

CITY UNIVERSITY OF HONG KONG

Course code & title : EE3918 Power Electronics and Drive Systems

Session : Semester B, 2002-2003

Time allowed : 2 hours and 30 minutes

This paper has FIVE pages.

Instructions to candidates:

1. The paper consists of SIX questions.
 2. Attempt any FOUR questions.
 3. All questions carry equal marks.
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Materials, aids & instruments permitted to be used during examination:

Approved portable battery operated calculator

Special materials (other than standard materials e.g. answer book or supplementary sheets) to be supplied to students:

1 graph paper

Q1.

- (a) Silicon-controlled rectifiers (SCR) are electronic devices commonly used in power rectification applications. With the aid of a circuit diagram, describe briefly the principle of operation of the SCR. State the methods of turning on and turning off the SCR. [15 marks]
- (b) A DC chopper with supply $V_s = 120$ V and an inductive load of $R = 24\ \Omega$ and $L = 0.6$ H is shown in fig.Q1. The thyristor has a latching current of 40 mA. A $50\ \mu\text{s}$ wide gate trigger pulse is applied to the thyristor. Will the thyristor turn on? Explain your answer. If the thyristor does not turn on, it is suggested to add a resistor R_1 in parallel with the R-L load. Find the value of R_1 that would just enable the thyristor to turn on. [10 marks]

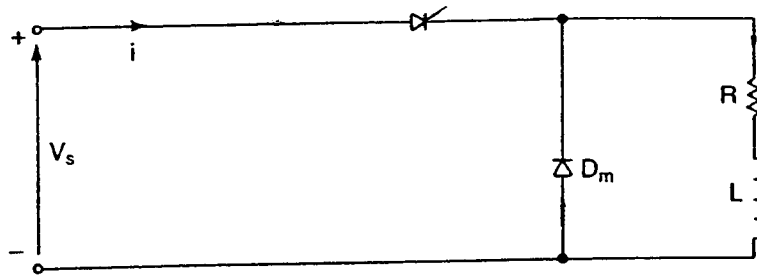


Figure Q1

Q2.

- (a) For three-phase induction motor drive systems, define synchronous speed, ω_s , and slip, s , and hence derive a relationship between the slip and the efficiency of the motor, η . State any assumptions made. [12 marks]
- (b) In motion transducers selection, discuss briefly the factors that may affect the selection criteria. What are the typical specifications for these transducers? [13 marks]

Q3.

A single-phase load of resistance $10\ \Omega$, in series with an inductance of $35\ \text{mH}$, is controlled by inverse-parallel-connected thyristors using phase angle delay. Taking the AC supply be $220\ \text{V}$, $50\ \text{Hz}$, and neglecting thyristor voltage drop,

- (a) determine the load current, $i(t)$, and the load power, P , at delay angle $\alpha = 0^\circ$;
[9 marks]
- (b) for $\alpha = 60^\circ$, estimate the extinction angle, x , and then determine the load power. Sketch the load current waveform;
[14 marks]
- (c) comment on the load power at different delay angles as obtained in (a) and (b).
[2 marks]

The square of the r.m.s. current, I_{rms}^2 , is given by

$$\frac{E_m^2}{2\pi|Z|^2} \left[(x - \alpha) - \frac{1}{2} \{ \sin 2(x - \Phi) - \sin 2(\alpha - \Phi) \} + \frac{\sin^2(\alpha - \Phi)}{\cot \Phi} \{ 1 - e^{2 \cot \Phi (\alpha - x)} \} + 4 \sin \Phi \sin(\alpha - \Phi) \{ \sin x e^{\cot \Phi (\alpha - x)} - \sin \alpha \} \right]$$

Q4.

- (a) What are the pros and cons between the switch-mode power supplies and linear power supplies?
[5 marks]
- (b) With the aid of circuit diagrams and waveforms, discuss briefly the operation of a boost-type dc-to-dc converter operating in continuous conduction mode, and hence derive an expression for the following:
 - (i) peak-to-peak ripple current of the inductor, ΔI_L ;
 - (ii) peak-to-peak ripple voltage across the load, ΔV_o .

State any assumptions made.

[15 marks]

- (c) What are the characteristics of the boost-type converter?
[5 marks]

Q5.

A 40 kW 1850 rpm separately excited DC motor is controlled by a converter as shown in Fig.Q5. The field circuit is kept constant at $I_f = 1.5$ A and the motor back emf constant, $K_v = 0.85$ V/A-rad/s. The armature resistance is $R_m = 0.12$ Ω and the viscous friction constant, $B = 0.3$ Nm/rad/s. The amplification of the speed sensor is $K_1 = 90$ mV/rad/s and the gain of the power controller, $K_2 = 120$.

- Determine the rated torque of the motor. **[3 marks]**
- Determine the reference voltage, V_r , in order to drive the motor at the rated speed. **[6 marks]**
- If the reference voltage remains unchanged, determine the speed when the motor develops the rated torque. **[4 marks]**
- If the reference voltage is reduced by 15%, determine the motor speed. **[4 marks]**
- If there is no feedback in an open-loop control, determine the speed regulation for a reference voltage of $V_r = 2.1$ V. **[6 marks]**
- Determine the speed regulation with a closed-loop control. **[2 marks]**

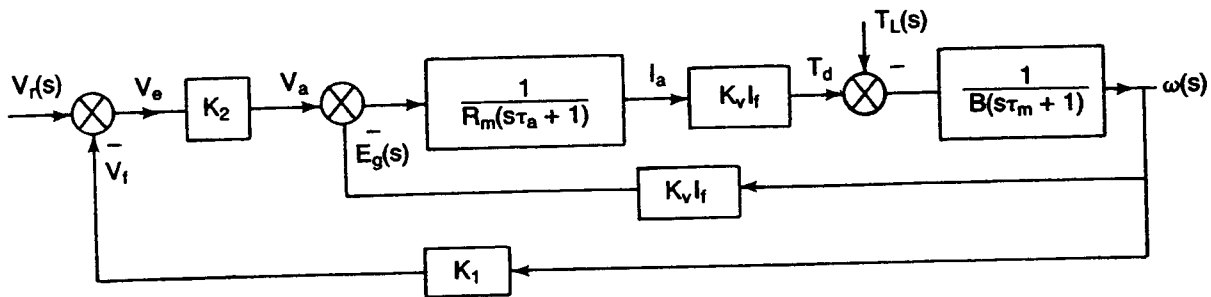


Fig.Q5

Q6.

A three-phase 460 V 60 Hz four pole Y connected induction motor has $R_s = 0.3 \Omega$, $R_r = 0.2 \Omega$, $X_s = 1.1 \Omega$, $X_r = 1.6 \Omega$, and $X_m = 19 \Omega$. The no-load loss, $P_{no\ load}$ is negligible. The load torque, which is proportional to the square of the speed, is 200 Nm at 1200 rpm. If the motor speed is 1000 rpm, determine the following:

- (a) load torque, T_L ; [2 marks]
- (b) rotor current, I_r ; [3 marks]
- (c) stator supply voltage, V_a ; [3 marks]
- (d) motor input current, I_i ; [5 marks]
- (e) motor input power, P_i ; [3 marks]
- (f) slip for maximum current, s_a ; [4 marks]
- (g) maximum rotor current, $I_{r(max)}$; [3 marks]
- (h) speed at maximum rotor current, ω_a . [2 marks]

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