



NATIONAL ELECTRICAL CODE

Understanding the Basics of Delta Transformer Calculations

Transformer configuration names like and derive from the way the windings are connected inside the transformer. These connections determine the way the transformer will behave, and they also determine the methods of calculation required for properly applying a given transformer. Delta-connected transformers have the windings of three single-phase transformers connected in series with each other to

Transformer configuration names like “delta” and “wye” derive from the way the windings are connected inside the transformer. These connections determine the way the transformer will behave, and they also determine the methods of calculation required for properly applying a given transformer.

Delta-connected transformers have the windings of three single-phase transformers connected in series with each other to form a closed circuit. The line conductors are connected to the unit where the two single-phase transformers meet. This configuration gets its name because in an electrical drawing it looks like a triangle (Greek symbol Δ for the letter “delta”). Many call it a high-leg system because the voltage from Line 2 to ground is higher than that of the other legs. For example, a 120V delta transformer will have a 208V leg.

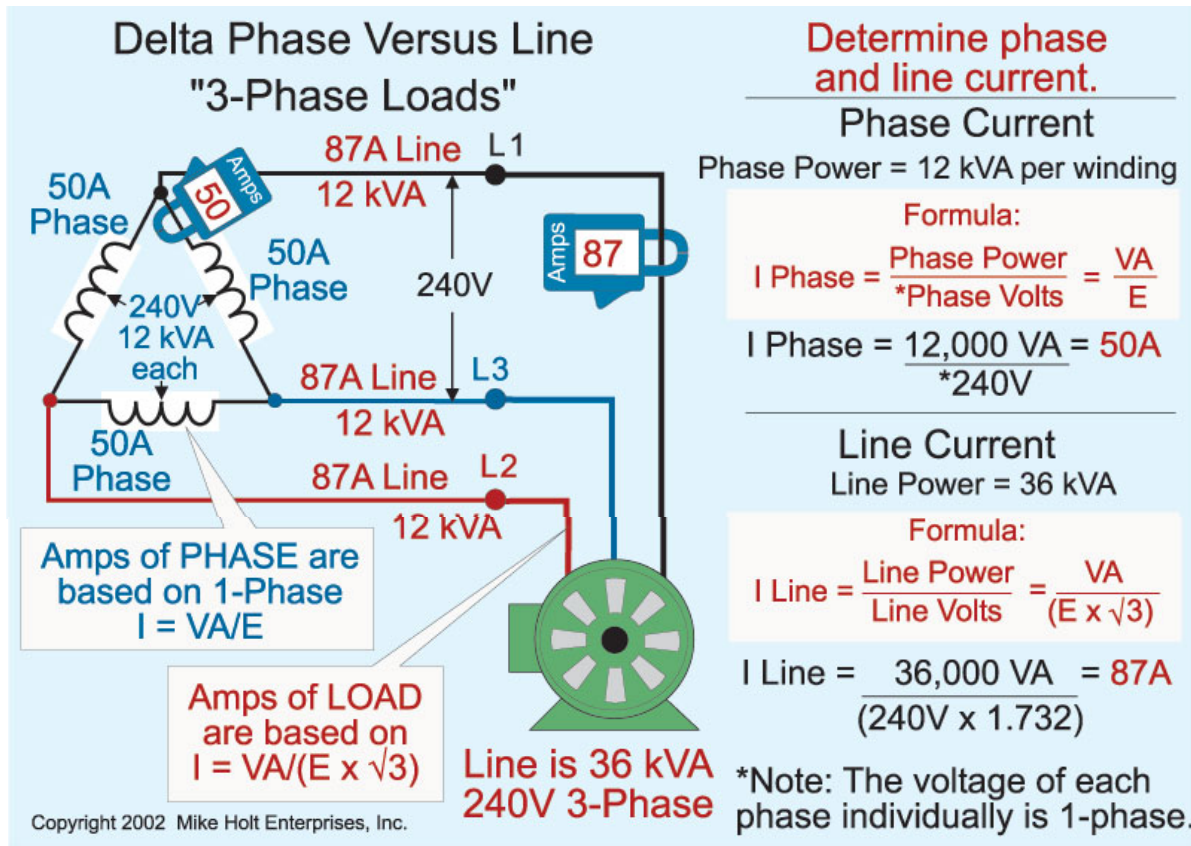


Fig. 1. It's important to note that the line current from a delta transformer doesn't equal the phase current. In this example, the line current is 87A and the phase current is 50A.

