ECE3600 Final given: Fall 24 12/10/24

Write Legibly! Closed book, Closed notes, Calculator OK.

1. What is the term used for devices which automatically try to restore power shortly after a trip?

2. Why are manually operated disconnect switches placed in substations?

3. What does a GCFI device detect to trip?

4. a) Large breakers come in what two types?

   b) Which type is the newer technology?

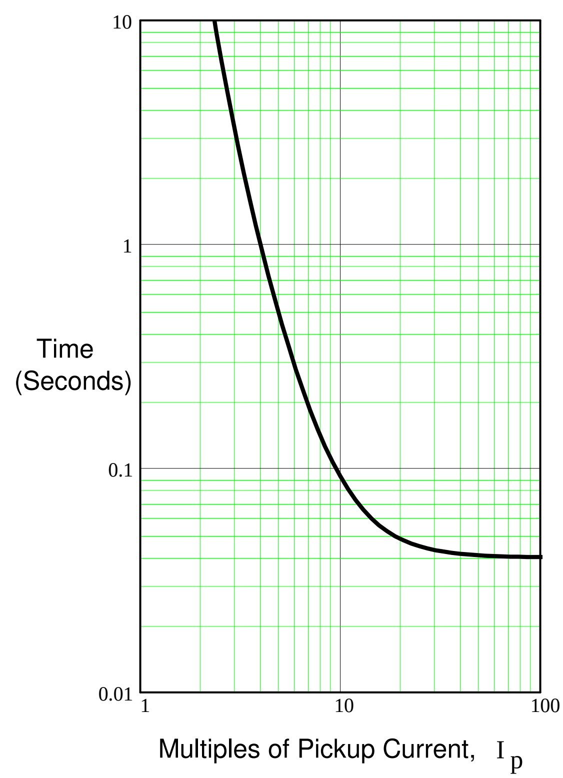
5. What two devices provide critical information to the relays?

6. What is the relationship between relays and breakers.

7. The time-delay curve of an over-current relay is shown.
   a) How long will it take to trip the breaker if the current is 4 times the pickup current?

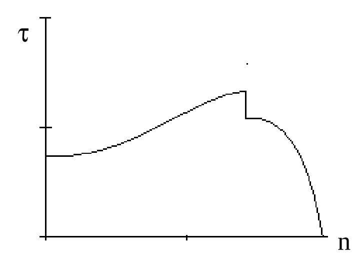
   b) How long will it take to trip the breaker if the current is 6 times the pickup current?

   c) What is the quickest this relay will trip the breaker?



