

EE 30372, Spring 2008

Final Exam

8 May, 2008

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 (30) _____

Problem 2 (20) _____

Problem 3 (15) _____

Problem 4 (40) _____

Problem 5 (30) _____

Total (135) _____

Name_____

1. Short answers (5 pts. each):

(a) A permanent magnet DC motor driven as a generator produces 60V (unloaded) when it is rotated at 500 rpm. What unloaded voltage will be produced if it spins at 2000 rpm?

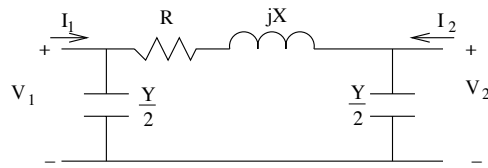
(b) A three-phase, grounded-neutral, Y-connected generator, maintaining rated voltage and phase in each leg, is driving an unbalanced resistive load absorbing 50A in phase a , 100A in phase b and 60A in phase c . What is the current in the line to ground?

(c) A transformer, rated at 50MVA and 600V/12kV, has internal impedances of $R_{pu} = 0.05\Omega$ and $X_{pu} = 0.1\Omega$. This transformer is to be installed in a system with base power of 40MVA, operating with low-side base voltage of 400V. Find the pu impedance under the installed system's base values.

(d) If a passive, balanced three-phase load is re-wired from Δ to Y configuration, and terminal voltage is unchanged, what is the power consumed after re-wiring if before, it consumed 10 kW?

(e) A single-phase, 60 Hz overhead transmission line with radius 3 cm and the two lines spaced 5 meters apart has shunt admittance of $j1 \times 10^{-7}$ Siemens/km and series impedance of $j0.5\Omega/\text{km}$. What will the admittance and impedance per kilometer be if we move the lines to 10 meters apart?

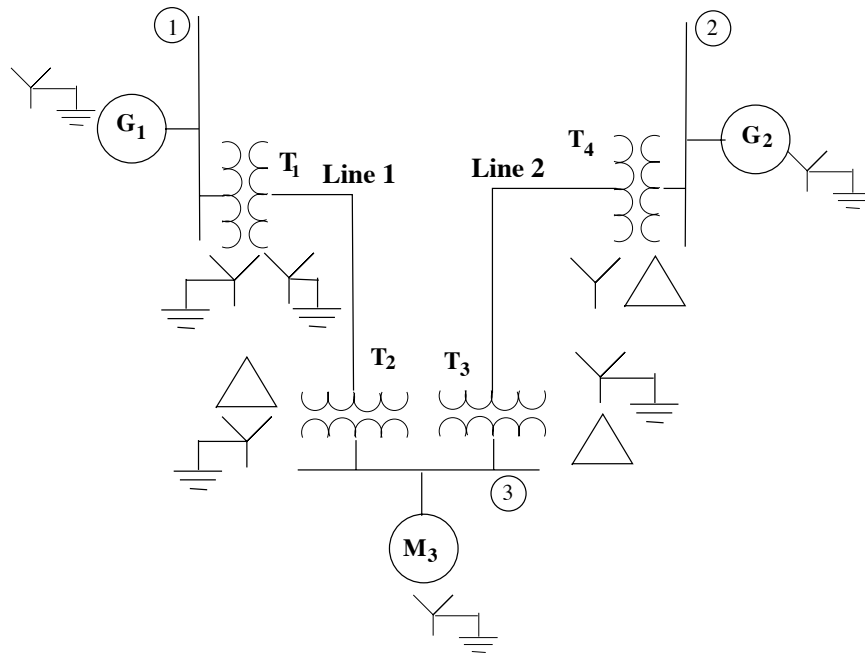
(f) A three-phase system with $V_{baseLL} = 480V$ and $S_{base3\phi} = 10MVA$ is producing apparent power in pu of $S_{pu} = 0.75$ with power factor 0.5 lagging. How many real watts and vars is it producing?



2. Above is our standard per-phase model for medium-length and long transmission lines. Let $Y = j0.2$, $R = X = 1.0$. More than one view of this system could be of interest; to the extent that it is helpful, you may use the knowledge that this system is just a special case of the network matrices discussed late in the course.
- (a) (10 pts.) Find the matrix \mathbf{Z} in the equations $\mathbf{V} = \mathbf{Z}\mathbf{I}$, where $\mathbf{V} = [V_1 \ V_2]^t$ and similarly for \mathbf{I} .

(b) (10 pts.) If $\mathbf{I}_1 = 0$ and $\mathbf{V}_2 = 1.0\text{V}$, find \mathbf{V}_1 .

3. (15 pts.) A shunt DC motor with armature resistance of $0.5\ \Omega$ and field resistance of $100\ \Omega$ is supplied with 100 volts. It is consuming 15 A under load, rotating at 1500 rpm. Mechanical and stray losses are constant at 300 W. The load then changes such that input current (at same terminal voltage) doubles to 30 A. Find the torque at the output shaft in both states, and the speed of rotation in the second state.



4. The components of the power system above have the following ratings:

Generator 1(G_1): 100 MVA, 10.0 kV, $X_1=0.2$ pu, $X_2=0.2$ pu, $X_{g0}=0.2$ pu

Generator 2(G_2): 100 MVA, 10.0 kV, $X_1=0.1$ pu, $X_2=0.1$ pu, $X_{g0}=0.1$ pu

Motor 3 (M_3): 100 MVA, 10.0 kV, $X_1=0.05$ pu, $X_2=0.1$ pu, $X_{g0}=0.1$ pu

All $Y - \Delta$ transformers: 100 MVA, 10/100 kV, $X_1 = 0.05$ pu, $X_2=0.1$ pu, $X_0 = 0.05$ pu

All $Y - Y$ transformers: 100 MVA, 10/100 kV, $X_1 = 0.1$ pu, $X_2=0.1$ pu, $X_0 = 0.05$ pu

All $\Delta - \Delta$ transformers: 100 MVA, 10/100 kV, $X_1 = 0.1$ pu, $X_2=0.1$ pu, $X_0 = 0.05$ pu

Line 1: $X = 10\Omega$

Line 2: $X = 20\Omega$

Regardless of transformer type, their high voltage sides will be connected to the transmission line.

(a) (10 pts.) Using the given numbering of the busses for rows/columns of matrices, find the per-unit admittance matrix for this system, in its balanced state, for power flow calculations.

(b) (10 pts.) Find and sketch the per-phase equivalent circuit for the zero-sequence symmetric component of this system

(c) (10 pts.) Find the values of the (3,3) and (3,2) elements of the \mathbf{Z}_{bus0} matrix, for the zero-sequence symmetric component.

(d) (10 pts.) Given the structure of this system, list a set of constraints in per-unit (all non-zero) for voltages and powers at the three busses which will allow a reasonable, stable solution to power flow.

5. Suppose we have the following per-unit bus admittance and impedance matrices for the three symmetric components of a 3-phase power system. The system has $S_{base} = 10$ MVA, and V_{baseLL} of 10 kV at all of the busses. Assume that in normal, balanced operation, the system behaves according to the positive-sequence parameters.

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

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

- (a) (10 pts.) The system is operating in a balanced and stable state, with all bus voltages at approximately 1.0 (*a* phase) pu. You get a call from the operator at bus 3, saying she needs to draw an additional 0.1 A pu (at PF 1). What will the voltages at all busses be if you allow her to draw this extra current?

(b) (10 pts.) A line-to-line fault (lines B & C) occurs at bus 1. Assuming that before the fault, all busses held voltage $1.0\angle 0^\circ$ 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 (real) voltage V_B at bus 2 during the fault of part (b).