Name: ________________________

ECE 476

Exam #2

Tuesday, November 15, 2011
75 Minutes

Closed book, closed notes
One new note sheet allowed, one old note sheet allowed

1. ________ / 25

2. ________ / 25

3. ________ / 30

4. ________ / 20

Total ________ / 100

1. (25 points total)

A generator bus (with a 1.0 per unit voltage) supplies a 150 MW, 50 Mvar load through a lossless transmission line with per unit (100 MVA base) impedance of j0.1 and no line charging. Starting with an initial voltage guess of $\mathbf{1.0\angle 30^\circ}$, determine the first iteration value of the load bus voltage (magnitude and angle) using the Newton-Raphson power flow method.

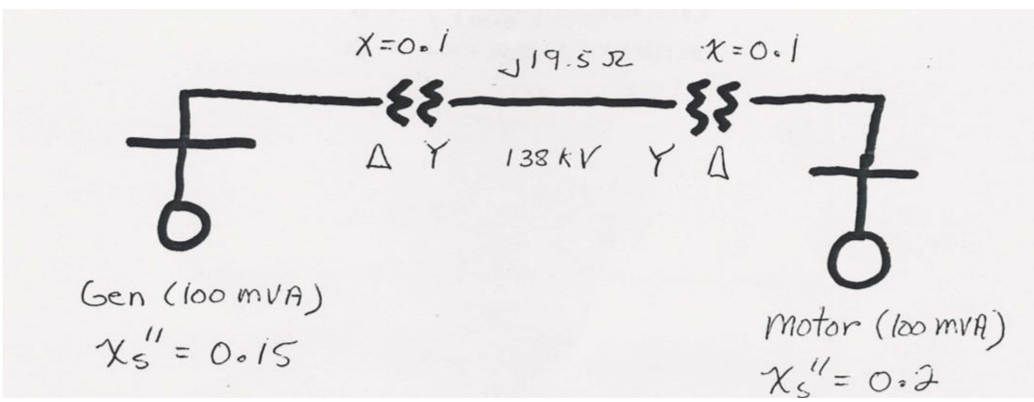
2. (25 points total)

For the balanced, three phase network shown below assume that all data is per unit on a 100 MVA base except for the transmission line reactance. Assume a 20 kV voltage base for the generator and motor, and a 138 kV voltage base for the transmission line.

(10pts) a) If the system is initially operating unloaded with all voltages at 1.0 per unit, what is the magnitude of the fault current (in amps) if a balanced, three phase fault occurs on the terminal of the generator on the left. You should neglect the dc offset current.

(8 pts) b) During the fault from part a, what is the per unit voltage magnitude on the terminal of the motor?

(7 pts) c) Repeat part a, except now assume that the generator is supplying 100 MVA with a 0.8 lagging power factor and a terminal voltage of 1.0 per unit.



3. Short Answer, ten problems, three points each

1. In the Fast Decoupled Power Flow formulation, we assume that:
   A. Shunt admittances (G) are zero and voltages are 1p.u. in the Jacobian
   B. sin(x)=0 and cos(x)=1
   C. Reactive power flows (Q) are negligible
   D. All of the above

2. For a solid (no fault impedance) single-line-to-ground fault the sequence networks are connected
   A. In parallel
   B. In a star configuration
   C. In series
   D. Just the positive and negative networks are connected since there is no fault impedance

3. Congestion on transmission lines (ie flows reaching line limits) will tend to cause Local Marginal Prices (LMPs) to:
   A. Always decrease
   B. Stay the same
   C. Always increase
   D. Some may increase and some may decrease

4. An impedance (distance) relay on a particular line may also act as a backup for a relay on another line. True or false?
   T. True
   F. False

5. A balanced three phase fault is the most common type of transmission line fault. True or false?
   A. True
   B. False

6. Generator penalty factors relate power generation to system losses. What values can the penalty factor for the slack bus (L_{slack}) have:
   A. $0 < L_{slack} < 1$
   B. $L_{slack} = 1$
   C. $L_{slack} > 1$
   D. Any value greater than 0

Continued on Next Page

7. For which fault types will there be a zero sequence current that is non-zero:
   A. 3 phase, L-L, SLG, DLG
   B. L-L, SLG, DLG
   C. SLG, DLG
   D. 3 phase, L-L

8. A wind turbine with just an induction generator (a Type 1 design) is usually modeled in the power flow as a PV bus. True or false?
   T. True
   F. False

9. Pick the positive sequence set:
   A. a = $0.5\angle 0°$, b = $1.0\angle +120°$, c = $2.0\angle -120°$
   B. a = $0.5\angle 0°$, b = $1.0\angle -120°$, c = $2.0\angle +120°$
   C. a = $0.5\angle 0°$, b = $1.0\angle 0°$, c = $2.0\angle 0°$
   D. a = $1.0\angle 30°$, b = $1.0\angle -90°$, c = $1.0\angle +150°$

10. For the general minimization problem $\min_x f(x)\ s.t.\ g(x) = 0$, we define the Lagrangian as $L(x, \lambda) = f(x) + \lambda^T g(x)$. Then $\nabla_\lambda L(x, \lambda) = 0$ is just a restatement of $g(x) = 0$. True or false?
    T. True
    F. False

4. (Short Answer: 20 points total – five points each)

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

B. Explain how you could use power flow analysis to approximate the penalty factor for a generator?

C. What is the purpose of power system economic dispatch, and what is a necessary condition for an economic dispatch of the generation?

