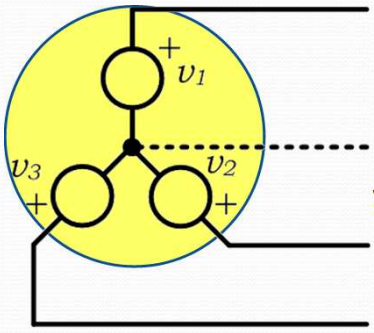
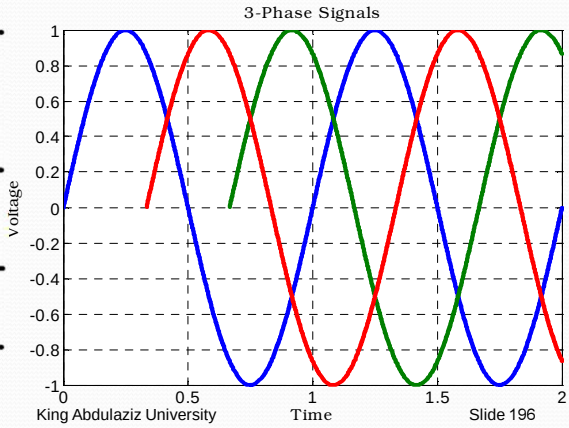
3-Phase Systems

Section 09

3-Phase Generators

- Method for transmitting alternating power
- Three conductors carrying three alternating currents with 360/3=120° shift between them

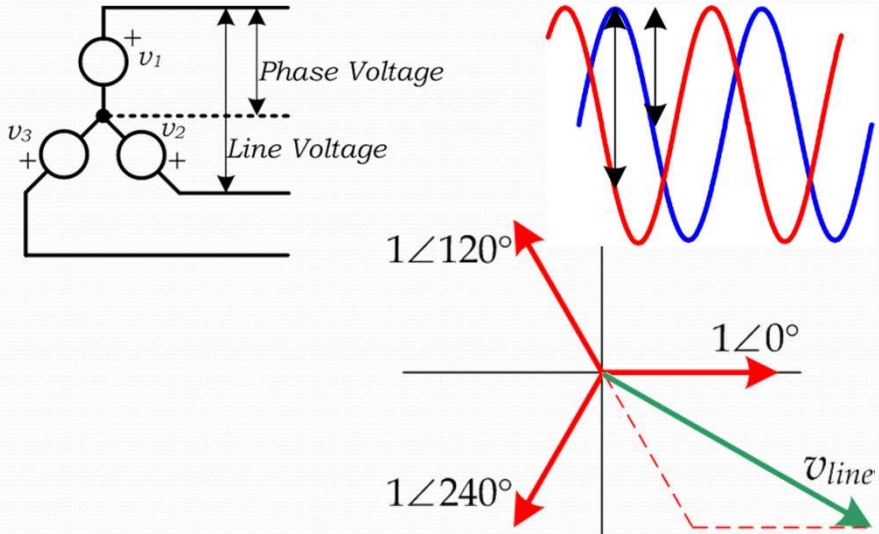




Why 3φ System?

- Multi-Phase Generation
  - constant power generation all the time
  - cost effective
- Usage
  - 1φ of each phase at homes
  - 3φ loads at industry

Vector Representation



Line Voltage

$$\begin{aligned} v_{12} &= v_1 - v_2 \\ &= 1\angle 0° - 1\angle 240° \\ &= 1 - (\cos 240 + j \sin 240) \\ &= \frac{3}{2} + j\frac{\sqrt{3}}{2} \end{aligned}$$

