National Exams May 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- In synchronous machine models explain the term armature reaction and for a round rotor machine distinguish between synchronous and magnetizing reactances. [5 Points]

A 9375-kVA three-phase Y-connected 13,800-V (line to line) two-pole 60-Hz turbine generator has an armature resistance of 0.064 Ω per phase and a synchronous reactance of 1.79 Ω per phase. Find the full-load generated voltage per phase at:

b- Unity power factor. [5 Points]
c- A power factor of 0.8 lagging. [5 Points]
d- A power factor of 0.8 leading. [5 Points]

PROBLEM 2

a- Discuss three causes of harmonics in the electric power distribution system. [4 Points]

The a.c. supply voltage to a single-phase full wave controlled rectifier is 120 V. The load circuit consists of a 30 V counter (back) e.m.f. E_c in series with a resistance R = 2.25 Ω. The conduction angle γ is maintained at 135°.

b- Find the minimum permissible value of the delay angle. [4 Points]
c- Find the delay angle α. [4 marks]
d- Find the value of the average load current. [4 Points]
e- The minimum value of α is changed to 12°. Find the value of the average load current. [4 Points]

PROBLEM 3

a- Explain how harmonics arise in an electric power distribution system, and list three ways of mitigating their effects. [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 240 V. The load is an ac motor represented by an R-L series combination whose value at fundamental frequency is given by:

$$R = 56\,\Omega \qquad \omega L = 4\Omega$$

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.4 . 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- Describe the functions of series smoothing reactors and shunt capacitors in power electronics and drive circuits. [5 Points]

The voltage input to a basic chopper circuit is V_i = 32 V. The period of the chopper is 3.2 ms. The load consists of a series combination of R = 0.27 Ω and an inductance L=0.5x10^{-3} H. The ratio of minimum to maximum values of the output current is 0.9. It is required to determine::

b- The time constant of the load circuit, and the on-time. [5 Points]

c- The maximum and minimum values of the output current. [5 Points]

d- The time domain expressions of the chopper output currents, and the values of the output current at t= 1 ms and t=3.1 ms, respectively [5 Points]

PROBLEM 5

a- 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.

b- Find the maximum output torque and line current when the supply voltage (line-to-line) is 460 V and the frequency supplied to the stator is 410 Hz. [7:5 Points]

c- Assume that the leakage reactance is changed so that the motor draws a line current of 85 A, when the stator input frequency is 420 Hz. Find the required value of leakage inductance, the line voltage and the corresponding 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

a- Explain the principle of speed control in a dc drive below base speed and how does it differ from control above base speed.[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 170 A all the time.

b- Find the armature voltage when the firing angle of the rectifier circuit is 48° and speed is 1750 rpm.[5 Points]

c- To drive the motor at a speed of 1000 rpm, a firing angle of 60° is required. Find the resistance of the armature circuit, the output power and torque under these conditions. [5 Points]

d- The firing angle is adjusted to 65°. Find the corresponding speed of the motor. [5 Points]