

National Exams May 2008
98 Elec B9 Power Electronics and Drives
Open Book examination

3 hours duration

NOTES

- 1 If doubt exists as to the interpretation of any question the candidate is urged to submit with the answer paper a clear statement of any assumptions made
- 2 Any non communicating calculator is permitted This is an Open Book examination Note to the candidates you must indicate the type of calculator being used i.e write the name and model designation of the calculator on the first inside left hand sheet of the exam work book
- 3 Any five questions constitute a complete paper Only the first five questions as they appear in your answer book will be marked
- 4 All questions are of equal value

PROBLEM 1

- a Explain the differences between multiple pulse modulation and sinusoidal pulse width modulation in terms of distortion factor and lower order harmonics [5 points]

A single phase full bridge inverter uses a multiple pulse width modulation scheme with two pulses per half cycle for voltage control Figure (1) is taken from Rashid s textbook to illustrate the terminology

- b Redraw Figure (1) for $p=2$ and hence determine the parameters α_1 α_2 and δ in terms of

the modulation index $M = \frac{A}{A}$ [5 points]

- c Find the fundamental and third harmonic waveforms in terms of the source voltage assuming that the modulation index $M=0.4$ [10 points]

The following expressions are useful in solving this problem

$$v_o(t) = \sum_{n=1,3,5} A_n \cos n\omega t + B_n \sin n\omega t$$

$$A_n = \sum_{m=1}^p \frac{4V_s}{n\pi} \sin \frac{n\delta}{2} \cos n(\alpha_m + \frac{\delta}{2})$$

$$B_n = \sum_{m=1}^p \frac{4V_s}{n\pi} \sin \frac{n\delta}{2} \sin(\alpha_m + \frac{\delta}{2})$$

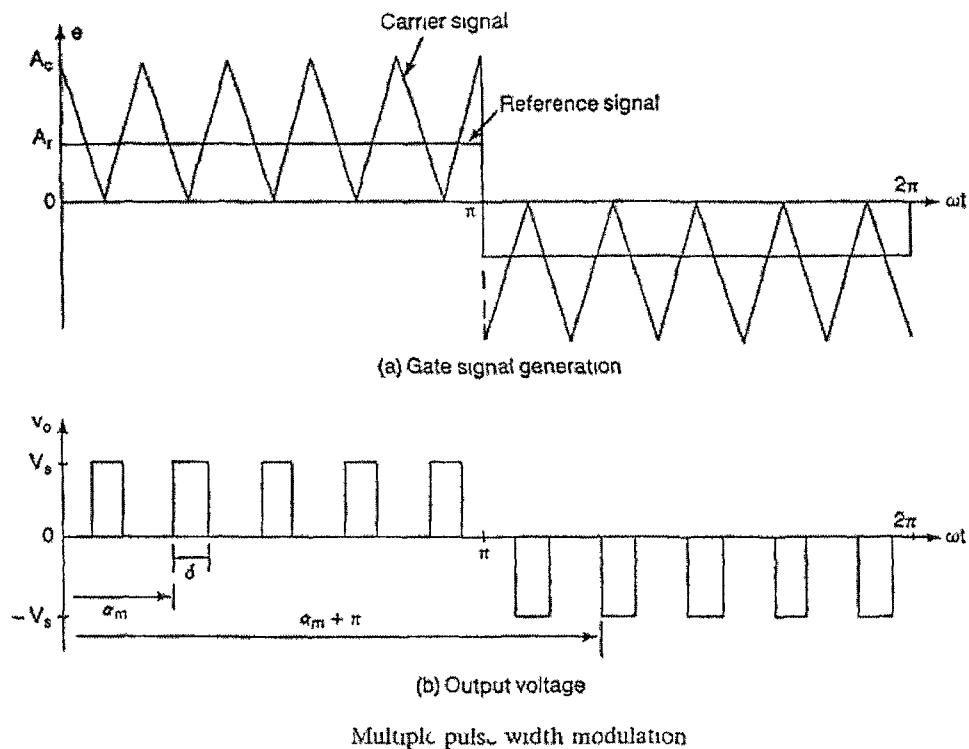


Figure (1)

PROBLEM 2

a Explain the principle of operation of basic chopper circuits and the effects of varying the on time on operational modes of the chopper [5 points]

The load on a basic chopper circuit consists of a series combination of $R = 10 \Omega$ an inductance $L = 15 \times 10^{-3} \text{ H}$ and a back emf $E_c = 20 \text{ V}$. The period of the chopper is $T = 0.2 \text{ ms}$. The dc supply voltage is 220 V .