Delta transformer current. In a delta transformer, the line current doesn't equal the phase current (as it does in a wye transformer). Because each line from a delta configured transformer is connected to two transformer phases, the line current from a 3-phase load will be greater than the phase current by the square root of 3. Note these formulas:

$$I_{\text{Line}} = I_{\text{Phase}} \times \sqrt{3}$$

$$I_{\text{Line}} = \text{VA}_{\text{Line}} \div (E_{\text{Line}} \times \sqrt{3})$$

$$I_{\text{Phase}} = I_{\text{Line}} \div \sqrt{3}$$

$$I_{\text{Phase}} = \text{VA}_{\text{Phase}} \div E_{\text{Phase}}$$

Delta LINE Currents
150 kVA Transformer
Primary: 480V 3-Phase
Secondary: 240/120V 3-Phase

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Determine primary and secondary line current.

Primary Line Current

Formula:

$$I_{Line} = \frac{\text{Line Power}}{(\text{Line Volts} \times \sqrt{3})} = \frac{VA}{(E \times \sqrt{3})}$$

$$I_{Line} = \frac{150,000 \text{ VA}}{(480V \times 1.732)} = 180 \text{ A}$$

Secondary Line Current

Formula:

$$I_{Line} = \frac{\text{Line Power}}{\text{Line Volts}} = \frac{VA}{(E \times \sqrt{3})}$$

$$I_{Line} = \frac{150,000 \text{ VA}}{(240V \times 1.732)} = 360 \text{ A}$$

If you plug some numbers in, you can more clearly see the effects of the delta configuration on currents. Let's try this with a 240V, 36kVA, 3-phase load (**Fig. 1** above).

First, let's solve for the line current (total line power=36kVA).

$$I_{Line} = VA_{Line} \div (E^{Line} \times \sqrt{3})$$

$$I_{Line} = 36,000VA \div (240V \times \sqrt{3})$$

$$I_{Line} = 87A$$

Now, let's solve for the phase current (phase power=12kVA, per winding).

$$I_{Phase} = VA_{Phase} \div E_{Phase}$$

$$I_{Phase} = 12,000VA \div 240V = 50A$$

You can also find the line and phase currents using the other two formulas shown above.

$$I_{\text{Line}} = 50\text{A} \times 1.732 = 87\text{A}$$

$$I_{\text{Phase}} = I_{\text{Line}} \div \sqrt{3}$$

$$I_{\text{Phase}} = 87\text{A} \div 1.732 = 50\text{A}$$

We can also use the formula: $I_{\text{Line}} = \text{VA}_{\text{Line}} \div (E_{\text{Line}} \times \sqrt{3})$. For example, what is the secondary line current for a 480V to 240/120V, 150kVA, 3-phase delta transformer (**Fig. 2**)? The answer is found as follows:

$$I_{\text{Line}} = \text{VA}_{\text{Line}} \div (E_{\text{Line}} \times \sqrt{3})$$

$$I_{\text{Line}} = 150,000\text{VA} \div (240\text{V} \times 1.732) = 360\text{A}$$

