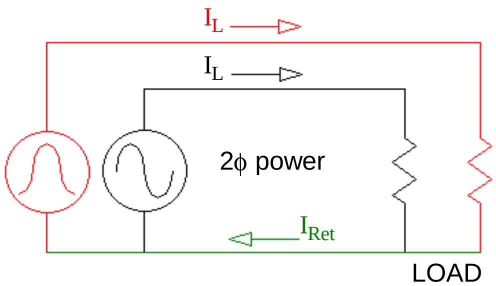
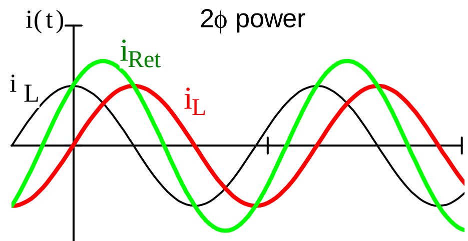
ECE 3600 3-Phase Power Justification

Single phase power pulses at 120 Hz. This is not suitable for motors or generators over about 5 hp.

2-Phase Power

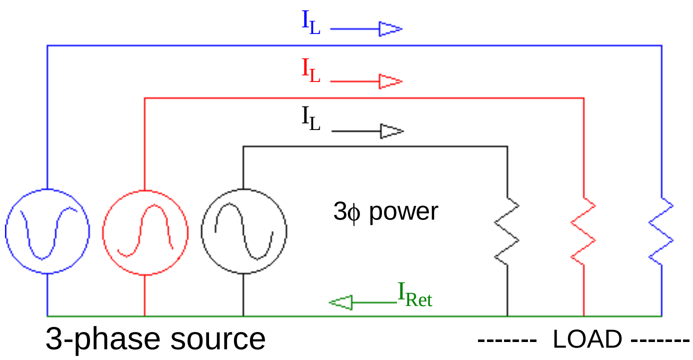
Two-phase power is constant as long as the two loads are balanced. But, the return current is larger than either load current.



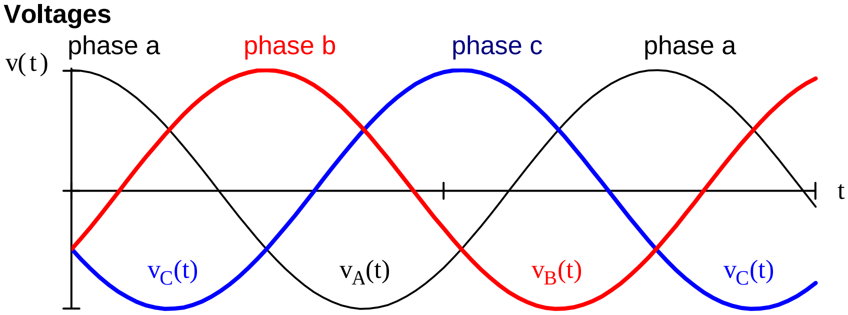


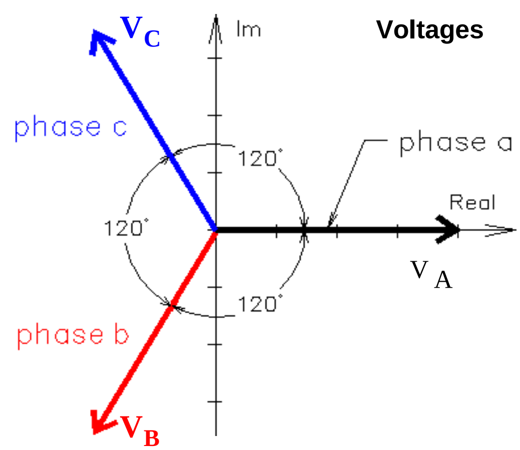
The return or "neutral" wire must be thicker than either "hot" line.

