ECE3600 Final given: Fall 13

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

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

1. What is the most energy-efficient type of common power plant? Hint: It's also one of the oldest.
2. Name 3 sources of electrical power for the grid which do not produce greenhouse gasses by normal operation.
3. Name at least 3 issues caused by the B-H hysteresis curve.
4. a) How many single-phase transformers are required to transform 3-phase power. Give the minimum number.

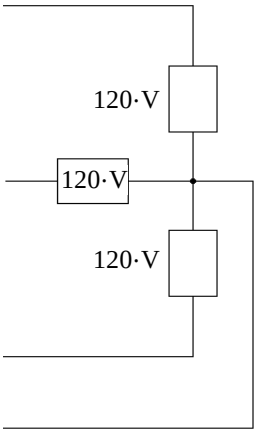
   b) Show how these single-phase transformers might be connected between the source (shown at left below) and a load (shown at right). Do not create an unbalanced load for the source.
   480V, 3-phase

   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.
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. 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.
7. How can you reverse the direction of rotation of a capacitor-start motor? That is, reverse the direction it starts. Choose from these answers.

   a) Reverse the leads to the capacitor.

   b) Reverse the leads to the main winding.

   c) Reverse the leads to the start winding.

   d) Reverse the positions of the capacitor and the start (second) winding.

   e) Reverse the leads to both the main and the start windings.

   f) Change which winding has the capacitor.
8. When we visited Terminal substation, we saw three different yards at three different line voltages. Power was also distributed locally at yet another line voltage. List as many of these voltages as you can remember.
9. Large power transformers are filled with _____ for two main reasons. Give one or both reasons.
   fill in blank
10. The breakers used in substations come in two main types, list them and indicate which type was newer technology.
11. You saw several capacitor banks at Terminal substation. We've talked in class about adding capacitors to correct power factor, but people in the power industry usually talk about the effects of adding capacitors differently. What do they say they add capacitors for?
12. You also saw two types of devices which looked like vertical insulators on a ground platform.

    a) Some of these were simply connected to ground. What was their purpose?

    b) Some of these had a box at the bottom for some device which was connected into the control buildings. What was their purpose?

13. The large transformers connected between the highest two voltage yards were wired in a special way.
    a) How were their windings wired?
    b) Name one or more advantages of this type of transformer
    c) Name one or more disadvantages of this type of transformer
14. The answer to life, the universe, and everything is....
15. a) What does the term "bundling" mean for high-voltage transmission lines?
    b) It is typically used for transmission lines with line voltages ≥ _____ fill in blank
    c) Name some of the reasons for doing this. (advantages)
    d) Are there disadvantages? Answer no or name one or more.

Do you want your grade and scores posted on the Internet?
If your answer is yes, then provide some sort of alias:

_____
otherwise, leave blank

The grades will be posted on line in pdf form in alphabetical order under the alias that you provide here. I will not post grades under your real name. It will show the homework, lab, and exam scores of everyone who answers here.

F13 Open book

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 abc sequence for all 3ϕ

1. (30 pts) A 480/120-V, 2.4-kVA transformer is subjected to an OC test and a SC test with the results below.

a) Draw a model of this transformer and find the values of all the elements of the model, including the turns ratio.

During the open-circuit test: $I_{OC} := 0.5 \cdot A$ $P_{OC} := 160 \cdot W$

During the short-circuit test: $V_{SC} := 20 \cdot V$ $P_{SC} := 60 \cdot W$

b) The transformer is connected to a primary source voltage of 360V and loaded with $\mathbf{Z_L} := (3 + 2 \cdot j) \cdot \Omega$.

(you may add these parts to your drawing if you wish.)

Find the secondary voltage. Magnitude only. $|\mathbf{V_2}|$ = ?

c) Is this transformer operating within its ratings? Show all evidence and calculate needed to to determine this.

