ECE330
Exam #1
Spring 2005

Name ___Solation___
(Print Name)

Section: (Circle One) 10 MWF (Sauer) 12:30 TuTh (Liu)

Problem 1 _______ Problem 2 _______ Problem 3 _______ Problem 4 _______

TOTAL: _______

USEFUL INFORMATION

Problem 1 (25 pts.)

Three single-phase loads are connected in parallel across a 60Hz source of 240 Volts.

Load #1: 6 KVA at 0.8 power factor lag
Load #2: 4 KW at 0.9 power factor lag
Load #3: 13 Amps at unity power factor

OUT

a) Find the total complex power consumed by these three loads.
b) Find the source current magnitude
c) Find the value of a capacitive VARS that should be added in parallel to these three loads to make the overall power factor 0.95 lag.

(a) $\bar{S} = 6k\angle \cos^{-1}.8 + \frac{4k}{.9}\angle \cos^{-1}.9 + 240 \times 13\angle 0$

$$
\begin{aligned}
&= 4800 + j3600 \\
&\quad 4000 + j1937 \\
&\quad 3120 \\
&\overline{11920 + j5537} = 13{,}143\angle 24.9^\circ
\end{aligned}
$$

(b) $13{,}143 = 240\, I \qquad I = 54.76\text{ A}$

(c) $\bar{S}_{new} = \frac{11920}{.95}\angle \cos^{-1}.95 = 11920 + j\,3918$

$Q_{add} = 5537 - 3918 = 1619$ VARS

Problem 2 (25 pts)

A balanced, 3-phase, 3-wire, 60Hz, Wye-connected source is serving a combination of balanced loads in various configurations. Measurement of the source line voltage indicates 480 Volts (line to line). Measurement of the source line current indicates 23 Amps. When 8 KVAR of capacitance (3-phase) is added in parallel to the other loads, the source voltage stays the same and the source line current changes to 18 Amps. What is the total 3-phase original load in Watts and Vars?

$$P + jQ = \sqrt{3} \times 480 \times 23 \angle \theta_1$$

$$P + j(Q - 8000) = \sqrt{3} \times 480 \times 18 \angle \theta_2$$

OR

(1) $P^2 + Q^2 = (\sqrt{3} \times 480 \times 23)^2 = 365.6 \times 10^6$

(2) $P^2 + (Q - 8000)^2 = (\sqrt{3} \times 480 \times 18)^2 = 223.9 \times 10^6$

(1)-(2): $0 - (-16{,}000Q + 8000^2) = (365.6 - 223.9) \times 10^6$

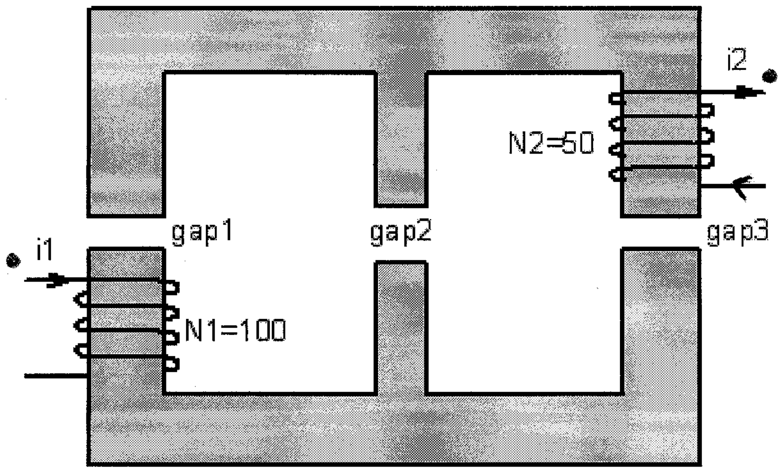
$16{,}000\, Q = 141.7 \times 10^6 + 64 \times 10^6$

$Q = 12{,}856$ VARS

$P = 14{,}153$ W

Problem 3 (25 pts)

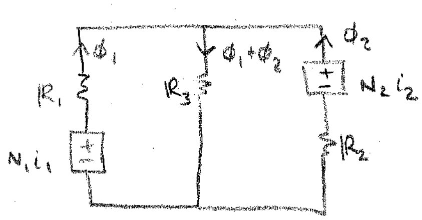
A magnetic piece with two coils is shown below. The permeability of the magnetic core is infinitely large, hence the magnetic reluctance of the metal materials can be ignored. The dimensions of the air gaps are summarized in the figure. Ignore fringing effect.



