3-Phase Analysis:

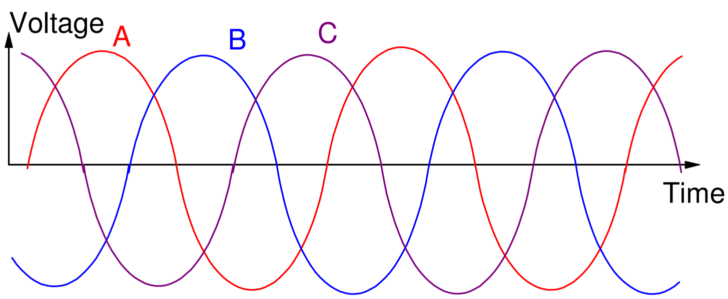
Objective:

- Define 3-phase power
- Be able to compute line-to-neutral and line-to-line voltages.
- Be able to compute the current drawn in delta and Y configurations.

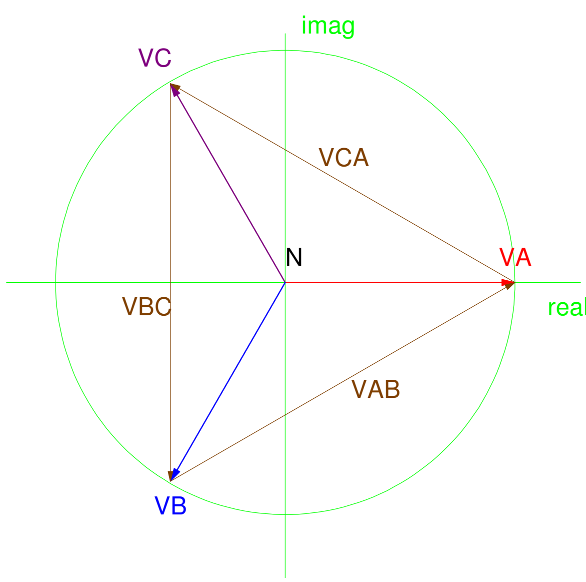
3-Phase:

3-phase AC signals are more efficient that since phase AC signals - especially when large amounts of power are being used. For single phase, the current (and torque) goes to zero 120 times per second. With 3-phase, the total torque is more constant.

The voltage for a 3-phase signal looks like the following:



Three AC signals make up a 3-phase signal: each one 120 degrees out of phase. If you treat VA as the reference (meaning define it to be zero degree relative phase shift), then the vector diagram for these three phases then are:



This gives the following relationship (V_{AN} means the voltage at a relative to the voltage at N, or ground):

$$V_{AN} = V\angle 0_0$$

$$V_{BN} = V\angle -120^0$$

$$V_{CN} = V\angle 120^0$$

You can also take the voltage from line to line:

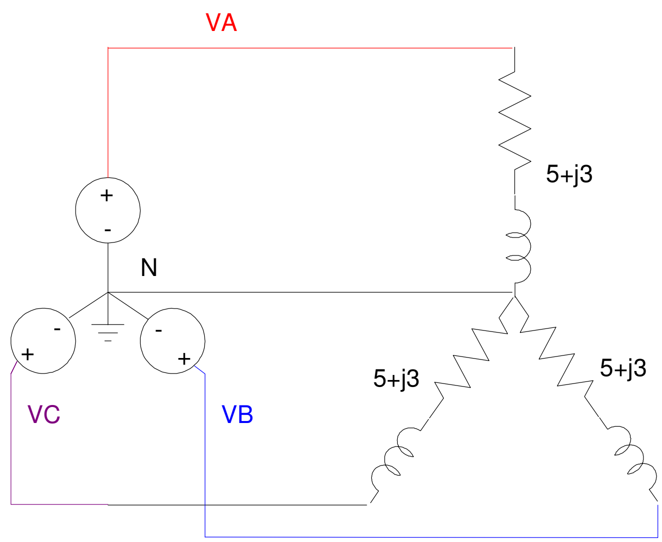
$$V_{AB} = V_{AN} - V_{BA} = \sqrt{3}\,V\angle 30^0$$

$$V_{BC} = V_{BN} - V_{CN} = \sqrt{3}\,V\angle -90^0$$

$$V_{CA} = V_{CN} - V_{AN} = \sqrt{3}\,V\angle 150^0$$

Y-Configuration:

Find the current in each phase and the total power consumed be the following 3-phase circuit. Also find the current on the neutral line (N). Assume 120Vrms.



