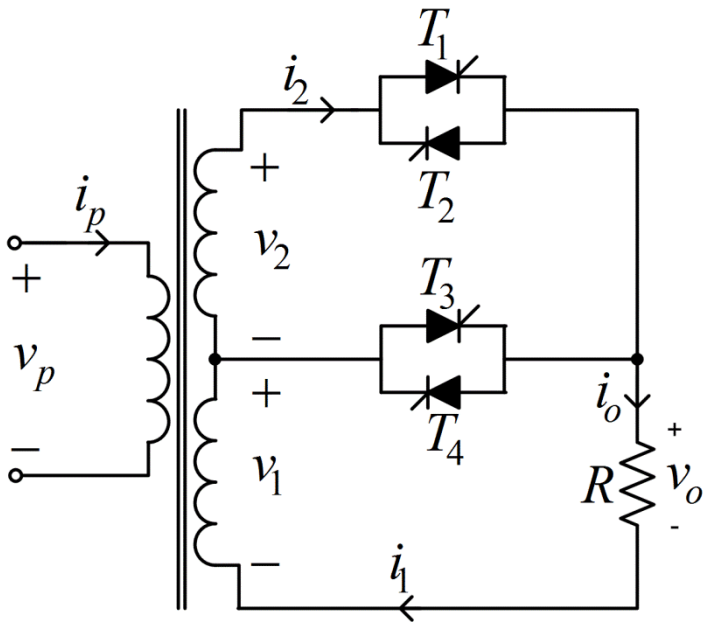

Figure 2(c)

(30 marks)

3. (a) A single-phase full-bridge PWM inverter is supplying power to an RL load ($R = 8\Omega,\ L = 20\,mH$) from an input dc source of 270 V. The inverter operates at duty cycle of 60% with a switching frequency of 50 Hz. Determine

(i) The rms value of the total output voltage

(4 marks)

(ii) The rms value of the fundamental and the two lowest-order harmonics.

(24 marks)

(iii) The rms value of the total harmonic component of the output voltage.

(8 marks)

(iv) The total harmonic distortion of the output voltage.

(8 marks)

(v) The voltage transfer ratio of the fundamental component of the inverter.

(6 marks)

(b) Design a three-phase bridge inverter to produce fundamental phase voltage of 225.16 V (rms), 60 Hz, across a star-connected resistive load of $15\ \Omega/phase$. The desired mode of operation of inverter is $180°$ conduction. Specify the value of input dc voltage and ratings of transistors.

(40 marks)

(c) Determine the distortion factor and harmonic factor for the three-phase inverter designed in Question 3(b).

(15 marks)

4. (a) List down at least two applications of boost converters.

(5 marks)

(b) Sketch circuit diagram of a buck-boost converter and describe its operation with the aid of key steady state waveforms leading to the derivation of an expression between input voltage V_{in} and output voltage V_o.

(45 marks)

(c) Design a dc-dc converter to produce a regulated output voltage of $-12\,V$ from a source that varies from 10 V to 14 V. The load power varies from 10 to 15 W. The output voltage ripple must be less than 1 percent for any operating condition. Determine the range of the duty cycle of the switch. Specify value of the inductor and capacitor, and explain how you made your design decisions.

(50 marks)

5. (a) Briefly explain the two modes of operation (with the aid of relevant current waveforms) of series resonant inverters with bidirectional switches.

(10 marks)

(b) The values of circuit parameters of a series resonant half-bridge inverter with bidirectional switches are: $C_1 = C_2 = 4\mu F$, $L_r = 40\mu H$, $R_L = 2\Omega$, $V_{dc} = 120\,V$ and $t_q = 20\mu S$. The switching frequency of inverter is: $f_o = 3.179\,kHz$. Estimate

(i) The dead time of the circuit (t_d).

(15 marks)

(ii) The peak current and voltage stress on the thyristors.

(30 marks)

(c) Design a resonant inverter to supply an output power of 800 W to a resistive load of 12 Ω. The load requires a 100 Hz ac current with THD no more than 10%. An adjustable dc source is available. Specify the dc input voltage, the size of resonant inductor L with current rating and capacitor C with voltage rating.

(45 marks)

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

(30 marks)

(b) Design a fly-back converter to produce an output voltage of 320-V from a dc source of 48-V. The required output power of converter is 1000-W. Design for continuous conduction mode of operation and the variation in the current of magnetizing inductor should not be more than 40% of the average current. The output voltage ripple must not be more than 2%.

(50 marks)

(c) Draw the circuit diagrams of resonant mode ac power supply and bidirectional ac power supply.

(20 marks)

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