EE 30372, Spring 2019
Exam 1
6 March, 2019

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. No leaps of faith - make sure the grader can easily understand what you've done.

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. Complex quantities will be in bold, and scalar quantities in normal font.

Problem 1 (30) ______

Problem 2 (20) ______

Problem 3 (30) ______

Problem 4 (20) ______

Total (100) ______

Name______________________________

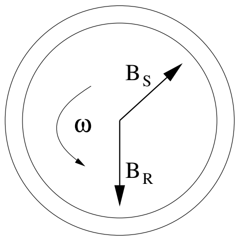
1. Short Stuff (5 pts each)

   (a) We have a 30 Hp (let this be at input, assuming 100% efficiency), 3-phase, 480V motor to be operated at rated power, and at power factor 0.8 lagging. We need to buy wire to feed it. How much line current will the wires need to carry?

   (b) The induction motor on which we did power factor correction with a capacitor in class operates at 60 Hz, and its label shows a rated speed of 1725 rpm. How many poles does this machine have?

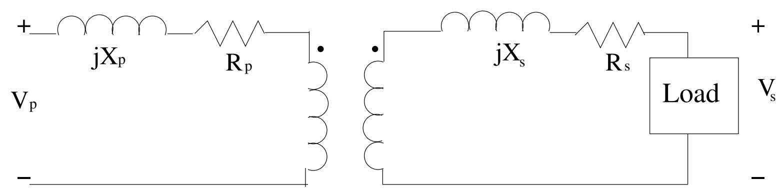
   (c) A 240V, 60 Hz, single-phase motor is consuming 1 kVA at power factor $1/\sqrt{2}$ lagging. If we want to correct to power factor of 1.0, what size capacitor should we place in parallel with the load?

(d) This figure shows a pair of magnetic fields with our usual labeling, and ω indicating the direction of rotation. Is it functioning as a generator or as a motor? Explain in a few words.



(e) A short-circuit test on a transformer yields the following: $V_{SC} = 30V, I_{SC} = 10A, P_{SC} = 60$ Watts. What parameters have we measured (show them in a transformer circuit model) and what are their values?

(f) If a 60 Hz, three-phase, two-pole induction motor is operating at slip of 5%, what electrical frequency will we observe on the rotor bars or windings?



2. Above is a *per-phase* model of a 3-phase transformer. The parameters are $N_p/N_s = 2$, $X_p = 4\Omega$, $R_p = 2\Omega$, $X_s = 2\Omega$, $R_s = 1\Omega$. We neglect the shunt magnetization current. At rated capacity of 3 kVA, core loss is 300W. The load is a 240V, 3-phase motor with both efficiency and power factor (lagging) having value 0.8.

   (a) (7 pts.) Sketch the simplified equivalent circuit of the transformer, with all entities referenced to the secondary. Label all the usual voltages and currents as well as equivalent impedances.

   (b) (5 pts.) Convert your circuit result from (a) into per-unit and again label the impedances.

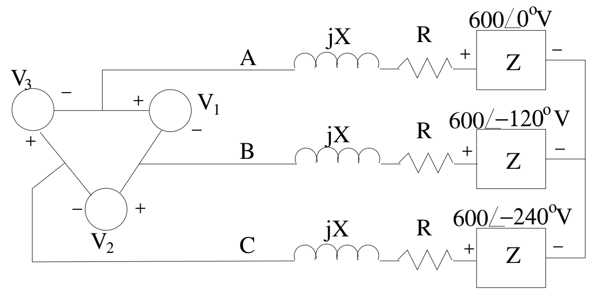
(c) (8 pts.) If the transformer is operating at its rated capacity as described above, what is its efficiency? Find also the voltage regulation

3. A 4160V (at ouput), 60 Hz, Y-connected, three-phase generator (such as the diesel-driven auxiliaries north of campus) is delivering 100A of current in each phase, supplying a load at power factor 0.8. Its internal per-phase impedance (jX_s) is $j6\Omega$. We neglect internal resistance.

(a) (10 pts.) Find the internally generated voltage $\mathbf{E_A}$. Draw an accurate phasor diagram for this state of operation. Label all the quantities we normally include on these diagrams.

(b) (10 pts.) Suppose we want to output the same wattage, but reduce the reactive power output to zero. What would be the percentage change in field current to achieve this new output, and what would the new $\mathbf{E_A}$ be? (You may assume a linear relationship between flux and field current.)

(c) (10 pts.) When we consider a parallel generator's output of reactive power, we work with a parameter s_Q relating VAR output to changes in output voltage. We've noted that this "house diagram" model is a linearization of the true relation. Assume we'd like to linearize around the point at which $Q_{out} = 0VAR$. Find the simplest, most useful expression you can that we might use for s_Q (as a function of variables other than V_ϕ, as is necessary in a linear model) as we vary the reactive power received from the generator without changing the field current or real power at the output. You may use the resistance-free generator model, with only reactive impedance.



4. Here we have a generic, balanced 3-phase system. Don't be confused by the somewhat different look of this graph; it's a Δ-connected source driving a Y-connected load, so $\mathbf{V_1}$, etc would be the usual Δ voltages. The common load impedance is $\mathbf{Z} = 30\angle 30^o\Omega$ and line impedances are $R = 1\Omega$ and $X = 2\Omega$.
(a) (10 pts.) What will be the magnitude and phase of the current $\mathbf{I_{BC}}$ through the source labeled $\mathbf{V_2}$?

(b) (10 pts.) Find the voltage $\mathbf{V_1}$ and the total complex power $\mathbf{S}_{3\phi}$ that the source must deliver.