

City University of Hong Kong

Course code & title : EE4101 Modern Power Electronics

Session : Semester A 2005 / 2006

Time allowed : Two hours

This paper has SIX pages (including this cover page).

1. This paper consists of five questions.
 2. Answer ANY FOUR questions.
 3. All questions carry equal marks.
 4. Start each question on a new page.
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Materials, aids & instruments permitted to be used during examination:

1. Portable battery operated calculator
 2. One reference book
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Answer ANY FOUR questions

Question 1

Fig. 1 shows the circuit diagram of an induction cooker. The ac mains voltage is rectified into a constant dc voltage by the capacitor C_{in} . By switching the transistor Tr at a high frequency, an alternating current flows through the induction coil and thus generates a magnetic field. When a metallic cooking utensil, such as the frying pan shown in Fig. 1, is placed above the coil, the magnetic field induces eddy currents in the utensil, generating heat without any physical contact between the coil and the utensil. However, Tr was found to be very hot and the line current was pulsating.

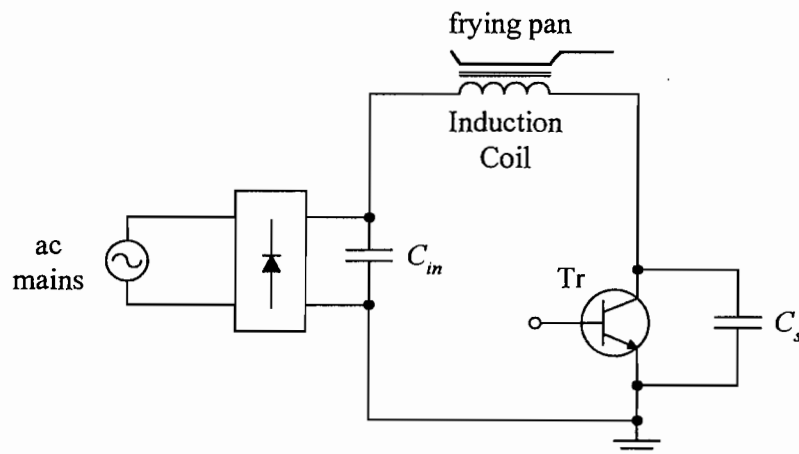


Fig. 1

- (a) Suggest a way to modify the above circuit, so that the temperature of Tr can be reduced and the input line current becomes sinusoidal. [5 marks]
- (b) With the aid of a timing diagram, briefly describe the operating principles of the circuit suggested in part a) and explain how to control the temperature of the frying pan. [10 marks]
- (c) Derive the expressions for the current stress and voltage stress of the transistor, in terms of the duty time of the transistor, the peak line voltage, and the inductance of the induction coil. [5 marks]
- (d) Suggest a circuit for high-power induction cookers. [5 marks]

Question 2

(a) Briefly explain how to turn off silicon-controlled rectifiers with forced commutation. [5 marks]

(b) Fig. 2 shows a switching circuit for powering an inductive-resistive (RL) load.

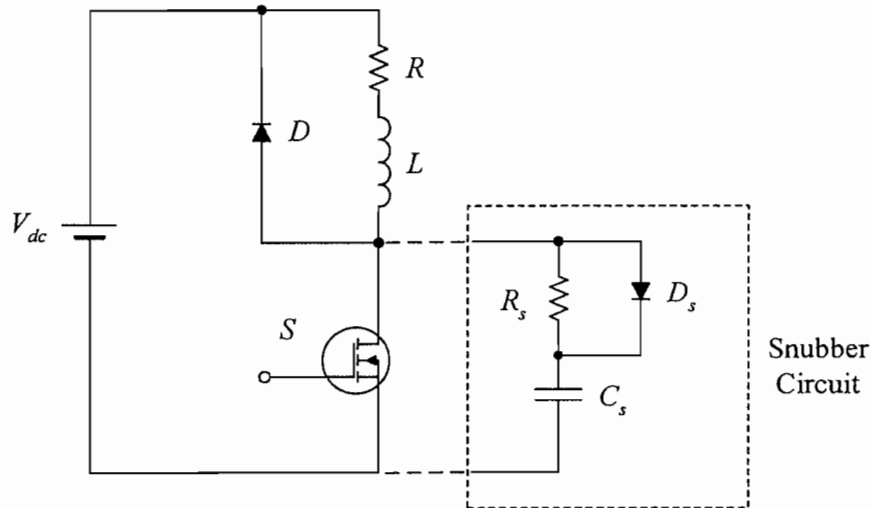


Fig. 2

Given:

On-state current of $S = I_{on}$

Turn-on time of $S = t_{on}$

Turn-off time of $S = t_{off}$

(i) Draw the switching trajectories of S with and without the snubber circuit, respectively. [5 marks]

(ii) Derive the expressions for
 (1) the turn-on loss and
 (2) the turn-off loss
 without the snubber circuit. [7 marks]

(iii) Derive an expression for the turn-off switching loss with the snubber circuit shown in Fig. 2. [8 marks]

Question 3

Fig. 3 shows the circuit diagram of a bi-directional dc/dc converter for the uninterruptible power supply. The converter has two modes of operation – charging mode and discharging mode. In the charging mode, the battery is being charged by the dc rail. In the discharging mode, the battery will discharge to the other loads through the dc rail.

