EE 30372, Spring 2018 Exam 1 7 March, 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. For full credit, simplify your answers as much as possible. You may use calculators for numerical evaluations but no programming capabilities. This exam is closed-book, but you are free to use formulae and conversions from the accompanying sheet or math handbook.

Remember that when three-phase voltages are given, they will be line-to-line by default. Voltage and current values are, unless otherwise noted, in rms.

Problem 1 (30)

Problem 2 (20)

Problem 3 (30)

Problem 4 (20)

Total (100)

Name____

1. Short Stuff (5 pts each)

(a) Two single-phase AC machines, M_1 and M_2 , are connected by a line having impedance $j5\Omega$. M_1 has voltage $1020\angle 0^{\circ}$ V and M_2 has voltage $1000\angle 0^{\circ}$ V. What is the total complex power output into the line by each of M_1 and M_2 ?

(b) What is the line current magnitude for a three-phase load at 208V consuming 12 Hp at power factor 0.7 lagging?

(c) On our oscilloscope, we measure the voltage between the A and B lines of a threephase supply as $100 \cos(120\pi t + 40^{\circ})$. In phasor notation, what would the rms voltage \mathbf{V}_{AN} be, if N is the neutral terminal? (d) Convert this load into a simple Y-connected configuration, with a single complex impedance ${\bf Z}$ in each branch.



(e) A 50Hz induction motor has operating speed of 1420 rpm. How many poles does it have in its windings?

(f) If a 60 Hz, three-phase, two-pole induction motor is operating at slip of 2% while delivering 2HP (neglecting any mechanical power losses), what induced torque would you expect it to deliver if slip increases to 4%?

2. A Y-connected, three-phase generator operating at 60 Hz, 2400 V (line-line terminal voltage) has output impedance in each phase of (1.0 + j6.0)Ω.
(a) (10 pts.) The generator is supplying, at its terminals, the rated voltage and 240kVA at power factor 0.9 lagging. Find line current at the output terminals and the generator's voltage regulation.

(b) (10 pts.) With the field current fixed as in part (a), what is the maximum real power the generator can deliver? (You may ignore the machine's internal resistance, R_A , for this part.) Compute the reactive power the generator is supplying or consuming in this state.



3. Above is the *per-phase* model of a 3-phase transformer. The parameters are $N_p/N_s = 5$, $X_p = 10\Omega$, $R_p = 5\Omega$, $X_s = 1\Omega$, $R_s = 0.5\Omega$. We neglect shunt impedances. The load has impedance $(20 + j15)\Omega$.

(a) (10 pts.) Find the equivalent circuit, with all entities referenced to the primary.

(b) (10 pts.) We apply 6kV (line-neutral) at the primary. What are the complex power delivered by the source at the input to the transformer, and the complex power actually delivered to the 3-phase load?

(c) (10 pts.) Construct an accurate phasor diagram for the transformer in the state described, showing individually the voltage drops across the transformer total equivalent resistance and reactance, and labeling pertinent angles. (This formulation is slightly different from our typical specification of voltage at the load, but all the same ideas apply.)



4. Above is a three-phase transformer's per-phase equivalent circuit, of the same form as in Problem 3. Set $X_p = 20\Omega$, $R_p = 5\Omega$, $X_s = 0.2\Omega$, $R_s = 0.05\Omega$. We will again neglect core loss and magnetization current. This time, we'll make $N_p/N_s = 30$, and use one phase of the transformer to drop distribution-level single-phase voltage of 7200V to a domestic supply at 240V. If your neighborhood features overhead distribution lines, this could be one of the transformers hanging on a pole near your house and supplying your home plus a few others with power. Suppose the transformer is rated to deliver 500A at 240V to the houses it serves.

(a) (10 pts.) Using the rated quantities for computing base power, and using the given voltages as their respective bases, convert the transformer circuit to per-unit, with a single, combined reactance and resistance.

(b) (10 pts.) Find the transformer's efficiency under rated, full-load conditions at power factor 0.8 lagging.