2. (32 pts) A 230 kV (nominal) transmission line has the following length and line parameters. $S := siemens$

$len := 180 \cdot km$ $r := 0.20 \cdot \frac{\Omega}{km}$ $x := 0.60 \cdot \frac{\Omega}{km}$ $g := 0 \cdot \frac{S}{km}$ $y := 4 \cdot 10^{-6} \cdot \frac{S}{km}$

a) Choose the most appropriate model for this transmission line and draw it, including the impedance and/or admittance value(s). Add a 3ϕ load at the receiving end of the transmission line.

The line current to the **load**, $\mathbf{I_R}$ (not $\mathbf{I_{Line}}$) is $250+100j$ A. **ECE3600 Final given: Fall 13 p3**

The magnitude of one phase of the Y-connected load impedance is 510Ω.

b) Find the load phase voltage, $\mathbf{V_R}$, magnitude. Assume its phase is 0^o (relative to the current given above).
$\mathbf{V_R}$ = ?

c) Find the line current in your model, $\mathbf{I_{Line}}$ (not $\mathbf{I_S}$) in a complex-number form. $\mathbf{I_{Line}}$ = ?

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

e) What is the "power angle" (δ)?

f) Find the impedance of one phase of the load, assuming Y-connected.

g) Find the power consumed by the entire load.

h) Find the power factor of the load.

i) Consider the source voltage and the load voltage of this transmission line. Is there anything weird about them? If yes, say what and tell me the cause of the of this weirdness.

3. (34 pts) A 1.5-hp, separately excited dc motor runs at 60% overall efficiency (includes power needed for the field) when operated at full load. Both the armature and field are hooked to a single $200\ \text{V}$ source. The rotational losses are proportional to the motor speed. Other important information is given below.

$\eta := 60\cdot\%$ $V_T := 200\cdot V$ $n_{fL} := 900\cdot rpm$ $R_A := 3\cdot\Omega$ $R_F := 160\cdot\Omega$ $1\cdot hp = 745.7\cdot W$

a) Find the power converted from electrical to mechanical, P_{conv} = ?

b) Find the rotational losses, P_{rot} = ?

c) (up to 5 pts extra credit)
Find the overall efficiency from the individual losses to double check the efficiency given above.

d) Find the no-load armature current. Show the algebra needed to find I_A from the basic equations.
The rotational losses are proportional to the motor speed.
Hint 1: This also means that the rotational losses are proportional to E_A, like this: $P_{rot2} = P_{rot1}\cdot\frac{E_{A2}}{E_{A1}}$
Hint 2: This turns out to be amazingly easy to calculate, no quadratic required.

e) The full-load speed is given above as n_{fL}. Find the no-load shaft speed.

f) The mechanical load on the shaft is reduced to half of full load. $P_{out} := 0.75\cdot hp$

Find the half-load shaft speed. Show the algebra needed to find E_A from the basic equations.
Hint: This is NOT amazingly easy to calculate, algebra and quadratic required.

