ECE 3600 Exam 3 given: Spring 23

DO NOT use erasable ink

First part, Write Legibly! Closed book, Closed notes, Calculator OK. 4/14/23

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

1. Last Friday we attended a lecture by Dr.Overbye.
   a) What information was he adding to the basic power-flow calculations?

   b) Dr. Overbye mentioned many ways this information would affect the power in a grid. Which did he talk about the most?

   c) What state did Dr.Overbye come from (also the state which figured most prominently in his figures and examples)?

2. List at least 3 common high-voltage transmission line voltages discussed in this class.

3. What insulates the wires from one another in an overhead transmission line?

4. Name the 3 most important parameters for transmission lines.

5. Which parameter dominates in lightly loaded lines (under 1 SIL)?

6. Which parameter dominates in heavily loaded lines (over 1 SIL)?

7. What does "bundling" mean?

8. Bundling;

a) Affects inductance:
   i) increases L
   ii) decreases L
   iii) little effect
   iv) unpredictable effect

   This is:
   i) good ii) bad
   iii) unimportant

b) Affects capacitance:
   i) increases C
   ii) decreases C
   iii) little effect
   iv) unpredictable effect

   This is usually:
   i) good ii) bad
   iii) unimportant

c) Affects resistance:
   i) increases R
   ii) decreases R
   iii) little effect
   iv) unpredictable effect

   Decreasing R is:
   i) good ii) bad
   iii) unimportant

d) Affects conductance to ground:
   i) increases G
   ii) decreases G
   iii) little effect
   iv) unpredictable effect

   This is:
   i) good ii) bad
   iii) unimportant

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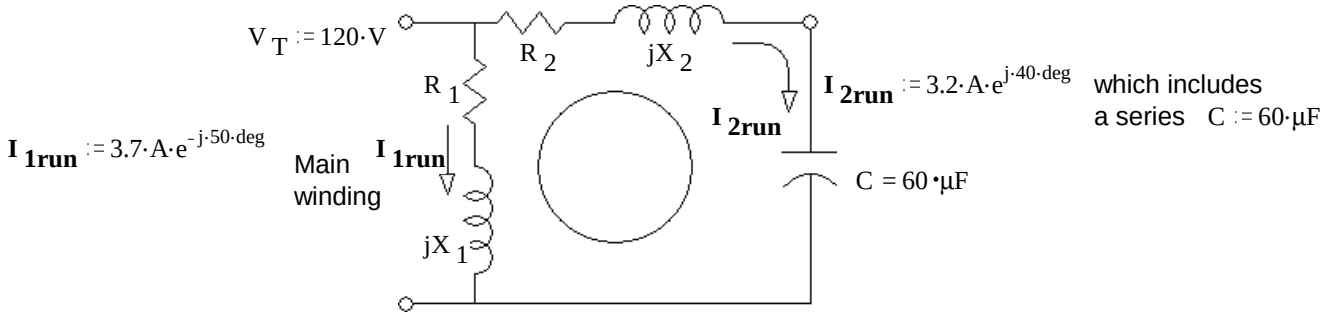
Second part, Closed book, 3 reference sheets Calculator OK.

1. (22 pts) A 1/3-hp, 120-V, 60-Hz, single-phase, capacitor-run, induction motor has two windings set 90° apart in the motor housing. The windings are NOT the same. At **normal run speed**, winding 1 draws 3.7 A at 50° lag. Winding 2 in series with an 60-μF capacitor draws 3.2 A at 40° lead.



a) Find the run-speed impedances of winding 1 and winding 2 without the capacitor. Find both in rectangular form.

b) At **startup**, the winding impedances are found to be:

$\mathbf{Z}_{1strt} := (8 + 10 \cdot j) \cdot \Omega$ $\mathbf{Z}_{2strt} := (12 + 10 \cdot j) \cdot \Omega$ without capacitor

Find the ideal capacitor to place in series with winding 2 at **startup**.
Note: the ideal capacitor would create the ideal phase difference between the winding currents.

