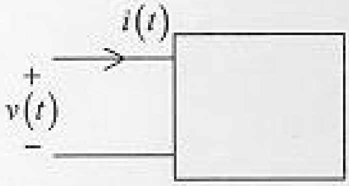
Problem 1 (30 pts.)

a) If $v(t) = 200\cos(377t - 10°)$ and $i(t) = 10\,sin(377t + 125°)$, find the complex power $P + jQ$, PF (specify lead or lag)

$P + jQ =$ $500\sqrt{2} - 500\sqrt{2}\,j$ $= 707.1 - 707.1j$ $P.F. =$ $1/\sqrt{2}$ Lead or Lag (circle one)



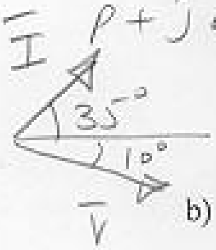
$v(t) = 200\cos(377t - 10°) \Rightarrow \bar{V} = \frac{200}{\sqrt{2}}\angle -10°$

$i(t) = 10\sin(377t + 125°)$

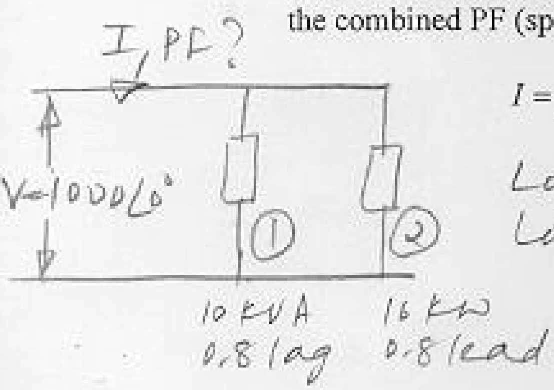
$= 10\cos(377t + 35°) \Rightarrow \bar{I} = \frac{10}{\sqrt{2}}\angle 35°$

$P + jQ = VI^* = \left(\frac{200}{\sqrt{2}}\angle -10°\right)\left(\frac{10}{\sqrt{2}}\angle -35°\right) = 1000\angle -45°$

$= 500\sqrt{2} - 500\sqrt{2}\,j$ kVA $\quad$ PF $= 1/\sqrt{2}$ lead



b) Two loads in parallel, 10 kVA at 0.8 PF lag and 16 kW at 0.8 lead are supplied by a source $\bar{V} = 1000\angle 0°$. Find the total current (magnitude) supplied by the source and the combined PF (specify lead/lag).



$I =$ 24.74 A $\quad P.F. =$ 0.97 $\quad$ Lead or Lag (circle one)

Load 1 : $S_1 = 10k(0.8 + j0.6) = 8 + 6j$ kVA

Load 2 : $S_2 = \frac{16k}{0.8}(0.8 - j0.6) = 16 - 12j$ kVA

$S = S_1 + S_2 = 24 - 6j$ kVA

$I = \left(\frac{S}{V}\right)^* = \frac{(24 + 6j)10^3}{1000\angle 0} = 24 + 6j = 24.74\angle 14°$ A

PF $= \cos 14° = 0.97$ lead

c) For the phase sequence a-b-c if $\bar{I}_{ab} = 15\angle 38°$ and $\bar{V}_{bc} = 10\angle -112°$ the total power $\bar{S}_T$ is 450 ∠−30° VA.

