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ELG 3316

Electric Machines & Power Systems

Answers / Solutions to Assignment #1

ASSIGNMENT #1 : ANSWERS/SOLUTIONS

Q1 105 kWh/month.

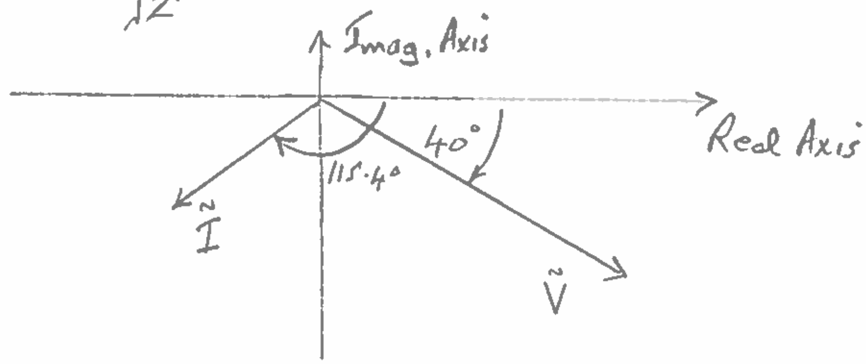
Q2 0.25 kWh.

Q3 (a) $i(t) = 25.6\sqrt{2}\cos(\omega t - 115.4°)$ Amps.

$\omega = 2\pi f = 2\pi(60) = 120\pi \simeq 377$ rads/sec.

(b). $\tilde{V} = \frac{100}{\sqrt{2}}\angle -40° = 70.71\angle -40°$ Volts

(c).



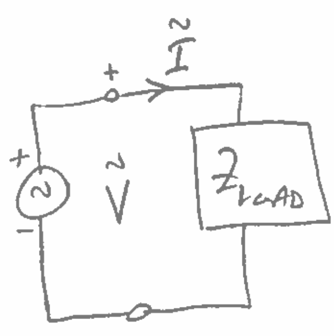
(d). $\tilde{S} = \tilde{V}\tilde{I}^* = (100\angle -40°)(25.6\angle -115.4°)^*$

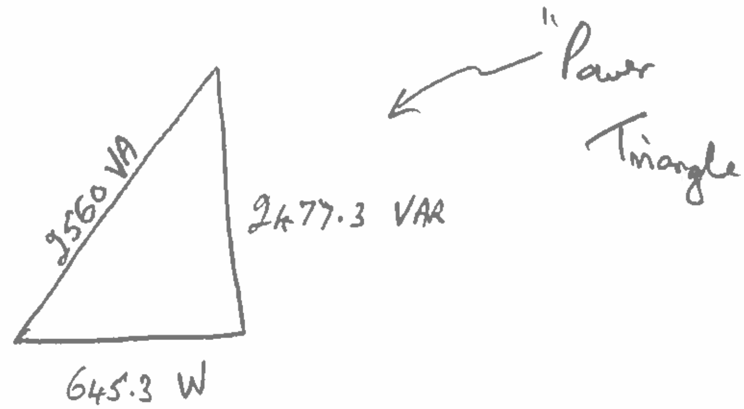
where $(25.6\angle -115.4°)^* = 25.6\angle 115.4°$

Recall that this turns out to be $\tilde{S} = |\tilde{V}||\tilde{I}|\angle\phi_{pf}$

$= 2560\angle 75.4°$ VA

$= \underbrace{645.3}_{P\ \text{(Watts)}} + j\underbrace{2477.3}_{Q\ \text{(VARs)}}$





(e). We can see from $\tilde{S}$ that $\phi_{PF} = 75.4°$.

So the power factor is $PF = \cos(75.4°) = 0.252$

Since $\phi_{PF} > 0$, we know that it is a lagging PF.

(f). In order to have a unity power factor (i.e. $PF = 1$)

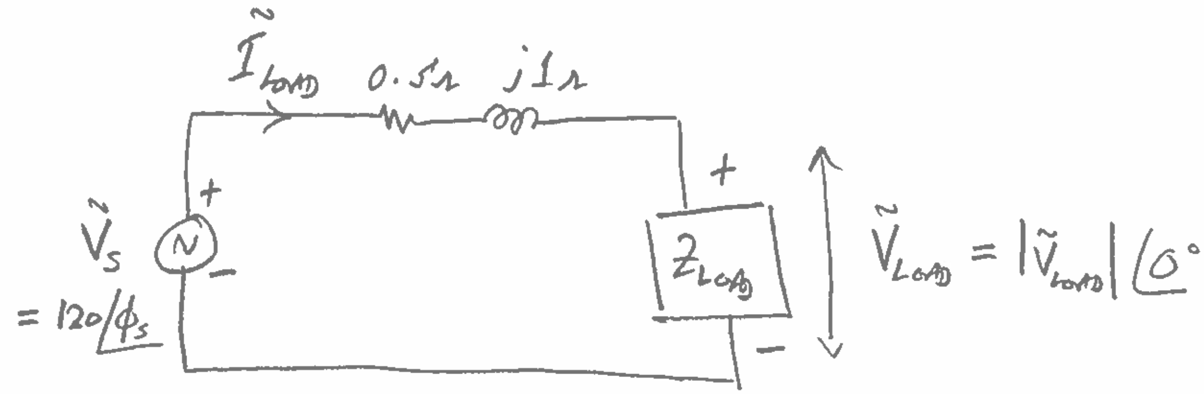
we must have $Q = 0$. At present $Q = 2477.3$.

