ECE 3600 Exam 3 given: Fall 23

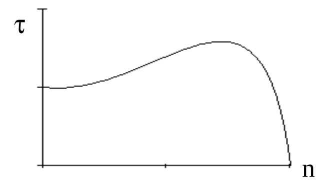
(Some space between problems has been removed.)

Write Legibly! Closed book, Closed notes, Calculator OK. 11/15/23

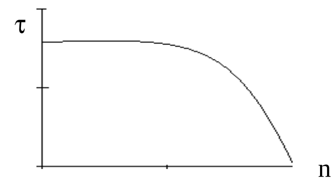
(15 pts) Questions If I can't read what you've written or you answer is ambiguous, I'll assume you don't know.

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

curve 1



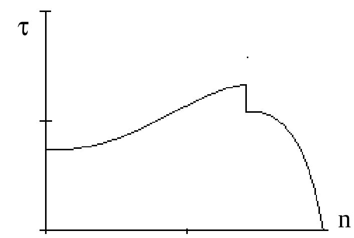
curve 2



b) This parameter is bigger in which motor?

c) The starting current is bigger in which motor?

2. a) The torque-speed curve shown at right is typical of what type of motor? (More than one answer is possible).



b) These motors have a special component not found in the other motors we studied. What is it?

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

4. 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) Change which winding has the capacitor.

c) Reverse the leads to the main winding.

d) Reverse the leads to the capacitor.

e) Reverse the leads to both windings.

f) Reverse the positions of the capacitor and the start (second) winding. That is, if the current used to flow through the capacitor and then the winding, make it flow through the winding and then the capacitor.

5. 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,

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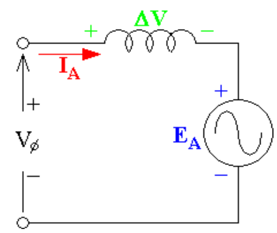
1. (35pts) A 20-hp, 60-Hz, Δ-connected, three-phase, 8-pole synchronous motor operates from a 600-V bus. Neglect electrical and mechanical losses.



   a) The shaft of the motor is spinning freely (no mechanical load). What is the power angle? Remember, the motor is not loaded and we neglecting all losses.

   b) The DC field current is 10 A. The armature current is 0 A. What is the value of E_A in this condition?

   c) The DC field current is increased to 11 A, assume the field is proportional to this current. The armature current is now 2 A and is leading the phase voltage by 90º. Draw the phasor diagram of this condition.

   d) Is the motor under or over excited?

   e) Find the synchronous reactance.

If you can't find X_S, or doubt your value, mark here ____ and use $X_S = 25\ \Omega$ for the rest of the problem.

If it still doesn't seem like you have enough information to answer the following parts, Ask. I will answer questions for points.

   f) Find the total reactive power "used" by the motor.

1. continued A mechanical load is now hooked to the motor so that the shaft torque is $\tau_{out} := 150 \cdot N \cdot m$

g) Find the mechanical power. P_{out} = ?

h) Find the power angle. δ = ?

i) Find the total reactive power used.

j) We would like to produce $4.2\ kVAR$ (use $-4.2\ kVAR$), no change in real power. Find the required E_A.

k) What does the operator change to get this new E_A, and to what new value.

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2. (30 pts) A 3-phase induction motor is Y-connected to a 340-V bus. It has the following equivalent circuit components:

$R_1 := 0.5 \cdot \Omega$ $R_2 := 0.8 \cdot \Omega$ $R_C := \infty$

$X_1 := 2 \cdot \Omega$ $X_2 := 1 \cdot \Omega$ $X_M := 20 \cdot \Omega$

currently running at $n_m := 1710 \cdot \mathrm{rpm}$ mechanical, rotational losses: $P_{mech} := 400 \cdot W$

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.

