Name: ________Answers______

ECEN 615

Exam #1

Tuesday, October 8, 2019

75 Minutes

Closed book, closed notes

One 8.5 by 11 inch note sheet allowed

Calculators allowed

1. ________ / 26

2. ________ / 24

3. ________ / 30

4. ________ / 20

Total ________ / 100

1. (26 points total)

For a three-phase electric grid, a generator bus (slack bus) supplies a 100 MW, 50 Mvar constant power load through a lossless transmission line whose parameters on 100 MVA three-phase base using the pi-model from class are Z = j0.15 per unit and Y/2 = j0.1 per unit. Also, there is a 10 Mvar shunt capacitor at the load bus.

A) Give the bus admittance matrix ($\mathbf{Y_{bus}}$) for the system.

$$\mathbf{Y}_{bus} = j\begin{bmatrix} -6.57 & 6.67 \\ 6.67 & -6.47 \end{bmatrix}$$

B) Calculate the voltage magnitude and angle at the load bus using the Newton-Rapson method. Use the flat-start with the slack bus voltage = 1.0 $\angle 0°$. Provide the values after the second iteration.

$$\mathbf{x}^{(0)} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \quad \mathbf{f}\left(\mathbf{x}^{(0)}\right) = \begin{bmatrix} 1 \\ 0.3 \end{bmatrix}, \quad \mathbf{J}\left(\mathbf{x}^{(0)}\right) = \begin{bmatrix} 6.67 & 0 \\ 0 & 6.27 \end{bmatrix}$$

$$\mathbf{x}^{(1)} = \begin{bmatrix} 0 \\ 1 \end{bmatrix} - \begin{bmatrix} 6.67 & 0 \\ 0 & 6.27 \end{bmatrix}^{-1} \begin{bmatrix} 1 \\ 0.3 \end{bmatrix} = \begin{bmatrix} -0.15 \\ 0.952 \end{bmatrix}$$

$$\mathbf{x}^{(2)} = \begin{bmatrix} -0.15 \\ 0.952 \end{bmatrix} - \begin{bmatrix} 6.28 & -1 \\ -0.95 & 5.72 \end{bmatrix}^{-1} \begin{bmatrix} 0.051 \\ 0.086 \end{bmatrix} = \begin{bmatrix} -0.161 \\ 0.935 \end{bmatrix}$$

2. (24 points total) (True/false)

Two points each. Circle T if statement is true, F if statement is False.

T **F** 1. Dispite concerns about the need to reduce carbon dioxide emissions, coal continues to be the source for most of the electricity generated in the US (as of the end of 2018).

T F 2. As of the end of 2018 Texas was the state with the most installed wind generation.

T F 3. The presence of a constant power load in a series dc circuit can result in multiple solutions for the load voltage and current.

T **F** 4. While dependent on the system topology, power transfer distribution factors (PTDFs) are independent of the transmission line impedance values

T **F** 5. The Bus Admittance Matrix (Y_{bus}-matrix) for a power system is guaranteed to never be singular

T **F** 6. For per-unit analysis, the impedance base is always the same everywhere in the system.

T F 7. For a phase-shifting transformer the transformer's impedance could be depedent upon the transformer's phase angle shift

T **F** 8. For North American electric grids, the North American Electric Reliabliity Corporation (NERC) requires that generators be operated at close to their maximum reactive power output in order to minimize system losses.

T F 9. If a real n by n matrix **A** is sparse and non-singular, sparse vector methods can be used to determine diagonal elements of the inverse of **A**.

T **F** 10. When solving a large case with the power flow with no generators on automatic generation control (AGC), any increase in the assumed real power output of one generator tends to get absorbed by nearby generators.

T **F** 11. The dc power flow algorithm discussed in class is most useful for modelling electric grids with a large number of high voltage DC (HVDC) transmission lines.

