ECE 525 Exam 1 July 2019

EXAMINATION RULES

1. This is an open-book/open-note take-home exam.
2. I can e-mail a MathCAD or Mathcad Prime file with the exam problems to you if you would like a copy.
3. Do your own work on this examination. You are on your honor. Therefore, you will neither give nor receive aid on this examination, except from the *course* instructor. If you violate this trust, you will receive the grade of zero for this examination.
4. Show all of your work! Make it neat. *No* partial credit will be given if I can not easily follow your work.
5. ***You have 3 days to complete the exam the exam from the time you receive it from your proctor.***
6. Pease read and sign the following statement when you finish the exam:

I certify that I have neither given nor have I received any help on this examination, except from the course instructor.

SIGNED: ____

PRINTED NAME:_______________________________________

DATE:_______________

1. _______________/25 pts

2. _______________/20 pts

3. _______________/25 pts

4. _______________/30 pts

Total: _______________/100 pts

1. (25 pts) Overcurrent Protection

(a) How does one determine the coordinating time between a protective device and a downstream device? Explain how this is implemented in a protection scheme if inverse time overcurrent elements are used? How might you implement it if you are only using instantaneous overcurrent elements?

(b) Why would an inverse time overcurrent could be combined with instantaneous overcurrent element? Sketch a combined characteristic for such an implementation and describe how it works. Describe an application where this would be used.

(c) How could symmetrical component based overcurrent elements improve the performance of overcurrent elements? What are the advantages? Is any special equipment needed to implement zero sequence or negative sequence based elements?

(d) As you begin setting inverse time overcurrent relays for a radial distribution system, the short circuit MVA looking into the transmission system is given as a range from 66 MVA to 90 MVA. Which value do you when determining minimum pick up levels for the relays and reclosers in the circuit? Which do you use for determining time dial settings?

(e) Due to power quality problems arising from voltage sags, an inductive reactance is added in the neutral to ground path of a transformer supplying several distribution feeders. Assuming the overcurrent protection uses phase elements and ground elements, will any settings need to be changed as a result? If so, which ones and how are they changed?

2. (20 pts) Current Transformers:

A. Describe what causes a CT to saturate. Comment on how this differs if the current is only at fundamental frequency versus a combination of fundamental frequency and a decaying dc offset.

B. How would CT saturation impact the performance of a overcurrent relay? If this causes a misoperation, in what way will it misoperate? Will it eventually give a correct output? Support your answer for each.

C. Do CT's work better with a small burden impedance or a large burden impedance? Explain

D. Explain why it is a bad idea for an unused CT to be open circuited? Does an open circuited CT impact the primary side power system? What should you do with a CT when the output is not needed (possibly temporarily)?

E. Is it sufficient to delay the onset of saturation or must it be avoided altogether? If so, how do you decide how much delay is acceptable? Explain

3. (25 pts) Voltage Transformers:

A. Would you be concerned about using a wound VT to measure voltage harmonics or other high frequency disturbances? How about if you only want to detect a transient event has occurs rather than accurate magnitude and angle? Explain your answer.

B. Repeat part A for a CVT. Explain your answer.

C. What options can be chosen to improve CVT performance when choosing a CVT? What are the trade-offs with these options?

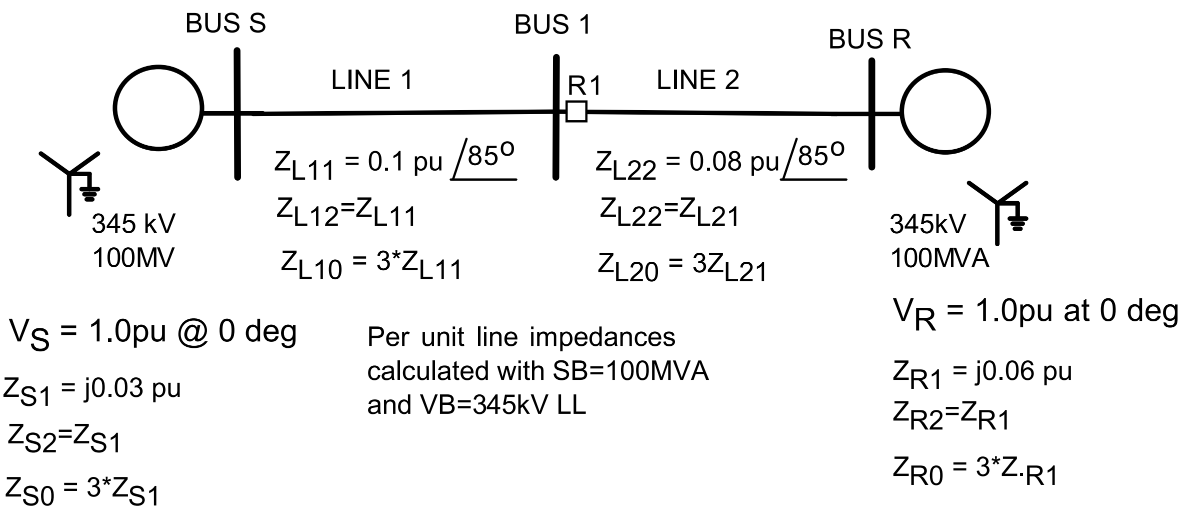
D. Is saturation normally a concern for VTs or CVTs? Are there circumstances where it could arise? Explain your answer and describe any circumstances.