for a-b-c phase sequence

$V_{ab} = 10\angle(-112° + 120°) = 10\angle 8°$

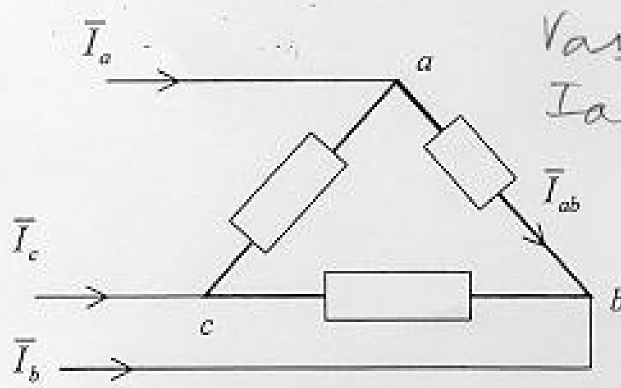
$I_{ab} = 15\angle 38°$

$S_T = 3S_\phi = 3V_{ab}I_{ab}^*$

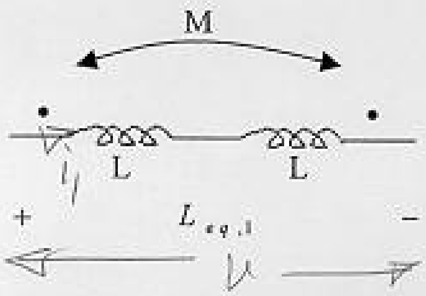
$= 3(10\angle 8°)(15\angle -38°)$

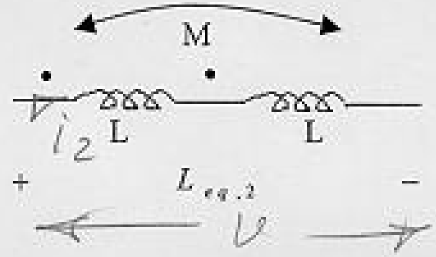
$= (30)(15)\angle -30°$

$= 389.7 - 225j$ VA



d)





$L_{eq,1} = 4\text{ H}$ $L_{eq,2} = 6\text{ H}$

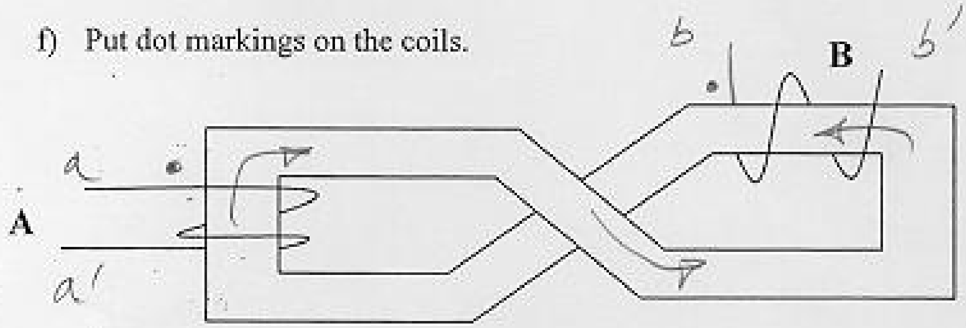
$L =$ <u>5/2 H</u> $L =$ <u>1/2 H</u>

$v = \underbrace{2(L-M)}_{4}\frac{di_1}{dt}$ $v = \underbrace{2(L+M)}_{6}\frac{di_2}{dt}$

e) Two coils which are coupled have $L_1 = 10$ mH, $L_2 = 20$ mH, and $M = 14$ mH. Find the coupling coefficient k.

$$k = \frac{M}{\sqrt{L_1 L_2}} = \frac{14\,m}{\sqrt{10m \cdot 20m}} = \frac{14}{\sqrt{200}} = 0.9899$$

f) Put dot markings on the coils.



Dots are placed at ab or a'b'.