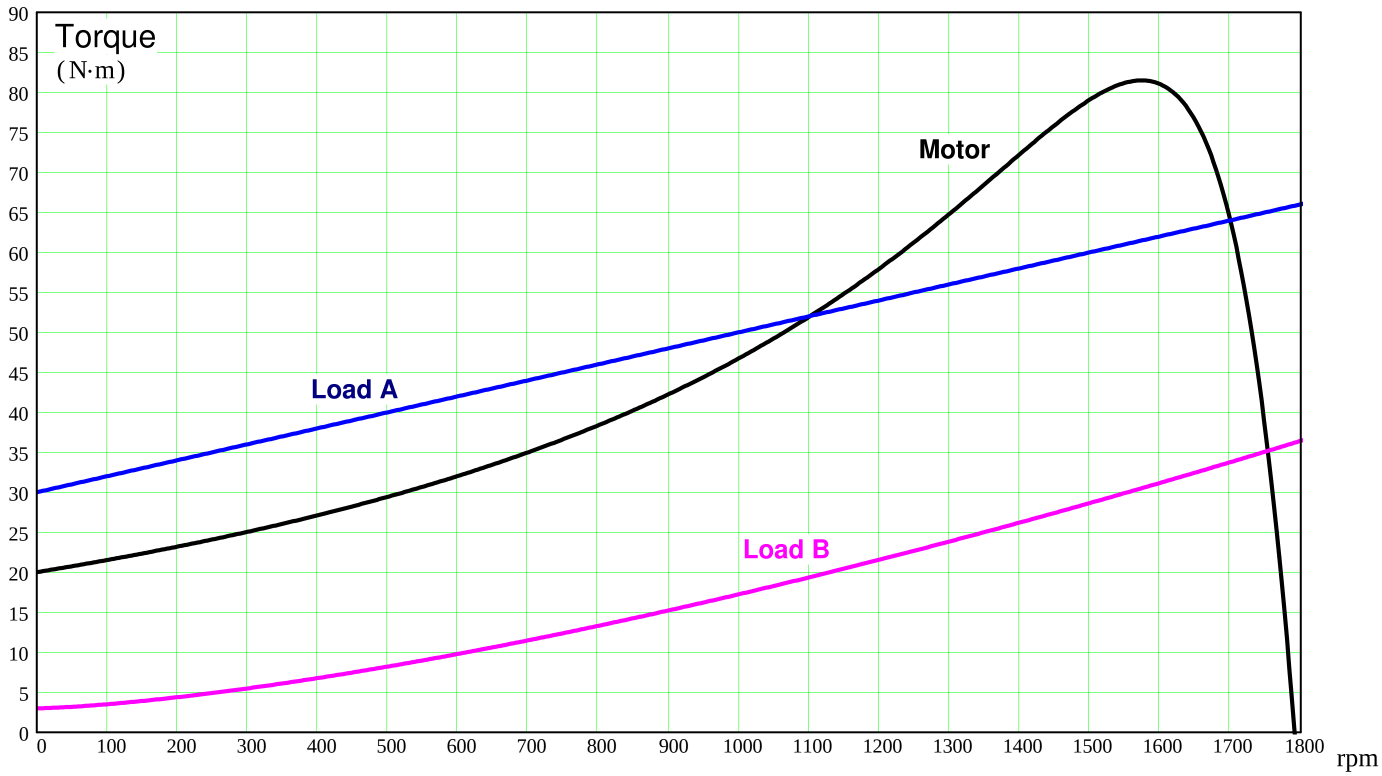
8. How does one set up the relays so as to minimize the impact of a fault on customers?

9. 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?

10. Three torque-speed curves are shown below. One is for a motor and the other two are for two different loads that could be attached to this motor. Most of your answers to the questions below will be approximate.



a) What kind of motor is it? Also state the number of poles, if applicable.

b) The motor is allowed to start with no load attached. After it has reached it's no-load speed, load A is attached. At what steady-state speed will the motor run?

c) If load A is attached to the motor *before* the motor is powered on, at what speed will the motor run after it's powered on and allowed to reach steady-state?

d) The motor is turned off and load B is attached to the motor instead of load A. The motor is then powered on. At some instant during start-up the motor and load will be spinning at 600 rpm. What is the difference between the motor torque and the load torque at that speed?

e) How can the two torques be unequal? What is that torque differential doing?

f) With load B is attached to the motor, at what speed will the motor eventually run?

11.a) DC motors are usually classified by the way the field is created or wired. What are the 4 types of DC motors.

1.

2.

3.

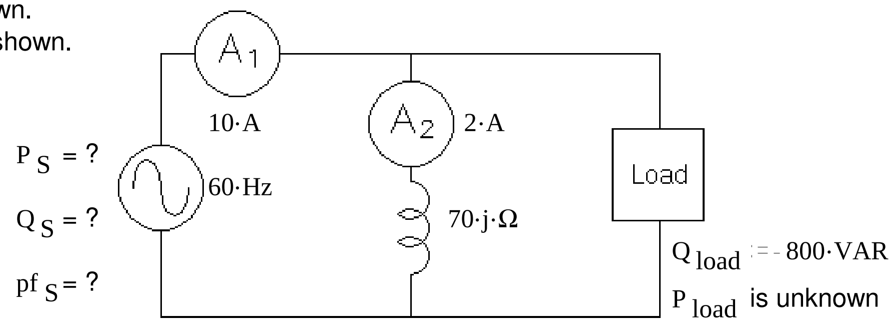
4.

b) One of these types is also commonly used with AC power, which one?

1. (30 pts) Consider the single-phase circuit shown. Two ammeters (A_1 and A_2) read the currents shown.

