Professional Engineers Ontario

Exam

07-Elec-A6 Power Systems and Machines

Fall 2011

Notes:

1. **FIVE (5)** questions constitute a complete exam paper. Unless you indicate otherwise, the first five questions as they appear in the answer book 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 ONE aid sheet 8.5" x 11" hand-written on both sides containing notes and formulae. Note, no example or solution problems, or figures, are allowed. The aid sheet must be submitted with the exam paper.

4. 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.

5. 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 12 kVA, 600/300 V, 60 Hz, single-phase transformer gave the following test results:

Open Circuit Test (HV side open):
Test Voltage = $(300 + j0)$ V
Test Current = $(0.6 - j0.8)$A

Short circuit Test (LV side shorted):
Test Voltage = $(40 + j0)$ V
Test Current = $(12.0 - j16.0)$A

Calculate:

a. the core loss at rated voltage;
b. the full load copper loss,
c. the approximate equivalent circuit parameters,
    i. referred to the HV side; and,
    ii. in per unit;
d. the load at which maximum efficiency occurs and the value of that efficiency; and
e. the voltage regulation when the load is 6 kVA, at unity power factor and at 300V.

Question 2

When operated at rated voltage and frequency with its rotor windings short circuited, a 500 hp wound rotor induction motor develops its rated full load output at a slip of 1.5 percent. The maximum torque this motor can develop is 200 percent of the full load torque. Neglecting stator leakage impedance and rotational losses (including core losses), calculate the following:

a. the rotor I^2R losses at full load, in kW;
b. the slip at maximum torque;
c. the rotor current at maximum torque as a per unit of the current at full load;
d. the torque at a slip of 20 percent in per unit; and,
e. the rotor current at a slip of 20 percent in per unit.

Question 3

A 600V, 100kVA, 6-pole, 60 Hz, Y-connected synchronous motor has a saturated synchronous reactance at rated voltage of 4.5 Ω per phase and negligible armature resistance. The motor runs at no load when connected to rated supply drawing a current of 12.0 A at a power factor of 0.05 leading. Calculate:

a. the excitation emf and the power angle of the motor; and,
b. the rotational losses of the motor.

If the mechanical load on the motor is increased, keeping the excitation constant until the power factor is unity, calculate:

c. the new power angle; and,
d. the new line current and power input.

Question 4

A 400 kW, 600V, DC series motor has an armature resistance of 0.04 Ω and a series field resistance of 0.06 Ω. When driving a load, the motor draws a current of 400 A from a 600 V source and runs at 1000 rpm. Neglecting rotational losses, calculate:

a. the power output; and,
b. the torque developed.

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 120V, 4-pole, 60Hz, 300 W, split phase fan motor gave the following test results:

No Load Test: V =120 V, I = 4.0 A, W = 110 W

Standstill Test: V = 40 V, I =5.0 A, W= 120 W

Main Winding Resistance = 2.4 Ω

Question 5 (continued)

a. Derive an equivalent circuit based on the double revolving field theory for the motor for running conditions.

b. Use the equivalent circuit to calculate the performance of the motor for a slip of 0.05. In particular, find:
   i. the current and power factor; and,
   ii. the power output and efficiency assuming the same rotational loss as during the no load test.

Question 6

a. The figure below represents a small factory supplied by a balanced 60 Hz, 600 V, 3ϕ source. Determine the wattmeter readings, W1 and W2, for the system as shown. What is the power factor?

b. If the induction motor is replaced by a synchronous motor that can operate at 0.8 pf leading while supplying the same power as the induction motor, determine the new wattmeter readings. What is the new power factor?

c. With the synchronous motor in place, it is determined that the power factor is below 0.9, and the factory will be penalized. How many kVARs of capacitor are needed to improve the power factor to 0.9?