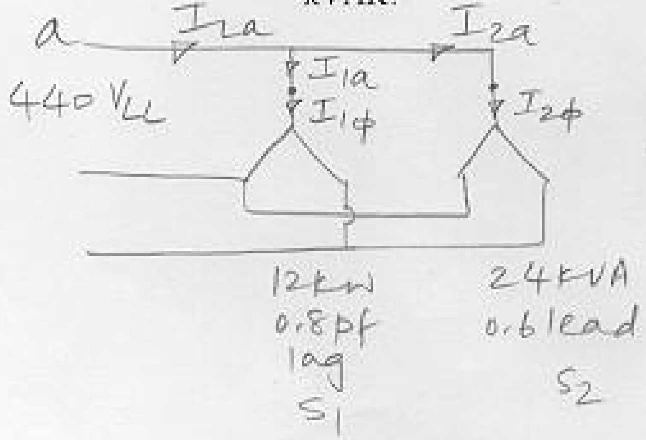
Problem 2 (35)

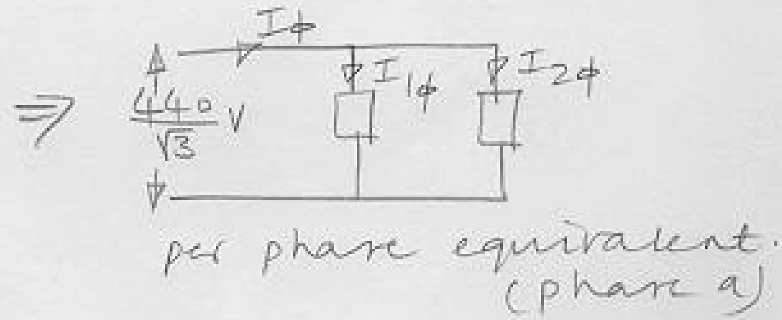
A three phase wye-connected load of 12 kW at 0.8 PF lagging is connected in parallel with another three phase wye-connected load of 24 kVA at 0.6 leading. The line to line voltage is 440 V.

(15) (a) Find (i) total complex power, (ii) PF (state lead or lag) and (iii) the line current.

(15) (b) Assuming $\bar{V}_{an}$ is reference phasor, compute the line currents in each load and the total line current in phasor form. Draw a phasor diagram.

(5) (c) Find kVAR needed to make the PF unity. Is it inductive or capacitive kVAR?





per phase equivalent. (phase a)

a) $S_1 = \frac{12k}{0.8}(0.8 + j0.6) = 12 + j9$ kVA

$S_2 = 24(0.6 - j0.8) = 14.4 - 19.2j$ kVA

$S_T = S_1 + S_2 = \boxed{26.4 - 10.2j \text{ kVA}} = 28.3\times10^3 \angle -21.13^\circ$ VA

$\boxed{PF = 0.933 \text{ lead}}$

$|S_T| = \sqrt{3}\cdot 440 \cdot I_L \Rightarrow I_L = \frac{28.3k}{\sqrt{3}\cdot 440} = \boxed{37.14 \text{ A}}$

b) See the phasor diagram for phase 'a' on the next page.

subscript 'a' : phase a quantities

'1' : Load 1

'2' : Load 2

'ϕ' : phase quantities

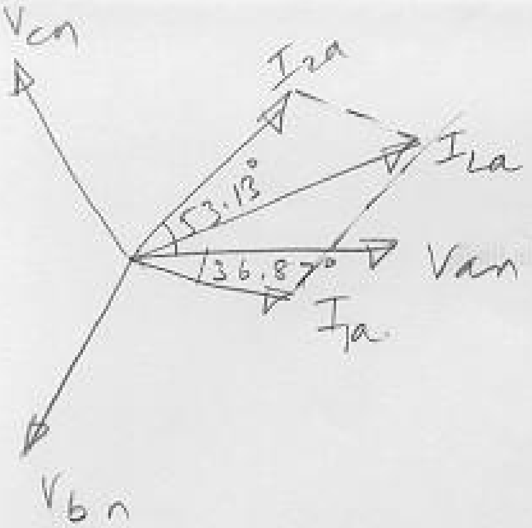
'L' : Line quantities

Ans:

$I_{L_1} = 19.68\angle -36.87^\circ$ A

$I_{L_2} = 31.49\angle 53.13^\circ$ A

$I_L = 37.14\angle 21.13^\circ$



Phasor Diagram for phase 'a'.

