National Exams December 2013

07-Elec-B8, 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 $M = \frac{A_r}{A_c}$. [5 points]

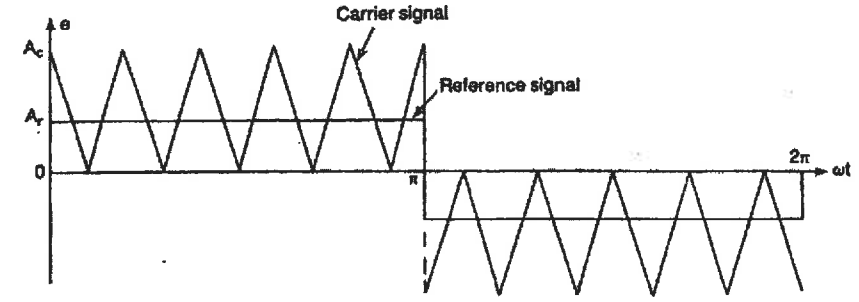
c- Find the fundamental and third harmonic waveforms in terms of the source voltage assuming that the modulation index M=0.4. [10 points]

The following expressions are useful in solving this problem:

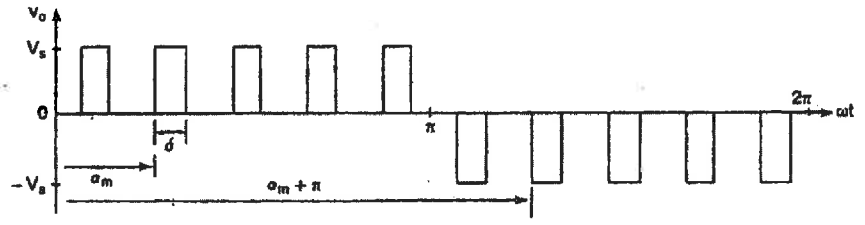
$$v_0(t) = \sum_{n=1,3,5,..} A_n \cos n\omega t + B_n \sin n\omega t$$

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

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



(a) Gate signal generation



(b) Output voltage

Multiple-pulse-width modulation.

Figure (1)

PROBLEM 2

a- Explain the difference between leakage and synchronous reactances. [5 points]
b- Describe the reactive capability curves of a synchronous machine and the effect of coolant pressure on the machine performance. [5 points]

A salient-pole synchronous machine is connected to an infinite bus through a link with reactance of 0.2 p.u. The direct-axis and quadrature-axis reactances of the machine are 0.9 and 0.65 p.u, respectively. The excitation voltage is 1.3 p.u., and the voltage of the infinite bus is maintained at 1 p.u.

c- For a power angle of 30°, compute the active and reactive power supplied to the bus.[5 points]
d- For an active power of 0.85 p.u, determine the torque angle and the reactive power. [5 points]

PROBLEM 3

a- Explain the differences between current-fed inverters and voltage-fed inverters. [5 points]

b- It is known that the n^{th} Fourier Series coefficient for the output side of a single-phase, full wave bridge, single pulse modulation inverter is given by:

$$b_n = \frac{4V_d}{n\pi}\sin\frac{n\delta}{2}$$

Show that the ratio of the fifth harmonic to third harmonic component is given by:

$$\frac{b_5}{b_3} = \frac{3}{5}\left[\frac{5\sin\frac{\delta}{2} - 20\sin^3\frac{\delta}{2} + 16\sin^5\frac{\delta}{2}}{3\sin\frac{\delta}{2} - 4\sin^3\frac{\delta}{2}}\right]$$

[5 points]

The dc supply to a single-phase, full wave bridge, single pulse modulation inverter is 220 V. The load is an ac motor. The motor is represented by an R-L series combination whose value at fundamental frequency is given by:

$R = 8.2\,\Omega$ $\qquad\qquad$ $\omega L = j6.1\Omega$

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.275. Find the ratio of the third harmonic to fundamental components of the voltage output. [5 points]

d- Find the fundamental, third, and fifth harmonic components of the inverter output current (feeding the motor). [5 points]

Useful Trig Identities:

$\sin 3\theta = 3\sin\theta - 4\sin^3\theta$

$\sin 5\theta = 5\sin\theta - 20\sin^3\theta + 16\sin^5\theta$

PROBLEM 4

a- Explain functions of clamping capacitors and smoothing reactors in inverter circuits. [5 Points]

The voltage input to a basic chopper circuit is V_i = 30 V. The load consists of a series combination of R = 0.275 Ω and an inductance such that the time constant is 1.475 ms. The maximum value of the output current is 92 A and the on-time is 2.4 ms. It is required to find:

b- The period of the chopper. [5 Points]

c- The minimum value of the output current. [5 Points]

d- Suppose now that the resistance of the load circuit is increased to 0.375Ω while the inductance is kept constant at its original value. Find the maximum and minimum values of the output current if the period and on time remain unchanged. [5 Points]

PROBLEM 5

List at least three undesirable effects of using high frequency PWM drives. [5 points]

A three-phase, four-pole induction motor has a total leakage inductance of 1.25 mH, negligible resistance, and operates from a constant volt per Hz drive.

a- Assume that the maximum output torque is 245 N.m. at a speed of 1500 rpm, when the frequency supplied to the stator is 60 Hz. Find the required supply voltage (line-to-line), and the motor's line current. [7.5 points]

b- Assume that the motor draws a line current of 185 A, when the stator input frequency is 62.5 Hz. Find the required supply voltage (line to line,) and the maximum output torque. [7.5 points]

Use the following approximation for the value of maximum developed torque:

$$T_{\max} = \frac{[V_{LL}]^2 P}{4[\omega_i]^2 L_T}$$

Here P is the number of poles, L_T is the total leakage reactance, and $\omega_i = 2\pi f_i$

PROBLEM 6 December 2010

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 three-phase, full wave bridge rectifier circuit feeds the armature terminals of a separately excited dc motor. The ac voltage source is 230 V (line-to-line). The motor draws an armature current of 118 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 44.5° and speed is 1700 rpm.[5 points]

c- To drive the motor at a speed of 995 rpm, a firing angle of 55.5° is required Find the resistance of the armature circuit, the output power and torque under these conditions. [5 point]

d- The firing angle is adjusted to 64.5°. Find the corresponding speed of the motor. [5 points]