D. An ideal inductor with L = 1 H is connected in series with an ac voltage source (**v(t) = sin(t) volts**) and a switch. The switch, which is initially open, is closed at t = 0. Sketch the current through the circuit (as a function of time) for the first few cycles for $t \geq 0$.

Quiz 2

ECE 476

Name:______________________

1. A 60-Hz single –phase, two-wire overhead line has solid cylindrical copper conductors with 2.4 cm diameter. The conductors are arranged in a horizontal configuration with 3 m spacing. Calculate the inductance of each conductor due to both internal and external flux linkages in mH/km (40 points).

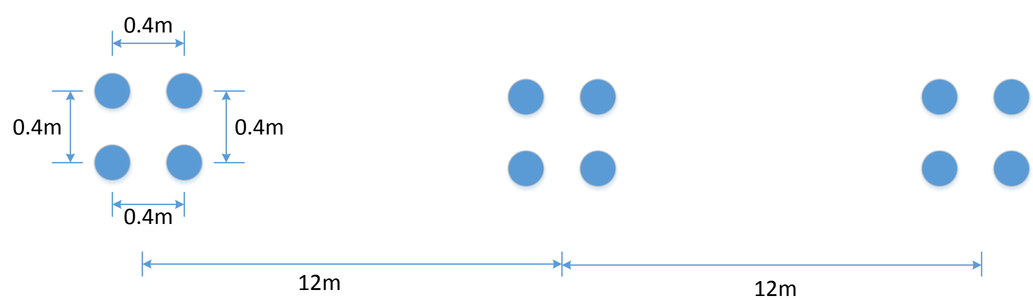
$$L_x = L_y = 2 \times 10^{-7} Ln\left(\frac{D}{r'}\right) H/m$$

$$D = 3m$$

$$r' = 0.7788 \times r = 0.7788 \times \left(\frac{0.024}{2}\right) = 9.346 \times 10^{-3}$$

$$L_x = L_y = 2 \times 10^{-7} Ln\left(\frac{3}{9.346 \times 10^{-3}}\right)\frac{H}{m}\left(\frac{1000m}{km}\right)\left(\frac{1000mH}{H}\right) = 1.154\, mH/km$$

2. The figure below is a completely transposed three-phase overhead transmission line with bundled phase conductors. All conductors have a radius of 2 cm.



   a. Determine the inductance per phase in mH/km (40 points).

$$r' = 0.7788 * 0.02 = 0.0156$$

$$R_b = \sqrt[4]{(r')(0.4)(0.4)\left(\sqrt{2} \times 0.4\right)} = 0.1938m$$

$$D_{eq} = \sqrt[3]{D_{AB}D_{BC}D_{CA}} = \sqrt[3]{(12)(12)(24)} = 15.12m$$

$$L = 0.2Ln\left(\frac{D_{eq}}{R_b}\right) = 0.2Ln\left(\frac{15.12}{0.1938}\right) = 0.8714\, mH/km$$

   b. Find the inductive line reactance per phase in Ω/km at 60 Hz (20 points).

$$X = \omega L = 2\pi 60 \times 0.8714 \times 10^{-3} = 0.3285\, \Omega/km$$

Name: Solutions

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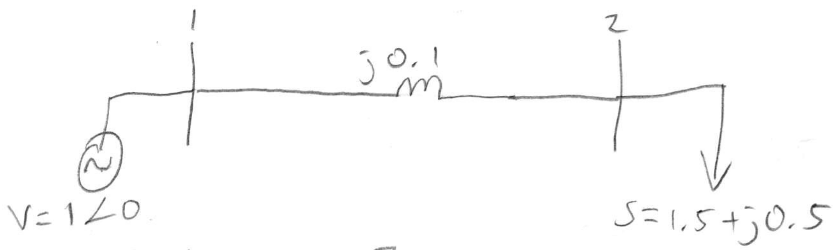
Total ________	/ 100

1. (25 points total)

A generator bus (with a 1.0 per unit voltage) supplies a 150 MW, 50 Mvar load through a lossless transmission line with per unit (100 MVA base) impedance of j0.1 and no line charging. Starting with an initial voltage guess of **1.0∠30°**, determine the first iteration value of the load bus voltage (magnitude and angle) using the Newton-Raphson power flow method.



