

ECE 2500 Exam 3 given: Spring 25

DO NOT use erasable ink

1. (22 pts) A 1/2-hp, 120-V, 60-Hz, single-phase, capacitor-run, induction motor has two windings set 90° apart in the motor housing. The windings are NOT the same. At Startup, winding 1 draws 6 A at 30° lag. Winding 2 in series with an $80\text{-}\mu\text{F}$ capacitor draws 4.5 A at 35° lead.

$$V_T := 120 \cdot V \quad \mathbf{I}_1 := 6 \cdot A \cdot e^{-j \cdot 30 \cdot \text{deg}} \quad \mathbf{I}_2 := 4.5 \cdot A \cdot e^{j \cdot 35 \cdot \text{deg}} \quad \text{which includes a series } C := 80 \cdot \mu\text{F}$$

- a) Find the impedance of winding 1 and winding 2 without the capacitor. Find both in rectangular form.

- b) The capacitor is removed from winding 2 and placed in series with winding 1 instead. Find the new phase angle difference and the new current magnitudes. Note any and all improvements.

- c) There will be one other major change in the motor startup with this new configuration. We didn't directly discuss this in class, but you can figure it out if you understand how the startup works. What will be different?

1, continued. For the rest of this problem, keep the configuration of part b).

d) At **run speed**, the winding impedances are found to be:

$$Z_{1run} := (30 + 20j) \cdot \Omega$$

$$Z_{2run} := (40 + 30j) \cdot \Omega$$

both without capacitor

Find a different capacitor to replace the $80\text{-}\mu\text{F}$ capacitor in series with **winding 1**.

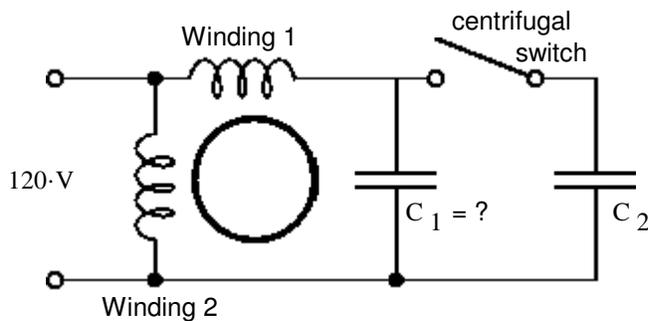
Choose this capacitor to make the current magnitude in the two windings exactly the same at run speed. (Don't worry about the phase angles.)

If the current magnitudes must be the same, then the impedance magnitudes must be the same.

e) The motor has a centrifugal switch which switches at half speed. See drawing, below.

- Circle one:
- i) The centrifugal switch should be closed at start and open (as shown) at run speed.
 - ii) The centrifugal switch should be open (as shown) at start and closed at run speed.

Find the values of the two capacitors below so as to meet the conditions of parts b) and d). Write them down below.



2. (37 pts) A separately excited dc motor is rated at 2-hp, 1200rpm, armature: 150 V 14A, field: 150 V 0.8A.

- a) The field is connected to the rated voltage and then you spin this motor with another motor at 900rpm. Nothing but a voltmeter is hooked to the armature terminals and it measures 88 V .
Find R_A from this information and the ratings.

$$1 \cdot \text{hp} = 745.7 \cdot \text{W}$$

If you can't find R_A , mark an X here _____ and use 2.5Ω for the rest of the problem.

Unless stated otherwise, assume rated voltages below.

- b) Find the rotational losses when operated at full load. $P_{\text{rot}} = ?$

- c) Find the overall efficiency (includes power needed for the field) when operated at full load.

- d) Find the no-load armature current. Show the algebra needed to find I_A from the basic equations.

The rotational losses are proportional to the motor speed.

Hint 1: This also means that the rotational losses are proportional to E_A , like this:

Hint 2: This turns out to be amazingly easy to calculate, no quadratic required.

$$P_{\text{rot}2} = P_{\text{rot}1} \cdot \frac{E_{A2}}{E_{A1}}$$

If you can't find I_{A1} , mark an X here _____ and use 1.5A for the rest of the problem.

2. e) Find the no-load shaft speed.

f) The mechanical load on the shaft is increased and the motor slows down to: $n_{new} := 1300\text{-rpm}$

Find the load power at this speed. Remember that the rotational losses are proportional to the motor speed.

g) The field voltage is reduced to 120V and the armature is left at the rated voltage.
The load is then adjusted so that the speed is again 1300rpm.

Find the armature current at this field voltage.

h) Would it be OK to operate this way for a long time?

3. (30 pts) A 345 kV (nominal) transmission line has the following length and line parameters. S := siemens

$$\text{len} := 120 \cdot \text{km} \quad r := 0.08 \cdot \frac{\Omega}{\text{km}} \quad x := 0.6 \cdot \frac{\Omega}{\text{km}} \quad g := 0 \cdot \frac{\text{S}}{\text{km}} \quad y := 6 \cdot 10^{-6} \cdot \frac{\text{S}}{\text{km}} \quad j$$

- a) Choose the most appropriate model for this transmission line and draw it, including the impedance and/or admittance value(s). Add a 3 ϕ load at the receiving end of the transmission line.

The line voltage at the **source** is 345kV. The line current from the **source** (I_S) is 500A and it leads the line-to-neutral voltage by 12° .

- b) Find the line current in your model, I_{Line} (not I_S) in a complex-number form. $I_{\text{Line}} = ?$

Be sure to clearly indicate which value you assume to be 0° .

- c) Find the load phase voltage, V_R , magnitude and phase. $V_R = ?$

d) What is the line voltage at the load (magnitude)?

e) What is the "power angle" (δ)?

f) Find the impedance of one phase of the load, assuming Y-connected.

g) Find the power consumed by the entire load.

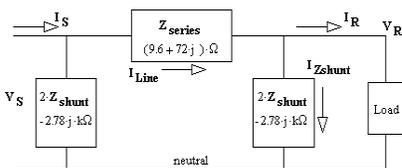
h) Find the power factor of the load. Indicate if it is leading or lagging.

_____ / 30

Total _____ / 100

Answers

1. a) $(17.32 + 10j) \cdot \Omega$ $(21.84 + 17.86j) \cdot \Omega$ b) $92.5 \cdot \text{deg}$ Angle difference is much closer to the ideal of 90° .
 c) It will start spinning in the opposite direction $4.15 \cdot \text{A}$ $4.25 \cdot \text{A}$ currents are both less and closer in value
- d) $44.2 \cdot \mu\text{F}$ e) i) $44 \cdot \mu\text{F}$ $36 \cdot \mu\text{F}$ 2. a) $2.333 \cdot \Omega$ b) $151.3 \cdot \text{W}$ c) $67.2 \cdot \%$ d) $1.289 \cdot \text{A}$ e) $1503 \cdot \text{rpm}$
 f) $1083 \cdot \text{W}$ g) $20.7 \cdot \text{A}$ h) NO



3. a) b) $(489.1 + 32.25j) \cdot \text{A} = 490.1 \text{A} \angle 3.773^\circ$
 c) $(196.8 - 35.52j) \cdot \text{kV} = 200 \text{kV} \angle -10.23^\circ$ d) $346.4 \cdot \text{kV}$ e) $10.23 \cdot \text{deg}$
 f) $(416.5 - 40.82j) \cdot \Omega = 418.5 \Omega \angle -5.6^\circ$ g) $285.3 \cdot \text{MW}$ h) 0.995 leading