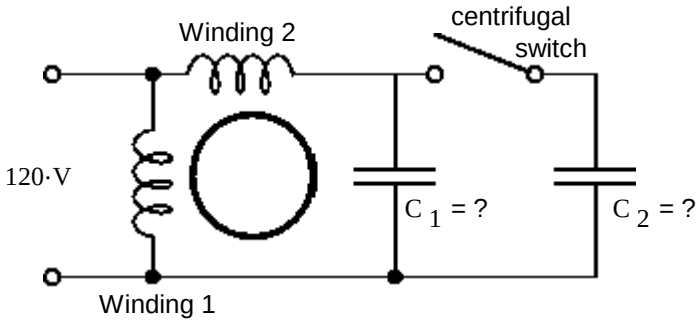
More on next page ===>

c) The motor has a centrifugal switch which switches at half speed. See drawing, below.

Circle one: i) The centrifugal switch should be closed at start and open (as shown) at run speed.

ii) The centrifugal switch should be open (as shown) at start and closed at run speed.

Find the values of the two capacitors below so as to meet the conditions of parts a) and b). Write them down below.



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2. (30 pts) A 3-hp dc motor has the following nameplate information: 160 V, 1200 rpm, 16 A, $R_A = 0.5\ \Omega$, and $R_F = 300\ \Omega$. The field is shunt connected and the 16 A includes the field current. Assume rotational losses are constant.

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.

2. c) Find the required armature current for a developed power of $1.5\ \text{hp}$ with $V_T = 160\ \text{V}$. $P_{conv} := 1.5 \cdot \text{hp}$

d) Find the output power if the developed power is $1.5\ \text{hp}$ with $V_T = 160\ \text{V}$.

e) Find the shaft speed if the developed power is $1.5\ \text{hp}$ with $V_T = 160\ \text{V}$.

f) A deranged Mouse chews through part of the field winding so that the field current drops and the field flux drops to 60% of its former value. Find the shaft speed if the developed power is still $1.5\ \text{hp}$ with $V_T = 160\ \text{V}$. Note: before you make this problem much harder than it really is, It is OK to use the same I_A and E_A as you found and used in parts c) through e).

3. (30 pts) A permanent-magnet DC motor is coupled to a mechanical load. If it is hooked to a 8-V source, it draws 2.2A and spins at 20rad/sec. If it is hooked to a 20-V source, it draws 4.0A and spins at 80rad/sec.

   a) Find R_A and $K\phi$. Hint: Solve 2 equations for 2 unknowns.
   Keep at least 4 significant digits for all your numbers. The results are very sensitive to roundoff errors.
   Note: The mechanical load power is an unknown function of speed.

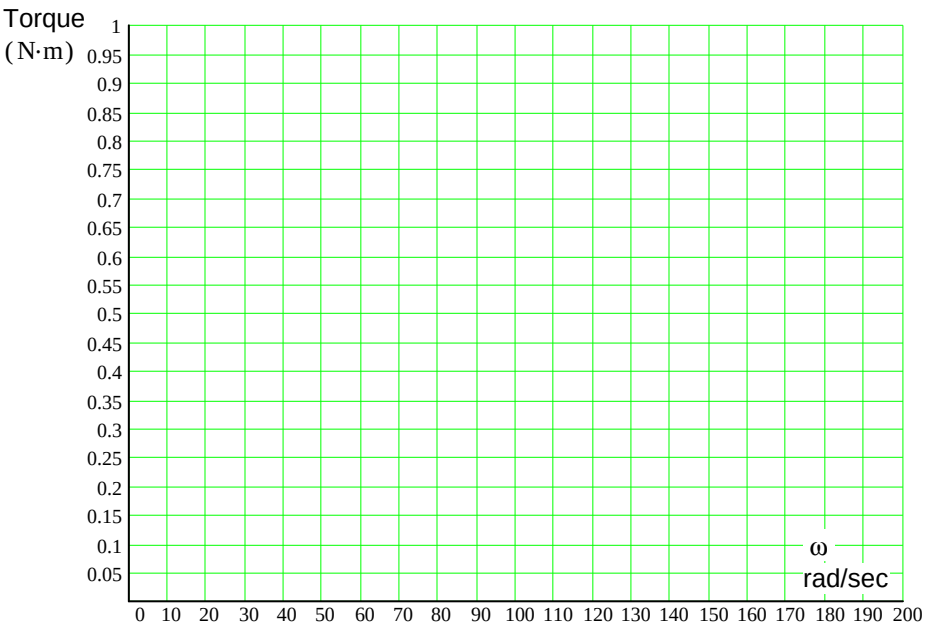
$$V_{T1} := 8\cdot V \qquad I_{A1} := 2.2\cdot A \qquad \omega_1 := 20\cdot\frac{rad}{sec} \qquad V_{T2} := 20\cdot V \qquad I_{A2} := 4.0\cdot A \qquad \omega_2 := 80\cdot\frac{rad}{sec}$$

