

**University of Saskatchewan**  
**Department of Electrical Engineering**  
**EE 444.3 Electric Machines II (Term 1)**  
**Final Examination (Total Duration: 3 hrs)**

**Dated: Dec. 9, 2004**  
**Instructor: Dr. Rama Gokaraju**

**Time: 9:00 am – 12:00 pm**  
**Total Marks: 50**

**Instructions:**

- 1) This examination paper consists of 7 problems and 4 pages in total.
- 2) This is a closed-book examination. Two-page formula sheet is allowed. Solved examples in the formula sheet are not allowed.
- 3) Your solutions should be methodical (write the steps of numerical computations clearly). You would be severely penalized if your solutions are illegible.
- 4) Mark allotted for each problem is shown on the right margin.

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✓ **Problem 1**

The following data are taken from the open and short-circuit characteristics of a 45-kVA, three-phase, Y-connected, 220 V (line-to-line), six pole, 60 Hz synchronous machine. From the open-circuit characteristic

Line-to-line voltage = 220 V

Field Current = 2.84 A

From the short-circuit characteristic

Armature current, A	118	152
Field current, A	2.20	2.84

From the air-gap line

Field current = 2.20 A

Line-to-line voltage = 202 V

Compute the unsaturated value of the synchronous reactance, its saturated value at rated voltage, and the short-circuit ratio. Express the synchronous reactance in ohms per phase.

**8 Marks**

**Problem 2**

A 2000-hp, unity power factor, three-phase Y-connected, 2300 V, 30-pole, 60 Hz synchronous motor has a synchronous reactance of 1.95 Ω/phase. For this problem all losses may be neglected.

- ✓ a) Compute the maximum torque which this motor can deliver if it is supplied with power from a constant-frequency, constant-voltage, three-phase source, commonly called an infinite bus (in this case 2300 V line-line), and if its field excitation is constant at the value which would result in unity power factor at rated load.
- \* b) Instead of the infinite-bus of part (a), suppose that the motor is supplied with power from a three-phase Y-connected 2300 V, 1750 kVA, 2-pole, 3600 rpm turbine generator whose synchronous reactance is 2.65 Ω/phase. The generator is driven at rated speed, and the field excitations of generator and motor are adjusted so that the motor runs at unity power factor and rated terminal voltage at full load. The field excitations of both machines are then held constant, and the mechanical load on the synchronous motor is gradually increased. Compute the maximum motor torque under these conditions and the terminal voltage when the motor is delivering its maximum torque.

8 Marks

**Problem 3**

The per-phase equivalent circuit shown in Figure 1 of a three-phase, 600 V, 60 Hz, four-pole, Y-connected wound-rotor induction motor has the following parameters:  $R_1 = 0.75 \Omega$ ;  $R_2' = 0.80 \Omega$ ;  $X_{11} = X_{22}' = 2.0 \Omega$ ,  $X_M = 50 \Omega$ . Neglect the core losses.

- a) Find the slip at which the maximum developed torque occurs.
- b) Calculate the value of the maximum torque developed.
- \* c) Determine the starting torque.
- d) What is the range of speed for stable operation of the motor.
- \* e) Compute the per-phase referred value of the additional resistance that must be inserted in the rotor circuit in order to obtain the maximum torque at starting.

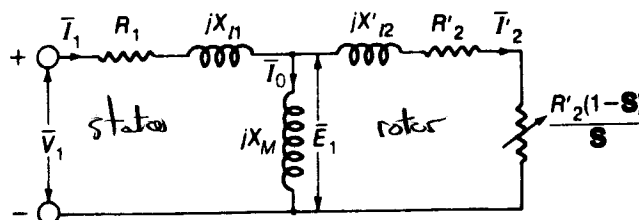


Figure 1

8 Marks

**Problem 4**

A 3-phase squirrel cage induction motor has maximum torque equal to twice the full-load torque. Determine the ratio of motor starting torque to its full-load torque, if it is started by

- a) Direct-on-line starter
- b) Y- $\Delta$  starter
- c) Auto-transformer starter with 70% tapping

The per phase rotor resistance and per phase standstill reactance referred to stator are  $0.2 \Omega$  and  $2 \Omega$  respectively. Neglect stator impedance.

**8 Marks**

**Problem 5**

A single-phase,  $110 V$ ,  $60 Hz$ , 4-pole induction motor has the following constants in the equivalent circuit, Figure 2:  $R_1 = R_2' = 2 \Omega$ ,  $X_1 = X_2' = 2 \Omega$ ,  $X_m = 50 \Omega$ . There is a core loss of  $25 W$  and a friction and windage loss of  $10 W$ . What is the relative amplitude of the resultant forward-rotating flux to the resultant backward-rotating flux at 5% slip?

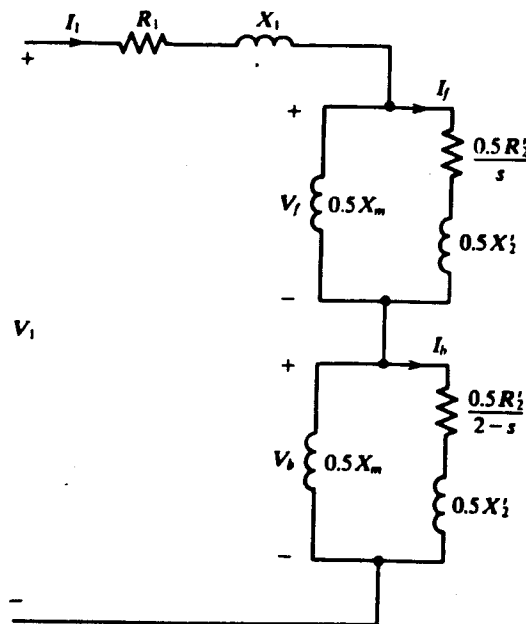


Figure 2

**6 Marks**

**Problem 6**

A 220 V, 1.5 hp, 50 Hz, six-pole, capacitor-start induction motor has the following main-winding impedances:

$$R_1 = 1.30 \, \Omega \quad X_1 = 2.01 \, \Omega \quad X_M = 105 \, \Omega$$
$$R_2' = 1.73 \, \Omega \quad X_2' = 2.01 \, \Omega$$

At a slip of 0.05, the motor's rotational losses are 291 W. The rotational losses may be assumed constant over the normal operating range of the motor. Find the following quantities for this motor at 5% slip:

(a) Stator current (b) Stator  $pf$  (c) Input power (d)  $P_g$  (e)  $P_{conv}$  (f)  $P_{out}$  (g)  $T_{ind}$  (h)  $T_{load}$  (i) Efficiency.

**8 Marks****Problem 7**

For a particular application, a three-phase stepper motor must be capable of stepping in  $10^\circ$  increments. How many poles must it have? How many pulses per second must be supplied to the control unit of the motor to achieve a rotational speed of 600 rpm.

**4 Marks**

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