## EE 30372, Spring 2013 <br> Final Exam <br> 8 May, 2013

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. As usual, three-phase voltages are given as line-to-line by default.

Problem 1 (30) $\qquad$

Problem 2 (15) $\qquad$

Problem 3 (40) $\qquad$

Problem 4 (20) $\qquad$

Problem 5 (20) $\qquad$

Total (125)

1. Shorter exercises ( 5 pts. each):
(a) If the A line of your dorm's 208 V 3-phase, Y-connected AC power system is feeding 1200 W of light bulbs, the B line is supplying 360 W and the C line is supplying 1800 W , what is the current in the neutral line? Assume all these lines have power factor of unity.
(b) The Olive bus is sending current of $800 \angle-30^{\circ} \mathrm{A}$ to the Westside substation, while holding voltage $35 \angle 10^{\circ} \mathrm{kV}$. The bus is also supplying a local factory with 20MVA at power factor 0.8 lagging. The Olive bus is, in turn supplied by a transmission line at the same voltage. What is the current the Olive bus is receiving from its supply transmission line?
(c) A $13.8 \mathrm{kV} / 138 \mathrm{kV}$ transformer, when referenced to its low voltage side, has per-phase impedance of $(2+j 10) \Omega$. It is to be installed in a system with $S_{b a s e}$ of 5 MVA . What will be the per-phase impedance in per-unit values?
(d) If a three-phase, 60 Hz motor at 480 V is receiving line current of 25 A , operating at power factor 0.8 lagging and efficiency $75 \%$, what will its approximate horsepower rating be?
(e) A load at 1.0 V p.u. is receiving $0.5 \angle+30^{\circ} \mathrm{A}$ p.u. of AC current through a (short) transmission line having per-unit impedance of $0.2+\mathrm{j} 0.5 \Omega$ p.u. Sketch an accurate phasor diagram of the line.
(f) A length of 60 Hz , single-phase distribution line of diameter 3 cm has inductive impedance of $x_{l}=1 \Omega /$ mile when the two conductors are 1 meter apart. What will be the line's inductance if the conductors are placed 5 meters apart?

2. ( 15 pts .) Above is a per-phase equivalent circuit model of a Y-connected, three-phase induction motor, operating at $50 \mathrm{~Hz}, 600 \mathrm{~V}$. The parameters are $X_{1}=2 \Omega, R_{1}=1 \Omega, X_{M}=40 \Omega$, $X_{2}=2 \Omega$ and $R_{2}=1.5 \Omega$. At its rated load, it has mechanical speed of 1140 rpm . The mechanical losses are 600 W and core losses 700W. Find the motor's efficiency.
3. Below are the per-unit bus admittance and impedance matrices for the three symmetric components of a 3-phase power system. The system has $S_{\text {base }}=20 \mathrm{MVA}$, and $V_{\text {base }}$ of 35 kV at all of the buses. Assume that in normal, balanced operation, the system behaves according to the positive-sequence parameters. All transmission lines are short; that is they have shunt capacitance modeled as zero.

$$
\begin{aligned}
& \mathbf{Y}_{\text {bus } 0}=\left(\begin{array}{ccc}
-j 5 & 0 & 0 \\
0 & -j 10 & j 4 \\
0 & j 4 & -j 4
\end{array}\right) \mathbf{Y}_{\text {bus } 1}=\left(\begin{array}{ccc}
-j 4 & j 2 & j 1 \\
j 2 & -j 4 & j 1 \\
j 1 & j 1 & -j 5
\end{array}\right) \mathbf{Y}_{\text {bus } 2}=\left(\begin{array}{cc}
-j 5 & j 2 \\
j 2 & -j 6 \\
j 1 & j 4 \\
j 1 & -j 10
\end{array}\right) \\
& \mathbf{Z}_{b u s 0}=\left(\begin{array}{ccc}
j 0.2 & 0 & 0 \\
0 & j 0.17 & j 0.17 \\
0 & j 0.17 & j 0.42
\end{array}\right) \mathbf{Z}_{b u s 1}=\left(\begin{array}{ccc}
j 0.40 & j 0.23 & j 0.13 \\
j 0.23 & j 0.40 & j 0.13 \\
j 0.13 & j 0.13 & j 0.25
\end{array}\right) \mathbf{Z}_{b u s 2}=\left(\begin{array}{ccc}
j 0.28 & j 0.15 & j 0.09 \\
j 0.15 & j 0.31 & j 0.14 \\
j 0.09 & j 0.14 & j 0.16
\end{array}\right)
\end{aligned}
$$

(a) (10 pts.) The system is idle, with all sources off-line, but wired according to the positivesequence matrices above. During no-fault, balanced operation, a source at voltage 2.0 Vpu is connected to bus 2. What are the voltages at buses 1 and 3?
(b) (10 pts.) A single line-to-ground fault (line A) occurs at bus 3. Assuming that before the fault, all buses held voltage $1.0 \angle 0^{0}$ in the A phase and all of the system was balanced, find the fault currents in all phases at bus 3 (in p.u.).
(c) (10 pts.) Compute the voltage $V_{B N}$ (in "real" voltage) at bus 1 during the fault of part (b).
(d) (10 pts.) Find C-phase current between buses 1 and 3 after the fault.

4. (20 pts.) Above is a three-bus system in which bus 3 is slack at voltage $1.0 \angle 0^{\circ} V$, bus 2 requires power of $\mathrm{P}=0.3$ and $\mathrm{Q}=0.2$ and bus 1 requires $\mathrm{P}=0.3$ but supplies $\mathrm{Q}=0.3$. That is, by our conventional notation, $S_{2}=-0.3-j 0.2$ and $S_{1}=-0.3+j 0.3$. Using simple, direct calculations and reasonable approximations without appeal to iterative techniques, specify voltages for buses 1 and 2 which approximate this power flow setting and would thus form a useful initial estimate of the state of the system. Find the net power actually flowing into bus 2 if your voltages precisely desribed the state.
5. (20 pts.) You have the schematic of Feeder 33 from the Utilities Department of ND, from which we want to do power flow analysis. We place a bus at Hanks Aquatic Center. Using a Vbase of 4160 V , Sbase of 3MVA, and impedance values on the cable data sheet for 3 single 500 kcmil cables, find the non-zero per-unit entries in the row of the admittance matrix corresponding to the given bus. Identify and number the other buses of interest and use their numbers to identify rows and columns of the matrix. List these names and numbers on your exam. You do not need to figure out the total number of buses and the consequent dimension of the matrix; just give the segment of the row which includes the non-zero values. Assume, as we did in the project, that there will be a bus at the entrance to each building, that any line of less than 100 feet length may be assumed zero impedance, and that all marked cables are identical 500 kcmil. The line between Hanks and junction \#10704 is of negligible length. You may assume the 400 kVAR capacitor near Hanks is disconnected for this exercise.

