ECE 3600 Exam 2 given: Fall 13   (The space between problems has been removed.)

Name _____   ECE 3600   Exam #2   Fall 2013

Write Legibly!   This part of the exam is Closed book, Closed notes, No Calculator.

(22 pts) Questions   If I can't read what you've written or you answer is ambiguous, I'll assume you don't know.

1. To Bring a Synchronous Generator "On Line" you must do several things. Name at least 3. Be as specific as you can.

2. A 3-phase synchronous-machine is used as a generator.

   a) As a power plant operator, how do you generate more real power?

   b) Consider a 3-phase synchronous-machine phasor diagram. To increase the reactive power output (+VARs), what is the primary thing that should change? (All other changes in the phasor diagram will follow from this change.) Say what should change and whether it should increase or decrease.

   c) As a power plant operator, how do you make that happen?

3. The power angle of a synchronous generator is limited to what range of values?

4. a) A 3600-rpm, 3ϕ motor is rated for a Δ connection to a 480-V, 60-Hz bus. If this motor is to be operated from a 480-V, 50-Hz power system, what speed would you expect it to run?

   b) Is it safe to operate this motor from 480-V, 50-Hz without any other modifications? If no, say why.

   c) If the answer to b) is no, is there still a safe way to operate this motor from a 480-V, 50-Hz bus with modification(s)? If yes, tell what the modification is.

5. An induction motor is operated with a variable-frequency drive.
   a.1) How is the motor operated at slower-than-normal speeds?

   a.2) Is there something else which must also be reduced? If yes, what and why?

   b) How is the motor operated at higher-than-normal speeds?

The following problems were handed out to the student after finishing the closed-book part.

This part of the exam is open book, open notes. You <u>MUST</u> show work to get credit.   Show the correct units

1. (30 pts) You make the following measurements on a 3-phase, Y-connected, synchronous generator.

$$P_{3\phi} := 120 \cdot kW \qquad V_{LL} := 1247 \cdot V \qquad I_L := 65 \cdot A \qquad \delta := 15 \cdot deg$$

Unfortunately, you don't know the phase angle of current.

   a) Draw a phasor diagram of one of the two possible interpretations of these numbers. Find the induced armature voltage (E_A) and the synchronous reactance, power angle, (X_S).

$$E_A = ? \qquad X_s = ?$$

Hint:
$$\frac{Q_{1\phi}}{P_{1\phi}} = \frac{\left(\dfrac{V_\phi \cdot E_A \cdot \cos(\delta) - V_\phi^2}{X_s}\right)}{\left(\dfrac{V_\phi \cdot E_A \cdot \sin(\delta)}{X_s}\right)} = \text{simplify}$$

b) Draw a phasor diagram of other possible interpretation of these numbers.
   Find the induced armature voltage (E_A) and the synchronous reactance, power angle, (X_S).

$$E_A = ?$$
$$X_S = ?$$

c) This generator supplies supplementary power to a small residential community. These homes use very little
   reactive power, but all the distribution in this community is underground. When the generator is connected to
   the community's power distribution network, it supplies half of the required power, but the current from the power
   company only decreases by about 30%. Which of the calculations above is most likely correct?
   Give me the reasoning behind your answer (no calculations required).

d) What do you change at the generator to reduce the current flow from the power company?
   Tell me what you adjust and if you turn it up or down.

2. (30 pts) A 3-phase, Δ-connected, induction motor has the following equivalent circuit components:

$$R_1 := 0.2 \cdot \Omega \qquad R_2 := 0.5 \cdot \Omega \qquad R_C := \infty \qquad \text{currently}$$
$$X_1 := 0.4 \cdot \Omega \qquad X_2 := 0.6 \cdot \Omega \qquad X_M := 15 \cdot \Omega \qquad \text{running at} \quad n := 1710 \cdot \text{rpm}$$

   DON'T FORGET: Your powers are for the whole motor and your model is only for ONE phase.

   a) Draw the circuit model of one phase, and label the known parts and values.

   b) Find the slip. Make a reasonable assumption as necessary.

   c) The output shaft torque is $\tau_{load} := 60 \cdot \text{N} \cdot \text{m}$ Find the output power.

   d) The mechanical power losses (all lumped together) is $P_{mech\_loss} := 400 \cdot \text{W}$ Find P_{conv}

   e) Find $|I_2|$

   f) Find the line current. Note: Don't try any shortcuts here. You need to do your math with full
      $$|I_L| = ?$$ complex numbers. I advise you to assume the phase angle of I_2 is 0º.

