Name: Solutions

Section (Circle One) Overbye Krein

ECE 430

Exam #1

Fall 2004

October 6, 2004

Closed book, closed notes
One 8.5" by 11" inch note sheet and calculators allowed

1.	________	/ 25
2.	________	/ 35
3.	________	/ 25
4.	________	/ 15
Total	________	/ 100

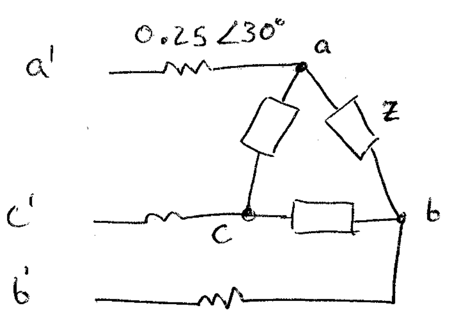
1. **(25 points)**

A delta connected load with each $Z = 8\angle 30°\Omega$ is supplied from a balanced three phase wye connected generator through lines having series impedance of $0.25\ \angle 30°\ \Omega$. The line-to-line voltage measured at the load is 208 volts (for the angle, please use load V_{ab} as the reference, such that $V_{ab} = 208\angle 0°$ volts).

a. Calculate the three load phase currents (magnitude and angle).

b. Calculate the magnitude of the line-to-line voltage at the generator.

c. Calculate the power factor at the generator (be sure to indicate leading or lagging).

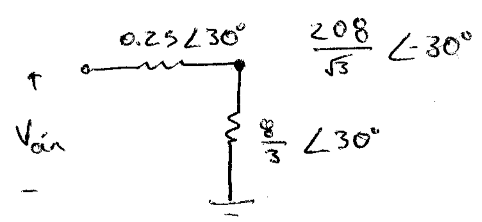


a) $I_{ab} = \frac{V_{ab}}{Z} = \frac{208\angle 0}{8\angle 30} = \boxed{26\angle{-30°}\ A}$

$I_{bc} = \boxed{26\angle{-150°}\ A}$

$I_{ca} = 26\angle{-270°}\ A$ or $\boxed{26\angle 90°\ A}$

b) Use per phase analysis



$I_a = \sqrt{3}\, I_{ab}\angle{-30-\theta_i}$

$I_a = 45\angle{-60°}$

$V_{a'n} = 120\angle{-30°} + (45\angle{-60°})(0.25\angle 30°)$

$= 131.25\angle{-30°}$

$\boxed{V_{a'b'} = 227.3\angle 0°\ V}$

c) $pf = \cos 30° = \boxed{0.866\ \text{lag}}$

2. **(35 points)**

A 480/240 V, 4.8-kVA, 60-Hz, single-phase transformer is used to supply a 4.8 kVA load with a power factor of 0.8 lagging at rated voltage of 240 V.

a) If you assume the transformer is ideal, what would be the magnitude of the expected primary side (480 Volt side) current?

b) Again, if you assume the transformer is ideal, what is the equivalent impedance of the load viewed from the primary side of the transformer?

Next, the transformer is tested to determine its parameters. The parameters, all referred to the high side, are found to be $R_{eq1} = 3\ \Omega$, $X_{eq1} = 4\ \Omega$, $R_c = 6\ k\Omega$, and $X_m = 3\ k\Omega$. Using the approximate equivalent circuit and assuming the same load as mentioned above

c) What is the primary (high) side terminal voltage magnitude needed to supply the load at a voltage of 240 V and what is its % voltage regulation?

d) What is the transformer's efficiency (η) for this load?

e) Finally, assume that the load is replaced by a short circuit with the supply voltage adjusted to be equal to 480 V. Calculate the secondary short circuit current again using the approximate equivalent circuit.

a) $I = \left(\dfrac{4800\angle 36.87^\circ}{480\angle 0^\circ}\right)^* = \boxed{10\angle -36.87^\circ\ A}$

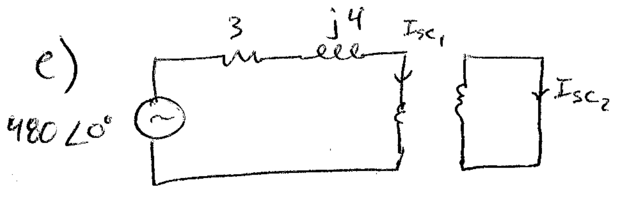
b) $Z = \dfrac{480\angle 0}{10\angle 36.8^\circ} = \boxed{48\angle 36.87^\circ\ \Omega}$

c) $V_p = 480\angle 0^\circ + (10\angle -36.87^\circ)(3+j4) = \boxed{528.2\angle 1.5^\circ\ V}$