The currents are:

$$I_A = \frac{V_{AN}}{5+j3} = \frac{120V\angle 0^0}{5+j3} = 20.58\angle -30.96^0 A$$

$$I_B = \frac{V_{BN}}{5+j3} = \frac{120V\angle -120^0}{5+j3} = 20.58\angle -150.96^0$$

$$I_C = \frac{V_{CN}}{5+j3} = \frac{120V\angle 120^0}{5+j3} = 20.58\angle 89.03^0$$

The current on the neutral line is

$$I_N = I_A + I_B + I_C = 0$$

Note that the current in the neutral line is zero. If you have a balanced load, you don't need a neutral line. If the load is almost balanced, the current on the neutral line will be small.

Utilities use this

- On 3-phase power lines, the 4th wire (neutral) is often much small than the other three. It doesn't need to carry much current.
- You can detect faults on one of the other phases by monitoring the current on the neutral line. If everything is OK, the neutral current should be zero or close to zero. If it isn't, something is wrong.
- When utilities deliver power to residential customers, each area receives only one of the three phases. The utilities try to keep the load seen by each phase approximately the same, however. This can be difficult in areas of rapid growth.

The power on each phase is

$$P_A = |I_A|^2 Z$$

$$P_A = (20.58A)^2 (5 + j3)$$

$$P_A = 2117 + j1270$$

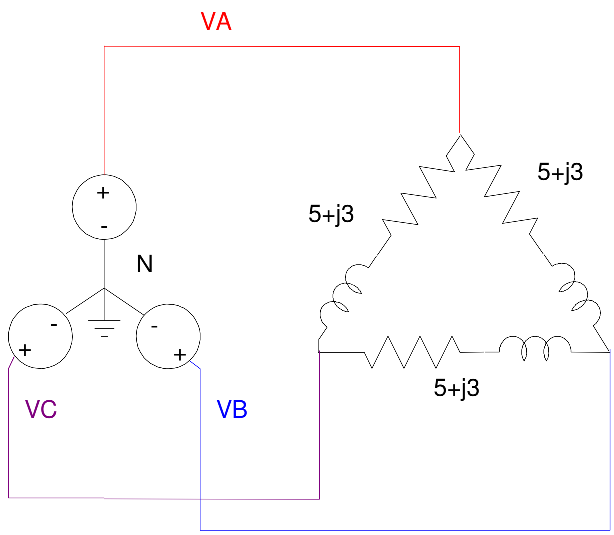
Each phase dissipates 2117W of energy (the real part) and consumes 1270 VARs (reactive power, the imaginary part.) By symmetry, the other phases are identical to phase A.

The total power is three times this:

$$P_{total} = 6532 + j3811 W$$

Delta Configuration:

You can also connect the loads (or power supplies) across the phases as shown below.



Problem: Find the current in each phase and the total power consumed be the following 3-phase circuit. Assume 120Vrms line-to-neutral voltages.

Solution:

$$I_A = I_{AB} + I_{AC}$$

$$I_A = \left(\frac{120\angle 0^0 - 120\angle -120^0}{5+j3}\right) + \left(\frac{120\angle 0^0 - 120\angle 120^0}{5+j3}\right) = 61.74\angle -30.96^0 A$$

$$I_B = I_{BA} - I_{BC}$$

$$I_B = \left(\frac{120\angle -120^0 - 120\angle 0^0}{5+j3}\right) + \left(\frac{120\angle -120^0 - 120\angle 120^0}{5+j3}\right) = 61.74\angle -150.96^0 A$$

$$I_C = I_{CA} - I_{CB}$$

$$I_C = \left(\frac{120\angle 120^0 - 120\angle 0^0}{5+j3}\right) + \left(\frac{120\angle 120^0 - 120\angle -120^0}{5+j3}\right) = 61.74\angle 89.04^0 A$$

The power in one phase (take Z_{AB} for example):

$$I_{AB} = \left(\frac{120\angle 0^0 - 120\angle -120^0}{5+j3}\right) = 35.64\angle -0.96^0$$

The power dissipated each phase is

$$P = |I|^2 Z$$

$$P = (35.64)^2 (5 + j3)$$

$$P = 6352 + j3811$$

The total power is three times this amount:

$$P_{total} = 19,059 + j11,435$$

Note that the power dissipated in a delta configuration is 3 times the power dissipated in a Y configuration. It makes a difference how you connect 3-phase devices.