So we must add a capacitor which will provide

a $Q = -2477.3$.

See Simulation Lab.

Q4



- No currents or voltages have been specified with a particular phase angle. Since phases are always relative we are free to select a phase reference with respect to which all other phases will be calculated. In this solution we have chosen the phase of the load voltage as the reference, with its phase at 0°. We cannot then select the phase of any other voltages or currents; these must be calculated. We have written the phase of $\tilde{V}_S$ as being ϕ_S; it must be calculated.

- $|\tilde{I}_{LOAD}| = 8$ ← This is given. But we don't know its phase. Thus we don't know $\tilde{I}_{LOAD}$.

$\cos\phi_{pf} = 0.85$ lagging ← The load pf is given.

So $\underline{\underline{\phi_{pf} > 0}}$

$\phi_{pf} = \cos^{-1} 0.85$
$= \underline{\underline{31.8^\circ}}$

The phase of $\tilde{V}_{LOAD}$ is $\phi_v = 0^\circ$

The phase of $\tilde{I}_{LOAD}$ is ϕ_i, but is not yet known.

Now by definition $\phi_{pf} = \phi_v - \phi_i \Rightarrow \phi_i = -31.8^\circ$

(where $\phi_{pf} = 31.8^\circ$ and $\phi_v = 0^\circ$)

$$\therefore \tilde{I}_{LOAD} = 8\angle{-31.8^\circ}$$

- Apply KVL around the circuit. This gives us

$$\tilde{V}_s - \tilde{I}_{LOAD}(0.5 + j1) - \tilde{V}_{LOAD} = 0$$

$\tilde{V}_s = 120\angle\phi_s$; $\tilde{I}_{LOAD}(0.5+j1) = (8\angle{-31.8^\circ})(0.5+j1)$; $\tilde{V}_{LOAD} = |\tilde{V}_{LOAD}|\angle 0^\circ$

$$(120\cos\phi_s + j\,120\sin\phi_s) - (7.61 + j\,4.69) - (|\tilde{V}_{LOAD}|\underbrace{\cos 0^\circ}_{1} + |\tilde{V}_{LOAD}|\underbrace{\sin 0^\circ}_{0}) = 0$$

Equate Real Parts of Both Sides: $120\cos\phi_s - 7.61 - |\tilde{V}_{LOAD}| = 0$ — (1)

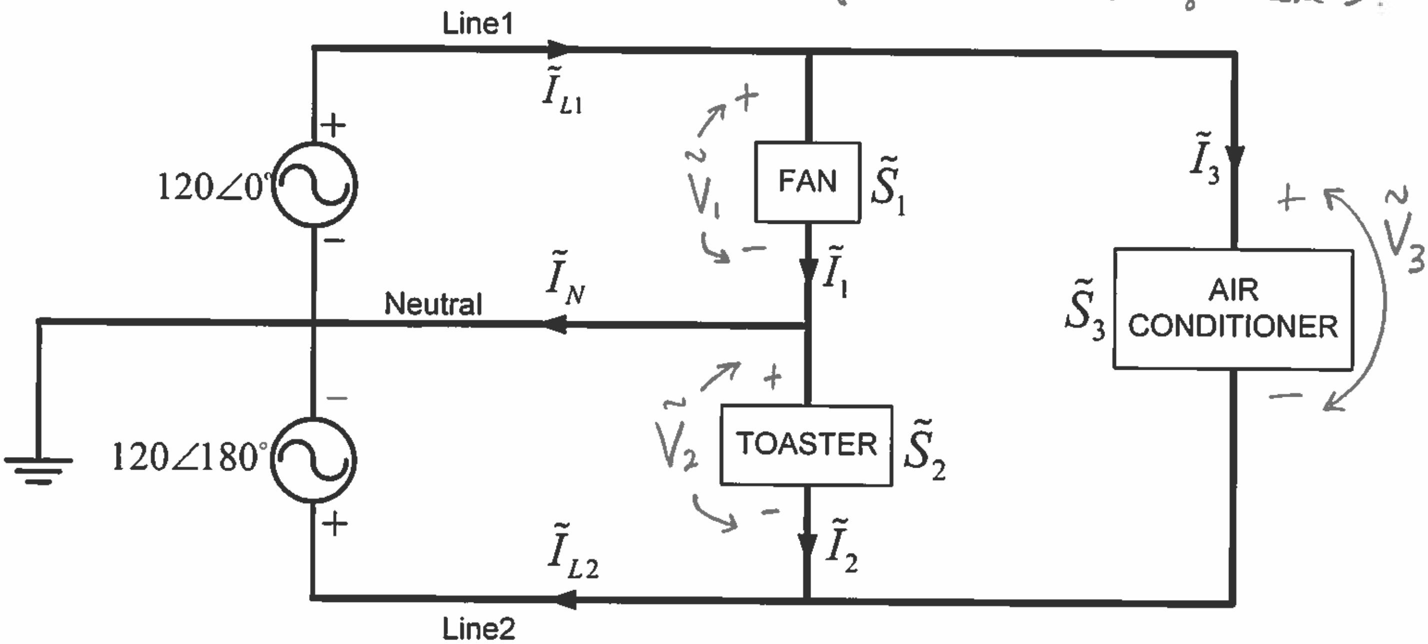
Equate Imag. Parts of Both Sides: $120\sin\phi_s - 4.69 = 0$ — (2)

