Auto-Transformers

Transformer Polarity

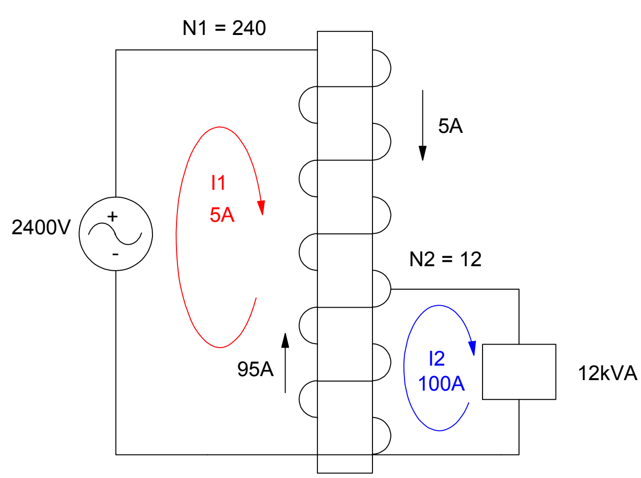
- Terminal H1 has the same polarity as L1
- Current entering at terminal H1 leaves at terminal L1. Ditto for H2 and L2.
- A dot indicates the same number (current into the dot terminal leaves the other dot terminal)

Nameplates

- Dash (240-120): Two voltages from two separate windings
- Slant (240/120): Two voltages from the same winding (there's a center tap)
- Cross (240x120): Two ways to connect the windings. One way (series) results in 240V. The other way (parallel) results in 120V.
- Wye (Y): Three phase Y connection
- Delta (Δ): Three phase delta connection

Auto-Transformers

An auto-transformer shares one portion of the windings for the high and low side. For example, a 2400V/120V autotransformer might be wired as follows:



Assume this autotransformer supplies a 12kVA load with a power factor of 1.00. Find the currents.

Solution: 2400V is the total voltage across the high-side of the transformer. The voltage on the low-side just picks off 1/20th of the turns, resulting in 120VAC.

The current on the low side is

$$I_2 = \frac{12kVA}{120V} = 100A$$

Power has to balance, so the current on the high side is

$$I_1 = \frac{12kVA}{2400V} = 5A$$

The current in the autotransformer is then

5A downward in the upper winding

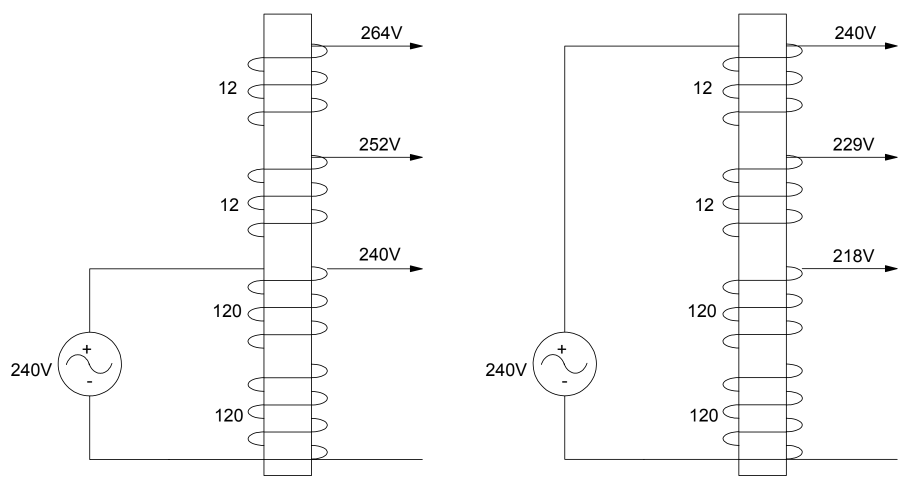
95A upward in the lower winding

Note that the autotransformer's current is less than the load current. This allows you to save some money reducing the amount of copper used. The cost is you need to have a common ground.

