Professional Engineers Ontario

Exam

07-Elec-A6 Power Systems and Machines

Spring 2012

Notes:

1. You must answer Question 1, and **FOUR (4)** other questions. Unless you indicate otherwise, the first five questions as they appear in the answer booklet will be the only ones marked. All questions are of equal value.

2. Start each question on a new page, and clearly indicate the question number. Only work written on the right hand pages of the answer booklets will be marked. Use the pages on the left side for rough work only - ***work presented on the left hand side pages will NOT be marked***.

3. You may use one of the approved Casio or Sharp calculators.

4. This is a closed book exam. Candidates may bring ONE aid sheet 8.5" x 11" hand-written on both sides containing notes and formulae. No examples, problem solutions, or figures, are allowed. The aid sheet must be submitted with the exam paper.

5. All ac voltages and currents are rms values unless noted otherwise. For three-phase circuits, all voltages are line-to-line voltages unless noted otherwise.

6. You are encouraged to use pencil for this exam.

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.

Question 1 - You must do this question.

a. What are three advantages of a three-phase power distribution system over a single-phase system?

b. Why do alternators driven by water wheels/turbines require many poles to generate the required frequency?

c. Alternators driven by steam turbines require only few poles to generate the required frequency. Why is that, and why is their construction different than that of the alternators driven by water turbines?

d. Why is a synchronous motor not self-starting?

e. What type of DC motor is best suited for an electric golf cart? Explain your answer.

f. Large utility customers with low power factor often pay a penalty for it. Why is that?

g. A distribution transformer is rated at 18 kVA, 20 kV/480 V, and 60 Hz. Can this transformer safely supply 15 kVA to a 415 V load at 50 Hz? Why or why not?

h. Why is the efficiency of an induction motor so poor at high slip?

i. Name and describe three means of controlling the speed of induction motors.

j. A small three-phase system is made up of the loads listed below. What is the total active (real) power supplied to the system, and the overall system power factor (pf)?

Load 1: S = 2.5 kVA, pf = 0.82 lagging;
Load 2: P = 2.5 kW, Q = 1.5 kVAR leading; and,
Load 3: P = 2.5 kW, pf = 0.82 lagging.

DO 4 OF THE NEXT 5 QUESTIONS

Question 2

A 120 V, 2400 rpm, DC shunt motor has an armature resistance of 0.4 Ω and a shunt field resistance of 160 Ω. The motor operates at its rated speed at full load and draws 14.75 A. The no-load current of the motor is 2 A. If an external resistance of 3.6 Ω is inserted in the armature circuit, calculate the new motor speed, the power loss in the external resistor as a percentage of the total power input, and the efficiency of the motor. Assume that rotational losses are proportional to the speed.

Question 3

Tests were conducted on a 7.5 hp, 4-pole, 60 Hz, Y-connected induction motor, having a rated current of 28 A, and the following results obtained:

DC test		
	$V_{DC} = 13.6$ V	$I_{DC} = 28.0$ A
No-load test		
	$V_T = 208$ V	$f = 60$ Hz
	$I_a = I_b = I_c = 8.17$ A	$P_{in} = 420$ W
Locked-rotor test		
	$V_T = 25$ V	$f = 15$ Hz
	$I_a = I_b = I_c = 27.9$ A	$P_{in} = 920$ W

a. Determine and sketch the per-phase equivalent circuit for this motor.

b. Determine the efficiency of the motor with rated load.

Question 4

The following test results were obtained for a 15 kVA, 2300/230 V transformer:

Open-circuit Test	Short-circuit test
$V_{OC} = 2300$ V	$V_{SC} = 47$ V
$I_{OC} = 0.21$ A	$I_{SC} = 6.52$ A
$P_{OC} = 50$ W	$P_{SC} = 160$ W

a. On what side of the transformer were each of the tests taken?

b. Determine and sketch the approximate equivalent circuit for this transformer, with all voltages referred to the high voltage side.

c. Determine the full-load voltage regulation and efficiency with 0.8 leading power factor.

Question 5

A 480V, 6-pole, 60 Hz, Y-connected synchronous has a per-phase synchronous reactance 1 Ω per phase and negligible armature resistance. Its full-load armature current is 60 A at a 0.8 power factor (pf) lagging. The generator has friction and windage losses of 1.5 kW, and core losses of 1.0 kW at full load. The field current has been adjusted so that the no-load terminal voltage is 480 V.

a. What is the speed of rotation of the generator?

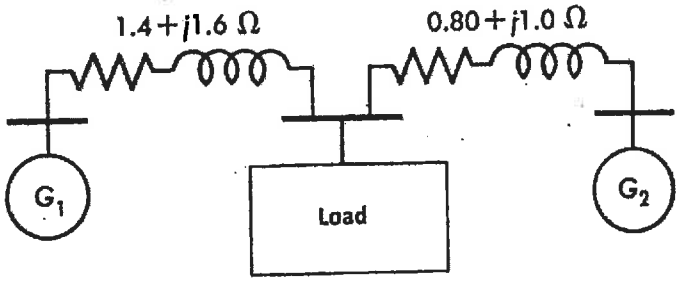
b. What is the terminal voltage and voltage regulation of the generator if:
   (i) it is loaded with the rated current and 0.8 pf lagging; and,
   (ii) it is loaded with the rated current and 0.8 pf leading?

c. What is the efficiency of this generator when it is operating with rated current and the pf is 0.8 lagging?

d. How much shaft torque must be applied by a prime mover at full load?

Question 6

The figure below is the equivalent circuit of a load supplied from 2 three-phase generating stations, over lines have the impedances per phase given on the diagram. The load requires 30 kW at 0.80 power factor (pf) lagging. Generator G_1 operates at a terminal voltage of 797 V (line-to-line), and supplies 15 kW at 0.80 pf lagging. Determine the required terminal voltage and power and reactive power output of Generator G_2.



Circuit for Question 6