3-Phase Power

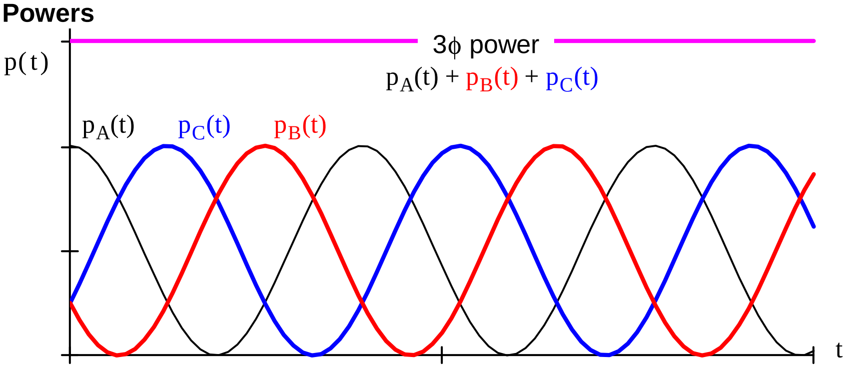


Voltages



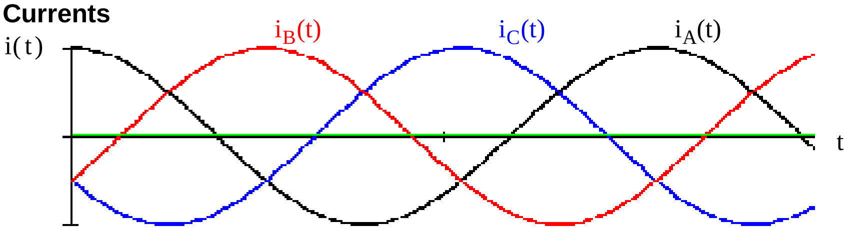


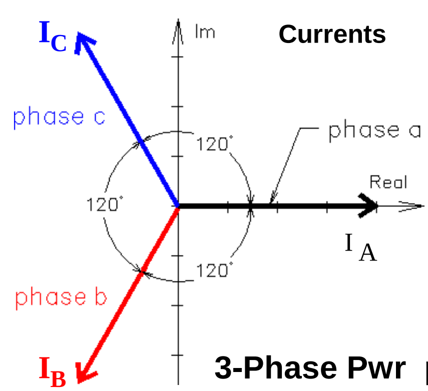
Powers



Three phase power is constant as long as the three loads are balanced.

Currents





If loads are balanced, ground return current will be zero. If the loads are close to balanced the relatively small return current can be carried by the earth ground.

Basics

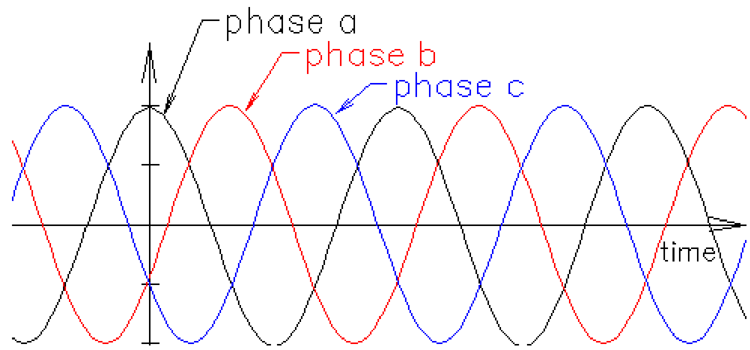
Single phase power pulses at 120 Hz. This is not good for motors or generators over about 5 hp.