   Find the following:

   a) The complex power supplied by the source and the power factor as seen by the source.



   b) How much current flows through the load (magnitude).

c) The power factor of the load.

d) Add an additional component to the drawing above in order to completely correct the power factor.
Find the value of the component.

e) With this new component in place, what does ammeter A_1 read now?

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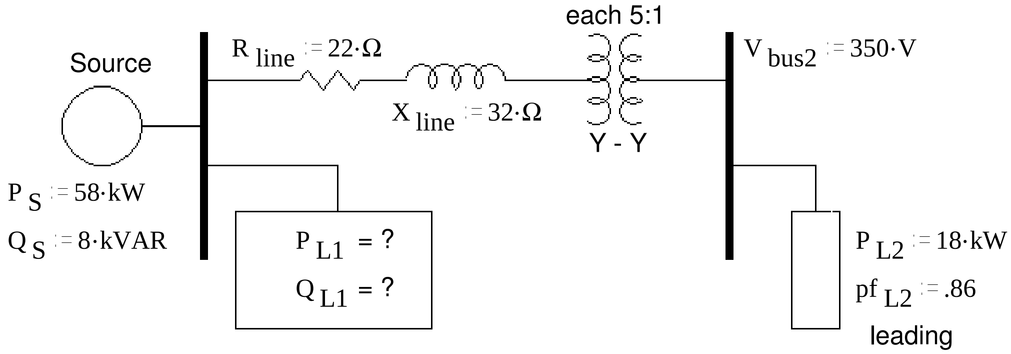
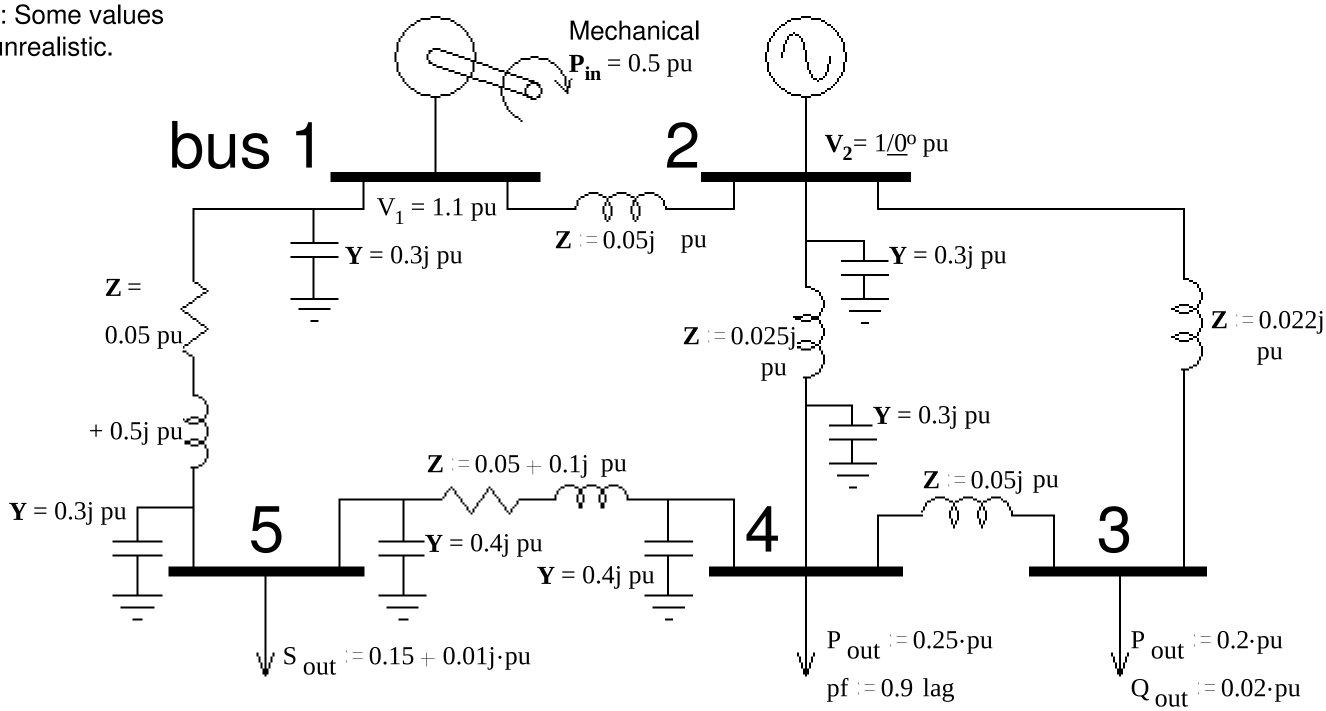
2. (26 pts) A one-line drawing of a 3-phase system is shown. Some 3-phase Ps and Qs are also shown. The 3-phase transformer is made of 3 individual single-phase transformers, each with a 5:1 turns ratio. Consider them to be ideal. They are hooked up Y - Y step-down so that the voltages on the left are 5x the voltages on the right. Remember that bus and line voltages are the same. a) Find the complex power consumed by load 1.

