## EE 30372, Spring 2007

## Final Exam

11 May, 2007

Show all your work and your answers clearly on the test pages. In any plots and sketches, label and include units (if possible) on anything that might be of interest. You are each allowed one two-sided 8.5 by 11 inch page of formulae for reference. Calculators may be used only for simple trigonometric and (complex variable) arithmetic operations. For full credit, simplify your answers as much as possible.

Problem 1 (25)

Problem 2 (15)

Problem 3 (15) $\qquad$

Problem 4 (65) $\qquad$

Total (120)

Name

1. Short answers (5 pts. each):
(a) A three-phase generator is producing 800 kW of output power at 6 kV (line-line). If it is driving a lagging load receiving 100 A of line current, by how many degrees is current lagging voltage at the terminals?
(b) You find the line-neutral voltages (in pu) at your three-phase bus to be $V_{A}=0.5 \angle 30^{\circ}$, $V_{B}=0.8 \angle-90^{\circ}$ and $V_{C}=1.2 \angle-180^{\circ}$. Find the negative sequence symmetric component voltage $V_{A 2}$.
(c) What are the three line-line voltages in the system of question (b)? Sketch the problem you're solving as phasors.
(d) Find the line-neutral impedance seen at the terminals of this three-phase load.

(e) A single-phase, 50 Hz overhead transmission line with radius 2 cm and the two lines spaced 6 meters apart has shunt admittance of $j 3 \times 10^{-7}$ Siemens $/ \mathrm{km}$ and series impedance of $j 0.5 \Omega / \mathrm{km}$. What will the admittance and impedance per kilometer be if we move the lines to 3 meters apart?
2. ( 15 pts.) Here is a reprint of question 1(a): "A three-phase generator is producing 800 kW of output power at 6 kV (line-line). If it is driving a lagging load receiving 100 A of line current, by how many degrees is current lagging voltage at the terminals?" Using a base power of 1 MVA and base voltage of 5 kV (line-line), and treating the load as a simple passive impedance, convert all parameters (voltage, current, apparent power, real power, reactive power, load impedance) to per-unit.
3. ( 15 pts .) A 2 MWatt $\Delta$-connected load at 13.8 kV (line-line) is operating at power factor 0.7 lagging. You want the total load's PF to improve to 0.9 to get a more favorable rate from the power company. If the system is at 60 Hz , what size capacitor should you add in parallel with each leg of the $\Delta$ load to reach $\mathrm{PF}=0.9$, assuming voltage at the load won't change?
4. Suppose we have the following bus admittance and impedance matrices for the three symmetric components of a 3-phase power system. Assume that in normal, balanced operation, the system behaves according to the positive-sequence parameters. There are no shunt admittances on lines, and any machine on a bus will have finite, non-zero internal impedance.
$\mathbf{Y}_{\text {bus } 0}=\left(\begin{array}{ccc}-j 4 & 0 & 0 \\ 0 & -j 3 & j 2 \\ 0 & j 2 & -j 2\end{array}\right) \mathbf{Y}_{\text {bus } 1}=\left(\begin{array}{ccc}-j 3 & j 1 & j 1 \\ j 1 & -j 3 & j 1 \\ j 1 & j 1 & -j 2\end{array}\right) \mathbf{Y}_{\text {bus } 2}=\left(\begin{array}{ccc}-j 5 & j 3 & j 1 \\ j 3 & -j 6 & j 2 \\ j 1 & j 2 & -j 3\end{array}\right)$
$\mathbf{Z}_{b u s 0}=\left(\begin{array}{ccc}j 0.25 & 0 & 0 \\ 0 & j 1.0 & j 1.0 \\ 0 & j 1.0 & j 1.5\end{array}\right) \mathbf{Z}_{b u s 1}=\left(\begin{array}{ccc}j 0.63 & j 0.38 & j 0.50 \\ j 0.38 & j 0.63 & j 0.50 \\ j 0.50 & j 0.50 & j 1.0\end{array}\right) \mathbf{Z}_{b u s 2}=\left(\begin{array}{ccc}j 0.56 & j 0.44 & j 0.48 \\ j 0.44 & j 0.56 & j 0.52 \\ j 0.48 & j 0.52 & j 0.84\end{array}\right)$
(a) (15 pts.) Assume that each of the lines between busses includes a step-up and step-down transformer. Sketch a power system, including machines connected to busses if appropriate, which would have these system matrices describing its connections for the sake of fault analysis. Specify transformer types, locations and grounding configurations.
(b) (15 pts.) A double line-to-ground fault (lines B \& C) occurs at bus 1. Assuming that before the fault, all busses held voltage $1.0 \angle 0^{0}$ in the A phase and all of the system was balanced, find the fault currents in phases $B$ and $C$ at bus 1 .
(c) (10 pts.) Compute the voltage $V_{B}$ at bus 2 during the fault of part (b).
(d) (10 pts) In the absence of any faults, and with all machines having initially zero internal volts, an ideal three-phase voltage source with voltage of $1 \angle 0^{\circ}$ pu is connected to bus 2 . What will the voltage be at bus 1 in this balanced system?
(e) (15 pts) With the same system matrices as given, and the three phases balanced, let bus two be the slack bus and bus one a load bus with $\mathrm{P}=\mathrm{Q}=-0.2$. Bus 3 is a load bus with $\mathrm{P}=\mathrm{Q}$ $=0$; explain why this should be true from the given information. Write the equations for the two load bus updates in Gauss-Seidel power flow calcuation, leaving voltages as unknowns but using constants everywhere else possible. Compute the first updated values of the two load bus voltages, beginning from the "flat" start at 1 V on each bus.