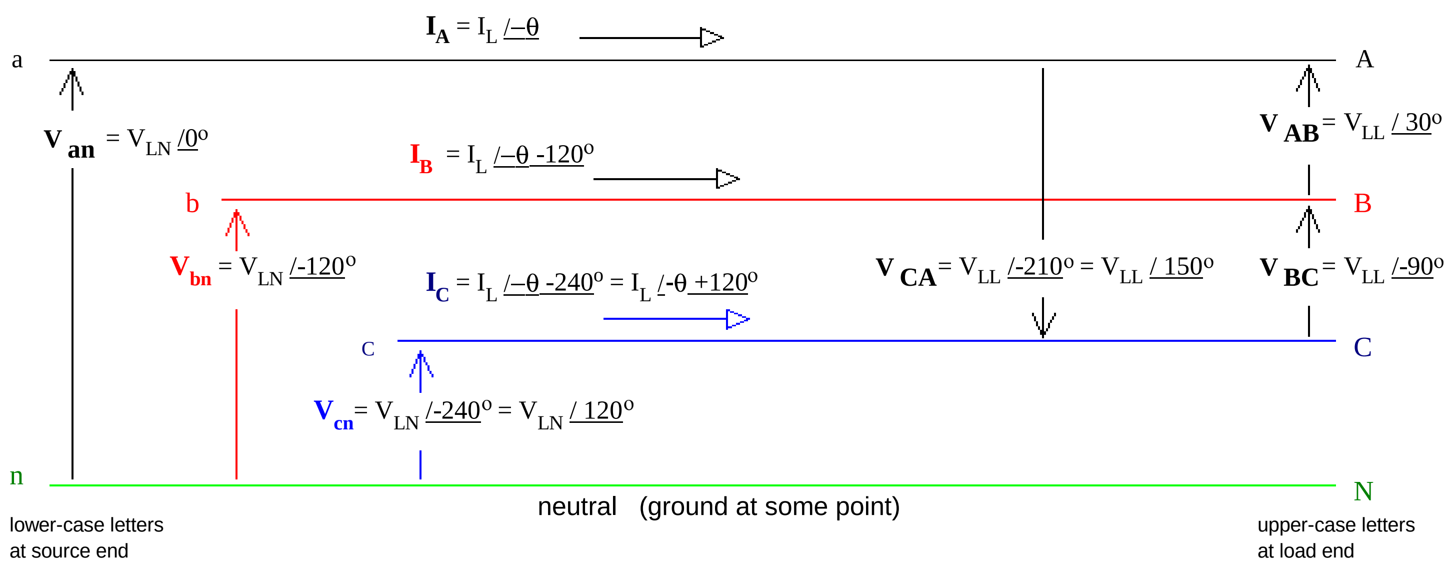
Three phase power is constant as long as the three loads are balanced.

Three lines are needed to transmit 3-phase power. If loads are balanced, ground return current will be zero.

The 3 lines coming into your house are **NOT** 3-phase. They are +120 V, Gnd, -120 V. (The two 120s are 180º out-of-phase, allowing for 240 V connections)