- b Find the critical value of the on time for which the minimum value of the load current is zero [5 point]
- c Find the value of the maximum load current corresponding to the conditions of part (b) [5 points]
- d Assume that $t_o = 0.5 T$ determine the minimum and maximum values of the instantaneous load current [5 points]

PROBLEM 3

- a Explain the principle of operation of a basic single phase half wave controlled rectifier supplying a resistive load [5 points]
- b Explain how the operation of a basic single phase half wave controlled rectifier is affected if the load consists of resistance plus inductance in series with a dc voltage source [5 points]

Consider a half wave controlled rectifier supplying a resistive load. The rectifier operates initially at a delay angle $\alpha = 15^\circ$ while the maximum value of the ac input wave is $V_{\max 0}$. The maximum value of the ac input wave is changed to $0.8 V_{\max 0}$. Determine the corresponding relative change in the dc output voltage when the delay angle is changed to the following values

- c $\alpha_1 = 5^\circ$ $\alpha_2 = 10^\circ$ and $\alpha_3 = 45^\circ$ [5 points]
- d Repeat part (b) for a three phase controlled rectifier operating in continuous current mode [5 points]

PROBLEM 4

a Explain the principle of operation of ac controllers [5 points]

A single phase 575 V (rms) 60 Hz source supplies a full wave ac voltage controller. The controller powers an ac motor and the delay angle is adjusted to $\alpha = 51.6^\circ$. The corresponding conduction angle is $\gamma = 160^\circ$ and the average current through each thyristor is 65 A .

- b Verify that the load power factor is 0.85 [5 points]
- c Find the equivalent resistance and inductive reactance of the motor [10 points]

PROBLEM 5

- a Explain the consequences of decreasing the supply frequency to an induction motor below the rated value while maintaining the value of the supply voltage constant at rated value [5 points]

A three phase eight pole Y connected induction motor with negligible no load losses has the following parameters

$$R_s = 0.2 \Omega$$

$$R = 0.22 \Omega$$

$$X = 1.2 \Omega$$

$$X = 1.8 \Omega$$

$$X_m = 12.5 \Omega$$

The motor is controlled by a current source inverter and the input current is kept constant at 40 A. When the frequency is 50 Hz the developed torque is 180 N m. The approximate equivalent circuit corresponding to this mode of operation is given in Fig (2). Determine

- b The slip and rotor speed [7.5 points]
 c The terminal voltage per phase and the power factor [7.5 points]

Use the following torque formula for constant current operation

$$T = \frac{3[X I]^2 (R/s)}{s\omega \left[\left(R + \frac{R}{s} \right)^2 + (X_m + X + X)^2 \right]}$$

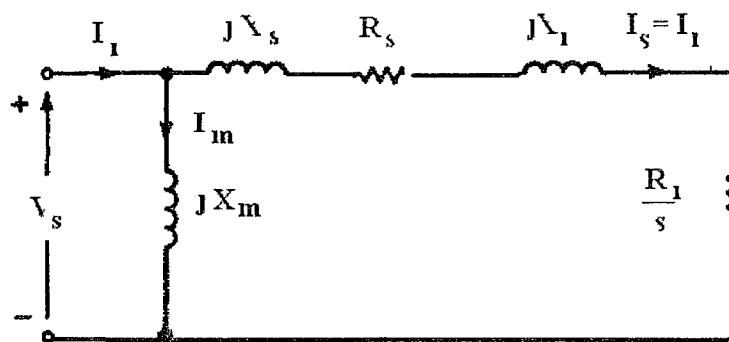


Figure (2) Approximate equivalent circuit for Constant current operation of a three phase induction motor

PROBLEM 6

- a What are the types of dc drives based on the input supply? What are the variables to be controlled in a dc variable speed drive? [5 points]

A separately excited dc motor is controlled by using a three phase full wave bridge rectifier circuit connected to the armature terminals. The ac voltage source is 460 V (line to line)

- b Find the armature voltage when the firing angle of the rectifier circuit is 60° [5 points]

The motor operates at a constant torque of 50 N m all the time

- c Assume that the speed is 1780 rpm for the conditions of part (b). To drive the motor at a speed of 750 rpm a firing angle of 70° is required. Find the output power, armature current and resistance of the armature circuit under these conditions. [5 points]
- d The firing angle is adjusted to 55° . Find the corresponding speed of the motor. [5 points]