ECE 3600 Exam 2 given: Fall 14

(The space between problems has been removed.)

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

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

1. a) A 3-phase step-up transformer is usually wired in what way? Y - Y Y - Δ Δ - Y Δ - Δ circle one

   b) A 3-phase step-down transformer is usually wired in what way? Y - Y Y - Δ Δ - Y Δ - Δ circle one

   c) Is it desirable for at least one side of a 3-phase transformer to be wired in a certain way? (yes) no circle one
   If yes, which way and why?

2. a) How many single-phase transformers are required to transform 3-phase power. Give the minimum number.

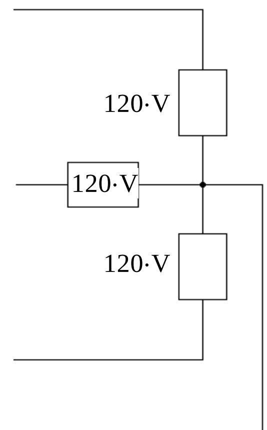
   b) Show how these single-phase transformers might be connected between the source (shown at left below) and a load (shown at right). Do not create an unbalanced load for the source.
   1247 V, 3-phase

   A ______

   B ______

   C ______

   N ______



   c) What is the required turns ratio of the transformers you showed above. Since you don't have a calculator, you may show a mathematical expression instead of a number.

3 a) List the bases of a per-unit system.

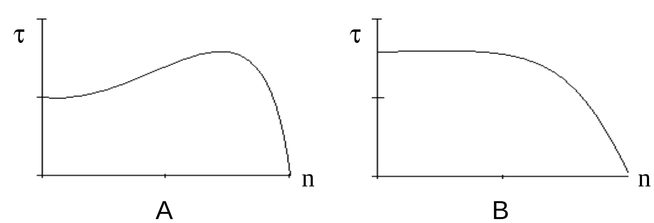
   b) When analyzing a power system, which, if any, of these bases should be constant throughout the system?

   c) For those bases that change from place to place throughout the system, which is the primary one that changes and what type of part causes the changes?

   d) Show how to find the remaining bases from those listed in parts b) and c).

4. To Bring a Synchronous Generator "On Line" you must do several things. Name at least 3. Be as specific as you can.
   1.
   2.
   3.
   4.
   5.

5. a) The torque-speed curves of 2 induction motors (A and B) are shown at right. Only one equivalent circuit parameter is different between the two. What is it?



   b) This parameter is bigger in which motor?

   c) The starting current is bigger in which motor?

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 MUST show work to get credit. Show the correct units for each value. Assume voltage and current values are RMS and $f := 60 \cdot Hz$. Assume normal abc sequence and balanced conditions for all 3ϕ.

1. (30 pts) A 60 Hz, 4-pole, 3-phase Y-connected synchronous generator supplies 90 kW to a 2.4 kV bus. The line current generated is 22 A and lags the generator phase voltage (V_ϕ) by 10.23°. The synchronous reactance is 30 Ω/phase. The field current is 10 A, DC, and the field flux is directly proportional to this current.

   a) Draw a phasor diagram and find the induced armature voltage (E_A) and the power angle, δ. E_A = ?

   δ = ?

   b) Find the total reactive power generated.

   c) The mechanical, rotational losses in this generator are: $P_{rot} := 5 \cdot kW$ What is the input shaft torque?

   d) The power angle, δ, is changed to 30°. The field current is NOT changed. What did the operator do to change the power angle? Say what changed and whether it increased or decreased.

   e) Find the power generated now with: $\delta := 30 \cdot deg$

   f) Did the reactive power also change? If yes, say whether it increased or decreased. No calculation is required.

   g) Find a new DC field current so that the reactive power output returns to that found in part b).

   h) Did the power angle change when the field current was changed? If yes, say whether it increased or decreased. No calculation is required.

