Massachusetts Institute of Technology Department of Electrical Engineering and Computer Science

6.061/6.690 Introduction to Power Systems

Quiz 2

Closed Book: Two Handwritten Crib Sheets Allowed

Please put your answers in the spaces provided on the quiz. You may, if you wish, turn in your work on additional sheets of paper. Hopefully you will get all the answers correct so I don't have to look at those sheets.

- **Problem 1** A Permanent Magnet DC machine (remember: this is just like a separately excited machine with fixed field excitation) has a measured armature resistance of 1Ω . When the rotor is locked so it can't rotate and the machine is driven by a current of 1 Ampere, the motor produces a torque of 1 N-m.
 - 1. If the machine is connected to a terminal voltage of 100 Volts DC, with mechanical loading of zero, how fast does it turn?

2. If the shaft is loaded with a torque of 5 N-m, what terminal voltage is required to make the motor turn at a speed of 100 Radians/Second?

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Figure 1: Lift Magnet

Problem 2 A lift magnet is shown in Figure 1.

The magnet has two poles, each 10 cm X 10 cm. It has a coil of 100 turns and is fed by a DC current source of I = 16A.

For the purpose of this problem, assume $\frac{1}{\mu_0} = 800,000$ m/H. The core of the lift magnet and the body it is lifting can be assumed to have infinite permeability.

1. If the gap g = 1mm, what is the total lifting force?

2. Assume the material saturates abruptly at a flux density of 2 T. What is the maximum lift force and at what gap does it occur?

Problem 3 An elementary single phase equivalent circuit for a three-phase induction motor is shown in Figure 2



Figure 2: Equivalent Circuit

Terminal voltage is 200 Volts, RMS, per phase. The reactances are $X_1 = 2.5\Omega$, $X_2 = 2.0\Omega$, $X_m = 10\Omega$ and the rotor resistance is $R_2 = 1\Omega$. This is a kind of odd machine that has an electrical frequency $\omega = 200$ Radians/second, or about 31.8 Hz. This is a four pole (p = 2) motor.

1. At what rotational speed does the motor achieve maximum (breakdown) torque? (Give this in radians/second.)

2. What IS that maximum torque?

Problem 4 This is about a synchronous generator meant for a power system with an electrical frequency of 400 Radians/second (or just about 63.7 Hz). It is a four pole machine, so its rotational speed is 200 Radians/second. This is a three-phase machine.

The machine is tested at its rated speed and, with a field current of 1000 Amperes, open circuit terminal voltage is measured to be 10,000 Volts, *Peak* in each phase.

With the terminals short circuited and operated at rated speed with a field current of 1000 Amperes, phase current is measured to be 1000 Amperes, *Peak*.

- 1. The machine is operated with a balanced three-phase current source that puts 1000 Amperes *Peak* in each phase winding. With 1000 Ampers DC in the field winding, what is the maximum torque the machine can produce?
- 2. Now the machine is operated with a balanced three-phase voltage source that puts 10,000 Volts *Peak* across each phase winding. What is the maximum torque the machine can produce if the field current is 1,000 A?
- 3. Now, operating as a generator with 10 kV terminal voltage across each phase winding and a current of 1,000 A *both Peak values*, and at unity power factor:
 - Draw a phasor diagram for this operation, showing internal voltage (E_{af}) , terminal voltage and voltage across machine reactance.

- What is the torque angle δ ?
- What is the field current?

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