   b) If we assume that the mechanical load torque combined with the internal frictional torque of the motor is some constant torque plus some torque that is proportional to speed, then we could express the induced torque like this:

$$\tau_{ind} = B\cdot\omega + D \qquad B \text{ and } D \text{ are constants and } \tau_{ind} = K\phi\cdot I_A$$

   Find the constants B and D from the information given above.

c) On the graph below, plot the two torque-speed "curves" of the motor, one for each V_T given. Also draw the load line. Put an "X" or "+" at the two points of operation given in the original problem statement.



Plot 3 Lines & 2 points

d) Confirm that the two end-point expressions given on your Exam 3 information sheet are correct. That is, confirm that when the speed is 0, the torque is $V_T K\phi / R_A$ and when torque is 0, the speed is $V_T / K\phi$. Show your work to derive the expressions from basic equations! These are a fully symbolic derivations.

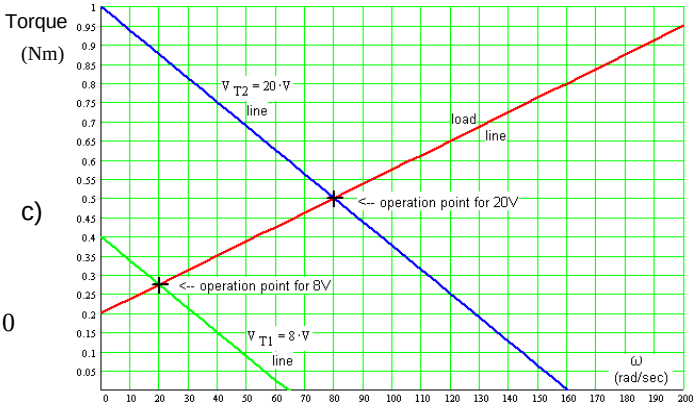
Answers _____ / 30

Total _____/ 100

1. a) weather info b) Wind and wind energy production c) Texas
2. 115·kV 138·kV 230·kV 345·kV 500·kV 765·kV any 3 of these
3. Air (and distance) 4. Resistance Inductance (reactance) Capacitance
5. Capacitance 6. Inductance (reactance) 7. More than 1 conductor / phase
8. a) ii) i) b) i) i) c) iv) i) d) ii) i)

Problems, 2nd part

1. a) $(20.85 + 24.845 \cdot j)\cdot\Omega$ $(28.73 + 20.10 \cdot j)\cdot\Omega$
   b) 135·µF c) i) 60·µF 75·µF
2. a) 87.4·% b) 118·W c) 7.15·A
   d) 1.34·hp e) 1233·rpm f) 2055·rpm
3. a) 2.5·Ω 0.125·V·sec b) 0.00375·N·m·sec 0.2·N·m c)



d) show algebraic derivations of:

$\tau = \dfrac{V_T \cdot K\phi}{R_A}$ when $\omega = 0$, and $\omega = \dfrac{V_T}{K\phi}$ when $\tau = 0$