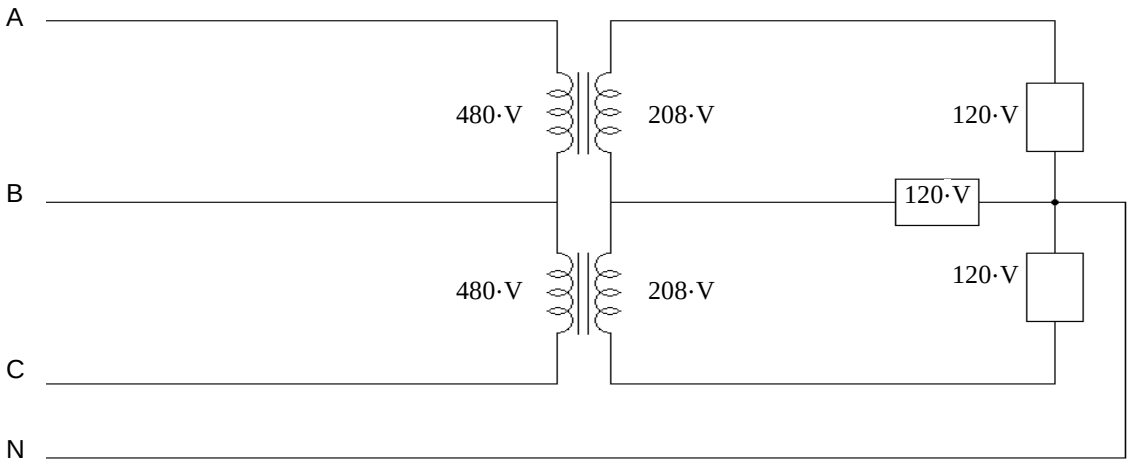
Answers

1. Hydroelectric
2. Hydroelectric wind solar (steam or solar-cells) nuclear geothermal 3 of these
3. Core losses Nonlinearities, esp. in the currents 3rd harmonic currents
   Sets voltage limits requires more windings so that the core flux can be less
   Requires larger, heavier cores 3 of these

ECE3600 Final given: Fall 13 p3

ECE3600 Final given: Fall 13 p4

4. a) 2 b)



c) $\frac{480\cdot V}{208\cdot V}$

5. Synchronous motors do not slow down, their speed remains constant

6. NO, all electric motors draw more current if the mechanical load is increased

7. b), c) & f) 8. 12.47·kV 46·kV 138·kV 345·kV

9. Oil Oil is a better insulator than air Oil is used to keep the transformers cool

10. Oil filled (old) Gas (SF_6) filled (newer) 11. To increase the voltage

12. a) Lightning arrestors b) Voltage measuring transformers

13. a) Y - Y autotransformer

b) The low-side current is the sum of the two currents within the windings, so the transformer windings can be smaller.

c) No isolation between voltages May not be used side by side with Δ-Y or Y-Δ transformers

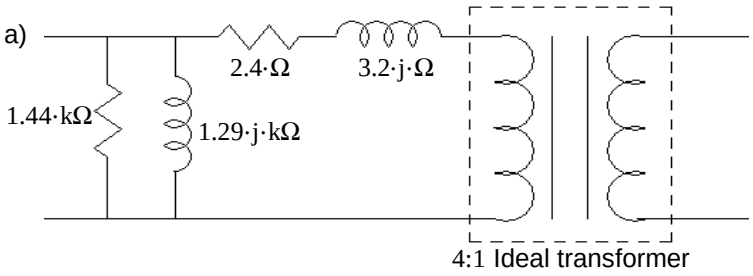
Requires a tertiary Δ winding to take care of third-harmonic currents 14. 42

15. a) Using more than one conductor per phase. b) 345·kV

c) Reduce corona discharge Decrease line inductance Increase line capacitance d) Costs more

Open Book

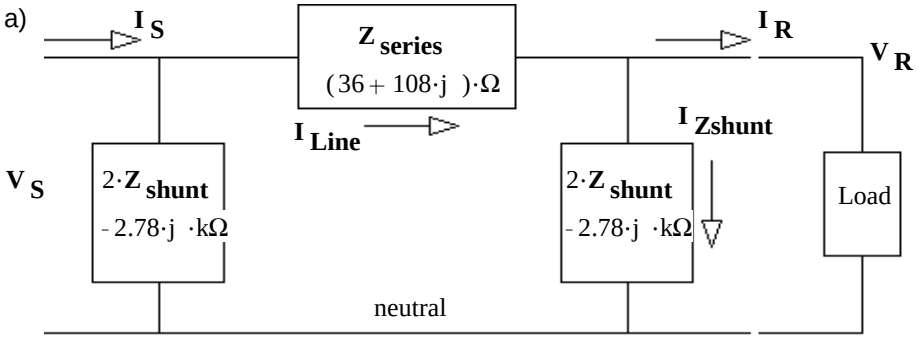
1. a)



b) 84.5·V

c) No 5.86·A > 5·A

2. a)



b) 137.3·kV

c) 291.3·A ∠ 30.9·deg

d) 232.4·kV

e) 13.97·deg

f) 510·Ω ∠ - 21.8·deg

g) 103·MW

h) 0.928

i) The source voltage is less than the load voltage. This is because the load is capacitive and the line is inductive.

3. a) 1.42·kW b) 300.3·W c) 60·% d) 1.71·A e) 998·rpm f) 951.5·rpm

ECE3600 Final given: Fall 13 p4