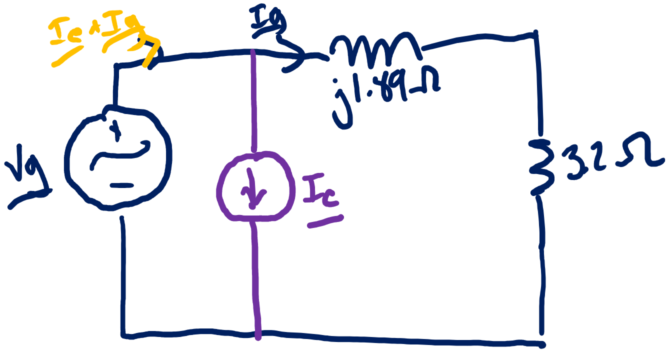
Announcements

Quiz Wednesday

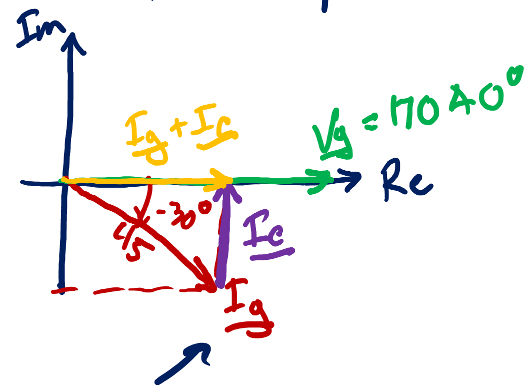
- Circuit with many L/R/C and sinusoidal input
  - Sketch Phasor circuit
  - Solve circuit for output
  - Sketch a Thevenin equivalent
- Series/parallel resonances may or may not occur



Can we return the grid PF to unity?

- Look at I_g from previous slide

$I_g = 45 \angle -30^\circ$



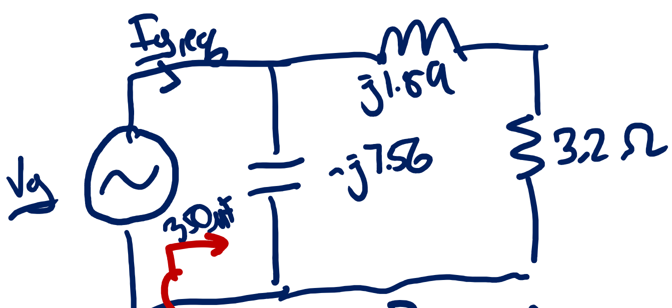
How do we generate I_c?

$$I_c = 45 \sin(30^\circ) \angle + 90^\circ$$

$$= 22.5 \angle 90^\circ \text{ A} = j22.5 \text{A}$$

$$Z_c = \frac{V_g}{I_c} = \frac{170 \angle 0^\circ}{22.5 \angle 90^\circ} = 7.56 \angle -90^\circ = -j7.56 = \frac{-j}{\omega C}$$

$\hookrightarrow C = 350 \mu F$



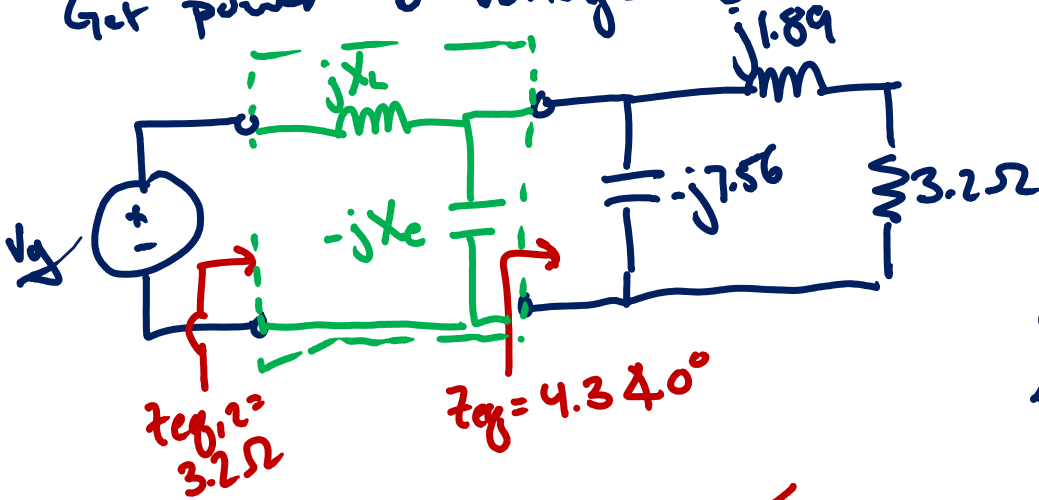
$$S_g = \frac{1}{2} V_g I_{g,req}^* = 3.3\text{kW} + j0\text{VAR}$$

