Professional Engineers Ontario

Exam

07-Elec-A6 Power Systems and Machines

Fall 2012

Notes:

1. **FIVE (5)** questions constitute a complete exam paper. 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. Note that no examples, solved problems, 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

A 100 kVA, 7200/240 V, 60 Hz, single-phase transformer gave the following test results:

Open-Circuit Test (HV side):
Voltage = 7200 V
Current = 0.65 A
Power = 425 W

Short-circuit Test (HV side):
Voltage = 250 V
Current = 13.889 A
Power = 1420 W

Also assume that the transformer will operate at full load, the load which has a 0.90 lagging power factor. Determine:

a. the approximate equivalent circuit for the transformer, with all values referred to the HV side;
b. the efficiency of the transformer; and,
c. the percentage voltage regulation.

Question 2

A three-phase, two-pole, 35 hp, 480 V, 60 Hz, Y-connected induction motor has the following equivalent circuit parameters in ohms per phase, all referred to the stator:

$R_1 = 0.322\ \Omega$; $R_2 = 0.196\ \Omega$; $X_1 = 0.675\ \Omega$; $X_2 = 0.510\ \Omega$; $X_m = 12.5\ \Omega$;

Rotational and core losses are 1850 W, and can be assumed constant. If the slip is 3%, determine the following:

a. the motor speed;
b. the stator current;
c. the output power;
d. the output torque; and,
e. the motor efficiency.

Question 3

A 13.2 kV, 50 MVA, 60 Hz, Y-connected cylindrical-rotor synchronous generator has an armature reactance of 2.49 Ω per phase. The armature resistance is negligible. If the generator delivers full-load current at rated voltage and 0.98 lagging power factor, determine:

a. the rated load current;
b. the internal generated voltage;
c. the power angle;
d. the voltage regulation and,
e. the phasor diagram for these operating conditions (include the internal generated voltage).

Question 4

A 250 V, DC shunt motor has an armature resistance of 0.1 Ω and a field resistance of 108 Ω. When fully loaded, the motor draws a current of 83A, friction and core losses are 811 W, and the motor turns at 840 rpm.

a. Determine the motor efficiency.

If now the mechanical load on the motor shaft is reduced such that the load torque is only a quarter of the original torque, calculate:

c. the new armature current; and,
d. the new operating speed.

Assume a linear magnetic circuit.

Question 5

A cross-section of a two-pole rotating machine is shown below in Figure 1(a). The rotor of the machine has a radius of 120 mm, and an axial length of 200 mm. Each pole covers an arc of 40°, and has the same axial length as the rotor. The coil for each pole has 360 turns, and the two coils are connected in series. Each air gap has length 1.5 mm. The yoke and pole material is made from iron having the magnetization curve shown in Figure 1(b). Draw the equivalent magnetic circuit for this system and determine:

a. the reluctance of each air gap;

b. the flux in each pole if the air-gap flux density is to 0.8 T;

c. the current required in the coils to produce the flux found in part (b) if all iron reluctances are ignored;

d. the flux density in the yoke of the machine, given that its outer radius is 210 mm and its thickness is 25 mm; and,

e. the coil current required for an air-gap flux density of 0.8 T if the yoke mmf is included, but the reluctances of the poles and rotor are ignored.

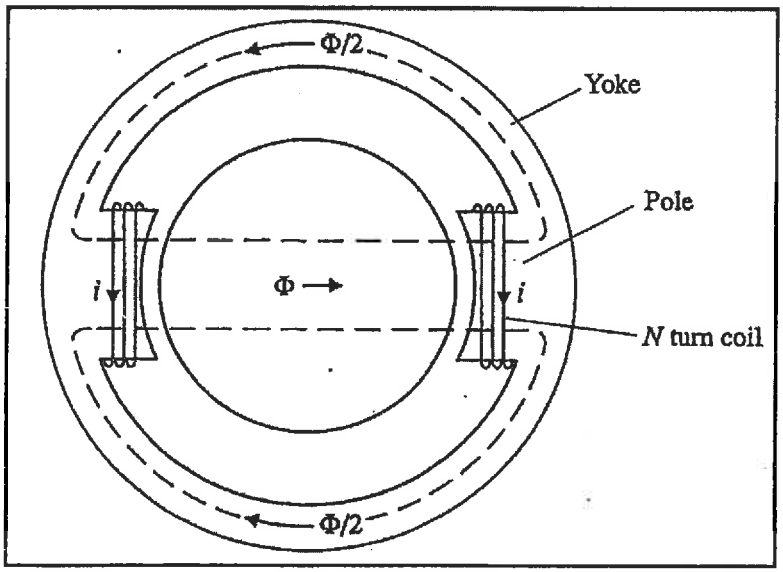

Figure 1 (a)