3-phase outlets have 4 connections

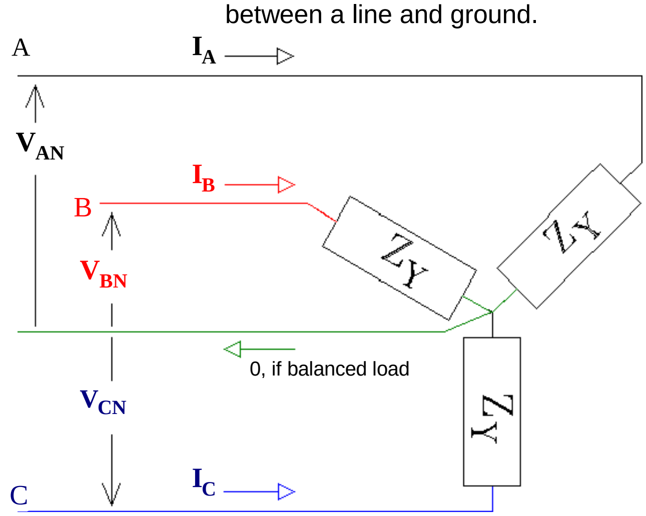


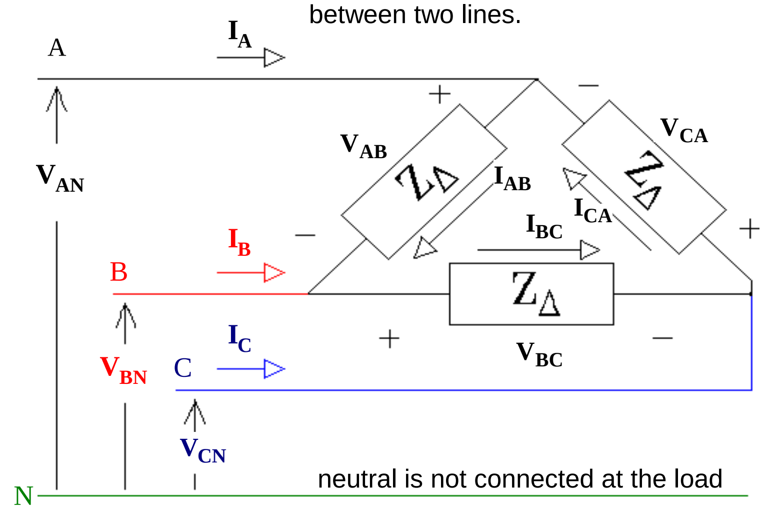


Connections to the 3 Lines

Wye connection:
Connect each load or generator phase between a line and ground.

Delta connection:
Connect each load or generator phase between two lines.





$$|V_{AN}| = |V_{BN}| = |V_{CN}| = V_{LN} = \frac{V_{LL}}{\sqrt{3}} = \frac{V_L}{\sqrt{3}}$$

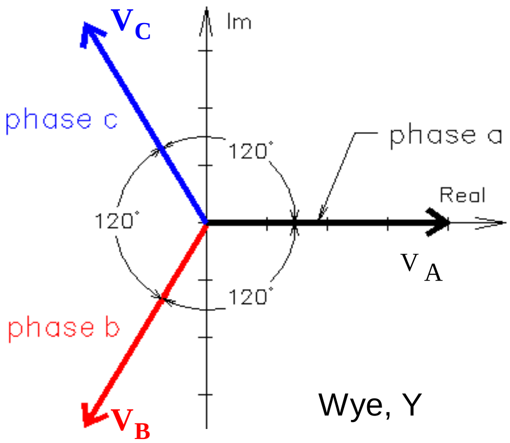
$$|I_A| = |I_B| = |I_C| = I_L = \sqrt{3}\cdot I_{LL}$$

$$|V_{AB}| = |V_{BC}| = |V_{CA}| = V_{LL} = \sqrt{3}\cdot V_{LN} = V_L$$

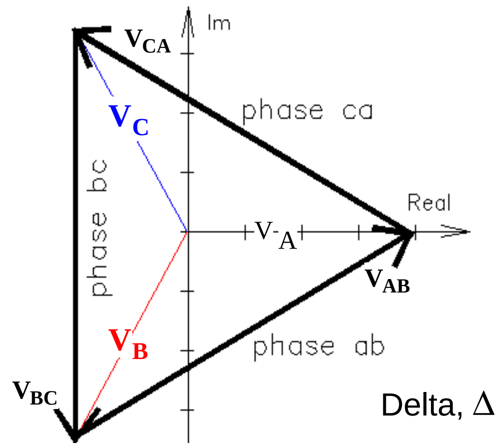
$$|I_{AB}| = |I_{BC}| = |I_{CA}| = I_{LL} = \frac{I_L}{\sqrt{3}}$$

To get equivalent line currents with equivalent voltages: $Z_Y = \frac{Z_\Delta}{3}$ $\qquad Z_\Delta = 3\cdot Z_y$

Wye, Y, connection:
Connect each load or generator phase between a line and ground.



Delta, Δ, connection:
Connect each load or generator phase between two lines.



$$V_{LN} = \frac{V_{LL}}{\sqrt{3}} \qquad I_L = \sqrt{3} \cdot I_{LL}$$

(Δ-connection)

$$V_{LL} = \sqrt{3} \cdot V_{LN} \qquad I_{LL} = \frac{I_L}{\sqrt{3}}$$

Apparent Power: $\left|\mathbf{S}_{3\phi}\right| = 3 \cdot \left|\mathbf{S}_{1\phi}\right| = 3 \cdot V_{LN} \cdot I_L = 3 \cdot V_{LL} \cdot I_{LL} = \sqrt{3} \cdot V_{LL} \cdot I_L$

Power: $P_{3\phi} = 3 \cdot P_{1\phi} = 3 \cdot V_{LN} \cdot I_L \cdot pf = 3 \cdot V_{LL} \cdot I_{LL} \cdot pf = \sqrt{3} \cdot V_{LL} \cdot I_L \cdot pf = S_{3\phi} \cdot pf$

$pf = \cos(\theta)$

Reactive power: $Q_{3\phi} = 3 \cdot Q_{1\phi} = 3 \cdot V_{LN} \cdot I_L \cdot \sin(\theta)$ etc... $= \sqrt{\left(\left|\mathbf{S}_{3\phi}\right|\right)^2 - P_{3\phi}^{\;2}}$

Cautions about "L" subscripts:

I_L is always the line current, same as would flow in a Y-connected device.

