

CITY UNIVERSITY OF HONG KONG

Module code & title : EE 6427 Modern Power Electronics
Session : Semester B 2003–2004
Time allowed : Three hours

This paper has SEVEN pages (including this page).

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1. This paper consists of 5 questions.
 2. Choose **ANY FOUR** questions. (25 marks per question)
 3. The full mark of this paper is 100.
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Materials, aids & instruments permitted to be used during examination:

1. Approved calculator
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Q.1

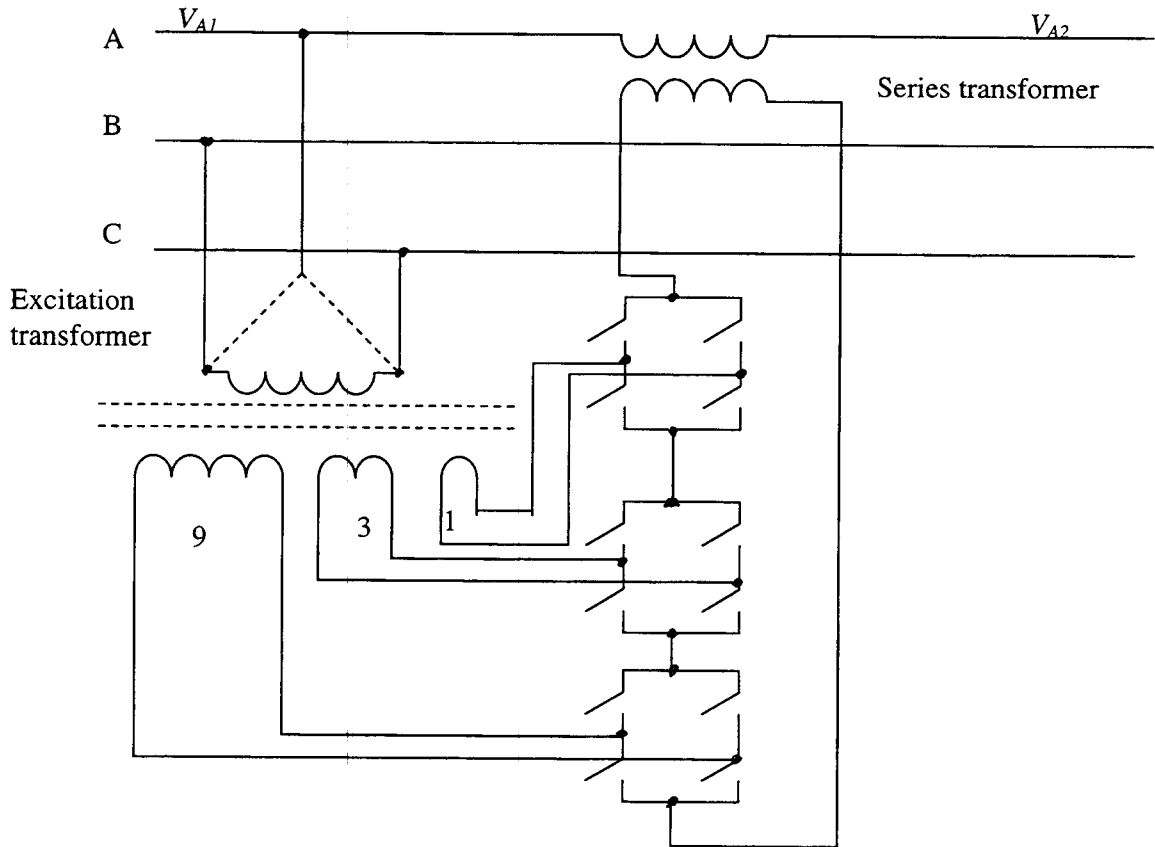


Fig.Q1 shows a part of a power electronic installation for controlling the power flow in Phase A of the 3-phase transmission line system. The secondary windings of the excitation transformer have a turns ratio of 9:3:1. Given that the power flow equation is

$$P = \frac{V_1 V_2 \sin \delta}{X}, \text{ where } P \text{ is the power flow; } V_1 \text{ and } V_2 \text{ are the voltages at the transmission}$$

and receiving ends of the transmission line respectively; δ is the load angle; X is the line impedance, with the aids of diagrams or table, explain

- (i) the phase connection arrangement of the excitation transformer (primary winding) to the 3-phase power supply; (5 marks)
- (ii) the reason for the 9:3:1 turns ratio of the secondary windings of the excitation transformer; (5 marks)
- (iii) the function of the three series-connected switching modules and the series transformer; (5 marks)
- (iv) the overall function of this system. (10 marks)

Q.2

- (a) Sketch a typical safe operating area of a power Bipolar Junction Transistor (BJT), giving reasons for the limits.