$\%\ Reg = \dfrac{528-480}{480} \times 100 = \boxed{10\%}$

d) $P_{losses} = \dfrac{528^2}{6000} + 10^2(3) = 346\,W \qquad \eta = \dfrac{4800\cdot 0.8}{4800\cdot 0.8 + 346} = \boxed{91.7\%}$

e)



$|I_{sc_1}| = \dfrac{480}{5} = 96\,A$

$|I_{sc_2}| = 2\cdot|I_{sc_1}| = \boxed{192\ A}$

3. (25 points)

Three loads are connected in parallel as follows: Load 1 (wired in delta) consumes 8 kW at a lagging power factor of 0.8, load 2 (wired in wye) consumes 10 kVA at a lagging power factor of 0.9, load 3 (wired in delta) consumes 4 + 3j kVA. The system line-to-line voltage is 480 V.

a) Compute the total line current (magnitude only) that supplies these loads.

b) Draw a per-phase equivalent circuit for this problem. Show the actual impedance values for each of the three loads.

c) How much capacitance (in kvar) must be connected in parallel with these three loads to correct the total power factor to 0.95 leading?

a) $I_L = ?$

1.	$\frac{8\text{ kW}}{.8}$	0.8 pf lag	$8 + j6$
2.	10 kVA	0.9 pf lag	$9 + j4.36$
3.	$4 + j3 \rightarrow 5$ kVA		$4 + j3$
			$21 + j13.36$

Total: $24.889 \angle 32.5°$ kVA

$S = \sqrt{3}\, V_L I_L \Rightarrow 24889 = \sqrt{3}(480) I_L$

$\boxed{I_L = 29.94 \text{ A}}$

b) Per Phase Equiv

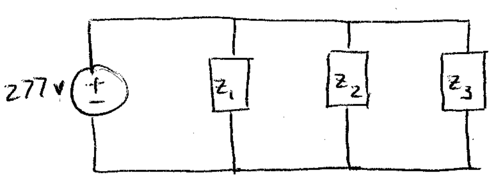
$S_{1\phi} = 8.296 \text{ kVA} = V I^*$

$V_\phi = 277.1$

$I_{\phi_1} = \frac{10000}{3V_\phi} = 12.03$ $\quad Z_1 = 23.04 \angle 36.9° \ \Omega$

$I_{\phi_2} = \frac{10000}{3V_\phi} = 12.03$ $\quad Z_2 = 23.04 \angle \cancel{36.9}\ 25.8° \ \Omega$

$I_{\phi_3} = 6.014$ $\quad Z_3 = 46.08 \angle 36.9°$



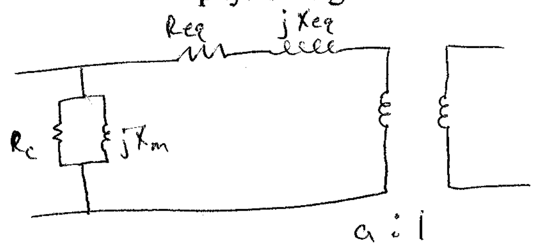
c) $S_T = 21 + j13.36$ kVA

$S_{T_{new}} = \frac{21}{.95} \angle \cos^{-1}(.95) = 21 - j6.9$ kVA

$Q_{cap} = 13.36 + 6.9 = \boxed{20.26 \text{ kVAR}}$

4. (Short answer, 15 points total)

(6 pts) a) Draw the circuit model for the real transformer discussed in class, and explain the physical significance of each circuit component in the model.



$R_{eq} = R_1 + a^2 R_2 \rightarrow R_1 =$ Winding 1 resistance

$R_2 =$ " 2 "

$X_{eq} = X_{\ell_1} + a^2 X_{\ell_2} \rightarrow X_{\ell_1} =$ leakage reactance of 1

$X_{\ell_2} =$ " " " 2

R_c = Core losses (Hysteresis & Eddy Currents)

X_m = magnetizing reactance due to finite core permeability

(6 pts) b) A 200 turn coil is wrapped around a toroid that has an average radius of 10 cm, a cross-sectional area of 50 cm^2 and a relative permeability of $\mu_r = 500$. Assuming that all flux is within the core, how much current must flow in the coil to generate a flux (in the core) of 0.005 Weber? Recall that $\mu_0 = 4\pi \times 10^{-7}$ H/m.

$\phi = \frac{\mu N i A}{2\pi r}$ hence $i = \frac{2\pi r \phi}{\mu N A} = \boxed{5A}$

(3 pts) c) Put dot markings on the coils