ECE 3600 Final given: Fall 09

(The space between problems has been removed.)

Write Legibly! If I can't read what you've written or you answer is ambiguous, I'll assume you don't know.

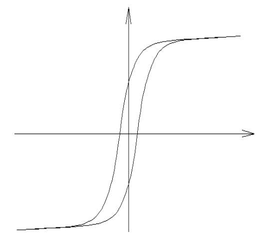
(38 pts) Questions This part of the exam is Closed book, Closed notes, No Calculator.

There are extra questions, so you can miss 6 pts and still get full credit.

1. What is cogeneration?

2. How does a combined-cycle, natural gas, power plant achieve its high efficiency?

3. a) Name the common curve shown at right.

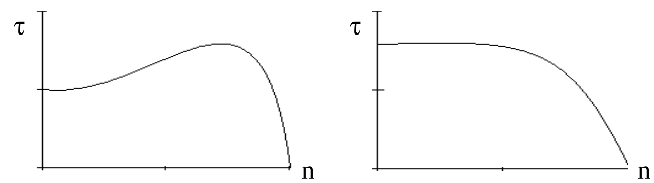


   b) Many of the electrical devices we studied contain a part which is characterized by this curve. What part is that?

   c) Name at least 2 issues caused by this part having this characteristic curve.

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

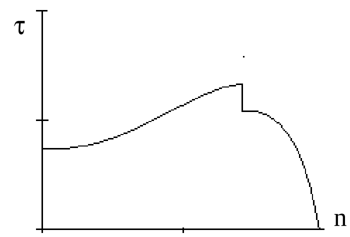
5. a) The torque-speed curves of 2 induction motors are shown at right. Only one equivalent circuit parameter is different between the two. What is it?



   b) This parameter is bigger in which motor?

   c) The starting current is bigger in which motor?

6. 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?

7. a) In the space at right, sketch the torque-speed curve of a series-wound DC motor (field in series with rotor).

   b) If this type of motor is used with an AC source, what is it called?

   c) Name at least 2 common uses of this type of motor.

8. List at least 3 common long-distance high-voltage transmission line voltages given in class.

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

10. a) Transmission lines can be modeled in 3 different ways. List the 3 model types below.

    1.

    2.

    3.

    b) How do you decide which model to use? Give specific number ranges of a specific variable below.

11. If the load hooked to a transmission line has a leading power factor, something counterintuitive can happen. What is that?

12. a) What is bundling (in transmission lines)?

    b) Name at least 2 effects of bundling.

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 $f := 60 \cdot Hz$ for all problems and normal a-b-c sequence for all 3ϕ

1. (29 pts) A 208-V, 3-phase, Y-connected, induction motor has the following equivalent circuit components:

$R_1 := 0.2 \cdot \Omega$ $\quad R_2 := 0.127 \cdot \Omega$ $\quad R_C := \infty$ $\quad$ currently running at $\quad n := 3510 \cdot rpm$

$X_1 := 0.3 \cdot \Omega$ $\quad X_2 := 0.4 \cdot \Omega$ $\quad X_M := 15 \cdot \Omega$ $\quad P_{AG} := 7.4 \cdot kW$

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

a) Find $|\mathbf{I_2}|$ Note: Use the P_{AG} for one phase, the slip and R_2 .

b) Find P_{RCL}

c) The output shaft torque is $\tau_{load} := 19 \cdot N \cdot m$ Find the output power

d) Find the mechanical power losses (all lumped together).

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

f) The stator copper losses P_{SCL}

g) The overall machine efficiency η

2. (27 pts) You make the following measurements on a 3-phase, Y-connected, synchronous generator.

$P_{3\phi} := 120 \cdot kW$ $\quad V_{LL} := 480 \cdot V$ $\quad I_L := 160 \cdot A$ $\quad X_s := 1.2 \cdot \Omega$

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 power angle, δ. $\quad E_A$ = ? $\quad \delta$ = ?

b) Draw a phasor diagram of other possible interpretation of these numbers.
Find the induced armature voltage (E_A) and the power angle, δ. $\quad E_A$ = ? $\quad \delta$ = ?

c) A traveling carnival uses a combination of this generator and the local power company to run its load, mainly induction motors. When the generator is connected to the carnival'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.

3. (31 pts) A 2-hp dc motor has the following nameplate information: 160 V, 1500 rpm, 11 A, $R_A = 0.6\ \Omega$, and $R_F = 500\ \Omega$. The field is shunt connected and the 11 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) $1\cdot hp = 745.7\cdot W$

   $V_T := 160\cdot V$ $\quad n_{FL} := 1500\cdot rpm$ $\quad I_{FL} := 11\cdot A$ $\quad R_A := 0.6\cdot\Omega$ $\quad R_F := 500\cdot\Omega$

   b) Find the rotational losses at nameplate operation.

   c) Find the required current for a developed power of 1.5 hp with $V_T = 160$ V.

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

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

   f) A dreaded E-cockroach chews through part of the field winding so that the field current drops by half and the field flux drops to 60% of its former value. Find the shaft speed if the developed power is still 1.5 hp with $V_T = 160$ V. Note: before you make this problem much harder than it really is, It is OK to use the same E_A and I_A as you found above in parts c) & d).