2. (25 pts) A 3-phase, 208-V, Δ-connected, induction motor has the following equivalent circuit components:

   $R_1 := 0.3 \cdot \Omega$ $R_2 := 0.6 \cdot \Omega$ $R_C := \infty$

   $X_1 := 0.4 \cdot \Omega$ $X_2 := 1 \cdot \Omega$ $X_M := 18 \cdot \Omega$

   currently running at $n_m := 1140 \cdot rpm$ mechanical, rotational losses: $P_{mech} := 500 \cdot W$

   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 line current (magnitude) Note: a number that may be helpful:

   $$\frac{1}{\frac{1}{j \cdot X_M} + \frac{1}{j \cdot X_2 + \frac{R_2}{s}}} = 7.699 + 5.81j \cdot \Omega = 9.645\ \Omega\ \underline{/\ 37.04^\circ}$$

   d) The stator copper losses

   e) The air-gap P_{AG}

   f) The power converted from electrical to mechanical form

   g) The rotor copper losses

   h) The overall machine efficiency

3. (22 pts) A 1/2-hp, 120-V, 60-Hz, single-phase, capacitor-run, induction motor has two windings set 90º apart in the motor housing. The windings are NOT the same. Winding 1 draws 6 A at 30°lag and winding 2 draws 4.5 A at 35°lead. These values are for 120-V startup an d with a 80-µF capacitor connected in series with winding 2.

$$\mathbf{I_1} := 6\cdot A\cdot e^{-j\cdot 30\cdot deg} \qquad \mathbf{I_2} := 4.5\cdot A\cdot e^{j\cdot 35\cdot deg} \qquad C := 80\cdot\mu F$$

a) Find the impedance of winding 1 and winding 2 without the capacitor. Find both in rectangular form.

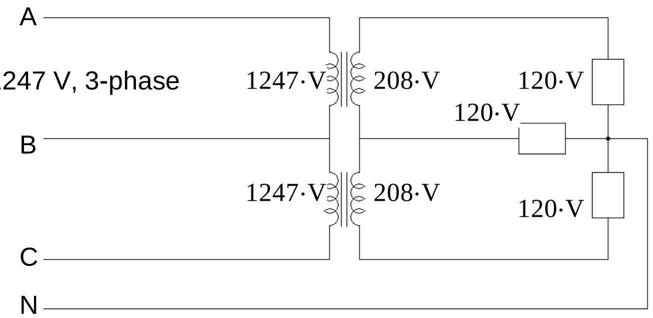
b) If the capacitor were disconnected from winding 2 and placed in series with winding 1 instead, find the new phase angle difference and the new current magnitudes. Did anything improve?

c) There will be one other major change in the motor startup with this new configuration. We didn't directly discuss this in class, but you can figure it out if you understand how the startup works. What will be different?

Answers **Closed-book part**

1. a) Δ - Y b) Y - Δ c) yes, Δ, to reduce third-harmonic currents.

2. a) 2 b)



c) $\frac{1247\cdot V}{120\cdot V\cdot\sqrt{3}} = 6$

3 a) S_{base} V_{base} I_{base} Z_{base} b) S_{base}

c) V_{base} Transformers d) $I_{base} = \frac{S_{base}}{V_{base}}$ $Z_{base} = \frac{V_{base}}{I_{base}}$

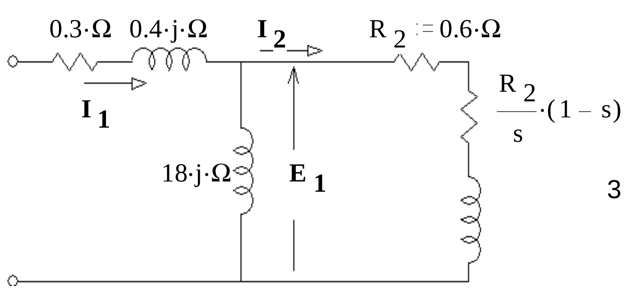
4. at least 3 of these
   1. Bring speed to the correct rpm so that the generator frequency matches the line frequency.
   2. Adjust the field current, I_f so that the generator voltage matches the line voltage.
   3. Readjust speed if necessary, check that the phases are in the correct sequence if necessary.
   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.

5. a) R_2 or rotor resistance b) B c) A

Open-book part 1. a) 1.64·kV 23.4º b) 16.2·kVAR c) 504·N·m d) Increased the input torque to the generator.

e) 113.4·kW f) decreased g) 10.45·A h) decreased

2. a)



b) 5·% c) 35.6·A d) 380·W

e) 9.75·kW f) 9.26·kW

g) 487·W h) 86.5·%

3. a) $17.32 + 10\cdot j\ \Omega$ $21.84 + 17.86\cdot j\ \Omega$

b) Angle difference is much closer to the ideal of 90º. Currents are both less and closer in value

c) It will start spinning in the opposite direction