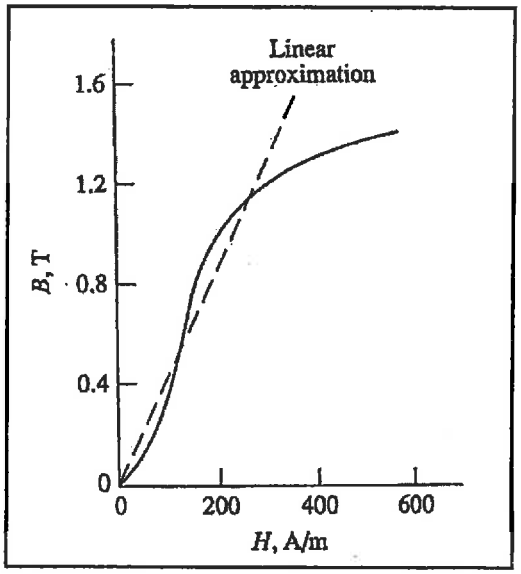

Figure 1 (b)

Question 6

a. Figure 2 below represents a small factory supplied by a balanced 60 Hz, 600 V, 3ϕ source. Determine the magnitude of the line currents, and the wattmeter readings, W1 and W2, for the system as shown.

b. If we want to bring the power factor up to 0.9 lagging, how many kVARs of capacitive reactance (connected in Y) are needed?

c. With the capacitors installed, what is the magnitude of the line current and what are the wattmeter readings?

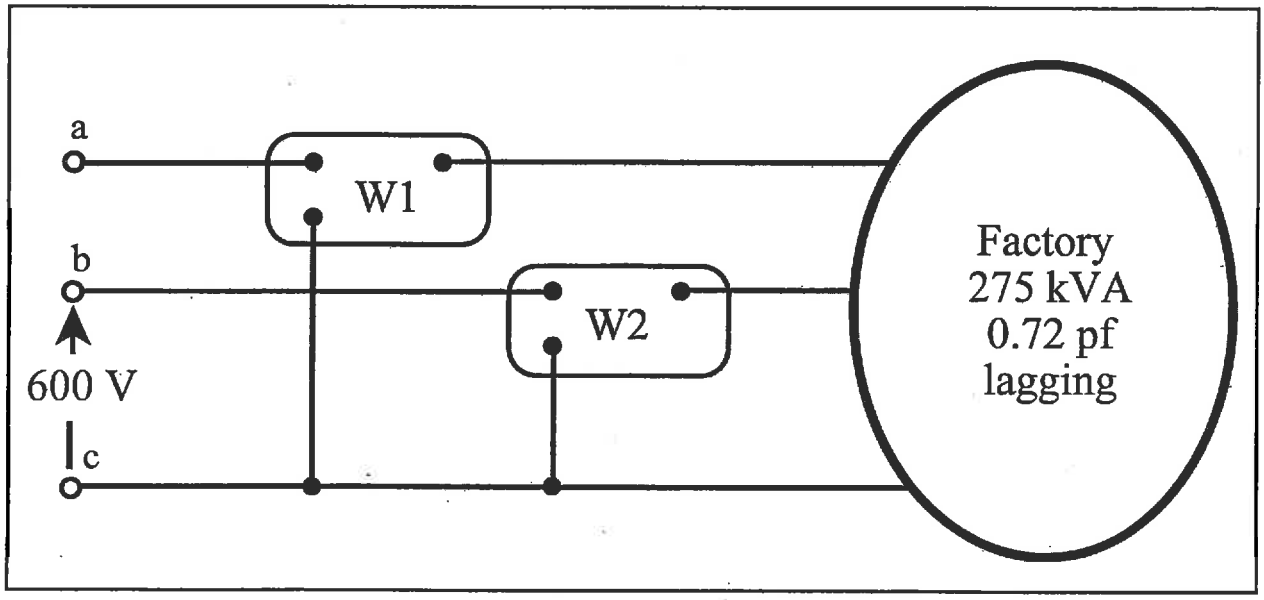

Figure 2