(6 marks)

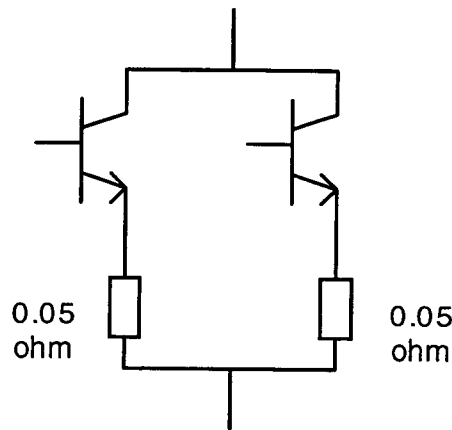
- (b) State a major difference between the safe operating areas of a power BJT and a power MOSFET.

(4 marks)

- (c) Explain why BJTs generally have higher current capability than power MOSFETs.

(5 marks)

- (d)



Two power bipolar transistors (BJT) are used in parallel with current sensing resistors of 0.05Ω to increase the current capability. The two switches and the sensing resistors are mounted on the same heatsink. Each switch has a thermal resistance (junction to heatsink) of 1°C/W . The sensing resistor has a thermal resistance (resistor to heatsink) of 1°C/W . The thermal resistance of the heatsink is 0.3°C/W . The energy loss per switch is 5mJ/A per switching cycle. The maximum current in the switch is 20A . The ambient temperature is 45°C , maximum allowable junction temperature is 125°C and the maximum allowable resistor temperature is 140°C . The maximum duty cycle is 99.9% .

If each switch carries 20A , calculate the maximum switching frequency.

(10 marks)

Q3

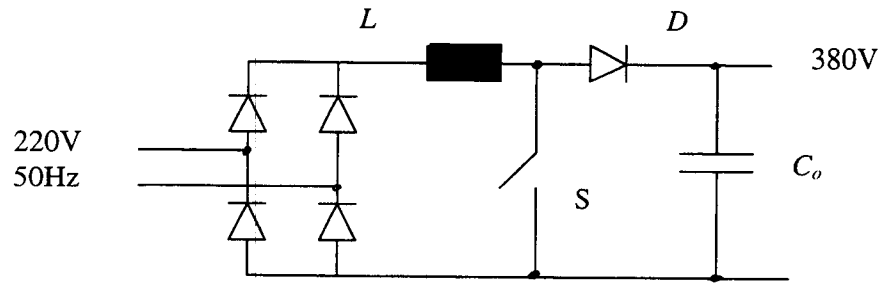


Fig.Q3

- (a) Explain, with the aid of circuit diagrams and typical waveforms, how a boost-type DC-DC converter (as shown in Fig.Q3) can be used to provide input power factor correction for AC-DC power conversion with the rectifier bridge. (8 marks)
- (b) The circuit in Fig.Q3 is fed with a load with an average DC voltage of 380V and a constant DC current of 5A. Assuming that the input power factor is unity and an overall energy efficiency is 100%, calculate:
- the required root-mean-square (rms) input current from the 220V, 50 Hz AC supply; (4 marks)
 - the minimum capacitance value for the output capacitor C_o of the boost converter in order that the voltage ripple across C_o be less than 25V. (7 marks)
- (c) This boost circuit may suffer a serious switching stress and electromagnetic interference (EMI) emission problems because of non-ideal power device behaviour. Give the reason for this problem and modify the circuit in order to suppress EMI. (6 marks)