$$Y_{bus} = \begin{bmatrix} -j10 & j10 \\ j10 & -j10 \end{bmatrix}$$

$$X = \begin{bmatrix} \theta_2 \\ V_2 \end{bmatrix} \qquad y = \begin{bmatrix} P_2 \\ Q_2 \end{bmatrix} = \begin{bmatrix} -1.5 \\ -0.5 \end{bmatrix} \qquad f(x) = \begin{bmatrix} P_2(x) \\ Q_2(x) \end{bmatrix}$$

Iteration 0

$$X_0 = \begin{bmatrix} 30^\circ \\ 1 \end{bmatrix} = \begin{bmatrix} \pi/6 \text{ rad} \\ 1 \end{bmatrix}$$

$$f(X_0) = \begin{bmatrix} P_2(X_0) \\ Q_2(X_0) \end{bmatrix} = \begin{bmatrix} V_1 V_2 B_{12} \sin(\theta_2) \\ V_1 V_2 (-B_{12}) \cos(\theta_2) + V_2^2(-B_{22}) \end{bmatrix}$$

$$= \begin{bmatrix} 1 \times 1 \times 10 \sin(30) \\ 1 \times 1 \times (-10) \cos(30) + 1^2 (10) \end{bmatrix}$$

$$= \begin{bmatrix} 5 \\ 1.34 \end{bmatrix}$$

$$J(x) = \begin{bmatrix} \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial V_2} \\ \frac{\partial Q_2}{\partial \theta_2} & \frac{\partial Q_2}{\partial V_2} \end{bmatrix}$$

$$\frac{\partial P_2}{\partial \theta_2} = -1\,(10 \times 1 \times \sin(30-90)) = 8.66$$

$$\frac{\partial P_2}{\partial V_2} = 1 \times 10 \cos(-90) + 10 \times 1 \times \cos(30-90) + 10 \times 1 \times \cos(90) = 5$$

$$\frac{\partial Q}{\partial \theta_2} = 1 \times (10 \times 1 \cos(30-90)) = 5$$

$$\frac{\partial Q_2}{\partial V_2} = -1 \times 10 \sin(-90) + 10 \times 1 \times \sin(30-90) + 10 \times 1 \times \sin(90) = 11.34$$

$$J(X_0) = \begin{bmatrix} -5 & -1.34 \\ -1.34 & 5 \end{bmatrix}$$

Iteration 1

$$X_1 = \begin{bmatrix} \pi/6 \\ 1 \end{bmatrix} + \begin{bmatrix} 8.66 & 5 \\ 5 & 11.34 \end{bmatrix}^{-1} \begin{bmatrix} -1.5-5 \\ -0.5-1.34 \end{bmatrix} = \begin{bmatrix} -0.358 \\ 1.23 \end{bmatrix}$$

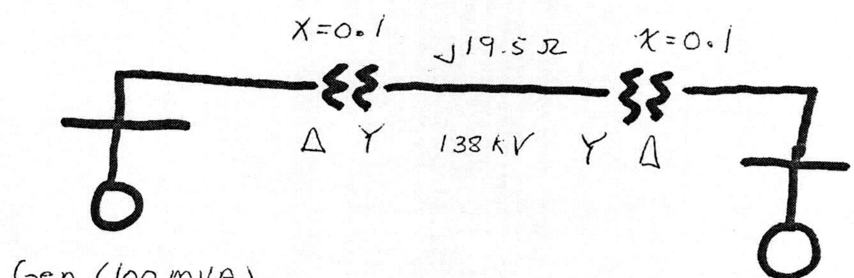
2. (25 points total)

For the balanced, three phase network shown below assume that all data is per unit on a 100 MVA base except for the transmission line reactance. Assume a 20 kV voltage base for the generator and motor, and a 138 kV voltage base for the transmission line.

(10pts) a) If the system is initially operating unloaded with all voltages at 1.0 per unit, what is the magnitude of the fault current (in amps) if a balanced, three phase fault occurs on the terminal of the generator on the left. You should neglect the dc offset current.

(8 pts) b) During the fault from part a, what is the per unit voltage magnitude on the terminal of the motor?

(7 pts) c) Repeat part a, except now assume that the generator is supplying 100 MVA with a 0.8 lagging power factor and a terminal voltage of 1.0 per unit.



Gen (100 MVA)

$X_s'' = 0.15$

Motor (100 MVA)

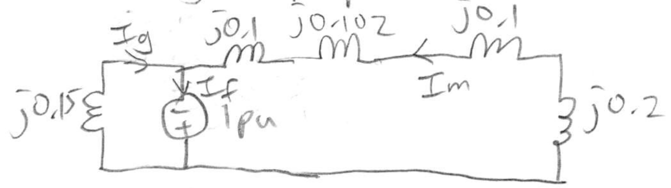
$X_s'' = 0.2$

a) Convert line impedance to p.u.