E. How might a CVT transient impact the performance of a protective relay response? Out of the types of elements discussed so far, which are more likely to be effected?

4. (30 pts) The voltage and current magnitudes and angles provided below the figure are the results as seen by a relay located at R1 on a simulated power system. Assume the primary side MVA base of 100MVA, and a voltage base of 345kV and a CTR of 1500/5 and PTR of 345kV/120V for the power system shown below. Assume that you have a relay with a directional element located at R1 with the forward direction set to look into LINE 2. The relay have multiple directional elements available to operate in parallel.

Do the following:

(a) [4 pts] Determine the value for the maximum torque angle (explain your reasoning behind this selection). Also explain why you need a maximum torque angle.
(b) [20 pts] Determine the direction to fault relative to the relay location using at least two significantly different methods for each fault and also try to identify the fault type. Explain how you made this determination and why you selected the methods you used (this reasoning may differ by case)
(c) [6 pts] List the settings you used for the directional elements in part (b). Note that you should not have different settings for each of the 4 cases, just a single set of settings. Also include any elements to qualify the elements to ensure security against misoperation.



CASE A:

$$\left|I_{abcFA}\right| = \begin{pmatrix} 5.2658 \\ 5.2658 \\ 5.2658 \end{pmatrix} \text{pu} \qquad \arg\left(I_{abcFA}\right) = \begin{pmatrix} -85.7889 \\ -205.7889 \\ 34.2111 \end{pmatrix} \text{deg}$$

$$\left|V_{abcFA}\right| = \begin{pmatrix} 0.3159 \\ 0.3159 \\ 0.3159 \end{pmatrix} \text{pu} \qquad \arg\left(V_{abcFA}\right) = \begin{pmatrix} -0.7889 \\ -120.7889 \\ 119.2111 \end{pmatrix} \text{deg}$$

CASE B:

$$\left|I_{abcB}\right| = \begin{pmatrix} 0 \\ 4.3201 \\ 4.3201 \end{pmatrix} \text{pu} \qquad \arg\left(I_{abcB}\right) = \begin{pmatrix} 0 \\ -10.3489 \\ -162.5532 \end{pmatrix} \text{deg}$$

$$\left|V_{abcB}\right| = \begin{pmatrix} 1.1935 \\ 0.3228 \\ 0.3228 \end{pmatrix} \text{pu} \qquad \arg\left(V_{abcB}\right) = \begin{pmatrix} 0.1121 \\ -121.451 \\ 118.549 \end{pmatrix} \text{deg}$$

CASE C:

$$\left|I_{abcC}\right| = \begin{pmatrix} 3.2957 \\ 1.2874 \\ 1.2874 \end{pmatrix} \text{pu} \qquad \arg\left(I_{abcC}\right) = \begin{pmatrix} -76.9625 \\ -126.6662 \\ 113.3338 \end{pmatrix} \text{deg}$$

$$\left|V_{abcC}\right| = \begin{pmatrix} 0.3159 \\ 1.1271 \\ 1.156 \end{pmatrix} \text{pu} \qquad \arg\left(V_{abcC}\right) = \begin{pmatrix} -0.7889 \\ -142.0355 \\ 121.4844 \end{pmatrix} \text{deg}$$

CASE D:

$$\left|I_{abcD}\right| = \begin{pmatrix} 1.2874 \\ 1.2452 \\ 2.2247 \end{pmatrix} \text{pu} \qquad \arg\left(I_{abcD}\right) = \begin{pmatrix} -6.6662 \\ 50.4357 \\ -158.6344 \end{pmatrix} \text{deg}$$

$$\left|V_{abcD}\right| = \begin{pmatrix} 0.9833 \\ 1.0374 \\ 0.6938 \end{pmatrix} \text{pu} \qquad \arg\left(V_{abcD}\right) = \begin{pmatrix} -9.6265 \\ -149.5794 \\ 96.1953 \end{pmatrix} \text{deg}$$