V_L is always the line-to-line voltage, same as across a Δ-connected device.

When a single phase is taken from a 3-phase panel, then the line voltage (V_L) of that single phase is the line-to-neutral voltage of the 3-phase input to that panel, so the value of V_L changes in the panel (isn't that nice?).

Z_L could be the load impedance, either Y-connected or Δ-connected, or it could be the line impedance--the impedance in the line itself, between the source and the load.

Cautions about "ϕ" or "ph" subscripts:

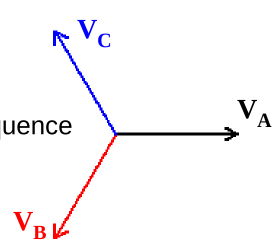
In our book: $V_\phi =$ the voltage across a single phase of a source or load and depends on the connection of that load, V_{LN} for Y-connected devices and V_{LL} for Δ-connected devices.

I_ϕ Also depends on connection.

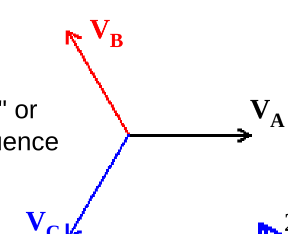
In **some** books: $V_\phi = V_{ph} = V_{LN}$ $\quad I_\phi = I_{ph}$ = current in a Y-connection **<= DON'T USE in this class**

Phase sequences:

abc, "positive" sequence

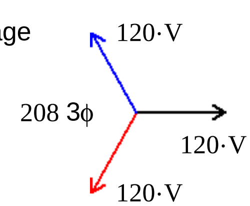


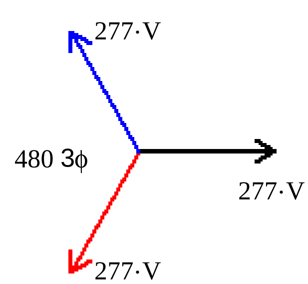
acb, "negative" or "reverse" sequence



Common usage: $V_L = V_{LL}$ = "line voltage" = line-to-line voltage

An unspecified voltage or a "line" voltage must always be assumed to be line-to-line,