   Hints: Work from load 2 back and if you don't use Ps and Qs to solve this problem it will be VERY HARD!



b) What is the efficiency of this system? $\eta = ?$

3. (24 pts) Consider the small power system shown below. values shown are per-unit. Note: Some values are unrealistic.



a) Identify each bus as "slack", "load", or "generator".

bus 1. ____________ 2. ____________ 3. ____________ 4. ____________ 5. ____________

b) Show $\mathbf{V_1}$, $\mathbf{V_3}$, $\mathbf{V_4}$ and $\mathbf{V_5}$ on the drawing (as letters, not values).

c) Show $\mathbf{I_1}$, $\mathbf{I_2}$, $\mathbf{I_3}$, $\mathbf{I_4}$ and $\mathbf{I_5}$ on the drawing and draw arrows to indicate the direction of each.

d) What is the 5x5 matrix shown below called? ____

$$\begin{bmatrix} \mathbf{I_1} \\ \mathbf{I_2} \\ \mathbf{I_3} \\ \mathbf{I_4} \\ \mathbf{I_5} \end{bmatrix} = \begin{bmatrix} \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & \mathbf{A} \\ \_\_ & \_\_ & \_\_ & \_\_ & \mathbf{B} \end{bmatrix} \cdot \begin{bmatrix} \mathbf{V_1} \\ \mathbf{V_2} \\ \mathbf{V_3} \\ \mathbf{V_4} \\ \mathbf{V_5} \end{bmatrix}$$

e) A number of the elements of the matrix are zero (0). Fill in all the zero elements.

f) Find elements **A** and **B** in the matrix above. I want numerical answers accurate to at least $\pm$ 0.01 pu.

4. (32 pts) A $345\ \text{kV}$ transmission line has the following length and line parameters.

$len := 180 \cdot km$ $\quad r := 0.15 \cdot \frac{\Omega}{km}$ $\quad x := 0.75 \cdot \frac{\Omega}{km}$ $\quad g := 0 \cdot \frac{S}{km}$ $\quad y := 3 \cdot 10^{-6} \cdot \frac{S}{km}$ $\quad S := siemens$

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 voltage at the **source** is 345kV.

The transmission line current ($\mathbf{I_{Line}}$) is 240A and it **leads** the line-to-neutral voltage at the source by 6°.

b) Find the line current from the **source** ($\mathbf{I_S}$) in your model in a complex-number form. $\quad \mathbf{I_S} = ?$

c) Find the load phase voltage, $\mathbf{V_R}$, magnitude and phase. $\mathbf{V_R}$ = ?

d) What is the line voltage at the load (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.