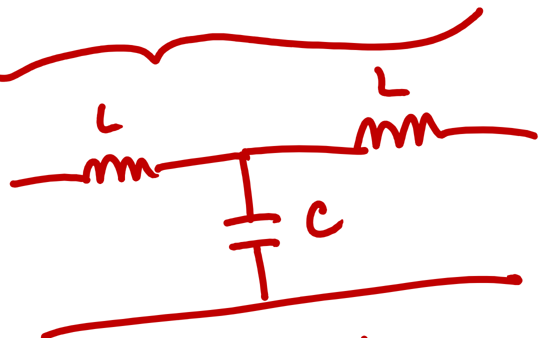
$$PF = \frac{P}{|S|} = 1$$

$$I_{g,req} = \frac{V_g}{-j7.56 \| (j1.89 + 3.2)} = \frac{170 \angle 0^\circ}{4.3 \angle 0^\circ}$$

$$Z_{req} = -j7.56 \| (j1.89 + 3.2) = 4.3 \angle 0$$

Get power & voltage to load back to 4.5kW / 170Vph





"T" Network

from previous slide:

$$3.2\Omega = \frac{X_c^2(4.3)}{4.3^2 + X_c^2}$$

$$0 = X_L - \frac{X_c(4.3)^2}{4.3^2 + X_c^2}$$

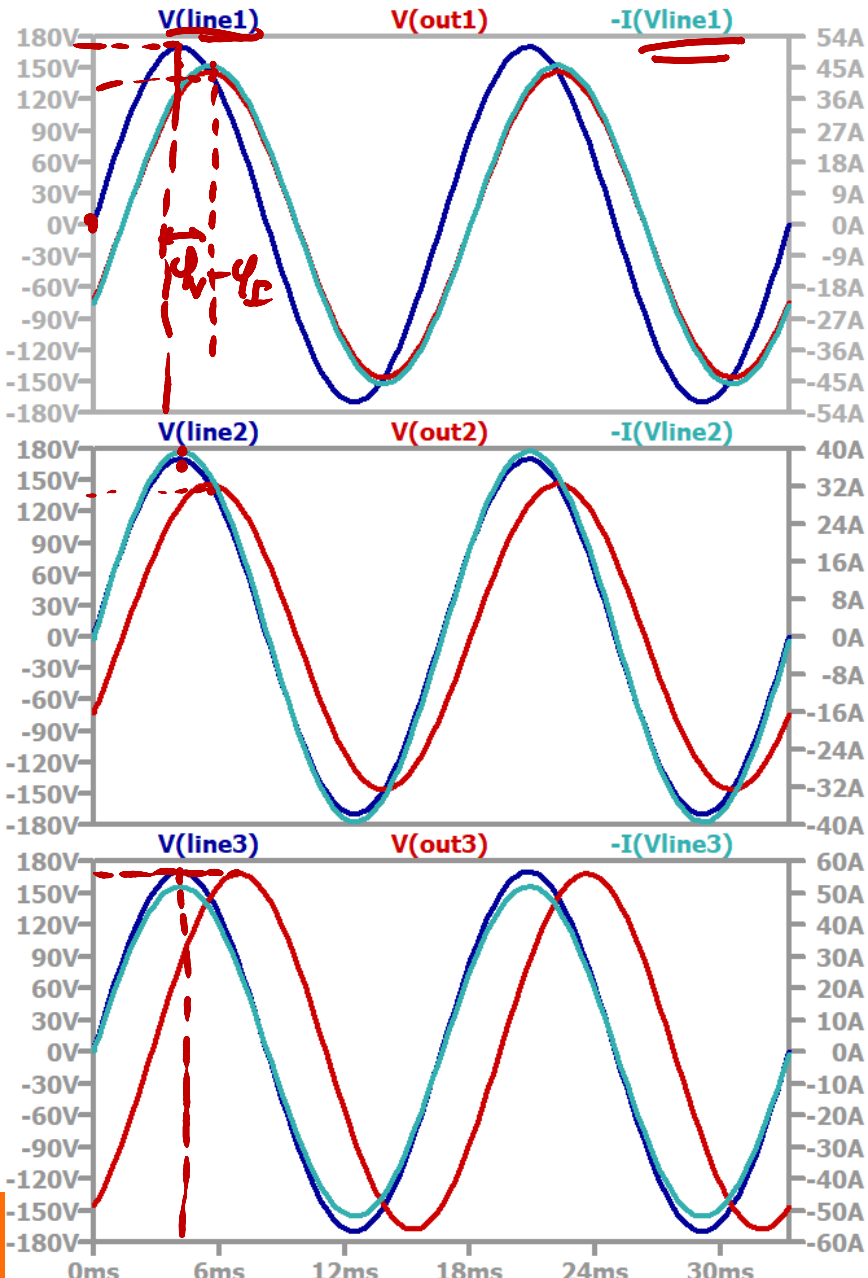
$X_c = 7.4\Omega = \frac{1}{\omega C}$

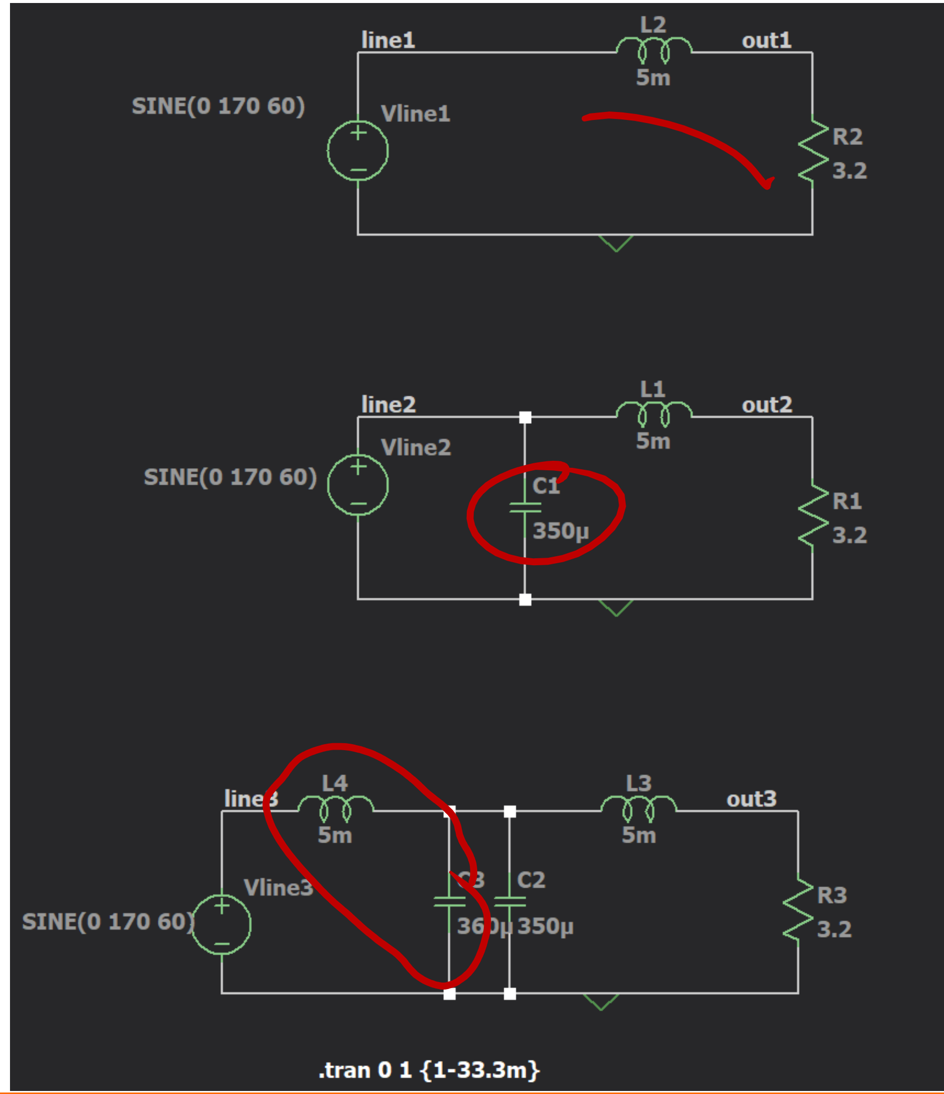
$X_L = 1.88\Omega = \omega L$

$C = 360\mu F$ @ $\omega = 2\pi 60$

$L = 5mH$

