Professional Engineers Ontario

Power Systems and Machines Exam

07-Elec-A6

DECEMBER 2008

Notes:

1. Attempt question 1 and FOUR (4) other questions (FIVE (5) questions in all). Unless you *clearly* indicate otherwise, the first five questions will be the only ones marked. All questions are of equal value.

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

3. This is a closed book exam. Candidates may bring in ONE aid sheet, 8.5" x 11" and hand-written on both sides, containing notes and formulae (no figures). Example problems and solutions are not allowed!
   Aid sheet must be submitted with the written exam paper.

4. Marks will be lost if answers do not include appropriate units.

5. All a.c. 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 may use pencil.

7. Parts of questions may or may not be related - read carefully!

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. Why is the iron core of a transformer laminated?

b. How can the direction of a three-phase induction motor be reversed?

c. Many DC shunt motors will automatically be switched off if the field is lost. Why is that?

d. What two methods can be used to reverse the direction of a DC shunt motor?

e. Give two reasons why a three-phase power system is preferable to three single-phase systems for delivering the same amount of power.

f. Describe two methods of varying the speed of three-phase induction motors.

g. Explain why induction motors have low power factor when lightly loaded.

h. A three-phase, 230 V, 60 Hz, 30 hp, Y-connected, six-pole squirrel cage induction motor operates with a shaft load that requires 21.3 kW to cross the air gap to the rotor. Rotor copper loss is 1.05 kW, and rotational losses are 300 kW. Determine:

i. the shaft speed;
ii. the mechanical power developed;
iii. the torque developed; and,
iv. the shaft (output) torque.

Question 2 - Synchronous Machines

A 9375 kVA, 13.8 kV, 60 Hz, two-pole, Y-connected, three-phase synchronous generator has a synchronous reactance of 1.8 Ω per phase and negligible armature resistance. Assume that the induced voltage is related to the field current by $E_f = 25I_f$, i.e., E_f is directly proportional to the DC field current.

a. Determine the field current required to establish:
(i) rated voltage across the terminals at no load; and,
(ii) rated voltage across the terminals when rated armature current is delivered at 0.8 power factor laggin.

b. Without changing the prime mover output, the field excitation of the generator is decreased by 20%. Calculate:
(i) the new power angle;
(ii) the new stator current; and,
(iii) the power factor.

c. Draw neatly labelled phasor diagrams for the operating conditions of parts (a) and (b).

Question 3 - DC Machines

A 240 V, DC machine has an armature circuit resistance of 0.4 Ω, and a shunt field circuit resistance of 150 Ω. The machine is operated as a shunt motor, and runs at 1600 rpm while drawing a line current of 36.6 A from a 240 V DC supply. A separate no-load test determined that rotational losses were 600 W.

a. Determine:
   (i) the output power of the motor in hp;
   (ii) the output torque in N-m; and,
   (iii) the motor efficiency.

b. If an external resistance of 0.6 Ω is inserted in series with the armature, determine (assuming the load torque remains unchanged):
   (i) the motor speed;
   (ii) the output power; and,
   (iii) the efficiency.

Question 4 - Induction Motors

The parameters for one phase of a three-phase, Y-connected, 8-pole, 220 V, 60 Hz, induction motor are:

St ator resistance is negligible

Stator reactance is 0.6 Ω

Magnetizing reactance is 23 Ω

Rotor resistance, referred to the stator, is 0.15 Ω

Rotor reactance, referred to the statro, is 0.23 Ω

At normal voltage and frequency, the full load slip is 0.03. Draw the equivalent circuit for the machine, and find:

a. the output power if 3% of the mechanical power developed is dissipated in windage and frequency;
b. the rotor copper loss;
c. the output torque (in N-m); and,
d. the starting the starting current.

Question 5 - Magnetic Circuits

For the magnetic circuit shown below in Figure 1, the core material is 1% silicon iron, for which the magnetization curve is shown in Figure 2. The depth of all core members is a uniform 75 mm. The remaining dimensions are as follows: $\delta_1 = 3$ mm; $\delta_2 = 2$ mm; $w = 125$ mm; $h = 150$ mm; and, $l = 50$ mm. Coil 1 has 100 turns. If $\phi_2 = 1$ mWb, find the flux, ϕ_1, and the current, I_1.

