# EE 498C, Spring 2002 <br> Final Exam <br> 7 May, 2002 

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. 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 (60) $\qquad$

Problem 2 (45) $\qquad$

Problem 3 (20) $\qquad$

Problem 4 (10) $\qquad$

Total (135)

Name $\qquad$

1. The components of the power system below have the following ratings:

Generator $1\left(G_{1}\right): \quad 100 \mathrm{MVA}, 13.8 \mathrm{kV}, X_{S}=0.6 \mathrm{pu}, X^{\prime}=0.3 \mathrm{pu}$, $X^{\prime \prime}=0.2 \mathrm{pu}, X_{2}=0.1 \mathrm{pu}, X_{g 0}=0.1 \mathrm{pu}$
Generator $2\left(G_{2}\right): \quad 50 \mathrm{MVA}, 13.8 \mathrm{kV}, X_{S}=0.6 \mathrm{pu}, X^{\prime}=0.3 \mathrm{pu}$,
$X^{\prime \prime}=0.2 \mathrm{pu}, X_{2}=0.1 \mathrm{pu}, X_{g 0}=0.1 \mathrm{pu}$
Motor $3\left(M_{3}\right)$ :
$25 \mathrm{MVA}, 11.5 \mathrm{kV}, X_{S}=0.8 \mathrm{pu}, X^{\prime}=0.3 \mathrm{pu}$,
$X^{\prime \prime}=0.2 \mathrm{pu}, X_{2}=0.1 \mathrm{pu}, X_{g 0}=0.1 \mathrm{pu}$
All $Y-\Delta$ transformers: $50 \mathrm{MVA}, 12.5 / 125 \mathrm{kV}, X_{1}=0.1 \mathrm{pu}, X_{2}=0.1 \mathrm{pu}, X_{0}=0.05 \mathrm{pu}$ All $Y-Y$ transformers: $\quad 20 \mathrm{MVA}, 12.5 / 138 \mathrm{kV}, X_{1}=0.1 \mathrm{pu}, X_{2}=0.1 \mathrm{pu}, X_{0}=0.05 \mathrm{pu}$
Line 1: $\quad \mathrm{X}=30 \Omega$
Line 2: $\quad X=20 \Omega$
Line 3: $\quad \mathrm{X}=20 \Omega$

(a)(15 pts.) The entire system is to be converted to its per-unit equivalent using the base of $50 \mathrm{MVA}, 13.8 \mathrm{kV}$ at Generator 2. Label your regions and find the base voltages and base impedances for all regions of the system. Then create the per-phase, per-unit equivalent circuit for the balanced system in steady state.
(b)(10 pts.) Find the system's $\mathbf{Y}_{\text {bus }}$ appropriate for power flow computations.
(c) (20 pts.) Suppose $\mathbf{M}_{\mathbf{3}}$ is consuming 50 MVA at PF 0.8 lagging and generator $\mathbf{G}_{\mathbf{1}}$ ( PV bus) is contributing $\mathrm{P}=30 \mathrm{MW}$ at its rated voltage. With bus 2 as the slack bus, set up the equations for iterative power flow analysis, using numerical values wherever possible. Use a "flat start" and compute the first Gauss-Seidel update of the voltage at bus 3 (assuming it's the first update anywhere). Do these computations in per-unit.
(d) (15 pts.) Create the zero-sequence equivalent circuit for the system for symmetric components analysis.
2. The one-line diagram below represents a balanced 13.8 kV 3 -phase system with line impedance of $\mathbf{Z}_{\mathbf{L}}=j 5 \Omega$. The load represented as $\mathbf{M}_{\mathbf{1}}$ varies between day and night. During the day, it consumes 3 MVA at rated voltage and power factor 0.8 lagging. At night, these values become 0.6 MVA and 0.95 lagging, respectively.

(a)(15 pts.) Find the necessary numerical values and draw a phasor diagram for this transmission line under daytime conditions with $\mathbf{Z}_{\mathbf{C}}$ disconnected.
(b)(15 pts.) The second item connected to the bus, $\mathbf{Z}_{\mathbf{C}}$, is a capacitor bank. Choose a value for the impedance $\mathbf{Z}_{\mathbf{C}}$ in order to raise the daytime power factor of the parallel load to 0.9.
(c) (15 pts.) Under the choice you've made for $\mathbf{Z}_{\mathbf{C}}$ in part (b), sketch the nightime phasor diagram for the transmission line, and compute the voltage regulation. If the generator is providing 13.8 kV at night under these conditions, what is the voltage at the load?
3. (20 pts.) For the initially unloaded generator below, find the expressions for the symmetric components of currents in the three phases, and voltages at the terminals of this generator with the given line-to-ground fault at terminal $\mathbf{c}$.

4. (10 pts.) Give your local address and the detailed location of the nearest three-phase power lines to it, as requested for class. Campus dwellers, give specifically the threephase line off campus nearest your dorm and not directly connected to the ND power plant.