$$v_{12} = \sqrt{3}\angle 30°$$

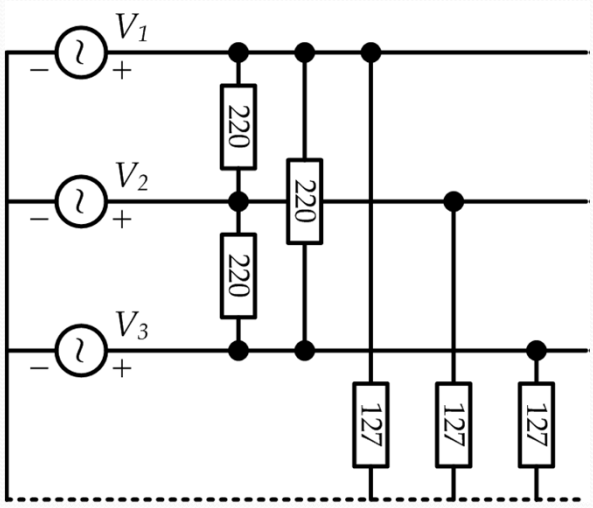
$$v_{23} = \sqrt{3}\angle -90°$$

$$v_{31} = \sqrt{3}\angle 150°$$

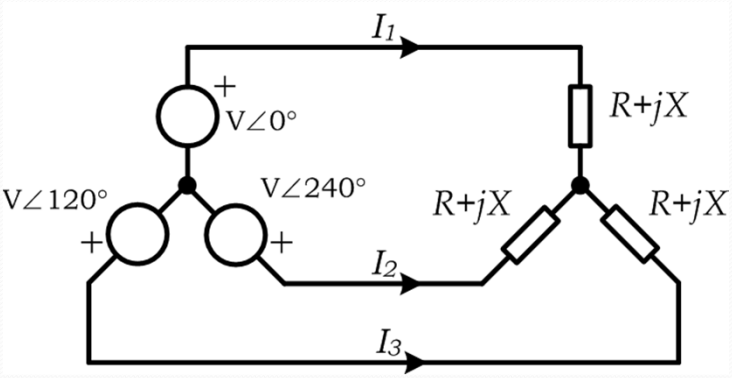
Examples

- If a phase voltage is 120V
  - Line Voltage = $120 \cdot \sqrt{3} = 208V$
- If a line voltage is 220V
  - Phase Voltage = $220 / \sqrt{3} = 127V$

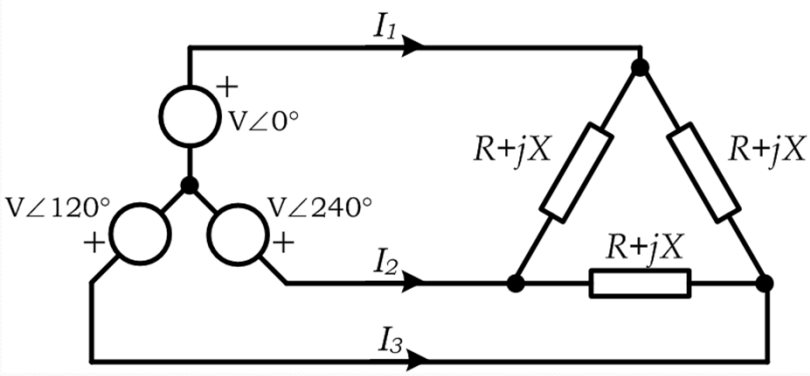
Load Distribution



Star-Start Connection



Star-Delta Connection



Power Factor (*pf*)

- Preferred Network when Q=o
- Let the angle between Voltage and Current be θ

$$pf = \cos\theta = \begin{cases} 1 & \theta = 0^\circ \\ 0 & \theta = 90^\circ \end{cases}$$

Power Factor

- For a single load:

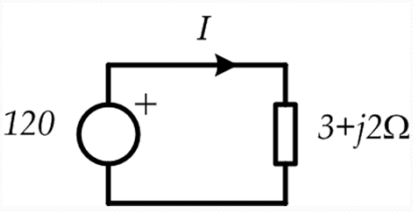
$$Z = R + jX_L$$

- The power factor can be expressed as:

$$pf = \frac{R}{\sqrt{R^2 + X_L^2}}$$

Example

- What is the power factor of the circuit shown?

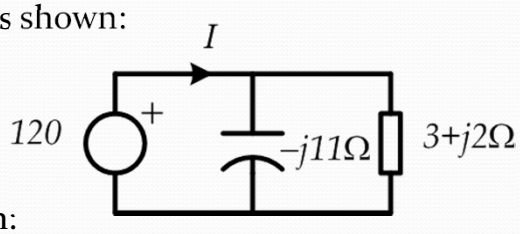


- Solution:

$$pf = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{3}{\sqrt{3^2 + 2^2}} = 0.832$$

Example

- Recalculate the power factor when a capacitor is added as shown:



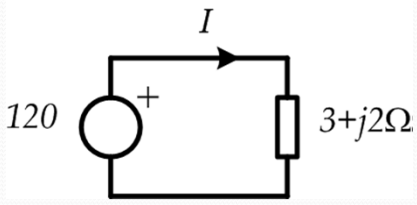
- Solution:

$$Z_{eq} = (3 + j2) // (-j11) = 4.03 + j1.1\Omega$$

$$pf = 0.964$$

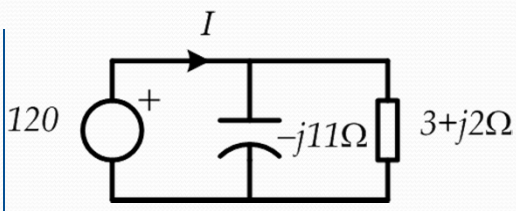
Example

- Calculate the Power and the total Volt-Ampere (S)?