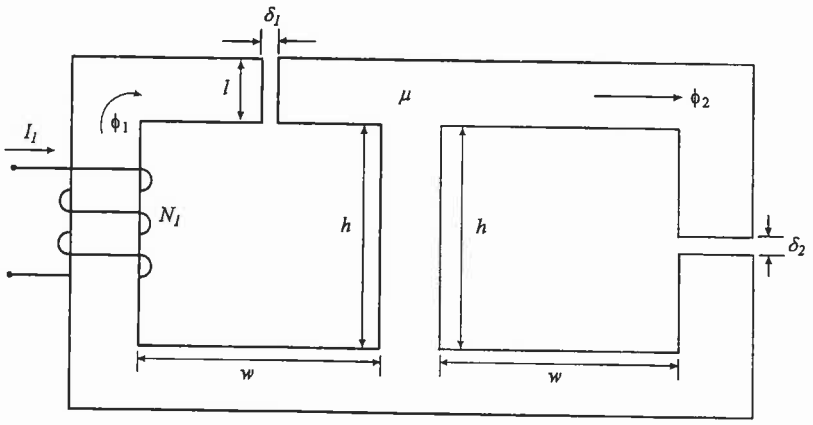

Figure 1

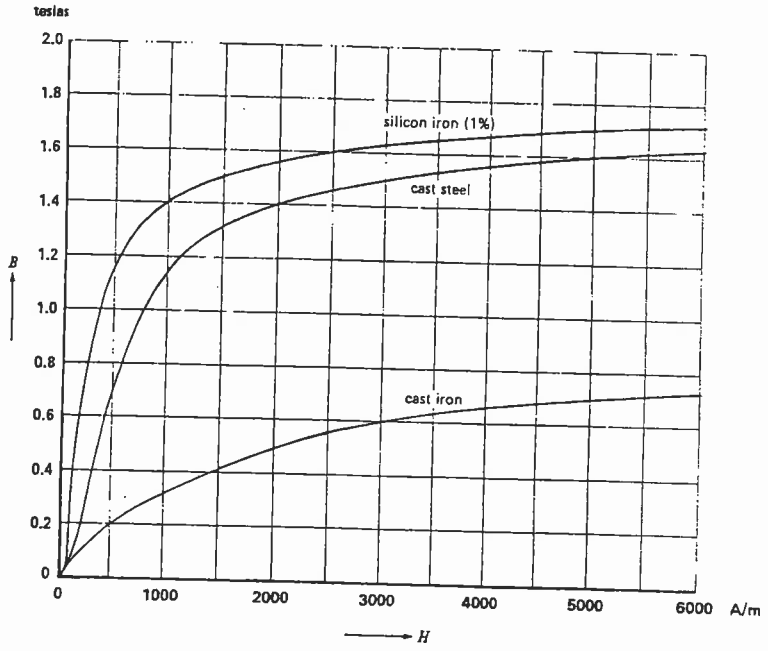

Figure 2

Question 6 - Transformers

A 100 kVA, 60 Hz, 7200/480 V, single-phase transformer has the following parameters:

$R_{HV} = 3.06\ \Omega$ $X_{HV} = 6.05\ \Omega$ $X_{m,HV} = 17{,}809\ \Omega$

$R_{LV} = 0.014\ \Omega$ $X_{LV} = 0.027\ \Omega$ $R_{c,HV} = 71{,}400\ \Omega$

The transformer load draws rated current at 480 V and 0.75 power factor lagging. Sketch the *approximate* equivalent circuit (indicating whether you are showing the HV or the LV side), and determine:

a. the transformer equivalent impedance, referred to the HV side;
b. the source voltage and regulation;
c. the transformer efficiency; and,
d. the output power to have maximum efficiency.

Question 7 - Three-phase circuits

An industrial plant is fed by a three-phase source of 460 V (line-to-line), 60 Hz. Its loads are:

1. a three-phase induction motor with nominal specifications of 50 kVA and a power factor of 0.86;
2. a synchronous motor having $X_S = 6.052\ \Omega$, that is operating at a pf of 0.62 leading; and,
3. three identical impedances, Z, connected in delta, where $\mathbf{Z} = 2 + j2\ \Omega$.

Determine:

a. the active and reactive power absorbed by the induction motor;
b. the induction motor line current;
c. the active and reactive power absorbed by the delta-connected load;
d. the active and reactive power of the synchronous motor if the plant is operating at unity pf;
e. the synchronous motor line current; and,
f. the excitation voltage of the synchronous motor.

END OF THE EXAM