EE 30372, Spring 2018
Final Exam
7 May, 2018

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 (20) ______

Problem 2 (40) ______

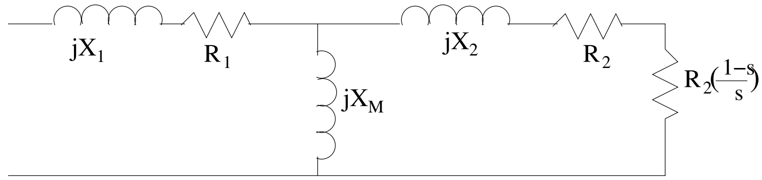
Problem 3 (20) ______

Problem 4 (20) ______

Total (10-) ______

Name________________________________

1. (20 pts.)



Above is a per-phase equivalent circuit model of a Y-connected, three-phase induction motor, operating at 60 Hz, 480V. The parameters are $X_1 = 2\Omega$, $R_1 = 1\Omega$, $X_M = 20\Omega$, $X_2 = 1\Omega$ and $R_2 = 0.5\Omega$. At its rated load, it has mechanical speed of 1728 rpm. The mechanical losses are 500W and core losses 600W. Find, at rated load, (a) the number of poles in the windings and the rotor slip; (b) the power converted from electrical to mechanical, P_{conv}; (c) the induced torque; (d) the output horsepower and (e) the motor's efficiency.

2. 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 30 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.

$$\mathbf{Y}_0 = \begin{pmatrix} -j5 & 0 & 0 \\ 0 & -j10 & j4 \\ 0 & j4 & -j4 \end{pmatrix} \mathbf{Y}_1 = \begin{pmatrix} -j4 & j2 & j1 \\ j2 & -j4 & j1 \\ j1 & j1 & -j5 \end{pmatrix} \mathbf{Y}_2 = \begin{pmatrix} -j5 & j2 & j1 \\ j2 & -j6 & j4 \\ j1 & j4 & -j10 \end{pmatrix}$$

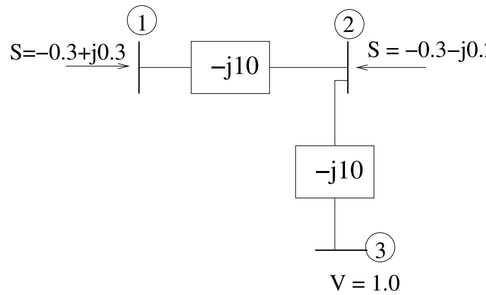
$$\mathbf{Z}_0 = \begin{pmatrix} j0.2 & 0 & 0 \\ 0 & j0.17 & j0.17 \\ 0 & j0.17 & j0.42 \end{pmatrix} \mathbf{Z}_1 = \begin{pmatrix} j0.40 & j0.23 & j0.13 \\ j0.23 & j0.40 & j0.13 \\ j0.13 & j0.13 & j0.25 \end{pmatrix} \mathbf{Z}_2 = \begin{pmatrix} j0.28 & j0.15 & j0.09 \\ j0.15 & j0.31 & j0.14 \\ j0.09 & j0.14 & j0.16 \end{pmatrix}$$

(a) (10 pts.) The system is idle, with all sources off-line, but wired according to the positive-sequence matrices above. In a no-fault, balanced state, a source at voltage 2.0Vpu is connected to bus 3. What are the voltages at buses 1 and 2?

(b) (10 pts.) The system is now operating at balanced, light load such that all buses have voltage $1.0\angle 0^0 pu$. A single line-to-ground fault (line A) occurs at bus 2. in the A phase. Find the fault currents in all phases at bus 2 (in p.u.).

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

(d) (10 pts.) Find C-phase current between buses 1 and 2 (in “real” amps) during the fault, and the losses in this line (in real Watts and VARs).



3. (20 pts.) Above is a one-line diagram of a three-bus, balanced three-phase system in which bus 3 is slack at voltage $1.0\angle 0^{o} V$, bus 2 requires power of P = 0.3 and Q = 0.2 and bus 1 requires P = 0.3 but supplies Q = 0.3. That is, by our conventional notation, $\mathbf{S}_2 = -0.3 - j0.2$ and $\mathbf{S}_1 = -0.3 + j0.3$. 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. Credit will depend on the relative accuracy and analytic support for your choices, but perfection is not expected. Find the net power actually flowing into bus 2 from the rest of the system if your voltages were to precisely describe the system state.

4. You have the schematic of Feeder 62 from the Utilities Department of ND, connected to the building in which you find yourself right now, and on which we want to do power flow analysis. We will use a Vbase of 4160V, Sbase of 1MVA, and impedance values on the Kerite cable data sheet for 3 single-conductor cables. The primary goal of this problem is to form the per-unit admittance matrix for this feeder. As we did in our previous exercises, we'll consider any path between busses that totals 160 feet or less to be zero impedance. Each transformer+building combination is modeled as having impedance to neutral(grounded) of j1.0pu. The 4160V generator at bus 6, *which we will re-label as our bus 1*, is Y-connected and solidly grounded, with internal impedance of j2.0. First, an important modification of the diagram: *All the switches in the junction box numbered I0612 directly above the ND logo are closed.*

   (a) (10 pts.) Identify and clearly number the buses of interest. Keep the number of buses to its minimum under our rules from previous work. Assume, as we did in the exercises, that there will be a bus at the entrance to each building, except in the short-connection case cited above. You will be turning in your system diagram with the labeled buses.

   (b) (10 pts.) Write the row of the admittance matrix that corresponds to Fitzpatrick Hall's bus in the space below, using the numbers on your labeled diagram to index rows and columns of the matrix. Make sure you turn in your calculations for this on the sheet provided with the diagram and Kerite spec sheet.