   g) Find P_{RCL}

   h) The stator copper losses P_{SCL}

   i) The overall machine efficiency η

3. (18 pts) A 1/3-hp, 120-V single-phase induction motor has two identical windings set 90° apart in the motor housing. Each winding draws 5 A at 20° lag when the rotor is locked and 2 A at 40° lag when the motor is running at its rated speed. This is with no added capacitors, so the motor would have to be started by hand.
   a) Find the ideal capacitor to place in series with one of the windings at startup.
      Note: the ideal capacitor would create the ideal phase difference between the winding currents.

   b) The ideal capacitor to place in series with one of the windings at rated speed is $22.5\,\mu F$.
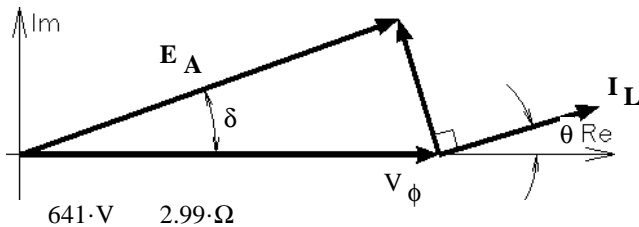   Find a compromise capacitor to place in series with one of the windings. Choose this capacitor
      to make the magnitudes of the currents in the two windings exactly the same at rated speed.

Answers   Closed-book part

1. 1. Bring speed to the correct rpm so that the generator frequency matches the line frequency.
   2. Adjust the field current, I_f so that the generator voltage matches the line voltage.
   3. Readjust speed if necessary, check that the phases are in the correct sequence if necessary.
   4. Wait until the phases align (0 volts difference between generator terminal and the line phase).
      Connect to the line at just the right moment.
   5. Increase input torque to produce real electrical power and and field current to produce reactive power.
   at least 3 of these

2. a) Increase the mechanical input power   b) Increase E_A c) Increase the field or rotor current   3. $0° < \delta < 90°$

4. a) $\dfrac{5}{6}\cdot 3600\cdot rpm = 3000\cdot rpm$ b) NO, The core will saturate.   Saturating the core would result in large currents.

   c) Y-connected $\dfrac{5}{6} = 0.833$ > $\dfrac{1}{\sqrt{3}} = 0.577$

5. a.1) The frequency is less than 60Hz.   a.2) The voltage must be reduced to prevent saturation of the core.

   b)   The frequency is greater than 60Hz.

Open-book part

1. a) My first assumption: b) My second assumption:

   641·V   2.99·Ω   890.2·V   4.15·Ω
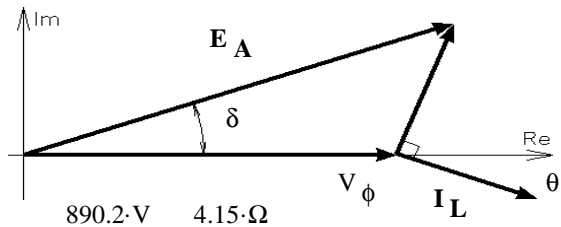
c) b) I_L lags V_ϕ

   Underground distribution creates a leading pf load, they are capacitive and use negative VARs. If the
   local generator were supplying those negative VARs, then the current would go down by about half and
   quite possibly more. The small reduction in current implies that the generator also consumes negative
   VARs (creates positive VARs). That is condition b).

d) Turn down the field current.

2. a)
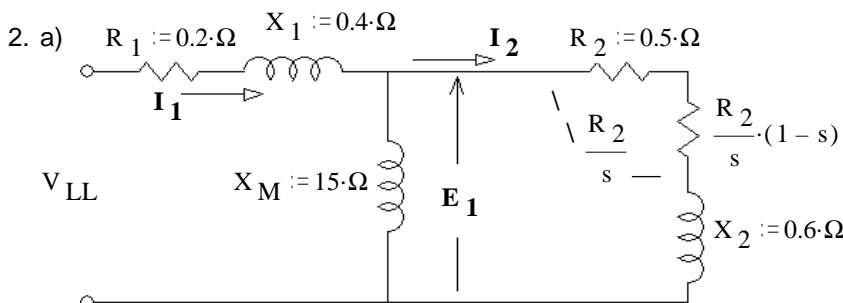
b) 0.05   c) 10.74·kW   d) 11.14·kW

e) 19.77·A   f) 42.31·A   g) 586.5·W

h) 358·W   i) 88.9·%

3. a) 37.8·µF   b) 34.4·µF