Simulation Example





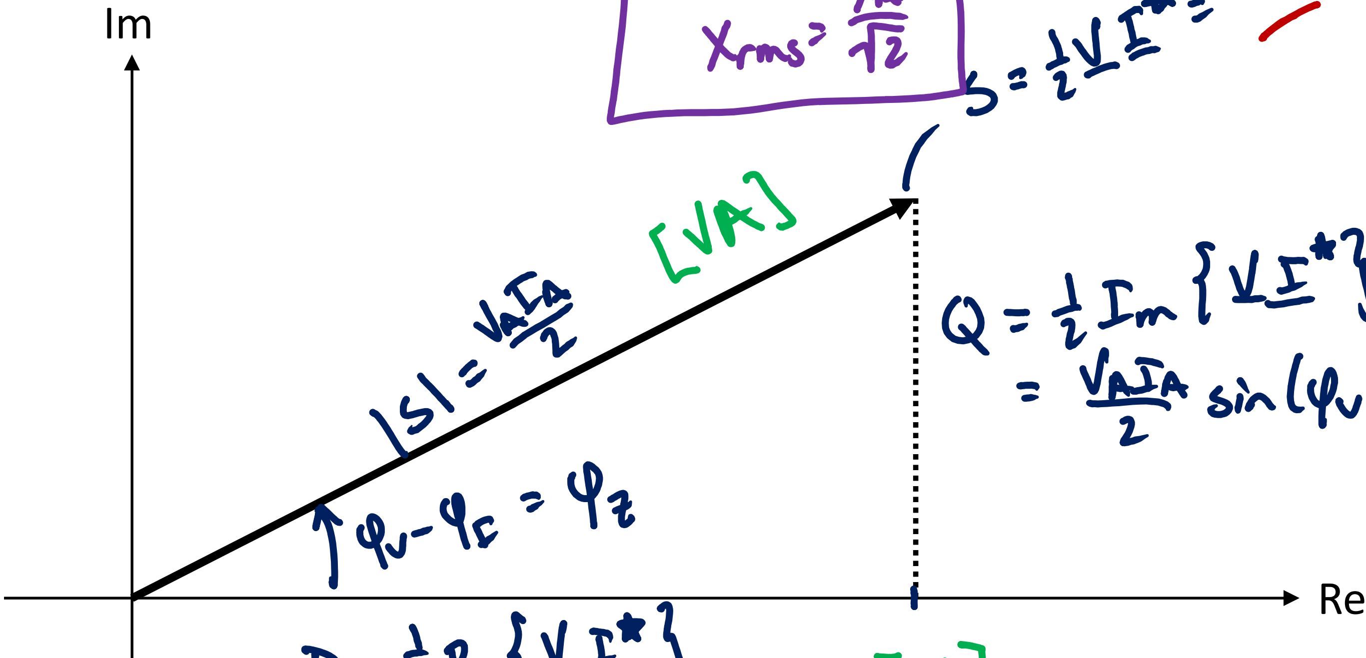
Power Triangle

$\underline{V} = V_A e^{j\varphi_V}$, $\underline{I} = I_A e^{j\varphi_I}$ } $S = \frac{1}{2}\underline{V}\underline{I}^* = \frac{1}{2}V_A I_A e^{j(\varphi_V - \varphi_I)}$

$\underline{V} = \underline{I}\, Z$

$X_{rms} = \frac{X_A}{\sqrt{2}}$

$S = \frac{1}{2}\underline{V}\underline{I}^* = \frac{V_A I_A}{2} e^{j(\varphi_V - \varphi_I)}$



$|S| = \frac{V_A I_A}{2}$

$\varphi_V - \varphi_I = \varphi_Z$

$Q = \frac{1}{2} \mathrm{Im}\{\underline{V}\underline{I}^*\} = \frac{V_A I_A}{2} \sin(\varphi_V - \varphi_I)$