$Z_{base} = \frac{V_{base}^2}{S_{base}} = \frac{138^2}{100} = 190.44$

$Z = \frac{j19.5}{190.44} = j0.102$

Using superposition



$I_g = \frac{1}{j0.15} = -j6.667$

$I_m = \frac{1}{j0.502} = -j1.992$

$I_f = -j8.66$ p.u.

$I_{base} = \frac{100000}{20\sqrt{3}} = 2886.75$

$I_f = -j8.66 \times I_{base} = -j25$ kA

b) $I_m = -j1.992 \times I_{base} = -j5.75$ kA.

$V_m = 1 - I_m(j0.2)$
$= 0.602$ pu.

c) The solution is the same as part a), since the superposition circuit is the same.

3. - Short Answer, ten problems, three points each

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   A. Shunt admittances (G) are zero and voltages are 1p.u. in the Jacobian
   B. sin(x)=0 and cos(x)=1
   C. Reactive power flows (Q) are negligible
   D. A and B

2. For a solid (no fault impedance) single-line-to-ground fault the sequence networks are connected
   A. In parallel
   B. In a star configuration
   C. In series
   D. Just the positive and negative networks are connected since there is no fault impedance

3. Congestion on transmission lines (ie flows reaching line limits) will tend to cause Local Marginal Prices (LMPs) to:
   A. Always decrease
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   T. True
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    B. a = 0.5∠0°, b = 1.0∠-120°, c = 2.0∠+120°
    C. a = 0.5∠0°, b = 1.0∠0°, c = 2.0∠0°
    D. a = 1.0∠30°, b = 1.0∠-90°, c = 1.0∠+150°

10. For the general minimization problem $\min_x f(x)\ s.t.\ g(x) = 0$, we define the Lagrangian as $L(x,\lambda) = f(x) + \lambda^T g(x)$. Then $\nabla_\lambda L(x,\lambda) = 0$ is just a restatement of $g(x) = 0$. True or false?
    T. True
    F. False

4. (Short Answer: 20 points total – five points each)

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

1. We can not specify power (S) for all buses because total generation must balance loads and losses.
2. We need an angle reference bus.

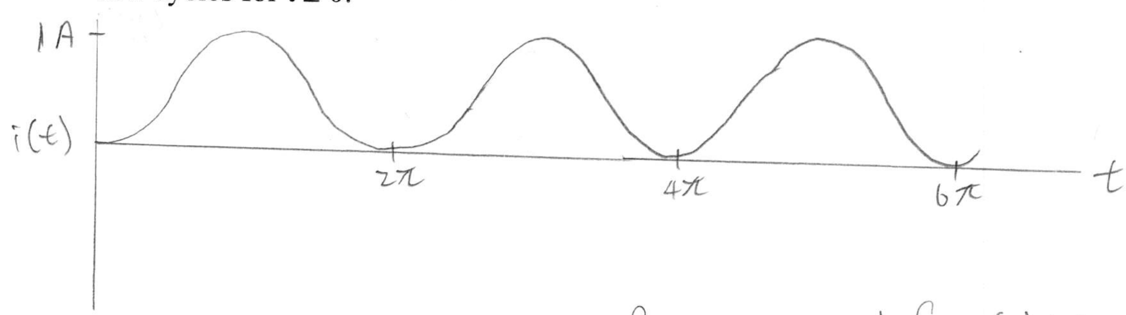
B. Explain how you could use power flow analysis to approximate the penalty factor for a generator?

Calculate the power flow for a base case. Use the solution to calculate line currents, and use the currents to find the loss on the line using $P_{loss} = I^2 R$. Increase the generation of one generator by 1 MW, and repeat to find the new losses. Use the change in losses to find the penalty factor.

C. What is the purpose of power system economic dispatch, and what is a necessary condition for an economic dispatch of the generation?

E.D. determines the generation for each generator that minimizes the instantaneous operating cost, subject to the constraint generation = load + losses.
The necessary condition is $\nabla f(x) = 0$, assuming no generator constraints are violated.

D. An ideal inductor with L = 1 H is connected in series with an ac voltage source (**v(t) = sin(t) volts**) and a switch. The switch, which is initially open, is closed at t = 0. Sketch the current through the circuit (as a function of time) for the first few cycles for t ≥ 0.



For an inductor, $i(t) = \frac{1}{L}\int v(t)\,dt = \frac{1}{1}\int \sin(t)\,dt = -\cos(t) + C$

At $t = 0$, $i(t) = 0$

$0 = -\cos(0) + C$

$C = 1$

$i(t) = 1 - \cos(t)$