Q4

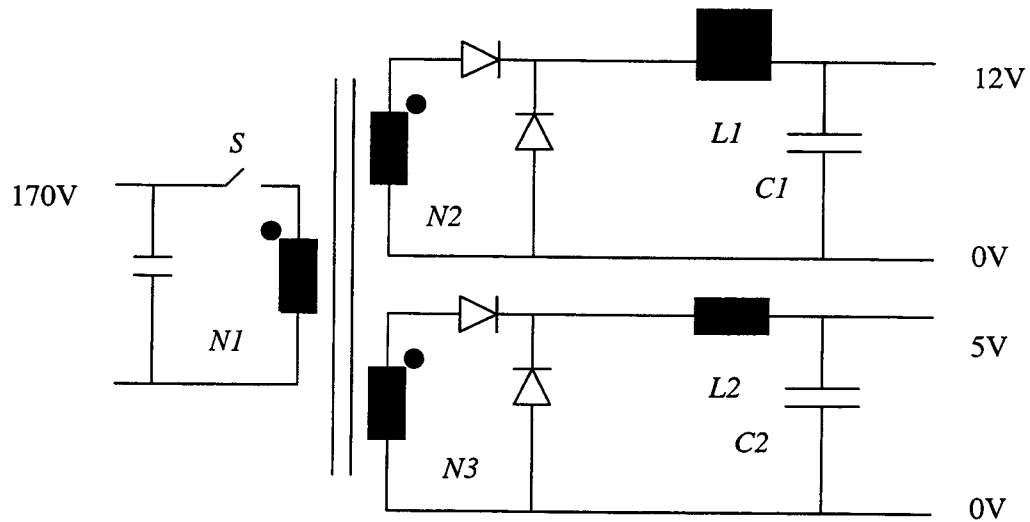
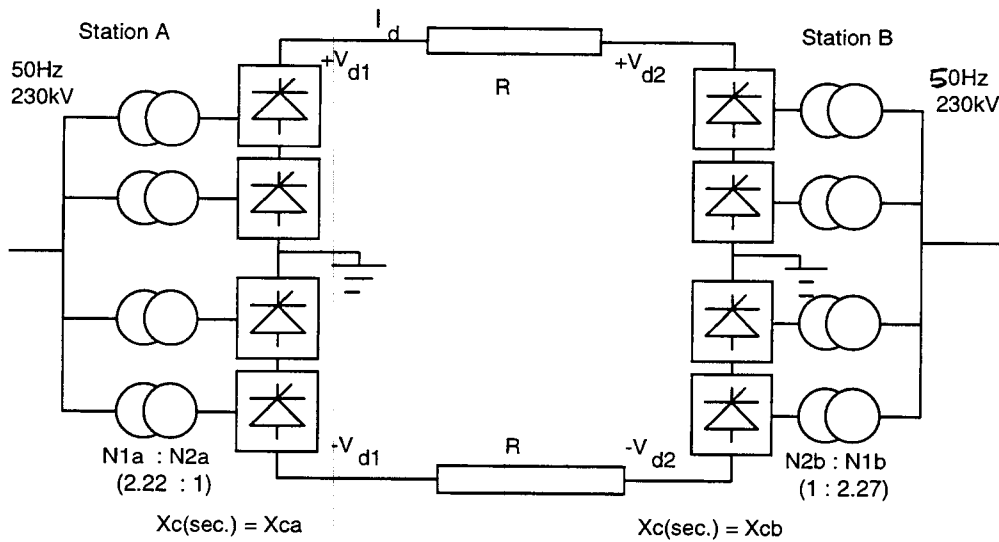


Fig.Q4

A forward converter (Fig.Q4) is required to provide two isolated dc voltage outputs of 12V and 5V. The input dc voltage is 170V. The switching frequency is set at 100kHz. The maximum duty cycle d must not exceed 0.4. The primary winding of the transformer has 100 turns (i.e. $N1=100$). The inductor currents become discontinuous when the load is reduced to 30% of the rated load. The 12V power supply is rated at 50W. The 5V power supply is rated at 20W.

- Determine the number of turns for the two secondary windings, i.e. $N2$ and $N3$.
(6 marks)
- If the duty cycle d is set at 0.4, calculate the filter inductances $L1$ and $L2$.
(6 marks)
- Determine the peak switch current.
(8 marks)
- The transformer is not ideal, explain how the circuit should be modified in order to recover the energy stored in the magnetizing inductance.
(5 marks)

Q5



A HVDC transmission system is 1000 km long and interconnects two 230kV AC systems. Terminal A is the energy sending station and is connected to an AC system of 50Hz, whilst terminal B is the receiving end connected to AC system of 50Hz. Each terminal station consists of four 6-pulse converter bridges (two converters per pole) with each pole rated at typical DC ratings of $\pm 250\text{kV}$. The turns ratios of the converter transformers for converter stations A and B are $N_{1a}/N_{2a} = 2.22$ and $N_{1b}/N_{2b} = 2.27$ respectively. The source leakage inductance (referred to the secondary winding) for converter transformers A and B are $L_{ca} = 25\text{mH}$ and $L_{cb} = 40\text{mH}$ respectively. The steady-state dc current is set at 1200A. Given that the minimum inverter extinction angle is 18° , the DC line winding resistance $15\text{m}\Omega$ per kilometre, and that the general equation for the mean dc converter output voltage V_d is:

$$V_d = \frac{3\sqrt{2}}{\pi} V_{LL} \cos \alpha - \frac{3X_c}{\pi} I_d, \text{ where } \alpha \text{ is the delay angle, } V_{LL} \text{ is the line to line voltage,}$$

I_d is the mean converter dc current and X_c the secondary transformer reactance, determine:

- the dc winding resistance (R) per pole; (3 marks)
- the secondary transformer reactances (X_{ca} and X_{cb}) for stations A and B respectively; (6 marks)
- the dc link voltages at both ends of the HVDC line; (8 marks)
- the delay angle of the converter in station A. (5 marks)
- Give three brief reasons why DC transmission is more favourable than AC transmission system over long distance (say at least 1000 km). (3 marks)

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