Name: _________Answers_________

ECEN 615

Exam #1

Thursday, October 18, 2018

75 Minutes

Closed book, closed notes

One 8.5 by 11 inch note sheet allowed

Calculators allowed

1. _________ / 24

2. _________ / 35

3. _________ / 20

4. _________ / 21

Total _________ / 100

1. (24 points total) (True/false)

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

<u>T</u>	F	1.	The phase angle of a phase-shifing transformer could be varied to control the amount of real power flowing through it.
T	**<u>F</u>**	2.	The number of PV/PQ buses always remains the same throughout the full process of solving the Newton-Raphson power flow.
T	**<u>F</u>**	3.	Capacitor banks should be switched on if the bus voltage is higher than needed.
T	**<u>F</u>**	4.	To minimize the total generation costs of a congested interconnected power system, the electricity market operator will always change the generators with the least incremental operating cost.
T	**<u>F</u>**	5.	Because the Dishonest Newton method uses the same Jacobian matrix for a few iterations and hence saves the computational time to solve for a new Jacobian at each iteration, it always takes less time to converge than the original Newton-Raphson method.
T	**<u>F</u>**	6.	Tinney scheme 2 is guaranteed to give the optimal ordering of sparse matrices to minimize the total number of fill-ins
<u>T</u>	F	7.	Circulating reactive power can be caused by having mismatched transformer taps.
T	**<u>F</u>**	8.	Texas is unique in that all electric load in the state is served by the Electric Reliability Council of Texas (ERCOT) and there are no ac connections to the rest of the country.
T	**<u>F</u>**	9.	Trying to specify more than one slack bus in a power flow with a single electric island will always result in a singular Jacobian.
<u>T</u>	F	10.	Power flow topology processing is used (in part) to determine when a power system model has multiple islands.
T	**<u>F</u>**	11.	Despite years of research, it is still essentially impossible to perform power system contingency analysis in parallel because of the inherent Jacobian coupling between the various contingency bus voltages
T	**<u>F</u>**	12.	A key advantage of the dc power flow is that one does not need to specify a slack bus.

2. (Short Answer: 35 points total – five points each (note problem continues on next page)

Your answers to not need to be more than 3 or 4 sentences at maximum, and some problems require less

a. For the equation $f(x) = x^3 - 10x^2 - 12x - 30 = 0$, starting with an initial guess of x =1, use Newton-Raphson to determine the value of x after the second iteration.

x(1)= -0.759, x(2)=4.77

b. What are power transfer distribution factors, how are they used, and how could you approximate them using a power flow (recognizing we have not yet covered analytic methods for calculating them)?

PTDFs tell the percentage of a particular real power transfer (between a seller and buyer) that flows on individual transmission lines and transforers. They could be approximated in the power flow by solving an initial power flow and noting the initial flows. Then apply the power transfer, calculate the difference in the flows and normalize by the transfer amount.

c. For power flow solutiuons give and explain the advantages and disadvantages of using the bus-branch versus node-breaker models.

Bus-branch tends to be used in planning in which one does not necessarily know the substation detail. The bus-branch models have fewer elements and few zero impedance branches. But they lack the detail of the node-breaker. The node-breaker is used in real-time operations and has full substation topology details. Hence it has more elements and requires some sort of topology processing to combine the nodes joined by zero impedance elements.

d. Assume there is a transformer between buses 1 and 2 with per unit impedance of z = 0.03 + j0.04, and that there is a off-nominal tap on the bus 1 side with a value of 1.05. Given the 2 by 2 bus admittance matrix for this transformer.

$$\mathbf{Y}_{\mathbf{bus}} = \begin{bmatrix} \dfrac{12-j16}{1.05^2} & \dfrac{-12+j16}{1.05} \\ \dfrac{-12+j16}{1.05} & 12-j16 \end{bmatrix} = \begin{bmatrix} 10.88-j14.51 & -11.43+j15.24 \\ -11.43+j15.24 & 12-j16 \end{bmatrix}$$

2. Continued

e. Using the LU approach, factor the matrix $\mathbf{A} = \begin{bmatrix} 2 & 0 & 4 \\ 0 & 1 & 4 \\ 4 & 4 & 8 \end{bmatrix}$

$$\mathbf{A} = \begin{bmatrix} 2 & 0 & 4 \\ 0 & 1 & 4 \\ 4 & 4 & 8 \end{bmatrix} = \mathbf{LU} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 2 & 4 & 1 \end{bmatrix} \begin{bmatrix} 2 & 0 & 4 \\ 0 & 1 & 4 \\ 0 & 0 & -16 \end{bmatrix}$$

f. Explain how PV buses are modeled in the power flow, and how power flow code could be modified to have a generator regulate the voltage at a bus that is not its terminal.

If a generator is regulating its own terminal voltage, then the associated reactive power balance equation could be omitted from the power flow equations. But this causes problems when generators switched from PV to PQ. A preferred alternative is to include the equation of the reactive power balance, but just implement the equation as the terminal voltage magnitude minus the desired voltage magnitude is equal to zero. Zeros are included for first neighbors to avoid having to reorder the Jacobian. To have a generator regulate a remote bus, just switch the equation to have the remote voltage magnitude minus the desired voltage magnitude is equal to zero. However, consideration is required to prevent zero diagonal elements during factoring the Jacobian.

g. Assuming you have a large, sparse, non-singular, symmetric matrix that is already factored. How could you quickly calculate a single diagonal element of the inverse of this matrix?

