ECE 3600 Exam 3 given: Fall 22

(Some space between problems has been removed.)

Write Legibly! Closed book, Closed notes, Calculator OK. 11/17/22

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

1. Why does a DC motor have brushes and a commutator?

2. How can you reverse the direction of rotation of a capacitor-start motor? That is, reverse the direction it starts. Choose **ALL** the possible ways from these answers:
   a) Reverse the leads to the start winding.
   b) Reverse the leads to the main winding.
   c) Reverse the leads to both windings.
   d) Change which winding has the capacitor.
   e) Reverse the leads to the capacitor.
   f) Reverse the positions of the capacitor and the start (second) winding.

3. An induction motor with just one winding connected to an AC source has what interesting behavior?

4. Most electric motors that we studied draw more current if the mechanical load is increased. Are there any that do not (in normal operating range)? Either answer NO or name the exception(s) and indicate how they do respond to increased mechanical load.

5. Most electric motors that we studied slow down if the mechanical load is increased. Are there any that do not (in normal operating range)? Either answer NO or name the exception(s) and indicate how they do respond to increased mechanical load.

6. Is there a readily available device, perhaps made for a different use, which could regulate the speed of a synchronous motor? If yes, name the device,

Problems

1. (30 pts) A 3-phase, Δ-connected, induction motor has the following equivalent circuit components:

$R_1 := 0.25\cdot\Omega$ $R_2 := 0.5\cdot\Omega$ $R_C := \infty$ currently running at $n := 1692\cdot\text{rpm}$

$X_1 := 0.4\cdot\Omega$ $X_2 := 0.8\cdot\Omega$ $X_M := 15\cdot\Omega$

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 $\tau_{load} := 60 \cdot N \cdot m$ Find the output power

d) The mechanical power losses (all lumped together) is $P_{mech\_loss} := 440 \cdot W$ Find P_{conv}

e) Find $|\mathbf{I}_2|$

f) Find the line current. $|\mathbf{I}_L| = ?$

Note: Don't try any shortcuts here. You need to do your math with full complex numbers. I advise you to assume the phase angle of $\mathbf{I}_2$ is 0º.

g) Find P_{RCL}

h) The stator copper losses P_{SCL}

i) The overall machine efficiency η

2. (32 pts) A 2-hp dc motor has the following nameplate information: 160 V, 1500 rpm, 11.5 A, $R_A = 1.2\ \Omega$, and $R_F = 500\ \Omega$. The field is shunt connected and the 11.5 A <u>includes</u> the field current.

   a) Find the efficiency of the motor at nameplate operation. (Include the field in your calculations) $1 \cdot hp = 745.7 \cdot W$

   b) Find the rotational losses at nameplate operation.

   Assume this rotational loss power remains constant at all speeds.

   c) Find the total required current (include field) for a output power of 1.5 hp with $V_T = 160$ V.

   d) Find the shaft speed if the output power is 1.5 hp with $V_T = 160$ V.

   e) The mechanical load on the shaft is changed and the motor speed changes to: $n_{new} := 1600 \cdot rpm$
   Find the load power, P_{out} , at this speed. This is a multi-step calculation.

3. (22 pts) A 1/3-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. At Startup, winding 1 draws 5 A at 30° lag. Winding 2 , in series with an 70-µF capacitor, draws 4 A at 35° lead.

$V_T := 120 \cdot V$ $\quad\quad$ $\mathbf{I_1} := 5 \cdot A \cdot e^{-j \cdot 30 \cdot deg}$ $\quad\quad$ $\mathbf{I_2} := 4 \cdot A \cdot e^{j \cdot 35 \cdot deg}$ which includes a series $C := 70 \cdot \mu F$

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?

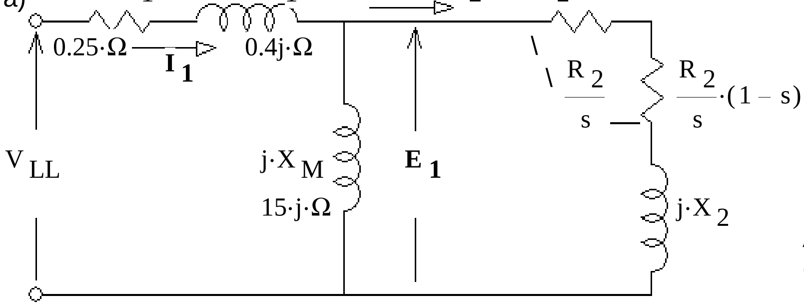
c) There will be one other major change in the motor startup with this new configuration. We didn't directly discuss this in class, but you can figure it out if you understand how the startup works. What will be different?

Answers **Questions**

1. The commutator is a series of bars or segments so connected to armature coils of a generator or motor that rotation of the armature will in conjunction with fixed brushes result in unidirectional current output in the case of a generator and in the reversal of the current into the coils in the case of a motor.
2. a b d 3. It won't start spinning without outside help
4. NO, all electric motors draw more current if the mechanical load is increased
5. Synchronous motors don't slow down if the mechanical load is increased
6. Yeah, a VFD (variable Frequency Drive) made for induction motors would work.

Problems

1. a)



b) $6 \cdot \%$ c) $10.63 \cdot kW$ d) $11.07 \cdot kW$
e) $21.7 \cdot A$ f) $44.8 \cdot A$

2. a) $81.05 \cdot \%$ b) $147.4 \cdot W$
c) $8.77 \cdot A$ d) $1534 \cdot rpm$ e) $327.4 \cdot W$

3. a) $(20.785 + 12 \cdot j) \cdot \Omega$ $\quad$ $(24.575 + 20.687 \cdot j) \cdot \Omega$
b) $91.34 \cdot deg$ $\quad$ $3.736 \cdot A$ $\quad$ $3.736 \cdot A$

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