Load 1:

$$\frac{12+j9}{3} = \frac{440}{\sqrt{3}}\angle 0 \; I_{1\phi}^{*}$$

$$I_{1\phi} = \left(\frac{(12+j9)\sqrt{3}}{3\times 440\angle 0}\right)^{*}$$

$$= \frac{(12-j9)\,k}{\sqrt{3}\times 440}$$

$$= 15.75 - 11.8j$$

$$I_{1a} = 19.68\angle -36.87^\circ$$

Load 2:

$$\frac{14.4-19.2j}{3} = \frac{440}{\sqrt{3}}\angle 0 \; I_{2\phi}^{*}$$

$$\Rightarrow I_{2\phi} = \frac{(14.4+19.2j)\,k}{\sqrt{3}\times 440\angle 0}$$

$$I_{2a} = 18.9 + 25.19j = 31.49\angle 53.13^\circ$$

$$I_{La} = I_{1a} + I_{2a} = 34.65 + 13.39j = 37.14\angle 21.13^\circ$$

in Y connection, phase & line currents are identical

Hence, $I_{1a} = 19.68\angle -36.87^\circ$

$I_{1b} = 19.68\angle -36.87^\circ - 120^\circ$

$I_{1c} = 19.68\angle -36.87^\circ + 120^\circ$

Similarly for I_{2a}, I_{2b}, I_{2c} & I_{La}, I_{Lb}, I_{Lc}.

c) KVAR needed to make the PF unity is 10.2. It is $\boxed{\text{inductive}}$ KVAr.

ans: $\boxed{10.2 \text{ KVAr.}}$

Problem 3

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 apparent 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 $R_{eq} = 3\Omega$, $X_{eq} = 4\Omega$, $R_c = 6K\Omega$, and $X_m = 3K\Omega$. Assuming the same load as mentioned above and using approximate equivalent circuit

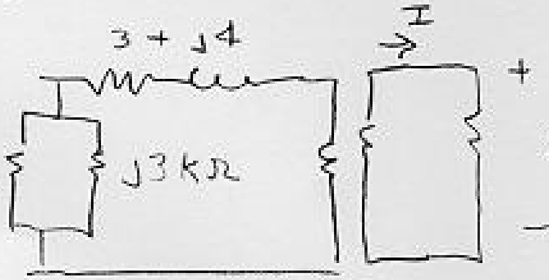
c) What is the primary (high) side terminal voltage magnitude needed to supply the load at a voltage of 240 V?

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

e) Finally, the load is accidentally shorted, resulting in a new load of 0 kVA (but with lots of current). Assuming the primary high side voltage during the short is 480 V, what are the transformer's total power losses during the short (before the circuit breakers trip).

a) $\frac{4800 \text{ kVA}}{480} = \boxed{10 A}$

b) $S_{Load} = 4.8\angle 36.89^\circ \text{ kVA} = V\cdot\left(\frac{V}{Z^*}\right)^* \Rightarrow \boxed{Z = 48\angle 36.89^\circ \Omega}$

c) 

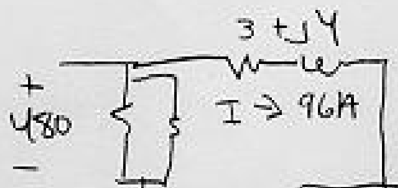
$I_s = 20\angle -36.89^\circ$

$I_p = 10\angle -36.89^\circ$

$V_{source} = 480\angle 0 + (3+4j)\, 10\angle -36.89 = 5.28 + j14 = \boxed{528.18\angle 1.51^\circ}$

d) $\eta = \frac{P_{out}}{P_{out} + P_{Losses}}$ $P_{out} = 3840 W$ $P_{Loss} = \frac{528^2}{6000} + 10^2 \cdot 3 = 346.5 W$

$\boxed{\eta = 0.9172}$

e) During short model is 

$P = 96^2 \cdot 3 + 480^2/6000 = 27,686 W = \boxed{27.6 kW}$