Gap 1: Distance: 5 mm; cross-sectional area: 1 cm^2
Gap 2: Distance: 6 mm; cross-sectional area: 0.5 cm^2
Gap 3: Distance: 5 mm; cross-sectional area: 1 cm^2

1) Identify the dot marking of the two coils;
2) Draw the magnetic equivalent circuit;
3) Find the <u>magnitude</u> of the self-inductances and the mutual inductance;

2)



$$R_2 = R_1 = \frac{5e^{-3}}{4\pi\times10^{-7}(1\times10^{-4})} = 3.98\times10^{7}\ AT/wb$$

$$R_3 = \frac{6e^{-3}}{4\pi\times10^{-7}(.5\times10^{-4})} = 9.55\times10^{7}\ AT/wb$$

3)

$$N_1 i_1 = R_1\phi_1 + R_3(\phi_1+\phi_2) \qquad N_1 i_1 = \phi_1(R_1+R_3) + \phi_2(R_3) \Rightarrow \phi_2 = \frac{N_1 i_1 - \phi_1(R_1+R_3)}{R_3}$$

$$N_2 i_2 = R_2\phi_2 + R_3(\phi_1+\phi_2) \Rightarrow N_2 i_2 = \phi_1(R_3) + \phi_2(R_2+R_3)$$

$$N_2 i_2 = \frac{R_2}{R_3}N_1 i_1 - \frac{R_2}{R_3}(R_1+R_3)\phi_1 + R_3\phi_1 + N_1 i_1 - (R_1+R_3)\phi_1 \Rightarrow \phi_1 = \frac{\left(1+\frac{R_2}{R_3}\right)N_1 i_1 - N_2 i_2}{R_1 + \frac{R_2}{R_3}(R_1+R_3)}$$

$$\phi_1 = 1.47\times10^{-6} i_1 - 5.2\times10^{-7} i_2$$

$$\lambda = N\phi = Li$$

$$\phi_2 = -1.04\times10^{-6} i_1 + 7.37\times10^{-7} i_2$$

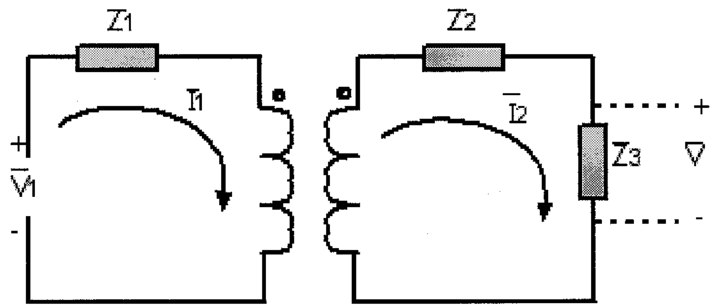
$$\lambda_1 = N_1\phi_1 = 1.47\times10^{-4} i_1 - 5.2\times10^{-5} i_2$$

$$\lambda_2 = N_2\phi_2 = -5.2\times10^{-5} i_1 + 3.68\times10^{-5} i_2$$

$$\Rightarrow \boxed{\begin{array}{l} L_1 = 0.147\,mH \\ L_2 = 0.0368\,mH \\ M = 0.052\,mH \end{array}}$$

Problem 4 (25 pts)

A circuit involving two mutually coupled inductor coils is illustrated below. Assume the self-inductances are L_1 and L_2, and the mutual inductance is M.



Suppose that

$$Z_1 = 100\angle 30\Omega$$
$$Z_2 = 150\angle(-30)\Omega$$

(1) Write two loop equations (use symbols);
(2) Suppose the load impedance z_3 is purely resistive in nature, and z_3=50Ω. Further, suppose the time domain input voltage V_1 is $100\sqrt{2}\cos(100t)$, find the time domain expression of load voltage V. (For this, assume L_1=1 H; L_2=2 H; M=1 H).

(1) $\bar{V}_1 = \bar{I}_1 Z_1 + (j\omega L_1)\bar{I}_1 - j\omega M \bar{I}_2$

$\bar{I}_2 Z_2 + \bar{I}_2 Z_3 + (j\omega L_2)\bar{I}_2 - (j\omega M)\bar{I}_1 = 0$

(2) $\bar{V} = \bar{I}_2 Z_3$

Solve for $\bar{I}_2$

$100\angle 0 = \bar{I}_1(100\angle 30°) + j100\bar{I}_1 - j100\bar{I}_2$

$\bar{I}_2(150\angle -30°) + \bar{I}_2(50) + j200\bar{I}_2 - j100\bar{I}_1 = 0$

$\bar{I}_2 = 0.2561 + j0.0463$
$= 0.2603\angle 10.24°$

$\bar{V} = (0.2603\angle 10.24°)(50)$

$\bar{V} = 13.015\angle 10.24°$

$\boxed{v(t) = 13.015\sqrt{2}\cos(100t + 10.24°)}$