FIND:

c) The line current (magnitude)

Note: a number that may be helpful: $$\frac{1}{\frac{1}{j \cdot X_M} + \frac{1}{\frac{R_2}{s} + j \cdot X_2}} = 9.182 + 7.948j \cdot \Omega = 12.145\ \Omega\ \underline{/\ 40.88}^{o}$$

 More on next page ===>

2. continued

d) The stator copper losses P_{SCL} = ?

e) The air-gap power P_{AG} = ?

f) The power converted from electrical to mechanical form P_{conv} = ?

g) The rotor copper losses P_{RCL} = ?

h) The overall machine efficiency η = ?

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3. (20 pts) A 1/3-hp, 120-V, 60-Hz, single-phase, capacitor-run, 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) Find a different capacitor to replace the capacitor of part a). Choose this capacitor to make the current magnitude in the two windings exactly the same at rated speed. (Don't worry about the phase angles.)

More on next page ===>

c) Find the input current (sum of both) magnitude and phase at rated speed with the capacitor of part b) in place.

d) With this capacitor in place, what is the power factor of the motor when running at rated speed.

e) The ideal capacitor to to get 90º phase difference at **rated speed** is $28.4\mu F$. Is the capacitor found in part b) also a good compromise between the answer of part a) and $28.4\mu F$?

circle one: yes no

_____ / 20

Total ________/ 100

__Answers__ **Questions**

1. a) R_2 or rotor resistance b) curve 2 c) curve 1

2. a) Split-phase or single-phase induction motor
   b) A centrifugal switch

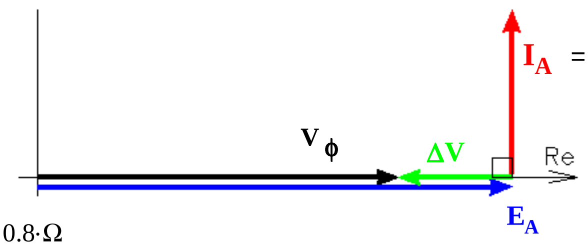
3. It won't start spinning without outside help

4. a,b,c

5. Yeah, a VFD (variable Frequency Drive) made for induction motors would work.

__Problems__

1. a) $\delta := 0 \cdot deg$ b) $600 \cdot V$ c)



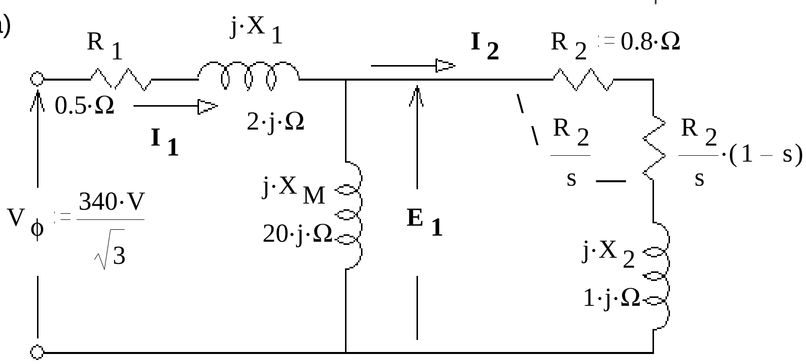
$I_A = \dfrac{\Delta V}{j \cdot X_s} = 2 \cdot A$

d) over excited e) $30 \cdot \Omega$ f) $-3.6 \cdot kVAR$

g) $14.14 \cdot kW$ h) $29.92 \cdot deg$ + or - accepted

i) $-990.6 \cdot VAR$ j) $710.2 \cdot V$ k) $11.84 \cdot A$

2. a)



b) $5 \cdot \%$ c) $14.14 \cdot A$ d) $299.9 \cdot W$

e) $5.509 \cdot kW$ f) $5.233 \cdot kW$

g) $275.4 \cdot W$ h) $83.21 \cdot \%$

3. a) $37.8 \cdot \mu F$ b) $34.4 \cdot \mu F$

c) 3.064 A $\angle 0^o$ d) 1 e) yes