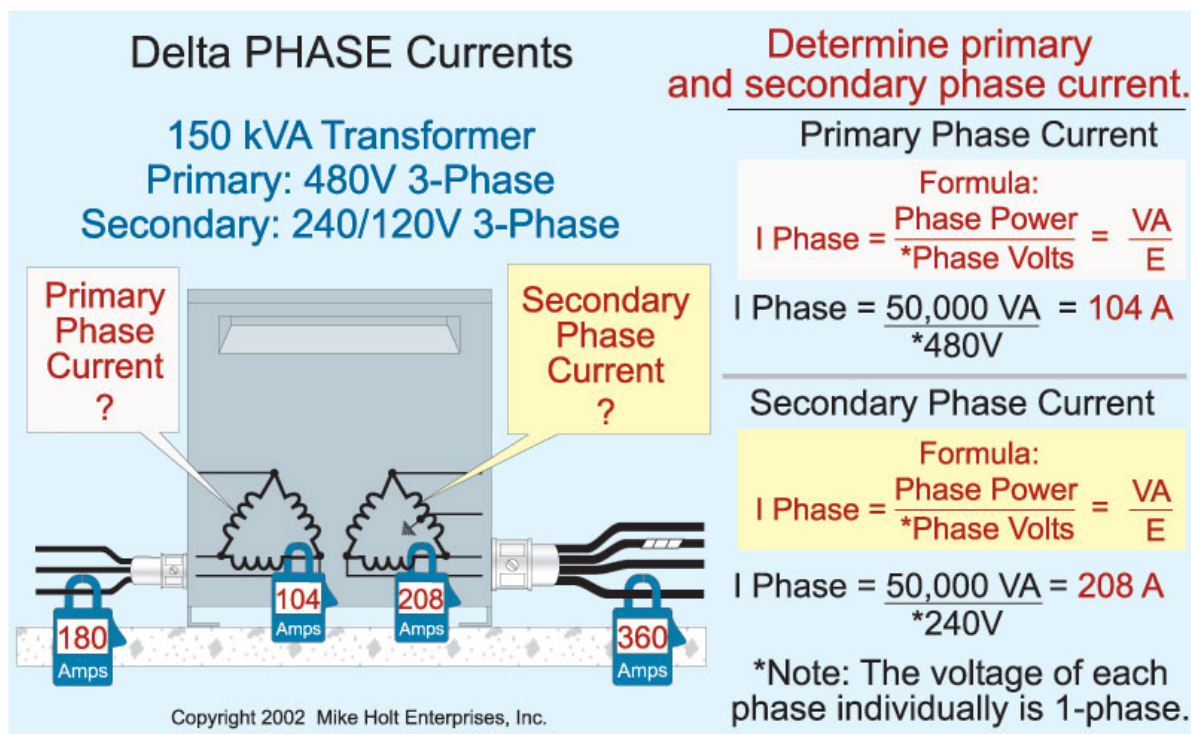


Fig. 3. When solving for phase current, don't forget to divide the overall transformer kVA rating by 3.

You can calculate the phase current of a delta transformer winding by dividing the phase VA by the phase volts: $I_{\text{Phase}} = \text{VA}_{\text{Phase}} \div E_{\text{Phase}}$. The phase load in VA of a 3-

on one winding).

Let's look at another example problem. What is the secondary phase current for a 480V to 240/120V, 150kVA, 3-phase delta transformer (**Fig. 3** above)?