Use spare vector methods, setting b to all zeros expect a one at the location of the desired diagonal element, say location j. Only xj needs to be calculated, and it will be the desired diagonal element of the matrix inverse. .

3. (20 points total)

The sparsity structure for a matrix **A** is given in the below table.

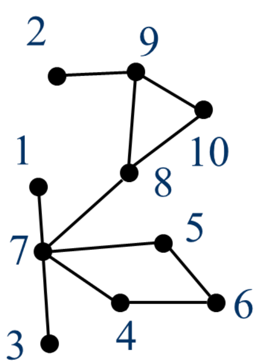
(a) Draw the associated graph of A.

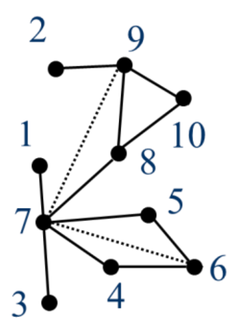
(b) Give the reordering using Tinney Scheme 1. On your graph from part a represent the new fill-ins using dashed lines.

(c) Give the reording using Tinney Scheme 2. Recopy the graph from part a (without the part b fill-ins), and again show the new fill-ins using dashed lines.

	1	2	3	4	5	6	7	8	9	10
1	X						X			
2		X							X	
3			X				X			
4				X		X	X			
5					X	X	X			
6				X	X	X				
7	X		X	X	X		X	X		
8							X	X	X	X
9		X						X	X	X
10								X	X	X

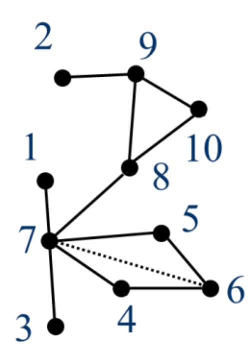
a)





b) Tinney 1 Ordering is 1, 2, 3, 4, 5, 6, 10, 8, 9, 7 (fill-ins between 6-7 and 7-9)

c) Tinney 2 Ordering is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
(fill-ins between 6-7)



4. (21 points total)

A generator bus **with a 1.05 per unit voltage** supplies a voltage dependent load through a lossless transmission line with per unit (100 MVA base) impedance of j0.1 and no line charging. The per unit voltage dependent load is such that the real power load is a constant and the reactive power flow varies with the cube of the bus voltage. That is,

$$P_L = 2.0$$

$$Q_L = 1.0\left|V_L\right|^3$$

where $|V_L|$ is the load bus voltage magnitude.

Starting with an initial voltage guess of **$1.05\angle 0°$**, determine the second iteration value of the load bus voltage (magnitude and angle) using the Newton-Raphson power flow method. ‘

The power balance equations at the load bus (assumed to be bus 2) are

$$P_2(\mathbf{x}) = |V_1||V_2|\left(10\sin\theta_2\right) + 2 = 0$$

$$Q_2(\mathbf{x}) = |V_1||V_2|\left(-10\cos\theta_2\right) + |V_2|^2\left(10\right) + 1|V_2|^3 = 0$$

where $\mathbf{x} = \begin{bmatrix}\theta_2 \\ |V_2|\end{bmatrix}$ and $|V_1| = 1.05.$

Then $\mathbf{J}(\mathbf{x}) = \begin{bmatrix} |V_1||V_2|\left(10\cos\theta_2\right) & |V_1|\left(10\sin\theta_2\right) \\ |V_1||V_2|\left(10\sin\theta_2\right) & |V_1|\left(-10\cos\theta_2\right) + 2|V_2|\left(10\right) + 3|V_2|^2 \end{bmatrix}$

$$\rightarrow \mathbf{x}^{(0)} = \begin{bmatrix}0 \\ 1.05\end{bmatrix} \rightarrow \mathbf{x}^{(1)} = \begin{bmatrix}0 \\ 1.05\end{bmatrix} - \begin{bmatrix}11.025 & 0 \\ 0 & 13.8075\end{bmatrix}^{-1}\begin{bmatrix}2 \\ 1.158\end{bmatrix} = \begin{bmatrix}-0.1814 \\ 0.9661\end{bmatrix}$$

Then repeat

$$\mathbf{x}^{(2)} = \begin{bmatrix}-0.1814 \\ 0.9661\end{bmatrix} - \begin{bmatrix}9.978 & -1.894 \\ -1.830 & 11.794\end{bmatrix}^{-1}\begin{bmatrix}0.170 \\ 0.258\end{bmatrix} = \begin{bmatrix}-0.203 \\ 0.941\end{bmatrix}$$

$$\rightarrow \begin{bmatrix}P_2(\mathbf{x}^{(2)}) \\ \mathrm{Q}_2(\mathbf{x}^{(2)})\end{bmatrix} = \begin{bmatrix}-0.002 \\ 0.012\end{bmatrix}$$