Circle one: Leading

Lagging

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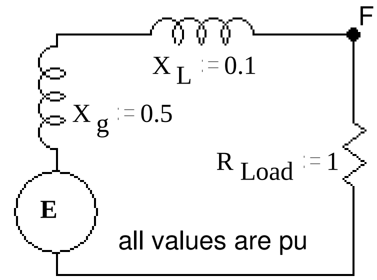

5. (32 pts) One phase of a balanced 3-phase system is shown here.
   A fault occurs point F. It is a dead short from line A to ground.
   a) $\mathbf{E} := 1.2 \cdot pu$ $X''_{g1} := 0.1 \cdot pu$ Find

You do not have enough information to show numbers or find numeric solutions, so just answer sybolically (show variables (letters with subscripts) and expressions).

b) Draw the circuit you would have to analyze to find the fault current.
   Identify the parts and Include the component voltages and currents at the fault.
c) Set up a mathematical expression (or expressions) to find the fault current. If you use thevenin values, make sure you show how to get them from items in the drawing. (Don't forget j & that the fault current is NOT $\mathbf{I}_{A1}$)

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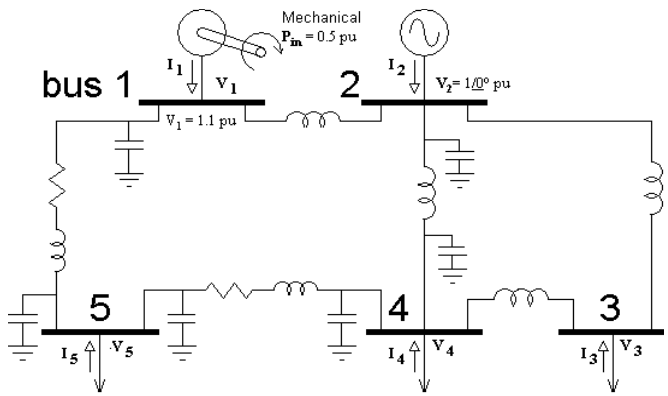
1. Reclosure
2. So that lineman working on the equipment can visually confirm that items are de-energized.
3. A difference between the outgoing and returning currents
4. a) Oil and gas b) gas
5. CTs and VTs
6. Relays control the breakers
8. Set relays so that breakers closest to the fault trip first
7. a) $1 \cdot \text{sec}$ b) $0.3 \cdot \text{sec}$ c) $0.04 \cdot \text{sec}$
9. a) Split-phase or single-phase induction motor b) Centrifugal switch
10. a) 3-phase, 4-pole induction motor b) $1700 \cdot \text{rpm}$ c) $0 \cdot \text{rpm}$ It can't start, load torque > starting torque
    d) $22 \cdot \text{N} \cdot \text{m}$ e) Accelerating the masses of motor rotor and load. f) $1750 \cdot \text{rpm}$ approximately
11. a) 1. Separately excited 2. Series excited 3. Shunt excited 4. Permanent magnet b) Series excited

1. a) $(1.3 - 0.52 \cdot j) \cdot \text{kVA}$ 0.928 b) $10.9 \cdot \text{A}$ c) 0.852 d) Add a 100mH inductor in parallel with the first. e) $9.285 \cdot \text{A}$

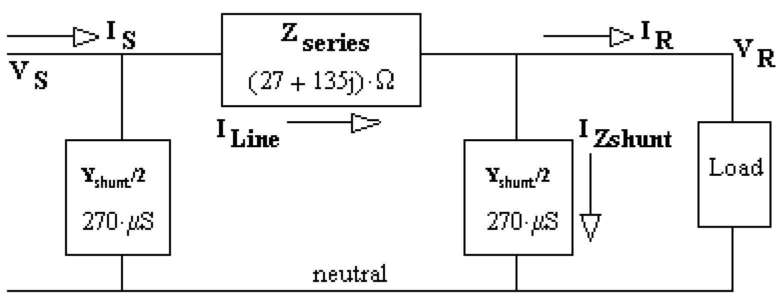
2. a) $36.85 \cdot \text{kW}$ 14.1kVAR b) $94.57 \cdot \%$