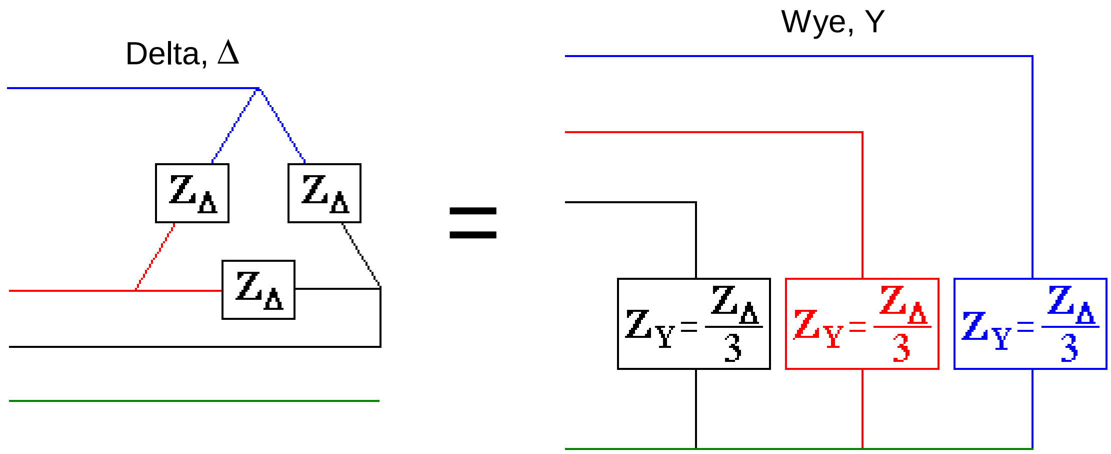




Our Approach

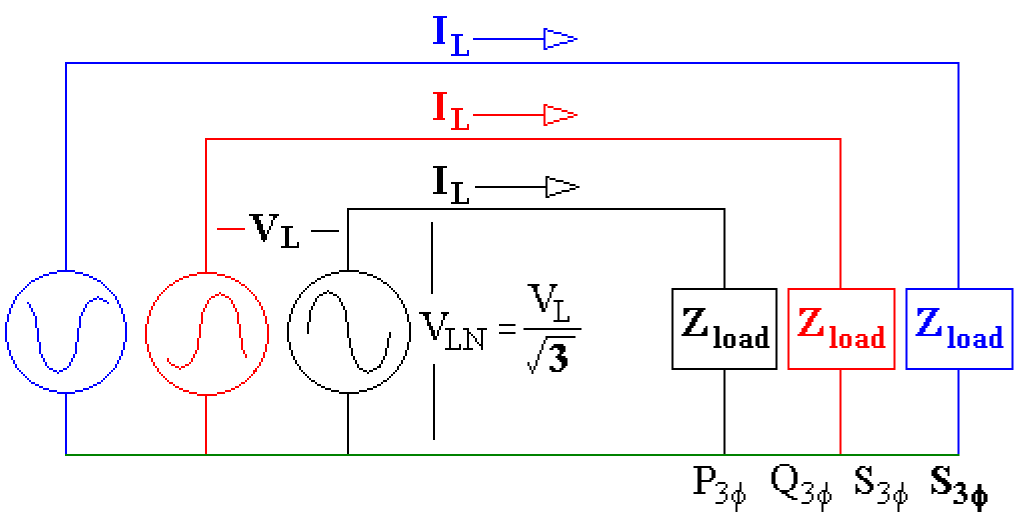
Only works if system is **Balanced** (Always so in our class, until we see faults)

1) Change all Δ-connected loads to equivalent Y-connected loads $Z_Y = \frac{Z_\Delta}{3}$

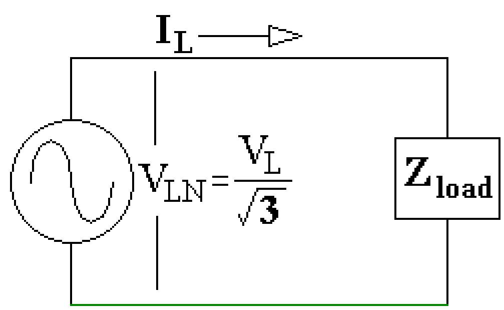


2) Find all voltages as V_{LN}, especially $V_{LN} = \frac{V_L}{\sqrt{3}}$

3) Change all power numbers to 1ϕ.



= 3 x



$P_{1\phi} = \frac{P_{3\phi}}{3}$ $\quad Q_{1\phi} = \frac{Q_{3\phi}}{3}$

$\mathbf{S_{1\phi}} = \frac{\mathbf{S_{3\phi}}}{3}$

$S_{1\phi} = |\mathbf{S_{1\phi}}| = \frac{S_{3\phi}}{3}$

4) Solve the remaining single-phase problem.

5) Return to "line" voltages and 3ϕ powers, as necessary.

$V_L = \sqrt{3} \cdot V_{LN}$

$P_{3\phi} = 3 \cdot P_{1\phi}$

$Q_{3\phi} = 3 \cdot Q_{1\phi}$

$|\mathbf{S_{3\phi}}| = 3 \cdot |\mathbf{S_{1\phi}}|$

$\mathbf{S_{3\phi}} = 3 \cdot \mathbf{S_{1\phi}}$

In rare cases, you may also need: $I_\Delta = I_{LL} = \frac{I_L}{\sqrt{3}}$

and: $\mathbf{Z_\Delta} = 3 \cdot \mathbf{Z_Y}$