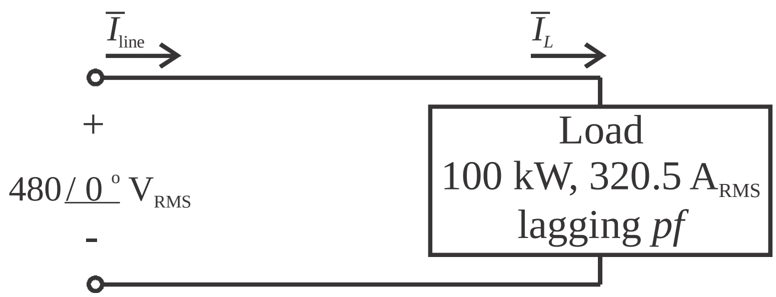
Example- A U.S. industrial plant (f = 60 Hz) is supplied by a 480 V_{RMS} power line, consumes 100 kW (measured using wattmeter), and draws a current of 320.5 A_{RMS} (measured using ammeter). Given the equipment in the plant, the power factor can be assumed to be lagging. For the best electrical rates, a power factor of $pf \geq 0.95$ is required. What range of capacitances connected in parallel will work? What capacitance will yield a $pf = 1$? What will be the input line current to the plant in each of these cases?

- Arbitrarily make the input voltage the phase reference (i.e., 0°).



- The apparent power for the load is-

$$S_L = V_{L,\text{rms}} I_{L,\text{rms}} = 480(320.5) \Rightarrow S_L = 153{,}840 \text{ VA} = 153.84 \text{ kVA}$$

- The power factor for the load is-

$$pf_L = \frac{P_L}{S_L} = \frac{100 \text{ kW}}{153.84 \text{ kVA}} \Rightarrow pf_L = 0.65 \text{ lagging}$$

- This leads to a power angle for the load of-

$$pf_L = \frac{100 \text{ kW}}{153.84 \text{ kVA}} = \cos(\theta_L) \Rightarrow \theta_L = \theta_1 = 49.4564°$$

- The load power angle can then be used to determine the current phase angle-

$$\theta_L = \theta_1 = \theta_V - \theta_I = 0° - \theta_I = 49.4564° \Rightarrow \theta_I = -49.4564°$$

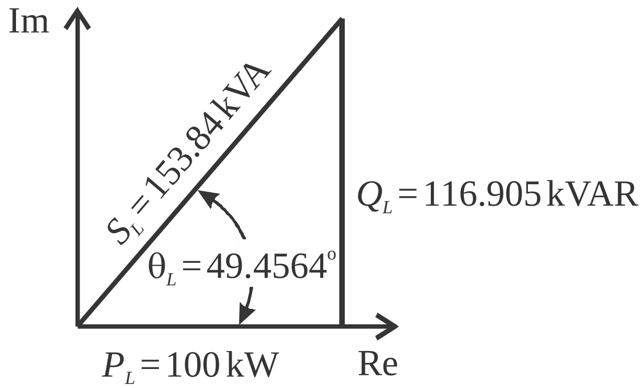
- The line/load current is then -

$$\boxed{I_L = I_{\text{line}} = I_{L,\text{rms}}\angle\theta_I \Rightarrow \underline{I_L = I_{\text{line}} = 320.5\angle -49.4564° \text{ A}_{\text{rms}}}}$$

- To complete the load power triangle, compute the load reactive power -

$$Q_L = P_L \tan(\theta_L) = 100\tan(49.4564°) \Rightarrow Q_L = 116.9047 \text{ kVAR}$$

Load power triangle



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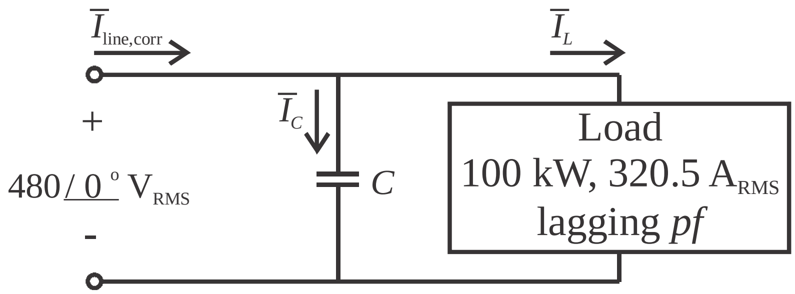
- Now, consider the corrected power factor situation (i.e., add a capacitor).



