National Exams December 2018

16-Elec-B8, Power Electronics and Drives

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 effect of load inductances on the output voltage of an ac controller. [5 points]

A single-phase, 220 V (rms,) 60-Hz source supplies a full-wave a.c voltage controller. The controller powers a 20-hp motor whose power factor angle is $\phi = 20^o$. The corresponding conduction angle is $\gamma = 160^o$.

b- Verify that the delay angle is $\alpha = 40^o$. [5 points]

c- Find the effective (rms) output voltage of the controller. [5 points]

d- Assume that the efficiency of the motor is 0.87; find the average current through each of the thyristors of the controller. [5 points]

PROBLEM 2

a- List and discuss five factors that influence the duration of the turn-off interval of an SCR. [5 points]

The ac supply voltage to a half-wave controlled rectifier is 120 V. The load circuit consists of a resistance R in series with an inductance L. The power factor of this load is 0.707.

b- Find the value of the delay angle α when the conduction angle is $\gamma = 145^o$. Find the load resistance R when the average value of the dc output current is 25 A. [7.5 points]

c- Assume that the conduction angle is adjusted to $\gamma = 150^o$, find delay angle α and the average value of the dc output current under the conditions of part (b) [7.5 points]

PROBLEM 3

a- Explain the principles 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 Ω, an inductance L= 15×10^{-3} H and a back emf E_c= 20 V. The period of the chopper is T= 0.2 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 $t_{on} = 0.5$ T, determine the minimum and maximum values of the instantaneous load current. [5 points]

PROBLEM 4

Explain three harmful effects of harmonics in electric power distribution systems. [5 points]

a- 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:

$R = 9\,\Omega$ $\qquad\qquad$ $\omega L = j5\Omega$

c- The modulation angle δ is selected such that the ratio of the fifth harmonic to third harmonic components of the voltage output is 0.2. 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 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 1.5 mH, negligible resistance, and operates from a constant volt per Hz drive.

b- Assume that the maximum output torque is 350 N.m. at a speed of 1800 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]

c- Assume that the motor draws a line current of 200 A, when the stator input frequency is 65 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

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 120 A all the time.

a- Find the armature voltage when the firing angle of the rectifier circuit is 42.5° and speed is 1720 rpm.[5 points]

b- To drive the motor at a speed of 1000 rpm, a firing angle of 57° is required. Find the resistance of the armature circuit, the output power and torque under these conditions. [5 points]

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