$P = \frac{1}{2} \mathrm{Re}\{\underline{V}\underline{I}^*\} = \frac{V_A I_A}{2} \cos(\varphi_V - \varphi_I)$

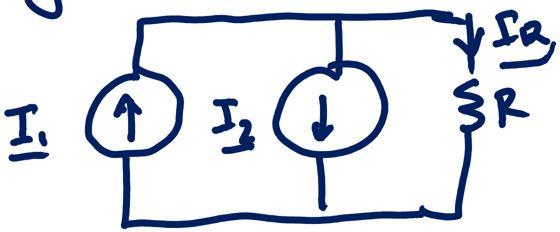
$PF = \frac{P}{|S|} = \cos(\varphi_V - \varphi_I)$ (leading or lagging) → inductive

(current w.r.t. voltage)

→ capacitive

Power Spectrum

Recall that power is a non-LTI calculation so superposition is not guaranteed to work



$I_1 = I_2$

by inspection $I_R = 0$ & $P_R = \phi$

If I incorrectly apply superposition to power calculations

$P_1 = I_{1rms}^2 R$ $P_2 = I_{2rms}^2 R$

$P_{tot} = (I_{1rms}^2 + I_{2rms}^2) R > \phi$

Superposition still works for calculating I_R

Interestingly, it does work if $i_1(t)$ & $i_2(t)$ are at different frequencies

$$P_R(t) = i_1(t)^2 R + i_2(t)^2 R = [I_{A1}^2 \cos(\omega_1 t)^2 R + I_{A2}^2 \cos(\omega_2 t)^2 R]$$

$$P_R(t) = [\underbrace{i_1(t) - i_2(t)}_{i_R(t) \text{ by superposition}}]^2 R$$

$$P = \frac{R}{T}\int_0^T I_{A1}^2 \cos(\omega_1 t)^2 + I_{A2}^2 \cos(\omega_2 t)^2 - 2 I_{A1} I_{A2} \cos(\omega_1 t)\cos(\omega_2 t)\, dt$$

$I_{A1} I_{A2} \left(\cos(\omega_1 t + \omega_2 t) + \cos(\omega_1 t - \omega_2 t)\right) \rightarrow \phi$

$$P = P_1 + P_2$$

END OF MATERIAL FOR MIDTERM EXAM 1

Chapters 10, 11, 13
Homeworks 1-5
Quiz 1 & 2
Experiment 1
Lectures 1-16 (& 19)