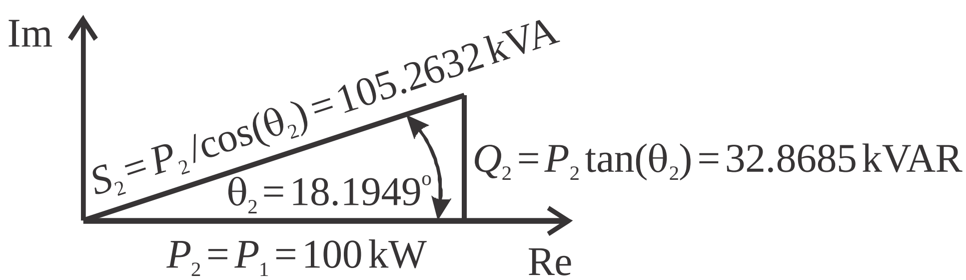
where $C = \dfrac{P_1[\tan(\theta_1) - \tan(\theta_2)]}{\omega V_{\text{rms}}^2}$

- The goal of a *pf* ≥ 0.95 leads to a desired power angle range of -

$$\theta_2 = \cos^{-1}(0.95) \quad \Rightarrow \quad \theta_2 = \pm 18.1949^\circ$$

- The minimum required capacitance, for a power factor of 0.95 **lagging** ($\theta_2 = +18.1949^\circ$, undercorrection), is -

$$C_{\text{min}} = \frac{100 \bullet 10^3 [\tan(49.4564^\circ) - \tan(+18.1949^\circ)]}{2\pi(60)\,480^2} \quad \Rightarrow \quad \underline{C_{\text{min}} = 0.9676 \text{ mF}}$$

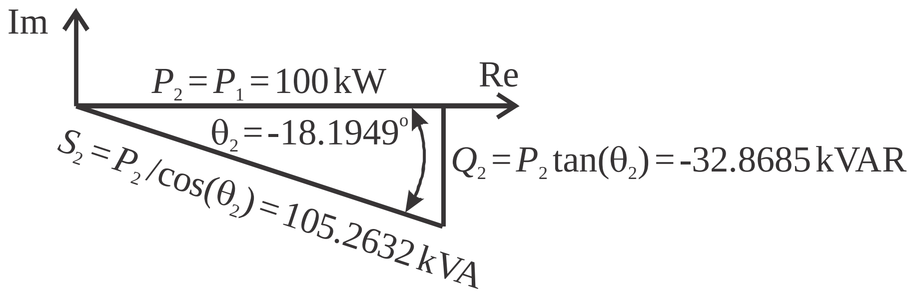


- The associated phasor rms current for a power factor of 0.95 **lagging** is -

$$\bar{I}_{\text{line, corr}} = \frac{S_2}{V_{\text{rms}}} \angle -\theta_2 = \frac{105.263 \bullet 10^3}{480} \angle -18.195^\circ \quad \Rightarrow \quad \underline{\bar{I}_{\text{line, corr}} = 219.3 \angle -18.195^\circ \text{ A}_{\text{rms}}}$$

- The maximum required capacitance, for a power factor of 0.95 **leading** ($\theta_2 = -18.1949°$, overcorrection), is -

$$C_{max} = \frac{100 \bullet 10^3 [\tan(49.4564°) - \tan(-18.1949°)]}{2\pi(60)\, 480^2} \Rightarrow \underline{C_{max} = 1.7243 \text{ mF}}$$



- The associated phasor rms current for a power factor of 0.95 **leading** is -

$$\overline{I}_{\text{line, corr}} = \frac{S_2}{V_{\text{rms}}} \angle -\theta_2 = \frac{105.263 \bullet 10^3}{480} \angle 18.195° \Rightarrow \underline{\overline{I}_{\text{line, corr}} = 219.3 \angle 18.195° \text{ A}_{\text{rms}}}$$

- The capacitance range to meet the $pf \geq 0.95$ goal is -

$$C_{min} = 0.9676 \text{ mF} \leq C \leq C_{max} = 1.7243 \text{ mF}$$

- For perfect correction, i.e., $pf = 1$ and $\theta_2 = 0°$, the required capacitance is -

$$C_{pf=1} = \frac{100 \bullet 10^3 [\tan(49.4564°) - \tan(0°)]}{2\pi(60)\, 480^2} \Rightarrow \underline{C_{pf=1} = 1.346 \text{ mF}}$$

- The associated phasor rms current for a $pf = 1$ (note $S_2 = P_2 = P_1$) is -

$$\overline{I}_{\text{line, corr}} = \frac{S_2}{V_{\text{rms}}} \angle -\theta_2 = \frac{100 \bullet 10^3}{480} \angle 0° \Rightarrow \underline{\overline{I}_{\text{line, corr}} = 208.3 \angle 0° \text{ A}_{\text{rms}}}$$

- Note that the rms line currents associated with the corrected power factors (219.3, 208.3, & 219.3 A_{rms}) are far smaller than the uncorrected rms current of 320.5 A_{rms} which would translate to significant reductions in transmission line losses which are proportional to $I^2_{\text{line,rms}}$.