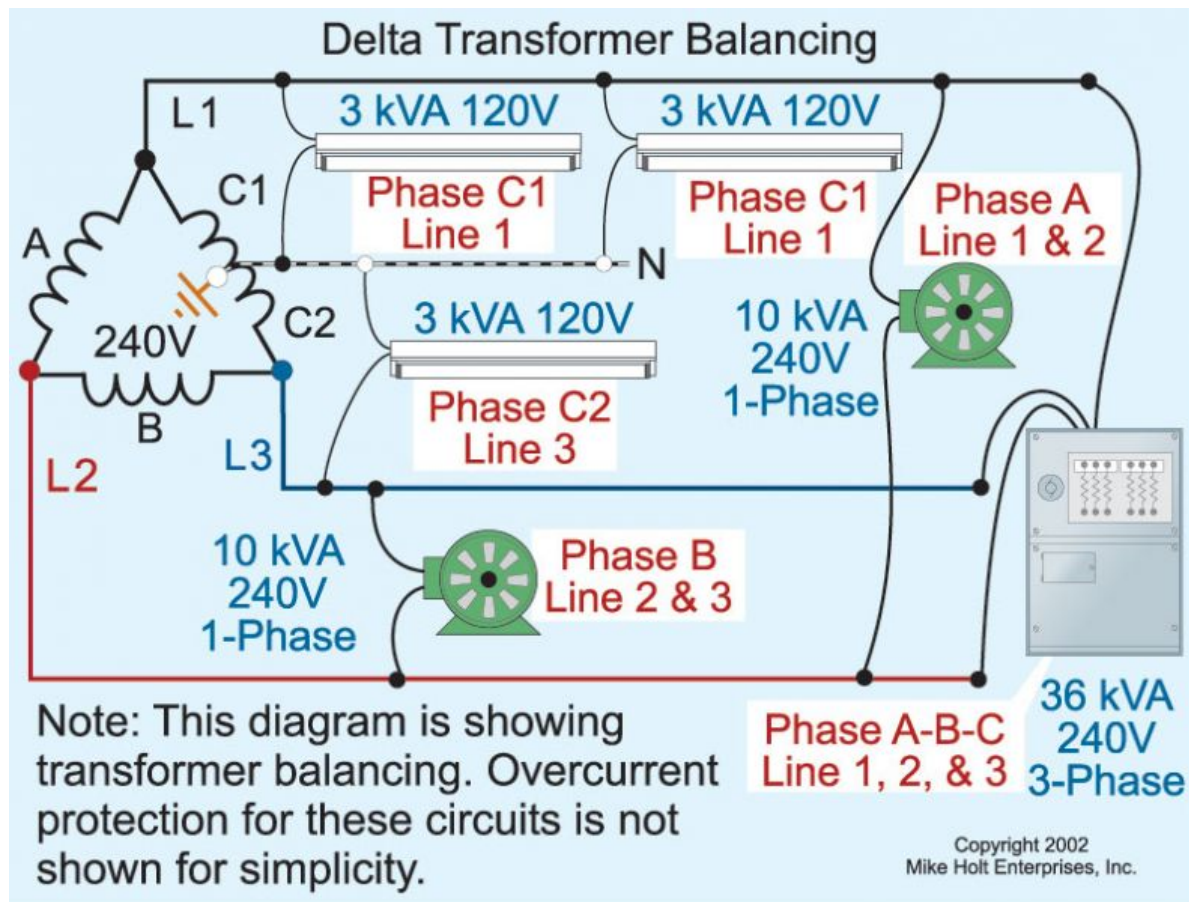
Phase power=150,000VA÷3 per phase

Phase power=50,000VA per phase

$I_{\text{Phase}}=50,000\text{VA}\div 240\text{V}$

$I_{\text{Phase}}=208\text{A}$

To better understand what happens in a delta system, try running these numbers with a 10A load and then with a 75A load.



Delta transformer balancing. To properly size a delta/delta transformer, the transformer phases (windings) must be balanced. You can do that with a two-step process:

Step 1. Determine the VA rating of all loads.

Step 2. Balance the loads on the transformer windings as follows:

-

3-phase loads: one-third of the load on each of the phases.

-

240V, single-phase loads: 100% of the load on Phase A or B. You can place some of the 240V, single-phase load on Phase C when necessary for balance.

-

120V loads: 100% of the load on C1 or C2.

To size the panelboard and its conductors, you must balance the loads in amperes. Why balance the panel in amperes? Why not take the VA per phase and divide by phase voltage? Because line current of a 3-phase load is calculated by the following formula:

$$I_{\text{Line}} = \text{VA} \div (\text{E}_{\text{Line}} \times \sqrt{3})$$

$$I_{\text{Line}} = 150,000\text{VA} \div (240\text{V} \times 1.732) = 208\text{A per line.}$$

If you took the per line power of 50,000VA and divided by one line voltage of 120V, you would come up with an incorrect line current of $50,000\text{VA} \div 120\text{V} = 417\text{A}$.

using two times the highest of “C1” or “C2.” The “C” transformer is actually a single unit. If one side has a larger load, that side determines the transformer size.

Refer to this load breakdown Refer to this load breakdown per phase for the practice problem below.
per phase for the practice
problem below.

Let's try another practice problem to reinforce these concepts. What size 480V to 240/120V transformer is required for the following loads: one 240V, 36kVA, 3-phase heat strip; two 240V, 10kVA, 3-phase loads; three 120V, 3kVA loads, single-phase (**Fig. 4**)?