② gives $\phi_s = \sin^{-1}\left(\frac{4.69}{120}\right) = 2.24^\circ$

If we substitute this into ① it gives us

$$|\tilde{V}_{LOAD}| = 112.28 \text{ Volts.}$$

Q4 (Note that I will be using some additional symbols, and so have indicated them on the circuit diagram. This must always be done).



- We can immediately write $\tilde{V}_1 = 120\angle 0°$ and $\tilde{V}_2 = -120\angle 180°$

  Just apply KVL.

- Fan

  $\tilde{V}_1 = 120\angle 0°$

  $|\tilde{I}_1| = 5$, but $\cos\phi_{PF} = 0.8$ lagging $\Rightarrow$ $\phi_{PF} = 36.87° \Rightarrow \phi_i^{(1)} = -36.87°$

  $\therefore \tilde{I}_1 = 5\angle -36.87°$

  Make sure you know why

- Toaster

  $\tilde{V}_2 = -120\angle 180° = 120\angle 0°$

  $|\tilde{I}_2| = 11$, and unity PF implies current in phase with voltage, so $\phi_i^{(2)} = 0°$

  $\therefore \tilde{I}_2 = 11\angle 0°$

- <u>Air Con</u> KVL gives $\tilde{V}_2 + \tilde{V}_1 - \tilde{V}_3 = 0$

$$\therefore \tilde{V}_3 = 120\angle 0^\circ + 120\angle 0^\circ = 240\angle 0^\circ$$

$|\tilde{I}_3| = 24$. Power factor is 0.85 lagging.

Thus $\phi_{pf} = 31.8^\circ \Rightarrow \phi_i = -31.8^\circ$

$$\therefore \tilde{I}_3 = 24\angle -31.8^\circ$$

(a). $\tilde{S}_{TOTAL} = \tilde{S}_1 + \tilde{S}_2 + \tilde{S}_3$

$\tilde{S}_1 = \tilde{V}_1 \tilde{I}_1^* = (120)(5)\angle 36.87^\circ$

$\tilde{S}_2 = \tilde{V}_2 \tilde{I}_2^* = (120)(11)\angle 0^\circ$

$\tilde{S}_3 = \tilde{V}_3 \tilde{I}_3^* = (240)(24)\angle 31.8^\circ$

DON'T FORGET THE CONJUGATE OPERATION!

$$\therefore \tilde{S}_{TOTAL} = \underbrace{6684}_{P_{TOTAL}} + j\underbrace{3413}_{Q_{TOTAL}} = 7505\angle 27^\circ$$

Total power consumed by house is $P_{TOTAL} = \underbrace{6684\ W}_{6.684\ kW}$

(b). $\tilde{I}_{L1} = \tilde{I}_1 + \tilde{I}_3 = 5\angle{-36.87^\circ} + 24\angle{-31.8^\circ} = 29\angle{-32.8^\circ}$ A

$\tilde{I}_{L2} = \tilde{I}_2 + \tilde{I}_3 = 11\angle{0^\circ} + 24\angle{-31.8^\circ} = 33.87\angle{-22^\circ}$ A

$\tilde{I}_N = \tilde{I}_1 - \tilde{I}_2 = 5\angle{-36.87^\circ} - 11\angle{0^\circ} = 7.6\angle{203.2^\circ}$ A

Note that the current in the neutral line is <u>not</u> zero.

This is not a three-phase system; we never said that currents in 'neutral' lines will always be zero. Only in balanced three-phase systems. In unbalanced three-phase systems it is also not zero.