$$I = \frac{120}{3 + j2} = 33.3\angle -34°A$$

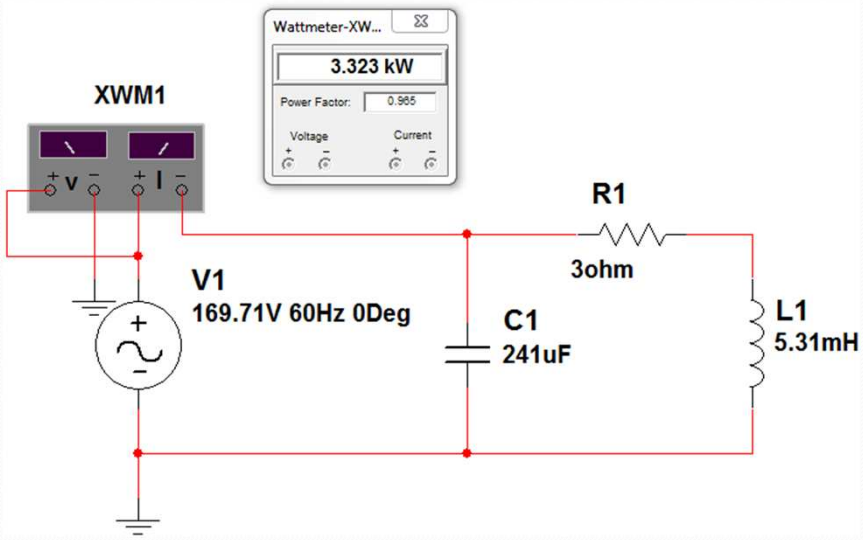
$$S = I^*.V = 3310 + j2233VA$$



$$I = \frac{120}{4.03 + j1.1} = 28.7\angle -15°A$$

$$S = I^*.V = 3327 + j891VA$$

Simulation



Power Factor Correction

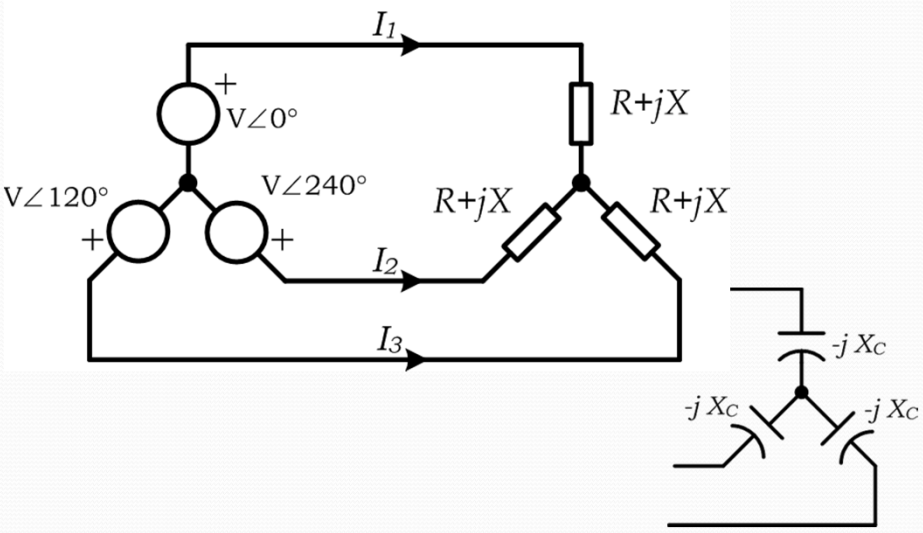
- How much parallel Capacitance to improve *pf*?

$$X_C = \left(X_L \cdot pf_{new} + R \cdot \sqrt{1 - pf_{new}^2}\right) \times \frac{pf_{new}}{pf_{new}^2 - pf_{old}^2}$$

- Example:
  - $Z_L = 3+j2\Omega$
  - $pf_{new} = 0.964$

$$X_C = \left(2 \times 0.964 + 3 \times \sqrt{1 - 0.964^2}\right) \times \frac{0.964}{0.964^2 - 0.832^2} = 11\Omega$$

Star-Start Connection



Star-Delta Connection