EE 30372, Spring 2012
Final Exam
8 May, 2012

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) ______

Problem 2 (20) ______

Problem 3 (30) ______

Problem 4 (40) ______

Total (120) ______

Name_______________________________

1. Shorter exercises (5 pts. each):
   (a) A transformer has per-unit impedance of 5%, rated at 100kVA and 480/4800 V. What is its per-unit impedance if we place it into a system in which we're using S_{base} = 200kVA and V_{base} = 6kV on the high side of the transformer?

   (b) If the load at a bus at 600V is receiving 20kW with power factor 0.7 lagging at 60 Hz, what size capacitor would we attach to the bus to bring the load's power factor to 1.0?

   (c) A load at 1.0V p.u. is receiving $0.5\angle{+30^o}$A p.u. of AC current through a (short) transmission line having per-unit impedance of 0.2+j0.5Ωp.u. Sketch an accurate phasor diagram of the line.

(d) A length of 60 Hz, single-phase distribution line of diameter 2 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 2 meters apart?

(e) A single-phase, 50 Hz voltage (in RMS) is given as $240\angle{-40^o}$V. How is this voltage written as a function of time?

(f) If two buses are separated by a line of impedance j0.5Ωp.u., and the bus with voltage 1.0 needs 1.0VAR p.u. of reactive power, to what should we set the voltage on the other bus?

2. (20 pts.) Load 1 is consuming 2MW and Load 2 is consuming 1MW in the above three-phase system, with both having power factor 0.8 lagging. The transmission line between them is medium-length, with parameters $R = 5\Omega$, $X = 30\Omega$ and $Y = 2 \times 10^{-5}\mathrm{Siemens}$. At Bus 1, we hold line-line voltage 20 kV. Find the voltage at Bus 2, the losses in Line 1, and the currents I_1 and I_2.

3. You are head of Utilities and suspect that the growth of ND's endowment is due not to Scott Malpass' investment acumen, but a massive illegal drug lab in central campus. This lab would need a lot of power, and you've noticed significant recent load increase on Feeder 51, of which you have a diagram. Your job is to descend into the system, detect excess loading and uncover the lab. If you wish to solve the following problems in per-unit, use S_{base} = 10 MVA and V_{base} = 4000V. The lines have impedances as given on the Kerite data sheet for 3 single-conductor cables.
   (a) (15 pts.) You have available a pair of voltmeters, which you attach at the bus at Cavanaugh Hall and at the connection in the bus box labeled $\#G0611$. You measure $4000\angle 0.0^o$ at the latter bus, and $4000\angle +0.5^o V$ at Cavanaugh. What are the complex power being delivered to bus $\#G0611$ and the losses in the line between the two busses?

(b) (15 pts) An event occurs at Zahm Hall which causes 1200 A of zero-sequence current, at phase zero degrees, to flow from the Cavanaugh bus to Zahm, in addition to the current flowing in the state described in (a). The Cavanaugh bus holds its voltage unchanged from (a). What are the resulting A,B,C phase voltages at the $\#G0611$ bus? Could this be the location of the illicit lab?

4. 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_{base} = 20 MVA, and V_{base} of 20 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.

$$\mathbf{Y}_{bus0} = \begin{pmatrix} -j5 & 0 & 0 \\ 0 & -j10 & j4 \\ 0 & j4 & -j4 \end{pmatrix} \mathbf{Y}_{bus1} = \begin{pmatrix} -j4 & j2 & j1 \\ j2 & -j4 & j1 \\ j1 & j1 & -j5 \end{pmatrix} \mathbf{Y}_{bus2} = \begin{pmatrix} -j5 & j2 & j1 \\ j2 & -j6 & j4 \\ j1 & j4 & -j10 \end{pmatrix}$$

$$\mathbf{Z}_{bus0} = \begin{pmatrix} j0.2 & 0 & 0 \\ 0 & j0.17 & j0.17 \\ 0 & j0.17 & j0.42 \end{pmatrix} \mathbf{Z}_{bus1} = \begin{pmatrix} j0.40 & j0.23 & j0.13 \\ j0.23 & j0.40 & j0.13 \\ j0.13 & j0.13 & j0.25 \end{pmatrix} \mathbf{Z}_{bus2} = \begin{pmatrix} j0.28 & j0.15 & j0.09 \\ j0.15 & j0.31 & j0.14 \\ j0.09 & j0.14 & j0.16 \end{pmatrix}$$

(a) (10 pts.) A line-to-line fault (lines B and C) occurs at bus 2. 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 2 (in p.u.).

(b) (10 pts.) Compute the voltage V_{BN} at bus 1 during the fault of part (a).

(c) (10 pts.) Sketch a per-phase circuit which could result in the given admittance and impedance matrices, and assign both zero-sequence impedance values and machine/transformer wiring configurations to the components.

(d) (10 pts.) When we set up power flow problems, the admittance matrices may be a bit different from what is given for the positive sequence above. Write the admittance matrix we would use to do conventional power flow analysis of this system. In balanced operation, we designate bus one as the slack bus (at 1.0V p.u.), and buses 2 and 3 as load buses. We find that the system is operating with $V_2 = 1.0\angle{-10^o}V$ and $V_3 = 0.9\angle{-5^o}V$. Find the power being provided by the slack bus.