ECE 3600 Exam 3 given: Fall 20

(Some space between problems has been removed.)

1. (35 pts) A 3-phase induction motor is Y-connected to a 480-V bus. It draws 15kW of real power and has a power factor of 0.88 . Some more knowns:

$X_M := 100 \cdot \Omega$ $\quad R_C := \infty$

$\mathbf{E_1} := (251 - j \cdot 17.6) \cdot V$ $\quad n := 1710 \cdot \text{rpm}$

The input, $V\phi$ is 0^o reference

Input power: $P_{in} := 15 \cdot kW$ at $pf := 0.88$

Stator copper loss: $P_{SCL} := 900 \cdot W$

The output shaft torque: $\tau_{load} := 72 \cdot N \cdot m$

a) Draw the model for this motor. This will be your working drawing, so you may want to add information from above. Use the standard labels for currents, voltages, and components. Leave room for values to be added later.

b) Find the line current. $\mathbf{I_L}$ = ?
Magnitude AND angle

c) Find R_1

d) Find $\left|\mathbf{I_2}\right|$ (may need complex number calculations)

e) Find P_{AG}

f) Find s

g) Find R_2

h) Find the rotor copper loss:

i) Find the shaft output power. The load torque is given above as: $\tau_{load} = 72 \cdot N \cdot m$

j) Find the mechanical power losses (all lumped together).

k) Find the overall machine efficiency η

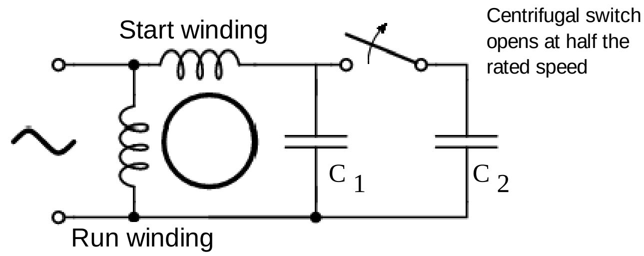
2. (30 pts)A 1/3-hp, 120-V, 60-Hz, single-phase, capacitor-run, single-phase induction motor has two identical windings set 90º apart in the motor housing. Each winding draws $7A$ at $64°$lag when the rotor is locked. This is with no added capacitors, so the motor would have to be started by hand.

   a) Find the ideal capacitor to place in series with one of the windings at **startup**.
   Note: the ideal capacitor would create the ideal phase difference between the winding currents.

   b) Each winding uses $141W$ at $pf = 0.85$ when the motor is running at its rated speed. This is with no added capacitors, so the motor would have to be started by hand. Find a different capacitor to replace the capacitor of part a). Choose this capacitor to make the current magnitude in the two windings exactly the same at rated speed. (Don't worry about the phase angles.)

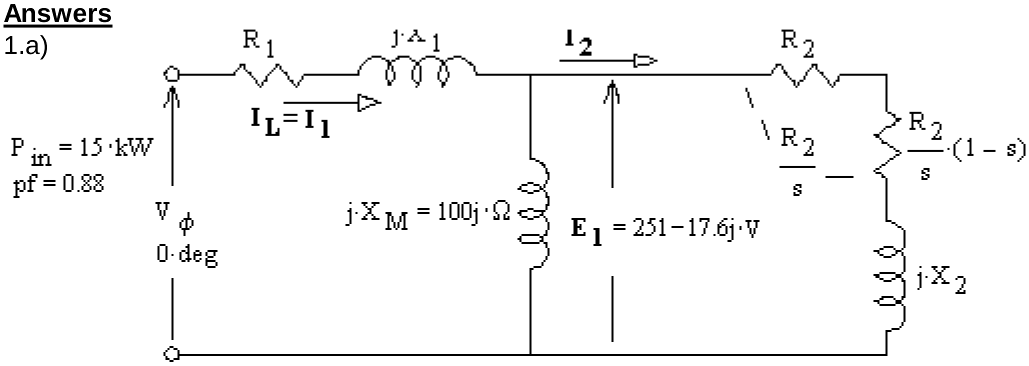
   c) Find the input current (sum of both) magnitude and phase at rated speed with the capacitor of part b) in place.

   d) If the motor had a centrifugal switch which opens at half the rated speed, devise a design to achieve the conditions of parts a) and b). Find all capacitor values needed.



Answers

1.a)



b) $20.5 \cdot A\ \underline{/ -28.4^o}$ c) $0.714 \cdot \Omega$

d) $19.6 \cdot A\ \underline{/ -21.6^o}$ e) $14.1 \cdot kW$

f) $5 \cdot \%$ g) $0.612 \cdot \Omega$ h) $705 \cdot W$

i) $12.9 \cdot kW$ j) $502 \cdot W$ k) $85.95 \cdot \%$

2. a) $139 \cdot \mu F$ b) $29 \cdot \mu F$ c) $2.35 \cdot A\ \underline{/ 0^o}$ d) $29 \cdot \mu F$, $110 \cdot \mu F$ use $30 \cdot \mu F$ & $100 \cdot \mu F$

3. a) $1514 \cdot W$ b) $395 \cdot W$ c) $1035 \cdot rpm$ d) $2.64 \cdot A$ f) $743 \cdot W$

3. (35 pts) A 1.5-hp, separately excited dc motor runs at 58% overall efficiency (includes power needed for the field) when operated at full load. Both the armature and field are hooked to a single 180 V source. The rotational losses are proportional to the motor speed. Other important information is given below.

$\eta := 58 \cdot \%$ $\quad V_T := 180 \cdot V$ $\quad n_{fL} := 900 \cdot rpm$ $\quad R_A := 3 \cdot \Omega$ $\quad R_F := 300 \cdot \Omega$ $\quad 1 \cdot hp = 745.7 \cdot W$

a) At full load, find the power converted from electrical to mechanical, $P_{conv} = ?$

b) At full load, find the rotational losses, $P_{rot} = ?$

c) Find the no-load shaft speed. The power required to overcome the rotational losses is proportional to the motor speed.

Hint: This also means that the rotational losses are proportional to E_A, like this: $P_{rot2} = P_{rot1} \cdot \frac{E_{A2}}{E_{A1}}$

d) Find the no-load armature current. $I_A = ?$

f) The mechanical load on the shaft is increased and the motor slows down to: $n_{new} := 950 \cdot rpm$
Find the load power, P_{out} , at this speed. This is a multi-step calculation.
Remember, the rotational losses are proportional to the motor speed.