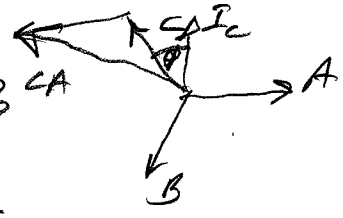
ECE 431

First Exam - Spring 2013 - Closed book, (standard class sheet allowed), 55 min.

Name: Solution

Problem #1 (35 points)

A balanced 3-phase, 208 Volt (line-line), ABC sequence source serves a balanced, 3-phase passive load. A Wattmeter is connected to read the voltage from line C to line A and the current into the load from line C -- it reads 1,350 Watts. An Ammeter indicates that line B current magnitude is 15 Amps.



a) How much real and reactive power does the load consume (3-phase)?

$1350 = 208 \times 15 \cos(150° - (120° - \phi))$

$= 208 \times 15 \cos(30 + \phi)$

$30 + \phi = 64.4° \quad \phi = 34.4°$

$\bar{V}_{CA} = 208 \angle 150°$

$\bar{I}_C = 15 \angle 120° - \phi$

$P_{3\phi} = \sqrt{3} \times 208 \times 15 \cos 34.4° = 4461\ W$

$Q_{3\phi} = \sqrt{3}\, 208 \times 15 \sin 34.4° = 3053\ VArs$

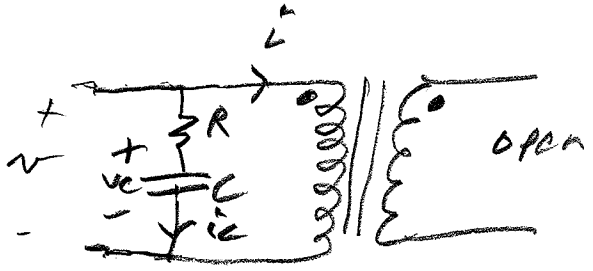
b) How much would the single Wattmeter (connected as above) read if you used power factor correction capacitors to correct the power factor of the load to unity?

$4461 = \sqrt{3} \times 208 \times I_{L_{new}} \qquad I_{L_{new}} = 12.38A$

$W_M = 208 \times 12.38 \cos 30° = 2230\ W$

Problem #2 (35 points)

a) Suppose you would like to observe the magnetic saturation curve of a transformer. Describe in as much detail as you can how you might do that. Explain how it would work (i.e. what would you measure and what would you multiply the measurements by to get the flux linkage vs exciting current?).

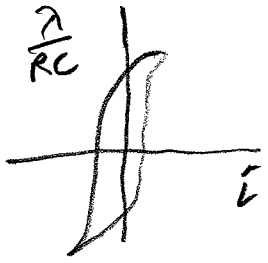


For $R \gg \frac{1}{\omega C}$) $\quad v = \frac{d\lambda}{dt} \approx i_c R = RC\frac{dv_c}{dt}$

$$\boxed{\lambda \simeq RC v_c}$$

measure i measure v_c

Plot v_c vs i



b) If 3 transformers (each rated for 250KVA) are connected in a delta-delta configuration, what would be the rating of the open-delta transformer bank created by removing one of the transformers?

$750\text{KVA} \times 0.58 = 435\text{ KVA}$

c) If a transformer nameplate indicates ratings of 2400Volts/240Volts, 60Hz, 25KVA, 7% Z, what would be the value of the short circuit current on the 240 Volt side if the 240 Volt side was shorted while rated voltage was applied to the 2400 Volt side?

$$I_{sc_{240}} = \frac{25k}{240} \times \frac{100}{7} = 1,488\text{A}$$

Problem #3 (30 points)

Determine the number of steps, frequency, and speed (in rpm) for the given movements of a stepper motor. Assume that only full steps can be taken. The stepper motor has 5 phases and 24 rotor teeth.

a) Turn 81° clockwise (CW) within 0.1 s.

b) Turn 135° counter-clockwise (CCW) within 0.3 s.

Steps/Rev = 5x24 = 120 steps/Rev ⇒ 3°/step

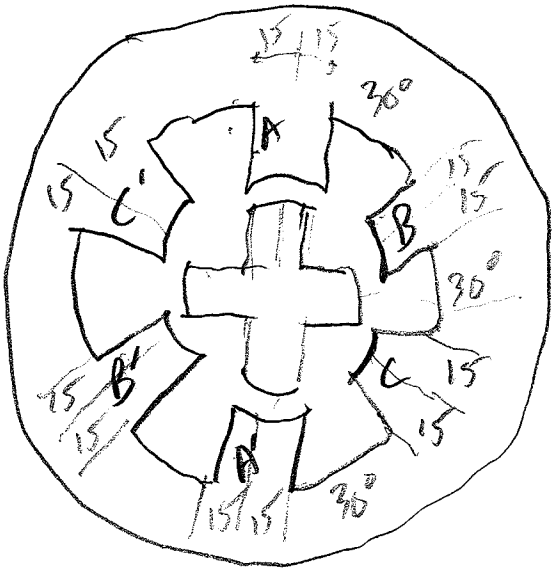
a) 81° ⇒ 27 steps in 0.1 sec ⇒ 270 steps/sec ⇒ $\frac{270 \text{ steps}}{120 \text{ steps}} \frac{60 \text{ sec}}{\text{min}}$

= 135 RPM

b) 135° ⇒ 45 steps in 0.3 sec ⇒ 150 steps/sec ⇒ $\frac{150}{120} \frac{\text{Rev}}{\text{sec}} \frac{60 \text{ sec}}{\text{min}}$

= 75 RPM

Draw a stepper motor with 6 stator poles and associated coils A across from A', B across from B', and C across from C', and 4 rotor poles with no coils and no magnets. The sequence is A, B, C, A', B', C' clockwise. The stator and rotor poles have the same arc length of about 30 degrees each. Show the rotor position lined up so that one rotor pole pair is directly lined up with the A and A' coils. What happens when A – A' is deenergized and B – B' is energized?



when A-A' is deenergized and B-B' is energized, the rotor will rotate counter clockwise 30°

Check $\frac{\text{steps}}{\text{Rev}}$ = 3x4 = 12

(30° per step)

$\frac{180° - 15° \times 6}{3} = \frac{90°}{3} = 30°$