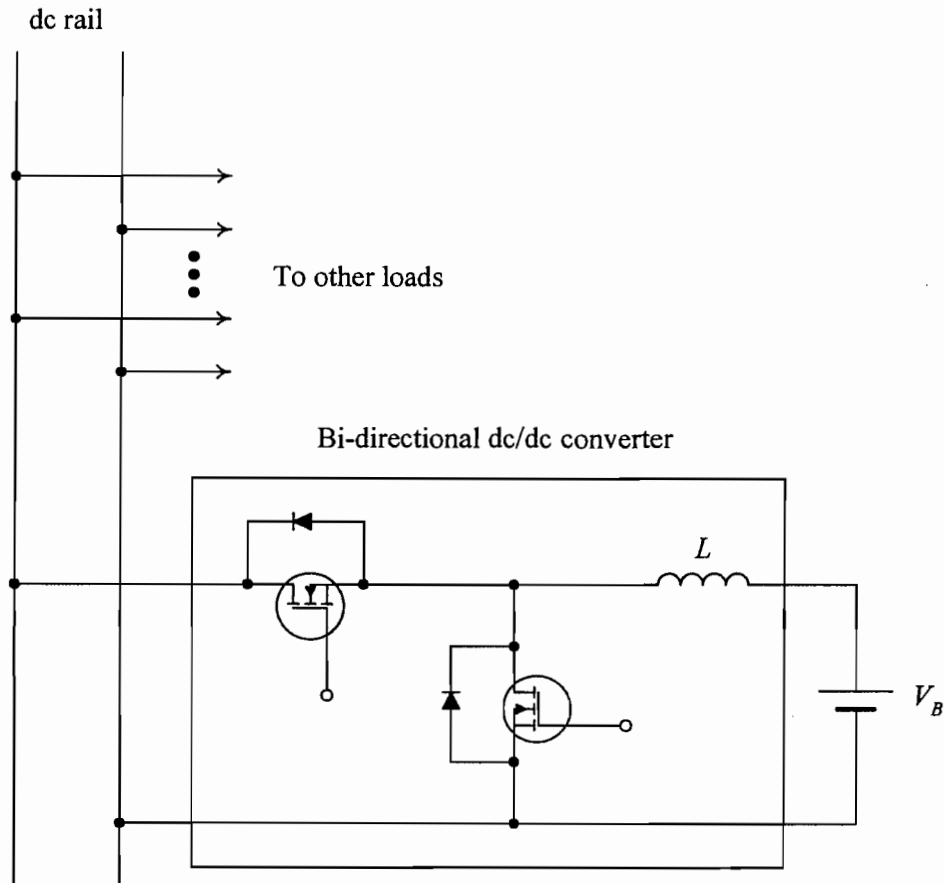


Fig. 3

- Describe the operation when the converter is in the charging mode. [3 marks]
- Describe the operation when the converter is in the discharging mode. [3 marks]
- If the switching frequency of the converter is f_s , determine the minimum value of L so that the inductor current is nonzero during the discharging mode. [10 marks]
- Suggest a modification of the above circuit to be one with soft switching. Discuss the merits and drawbacks of such a modification. [9 marks]

Question 4

In order to comply with international standards such as EN 61000-3-2 Class C appliances, many electronic ballasts consist of an input power factor corrector (PFC) and an output high-frequency ballast inverter. The structure is shown in Fig. 4.

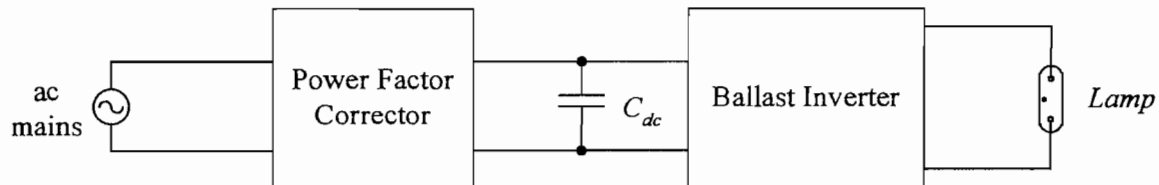


Fig. 4

- (a) Suggest an active PFC circuit and describe its operating principles. [15 marks]
- (b) If the ac mains voltage is 220V, suggest the voltage rating of the capacitor C_{dc} . Justify your suggestion. [5 marks]
- (c) Suggest a passive PFC circuit and describe its operating principles. [5 marks]

Question 5

Fig. 5 shows a burn-in system for testing the performance of the dc power supply PS. The power supply is operated at the rated conditions. Its output power is fed into the ac mains by a pulsewidth-modulated (PWM) inverter.

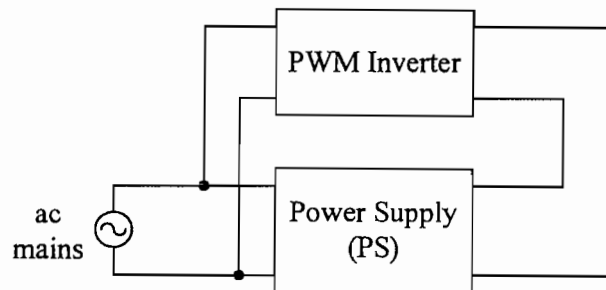


Fig. 5

- (a) Discuss the advantages of this burn-in method. [4 marks]
- (b) Suggest a circuit for the inverter and briefly describe its operation. [9 marks]
- (c) In order to ensure a high-quality power feeding into the grid, suggest a PWM modulation scheme for the inverter. [8 marks]
- (d) Explain why series resonant inverter is unsuitable for this application. [4 marks]

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