T F 12. Power flow topology processing can be used to determine if a power system model has multiple islands;

3. (Short Answer: 30 points total – five points each)
(note the problem continues on next page)

1. Give two reasons why the slack (reference) bus is needed for the power flow problem.

   To insure total generation is equal to total load plus losses and to provide an angle reference

2. Why would phase shifting transformers be used in a power system?

   Phase shifters can be used to control the power flow through the transformer itself or across an interface (such as the example given in class)

3. Explain circulating vars (circulating reactive power) including its relationship to transformer taps. Also address how to eliminate circulating vars.

   Circulating vars are caused by unbalanced transformer taps. When present there could be a large amount of reactive power flowing circulating through a loop of transformers. This can cause increased losses and increased transformer heating. Circulating vars can be eliminated by balancing the transformer taps.

Problem 3 continues on the next page

4. What are three of the key assumptions in developing the fast decoupled power flow? Explain why these assumptions are often reasonable for a high voltage power grid.

1) Transmission line/transformer resistance is low realative to reactance allowing the conductance terms to be ignored. 2) Voltage magnitudes are close to one per unit. 3) The phase angles across the lines are low. This is usually the case for a high voltage power system.

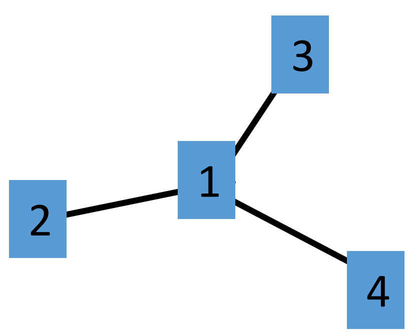
5. If you were to use the Newton-Raphson algorithm to solve $f(x) = x^3 - 3x^2 + x - 4 = 0$, what is an initial guess that would not work? Why?

An initial guess that results in a zero derivative would not work.

$$\frac{df(x)}{dx} = 3x^2 - 6x + 1 = 0 \rightarrow x = 1.816 \text{ or } 0.184$$

6. With topologically symmetric sparse matrices we discussed the concept of fills. What are fills and why are they needed? Draw a four bus network and arbitrarily label the buses 1 to 4. Then add some connections between the buses such that with your bus order and connections some fills would be required.

Fills are elements in a sparse matrix that are initially zero but can become non-zero when the matrix is factored. Hence there needs to be space to store this value. The below network would require fills but the fills could be eliminated by reordering (i.e., set the center bus number to 4).



4. (20 points total)

A. Give the LU factorization for the matrix

$$\mathbf{A} = \begin{bmatrix} 10 & -5 & 0 & 0 \\ -5 & 15 & -8 & 0 \\ 0 & -8 & 12 & -2 \\ 0 & 0 & -2 & 4 \end{bmatrix}$$

$$\mathbf{L} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -0.5 & 1 & 0 & 0 \\ 0 & -0.64 & 1 & 0 \\ 0 & 0 & -0.29 & 1 \end{bmatrix} \quad \mathbf{U} = \begin{bmatrix} 10 & -5 & 0 & 0 \\ 0 & 12.5 & -8 & 0 \\ 0 & 0 & 6.88 & -2 \\ 0 & 0 & 0 & 3.42 \end{bmatrix}$$

B. The LU factorization is given below for matrix (different from the one of part A) along with a vector **b**. Give the vector **y** from the forward substitution and the vector **x** from the backward substitution.

$$\mathbf{L} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -0.5 & 1 & 0 & 0 \\ 0 & -0.4 & 1 & 0 \\ 0 & 0 & -0.278 & 1 \end{bmatrix} \quad \mathbf{U} = \begin{bmatrix} 2 & -1 & 0 & 0 \\ 0 & 2.5 & -1 & 0 \\ 0 & 0 & 3.6 & -1 \\ 0 & 0 & 0 & 1.722 \end{bmatrix} \quad \mathbf{b} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\mathbf{y} = \begin{bmatrix} 1 \\ 0.5 \\ 0.2 \\ 1.0556 \end{bmatrix} \quad \mathbf{x} = \begin{bmatrix} 0.645 \\ 0.290 \\ 0.226 \\ 0.613 \end{bmatrix}$$