ELECTRIC MACHINERY

ECSE 461 - 001

APRIL 19, 2010 – 9:00 AM

Examiner: Joos, Geza

Assoc Examiner: Galiana, Francisco

Student Name:		McGill ID:									

INSTRUCTIONS:

- Attempt 6 out of the 7 questions.
- All 6 questions answered carry equal weight.
- This is an OPEN BOOK examination.
- CRIB SHEETS, NOTES and ASSIGNMENTS are permitted.
- STANDARD CALCULATOR permitted ONLY.
- This examination consists of 7 questions, of a total of 3 pages, including the cover page.
- This examination is PRINTED ON BOTH SIDES of the paper
- This examination paper MUST BE RETURNED

McGill
Department of Electrical and Computer Engineering

ECSE 461 – Electric Machinery

Winter 2010

Final Examination

Note: Any reasonable assumption can be made, provided adequate justification is given.

1. Three single phase loads, each rated 21 kW, 0.78 pf (lagging), 550 V, 60 Hz, are connected to a three-phase 460 V, 60 Hz supply.
   a) Indicate the load connection that gives the power consumption closest in value to rated. Compute, for each load, the voltage, current and power. Compute the line current and total power and reactive power.
   d) The three loads are connected in a Y configuration on the 460 V supply. Find the power consumed by each load. Compute the line current, total power and reactive power. Indicate the % change in power compared to Q(a).

2. A 60 kVA, three-phase, 4 pole, 460 V, 60 Hz, 0.85 pf, Y-connected synchronous generator has a synchronous reactance of 4.15 Ω per phase. All losses are neglected.
   a) The generator operates in stand-alone mode and supplies a 50 kW, 0.85 pf (lag) load. The terminal voltage is regulated at 460 V. Compute the generated voltage. Draw the V-I diagram. Draw the power/load angle (δ) curve, indicate the operating point and compute the maximum power. Compute the reactive power supplied by the generator.
   b) The generator excitation current is kept constant. The load power is reduced to 25 kW, the pf remains at 0.85 (lag). Find the terminal voltage and the voltage regulation. Draw the V-I diagram for operating conditions in Q(a) and Q(b).

3. A 10 kVA, 2400/347 V, 60 Hz, single phase transformer has the following equivalent circuit parameters in ohms referred to the respective winding: primary: 5.16 (resistive), 4.3 (inductive); secondary: 0.095 (resistive), 0.09 (inductive). The magnetizing branch, referred to the primary, has parameters of 51 k (resistive), 29 k (inductive).
   (a) A 5 kW, 0.5 pf load is connected to the secondary. Assuming rated voltage on the secondary, compute the current and voltage on the primary side. Compute the voltage regulation. Neglect the excitation branch.
   (b) Compute the transformer efficiency for the load in Q(a). Include all losses. Compute the excitation current drawn from the supply, and the total input current. Compute the reactive power consumed by the transformer, and indicate the % with respect to the total power drawn from the supply.

4. A 50 Hz, 750 kVA, three-phase, 2 pole, 2300 V, synchronous motor has a synchronous reactance of 7.75 Ω per phase. All losses are neglected.
   a) The motor draws 600 kW at unity pf, for rated voltage. Compute the generated voltage. Draw the V-I diagram and the power/load angle curve. Compute the maximum power.
   b) The motor drives the same load as in Q(a), and supplies 450 kVAr of reactive current (leading current). Compute the generated voltage and the change in excitation compared to Q(a). Draw the power/load angle curve for operating conditions in Q(a) and Q(b) on the same curve, indicating the maximum power.

5. An 8 pole, 4160 V, 1000 kW, 60 Hz three-phase squirrel cage induction motor has the following parameters, in Ω/phase:

   $R_1 = 0.220$ $X_1 = 1.95$ $X_m = 45.7$

   $R_2 = 0.207$ $X_2 = 2.42$

   Mechanical losses are neglected.

   a) For rated voltage and a 3 % slip, compute the shaft power and torque. Compute the input current and power factor. Draw the approximate torque/speed curve, indicating the synchronous speed. Estimate the slip at rated power.

   b) Find the starting torque and current. Indicate these values as a % of rated values. Recalculate the starting torque for a voltage reduced to 65 % of rated value.

6. An 4 pole, 500 kW, 2400 V, 60 Hz three-phase squirrel cage induction motor, operating as a wind turbine generator, has the following parameters, in Ω/phase referred to the stator:

   $R_1 = 0.122$ $X_1 = 1.364$ $X_m = 45.8$

   $R_2 = 0.317$ $X_2 = 1.32$

   Mechanical losses are assumed constant and equal to 3 % of rated power.

   a) The machine is connected to the 2400 V electric grid and operates at a -3.2 % slip (negative). Compute the speed, the developed power and torque. Compute the input current. Compute the real and reactive power drawn or injected into the grid.

   b) The wind turbine torque is reduced to 0, the generator remains connected to the grid. Find the real and reactive power drawn from the grid, assuming losses are supplied by the grid. Indicate the approximate machine speed. Draw the approximate torque/speed curve, indicating the operating points in Q(a) and Q(b).

7. For a 50 kW separately excited dc motor the following parameters are provided: 1740 rpm (full load, rated field current), 3450 rpm max, 600 V (armature), 92 A (full load), 1390 W field power, 0.412 Ω armature resistance. The rotational losses are equal to 1302 W at 1740 rpm.

   a) For rated armature voltage and current, and rated field current, find the internal voltage, developed power, shaft power, shaft torque. Compute the efficiency, including all losses. Find the no-load speed and speed regulation. Find the motor back emf constant for rated field current.

   b) The field current reduced to 60 % of rated value. For rated armature voltage and current, find the developed power and shaft torque. Find the no-load speed and speed regulation. Draw the approximate torque-speed curves for conditions in Q(a) and Q(b) on the same plot, indicating all know values.