S. KARAKI AMERICAN UNIVERSITY OF BEIRUT FALL 2007/ 2008

FACULTY OF ENGINEERING AND ARCHITECTURE

FINAL EXAM

ELECTRIC MACHINES AND POWER SYSTEMS FUNDAMENTALS (EECE 370)

CLOSED BOOK (2.5 HOURS) January 30, 2008

PROGRAMMABLE CALCULATORS ARE NOT ALLOWED.

THIS QUESTION SHEET MUST BE RETURNED WITH THE ANSWER BOOKLET.

NAME: _____ **ID#:** _____

1. A 20 kVA, 11000/380 V, 3-phase, Y-Y connected **distribution transformer** has an impedance referred to the primary of 100 + *j*500Ω. The components of excitation branch referred to the primary side are R_c = 490 kΩ and X_m = 100 kΩ. The transformer is supplying a load having an impedance of 8 + *j*4 Ω.

   a) Given a VA base S_B= 10000 VA and a base voltage on the primary side V_{B1} = 11000 V, determine the secondary base voltage, the base currents and base impedances on both sides of the transformer. Determine the transformer and load impedances in per unit. Draw the per unit equivalent circuit and label it with symbols and values.

   b) If the primary voltage is 1.04 per unit, what is the transformer input current and the active and reactive power supplied at the transformer primary in per unit and in real quantities? What is the secondary voltage of the transformer in per unit and in volts?

   c) Repeat Part b with a capacitor of –*j*5Ω connected across the load (i.e. in parallel with the load impedance). Compare these results with those of Part b and explain the differences observed in the results.

2. A **synchronous generator** is rated at 500 kVA, 380V, 50 Hz, 0.85 PF lagging, is Y-connected, and has two poles. Its armature resistance R_A and synchronous reactance X_S are 0.04 and 1.2 per unit on machine rating, respectively. Its friction and windage losses are 6 kW, its core losses are 7 kW, and it has miscellaneous losses equal to 1 kW. Its open-circuit characteristic is shown in Figure 1.

   a) If the generator is supplying power at rated conditions, what are the active and reactive power supplied by the generator, its internal voltage and the required field current?

   b) If the load drops by 25% but keeps the same power factor, what would be the terminal voltage of the generator with the field current kept at the value obtained in Part a?

   c) If the governor droop (ω versus P) characteristic has a slope of -5%, what would be the prime-mover torque required in Parts a, and b above?