Autotransformers can also work in reverse: change the source and load and you can increase 120V to 2400V in a similar manner. Current reverses direction in this case though.

Boost-Buck Transformers:

Suppose you want to be able to adjust the output voltage slightly. If a transformer has multiple windings, you can connect it as an auto-transformer and get several voltages out. For example, if you have four windings: 120V, 120V, 12V, 12V, you can boost the output up to 252V or 264V or reduce (buck) the output to 229V or 218V.



Boost (left) and Buck (right) Transformer

Transformers in Parallel:

What happens if you have a bunch of 100kVA transformers but have a 150kVA load?

If all transformers are identical, you can place two of them in parallel. By symmetry, each takes up half of the load.

If the transformers are different but close, you can place them in parallel. The transformer with the higher-output voltage will try to drive the transformer with the lower output voltage as well as the load. It takes more than its share of the load as a result. (see section 3.6)

A 2.2% difference in transformer ratings resulted in a circulating current equal to 30% of the transformer's rated current.

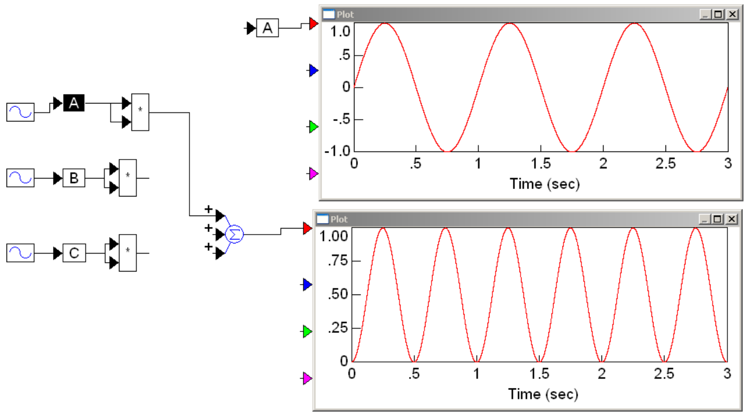
Moral: Don't place transformers in parallel when they have different ratings (different turns ratios)

Three-Phase Connections

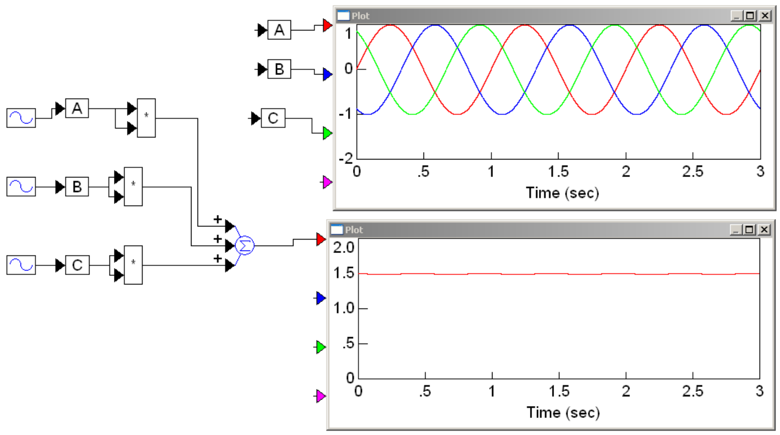
Three-phase power is more efficient to generate, transmit, and use than single-phase. If you are driving a resistor (or a motor - anything which consumers power), the power is proportional to the sum of the square of the voltage (or current)

$$P = \frac{V^2}{R} = I^2 R$$

With a single-phase line, the power oscillates from zero to 100%:



With three phase, the net torque is constant, which results in higher toque motors, more efficient energy generation, usage, etc.



Three phase also has the property than when you add the three signals together, they cancel. This allows you to use a very small (in theory, zero) neutral line with three-phase circuits.

Transmission Grids