- (a) three single-phase, 25kVA transformers
- (b) one 3-phase, 75kVA transformer
- (c) a or b
- (d) none of the above

Phase winding A=22kVA

Phase winding B=22kVA

Phase winding C=(12kVA of C1×2) = 24kVA

The answer is (c), a or b. You can use one single-phase 75kVA transformer or three 25kVA transformers for this load.

Now that you understand some transformer calculation basics and specifics on delta transformer calculations, you'll be able to size delta transformers correctly. Calculations, you'll be able to size any combination of delta and wye transformers.

current.

Sidebar: Know Your Terms

To avoid confusion with transformer calculations, it's important to have a firm grasp of some basic concepts (**Fig. 5** below). Once you're comfortable with these terms, you should be ready to tackle all types of transformer calculations.

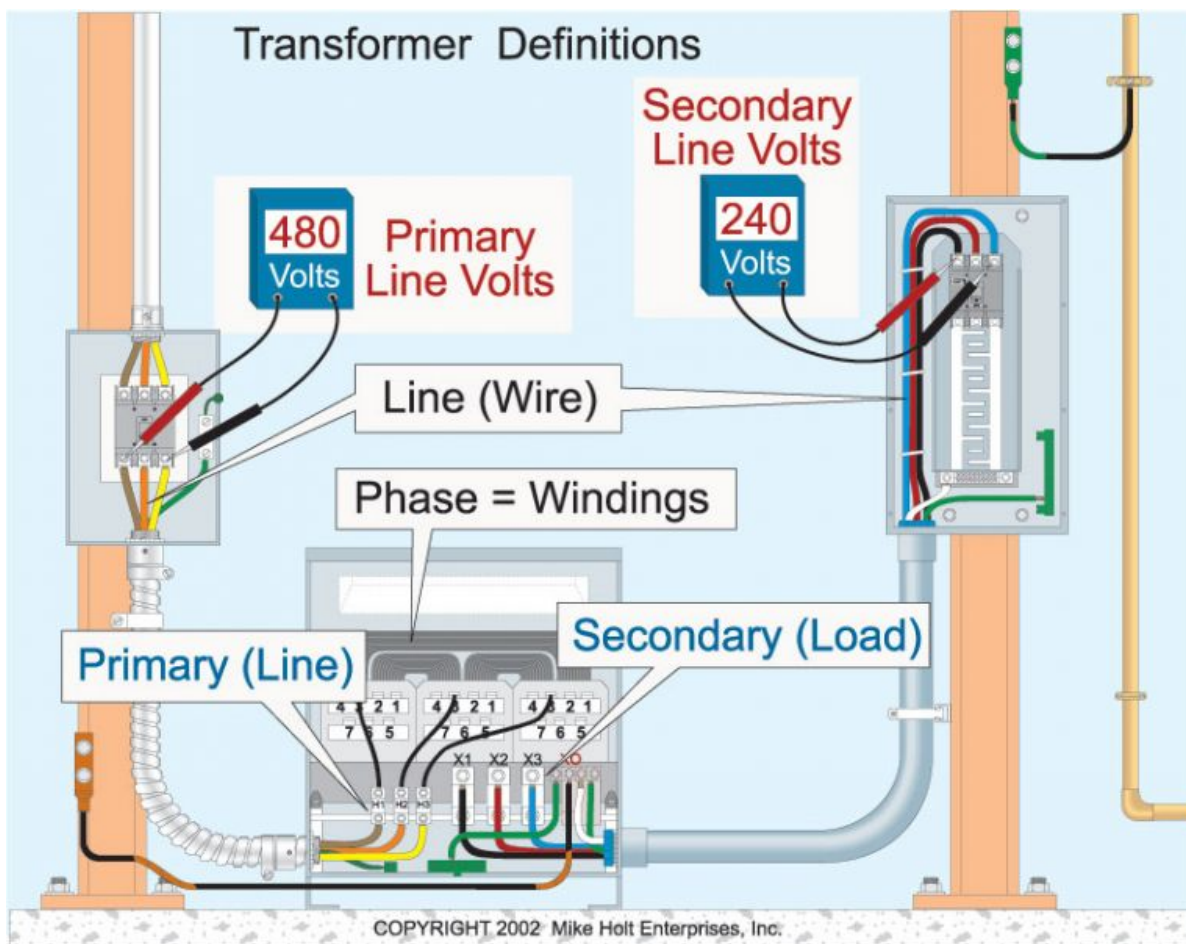


Fig. 5. Knowing transformer terms is key to proper calculations.