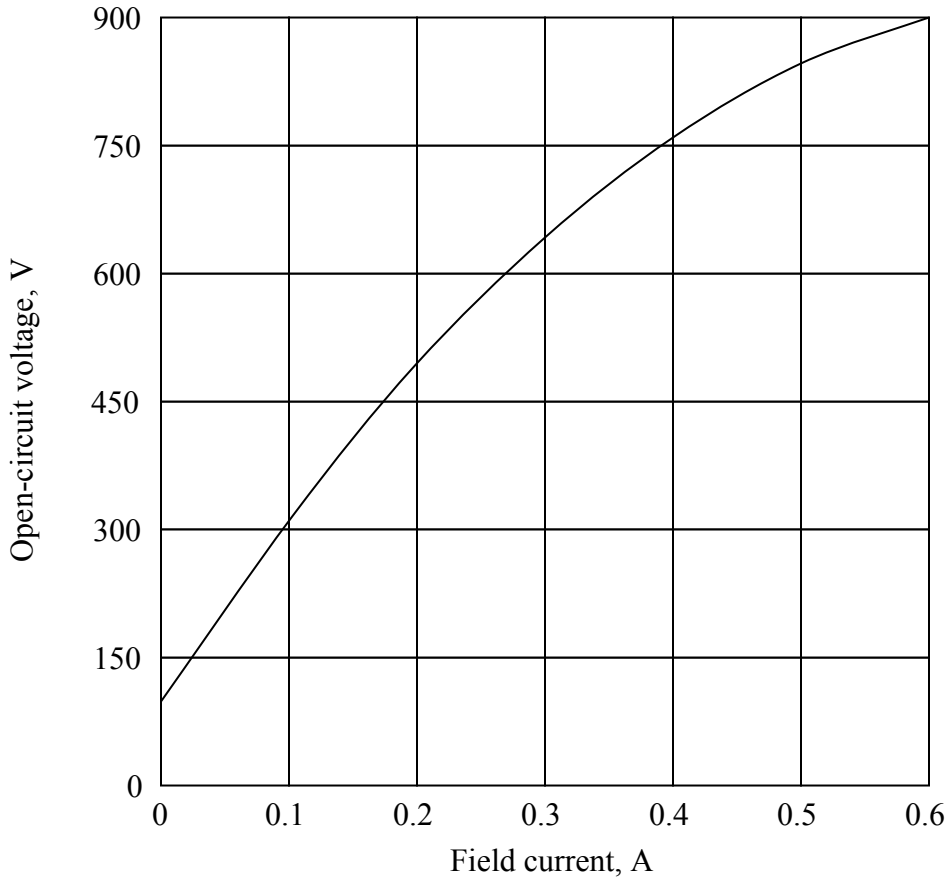

Figure 1: Open-Circuit characteristic for the generator in Problem 2

3. A 380V, 50Hz, 4-pole, and Y-connected **induction motor** (IM) has rated output power of 50 hp (1hp = 0.746kW) and a class B design. It has been tested in the Lab with the following results:

   No load: 380V, 8.6A, 2148W, 50Hz.
   Locked rotor: 98.7V, 70A, 5586W, 50Hz
   DC test: 36.4V, 70A

   a) Calculate the equivalent circuit parameters of this induction motor R_1, X_1, R_2, X_2 and X_m and the no-load rotational losses P_{rot}. Draw the IM equivalent circuit and label it with symbols and values.

   b) When the induction motor is delivering full load power, calculate its slip, rated current, and the active and reactive power taken from the supply.

   c) Calculate the starting current and starting torque of the motor.

4. The equivalent circuit of a **shunt dc motor** is shown in Figure 2 below. The motor is rated at 20 hp, 220V, 1200r/min and has an armature resistance R_A = 0.4Ω. Its field circuit has a field resistance R_F = 50 Ω and R_J can be adjusted from 0 to 75 Ω. The mechanical and core losses are 1000W. The supply voltage of the machine V_T = 220V. Assume the magnetization curve of the motor to be nearly linear.

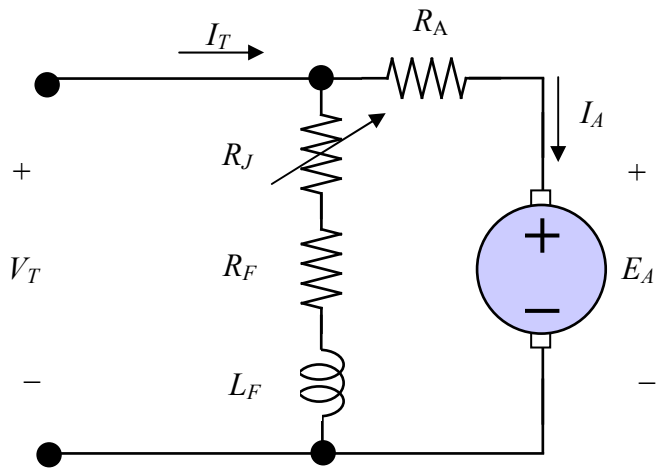

Figure 2: Equivalent circuit of dc shunt motor

a) The value of R_J is set at 50 Ω and the no-load speed of the machine is measured to be 1200 r/min. When the machine is loaded, what is its speed if the input current I_T is measured to be 50A.

b) For the conditions in Part a, what is the power delivered by the motor to the load and what is the corresponding torque? What is the machine efficiency?

c) If the load has a constant torque characteristic and R_J is set at 25 Ω, what are the new armature current I_A, the back emf E_A, and machine speed n?

5. Answer briefly the following **questions**:

a) Compare Class A and Class B induction motors for starting current and torque, pullout torque, slip. Which is the preferred design and why?

b) Sketch the phasor diagrams of a synchronous generator operating at lagging power factor and then at a leading power factor? Draw the diagrams assuming the generator the providing the same active power at the same terminal voltage magnitude. Comment on the differences.

c) Sketch the set up for the locked rotor and the no-load tests of an induction motor and describe what information is obtained from each. Also sketch the diagram for a dc resistance test of a Y-connected induction motor. What information is obtained from the test and why is the test carried out using dc and not ac?