4. (35 pts) A 230 kV transmission line is 220 km long and has the following line parameters. $S := siemens$

   $len := 220\cdot km$ $\quad r := 0.1\cdot\frac{\Omega}{km}$ $\quad x := 0.4\cdot\frac{\Omega}{km}$ $\quad g := 0\cdot\frac{S}{km}$ $\quad y := 3.4\cdot 10^{-6}\cdot\frac{S}{km}$

   a) Choose the most appropriate model for this transmission line and draw it, including the impedance and/or admittance value(s).

   b) Add a load impedance (at the receiving, or $\mathbf{V_R}$ end) on the drawing above. The load is 300Ω with a power factor of 0.9, **leading**. The line-to-line voltage at the source is 230 kV. Assume the source voltage, $\mathbf{V_S}$, phase is $\angle 0^o$. Find the line current, $\mathbf{I_{Line}}$ (not $\mathbf{I_S}$) in any form.
   Note: Don't try any shortcuts here. You need to do your math with full complex numbers, not magnitudes. There is a messy calculation of impedance, so work carefully. $\mathbf{I_{Line}} = ?$

   c) Same load and conditions as part b). Find the load phase voltage, $\mathbf{V_R}$, magnitude and phase. $\mathbf{V_R} = ?$

   Note: because the load power factor is leading, $|\mathbf{V_R}|$ is bigger than $|\mathbf{V_S}|$. If you didn't get this result, check your work!

   d) What is the line voltage at the load (magnitude)?

   e) How much total power is delivered to the load?

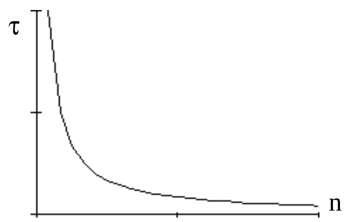
   f) Express this load in terms of SIL.

   g) What is the "power angle" (δ)?

P.S. No cockroaches were harmed in the making of this exam.
Its demise was its own damn fault!

Answers

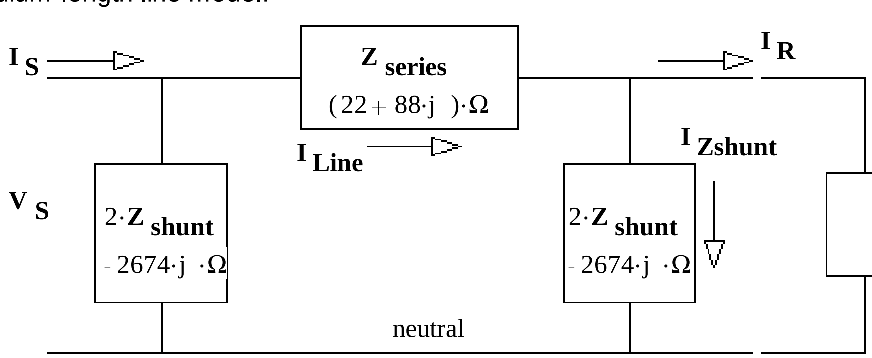
1. The "waste" heat of a some electrical generator is then used in another way, say water or air heating.
2. The "waste" heat of a gas turbine is then used to run a steam cycle generator.
3. a) B-H curve or Hysteresis curve   b) The core
   c) Core losses   Nonlinearities, esp. in the currents   3rd harmonic currents
   Sets voltage limits   Requires more windings so that the core flux can be less   2 of these
4. It won't start spinning without outside help
5. a) R_2 or rotor resistance   b) right-most   c) left-most
6. a) Split-phase or single-phase induction motor   b) A centrifugal switch
7. a)



   b) Universal motor
   c) Hand drill   Blender   Vacuum cleaner
   Food processor   Weed eater   Electric yard devices   2 of these
8. $115 \cdot kV$ $138 \cdot kV$ $230 \cdot kV$ $345 \cdot kV$ $500 \cdot kV$ $765 \cdot kV$ 3 of these
9. Air (and distance)
10. 1. Short   length < 50 mi   OR   length < 80 km
    2. Med   50 < length < 150 mi   80 < length < 240 km
    3. Long   length > 150 mi   length > 240 km
11. The receiving-end voltage can be greater than the sending-end voltage
12. a) Multiple wires per phase
    b) Reduce corona discharge   Decrease line inductance   Increase line capacitance   2 of these

Open Book

1. a) $22.0 \cdot A$ b) $185 \cdot W$ c) $6.98 \cdot kW$ d) $231 \cdot W$ e) $23.8 \cdot A$ f) $340.5 \cdot W$ g) $90.2 \cdot \%$
2. a) $260 \cdot V$ 41.7^o b) $399 \cdot V$ 25.7^o
   c) First case. The induction motors represent a lagging pf load, they use lots of VARs. If the local generator were supplying those 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 VARs (creates negative VARs). That is condition a).
   d) Turn up the field current.
3. a) $84.7 \cdot \%$ b) $149 \cdot W$ c) $7.185 \cdot A$ or $7.505 \cdot A$ (inc I_F)   d) $970 \cdot W$ e) $1520 \cdot rpm$ f) $2534 \cdot rpm$
4. a) Medium-length line model:



$Z_L := 300 \cdot \Omega$

$pf := 0.9$

$\mathbf{Z_L} := Z_L \cdot e^{-j \cdot acos(pf)}$

$\mathbf{Z_L} = 270 - 130.767j \cdot \Omega$

   b) $488 \cdot A$ 12.8^o c) $(131.8 - 44.29 \cdot j) \cdot kV$ d) $240.8 \cdot V$ e) $174 \cdot MW$
   f) $1.03 \cdot SIL$ g) 18.6^o