Line — The ungrounded (hot) conductor(s).

Line voltage — The voltage between any two line (ungrounded) conductors (A1 and A2 in **Fig. 6**). In a delta system, the line voltage equals the phase voltage. But the delta system also has a high-leg.

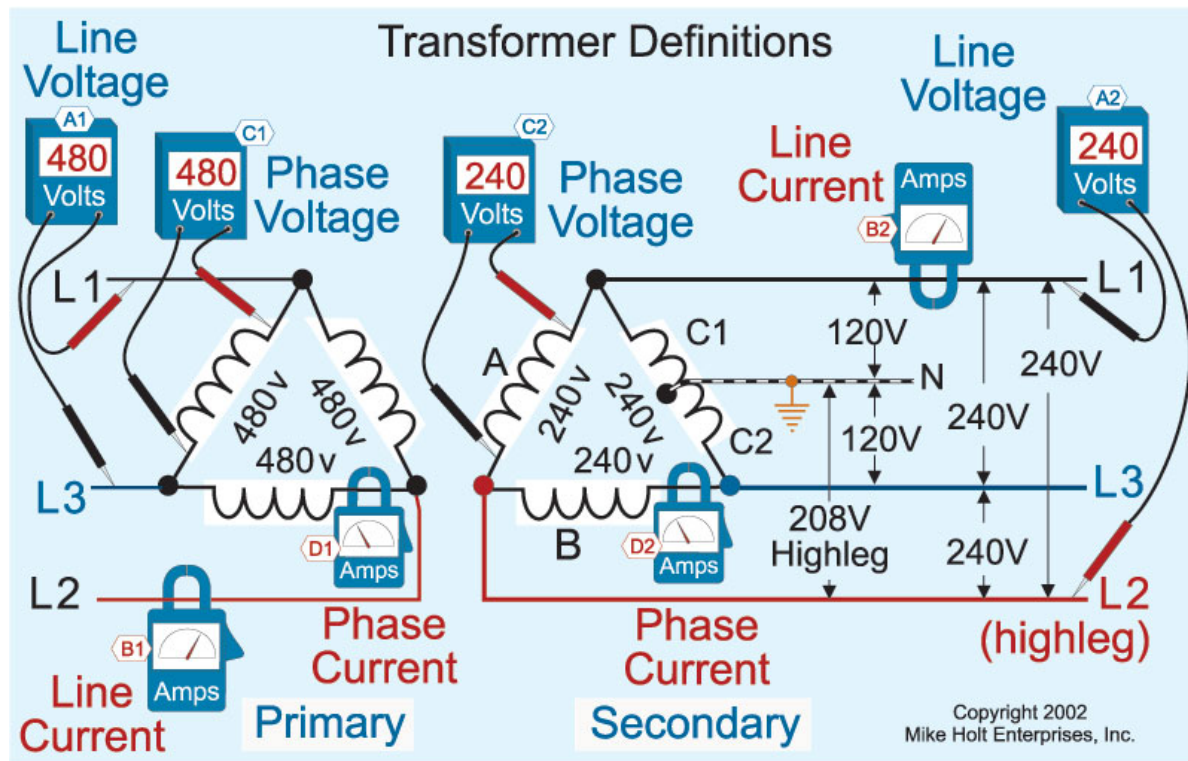


Fig. 6. Key voltage and current readings in a delta/delta system.

Phase current — The current flowing through the transformer winding (D1 and D2 in **Fig. 6**). In a delta system, the phase current is less than the line current by the square root of 3. In a wye system, the phase current equals the line current.

Phase load — The load on the transformer winding.

Phase voltage — The internal transformer voltage generated across one winding of a transformer. For a delta secondary, the phase voltage equals the line voltage. In a wye system, the phase voltage is less than the line voltage by the square root of secondary winding turns.

Unbalanced load (neutral current) — The load on the secondary grounded (neutral) conductors.