3. a) gen, slack, load, load, load
   b) Add $\mathbf{V_1}$, $\mathbf{V_3}$, $\mathbf{V_4}$ and $\mathbf{V_5}$ just like $\mathbf{V_2}$.
   c) Add $\mathbf{I_1}$, $\mathbf{I_2}$, $\mathbf{I_3}$, $\mathbf{I_4}$ and $\mathbf{I_5}$ with all pointing into the bus from outside the system.
   d) Admittance, Bus, or Bus admittance matrix
   e)
$$\begin{bmatrix} \_\_ & \_\_ & 0 & 0 & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ & 0 \\ 0 & \_\_ & \_\_ & \_\_ & 0 \\ 0 & \_\_ & \_\_ & \_\_ & \mathbf{A} \\ \_\_ & 0 & 0 & \_\_ & \mathbf{B} \end{bmatrix}$$



   f) $(-4 + 8 \cdot j) \cdot \text{pu} = 8.944 \cdot \text{pu} \angle 116.57 \cdot \text{deg}$
   $(4.198 - 9.28 \cdot j) \cdot \text{pu} = 10.19 \cdot \text{pu} \angle -65.66 \cdot \text{deg}$

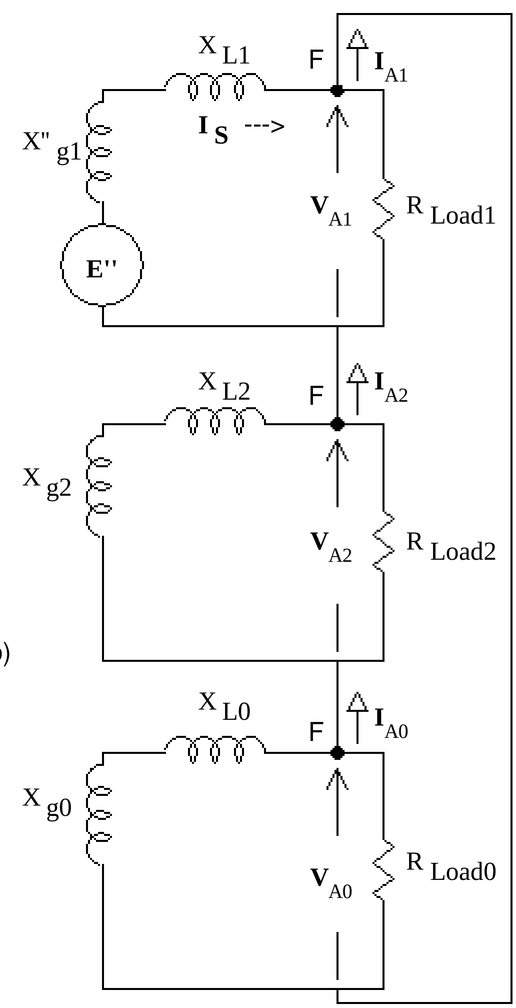
4. a)



   b) $(238.7 + 78.9 \cdot j) \cdot \text{A} = 215.4 \cdot \text{A} \angle 18.3 \cdot \text{deg}$
   c) $(196.1 + 32.9 \cdot j) \cdot \text{kV} = 198.9 \cdot \text{kV} \angle -9.523 \cdot \text{deg}$
   d) $344.5 \cdot \text{kV}$ e) $9.523 \cdot \text{deg}$
   f) $(858.2 - 39.1 \cdot j) \cdot \Omega = 859.1 \cdot \Omega \angle -2.61 \cdot \text{deg}$
   g) $138.0 \cdot \text{MW}$ h) 0.999 Leading

5. a) $(0.988 - 0.353 \cdot j) \cdot \text{pu} = 1.049 \cdot \text{pu} \angle -19.65 \cdot \text{deg}$

   b)



   c) $$\mathbf{I_S} = \frac{\mathbf{E''}}{\left(X''_{g1} + X_{L1}\right) \cdot j + \left(\dfrac{1}{R_{Load1}} + \dfrac{1}{\mathbf{Z_{Th2}} + \mathbf{Z_{Th0}}}\right)}$$

$$\mathbf{V_{A1}} = \mathbf{E''} - \mathbf{I_S} \cdot \left(X''_{g1} + X_{L1}\right)$$

$$\mathbf{I_A} = 3 \cdot \mathbf{I_{A1}} = 3 \cdot \frac{\mathbf{V_{A1}}}{\mathbf{Z_{Th2}} + \mathbf{Z_{Th0}}}$$