

## Why Wye ? Why Delta ? - Part 1 Transformer Connections

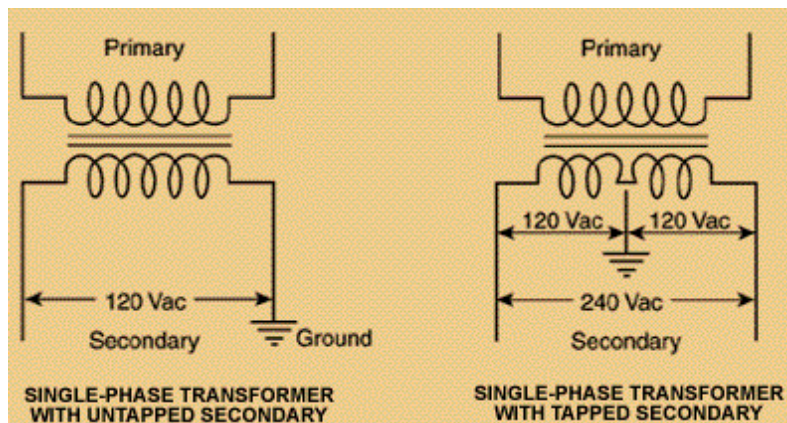
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One of the more confusing elements of three phase power is the winding connection schemes for inductive devices such as transformers and motors. Although most of us with a basic knowledge of AC power understand how motors and transformers operate, we seldom delve into those mysterious winding connections and their impact on performance. This simple, three part series will not make you an expert but, I hope it will make these connections a little more understandable.

### Single Phase Connections

A simple illustration of why a Wye or Delta connection is required in a three phase circuit is to look at a single phase connection. Figure 1 shows the schematics for two typical single phase transformers. The one on the left takes a higher primary voltage and produces 120 volts in the secondary. The one on the right takes that same primary voltage and produces 240 volts. It also has a grounded neutral, center tap that produces 120 volts between the tap and the outside terminals. Note that these illustrations do not show any difference in the number of primary and secondary turns. If it did, there would



be more in the primary than in the secondary since both are reducing the primary voltage. It is the turns ratio that determines the increase or decrease in voltage and current between the primary and secondary coils.

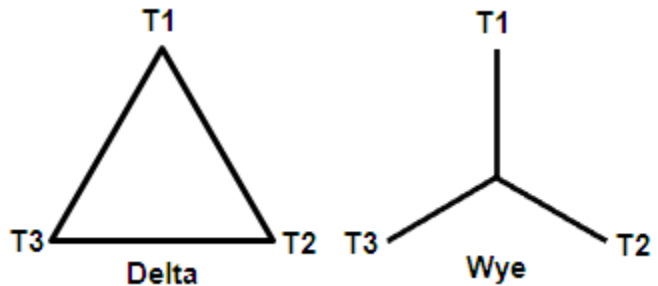
What stands out in this illustration is that there are only two connections at any point on the schematics. Both primary and secondary coils have two. The secondary on the left is connected hot to ground and the one on the right is connected hot to hot. The two center tapped voltages are also hot to ground. When we have three incoming phases the connection scheme is quite different and

that is the purpose of Wye and Delta connections.

### Three Phase Connections

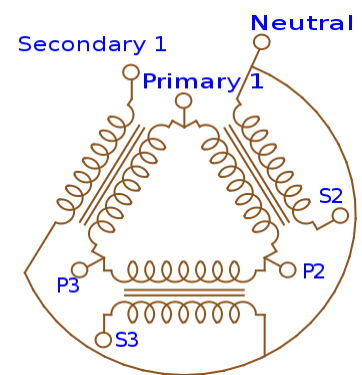
Three phase transformers consist of three separate sets of coils, each of which is connected to an individual phase. In order for voltage and current to flow through the coils there has to be some common connection among them. Figure 2 shows the two possible connections.

The Delta connection joins the coils as an equilateral triangle and applies the individual phases at each of the vertices. The Wye connection joins together one end of each of the coils



and applies the individual phases to the open ends. These two connections produce very different results when power is applied. An advantage of the Delta connection is higher reliability. If one of the three primary windings fails, the secondary will still produce full voltage on all three phases. The only requirement is that the remaining two phases must be able to carry the load. If one of the windings in a Wye primary fails, two of the phases of a Delta secondary will see a reduced voltage. If the secondary is also Wye connected, two phases will have reduced voltage and the other will have zero volts. An advantage of the Wye connection is that it can provide multiple voltages without the need for additional transformers. This can reduce cost in many applications.

The primary and secondary of a three phase transformer can be designed as Delta/Delta, Wye/Wye, Delta/Wye and Wye/Delta. Delta/Delta is used in many industrial installations while Delta/Wye is the most common configuration. Wye/Delta is used in high voltage transmission while Wye/Wye is seldom used due to potential unbalance. Figure 3 is the schematic for a Delta/Wye configuration. The primary is wound as Delta and the secondary is wound as Wye. The incoming phase voltages are applied at P1, P2 and P3 and S1, S2 and S3 are the output voltages.



I mentioned earlier that the output of the two connections is quite different. Either can be wound to produce a particular phase voltage but the phase to phase voltages will be different for the Wye and Delta connections. Let's take a look at two examples.

Figure 4 shows the secondary (output) side of a Wye connected, three phase transformer. The green line is a center tap that leads to ground. In this example the individual phases are 120 volts and each produce 120 volts when connected to the center tap. When connected phase to phase the voltage is just 208, not the 240 volts we might expect. Why? The answer is Wye. Wye connections produce a different phase angle among the phases and the phase angle determines the phase to phase voltage. If you are interested in learning more about phase angles and the phasor diagrams that measure them, see the "Changing Voltage Puzzler" on my website. The nice thing is that there is a constant that allows you to compute the phase to phase voltage produced by a Wye connection. The phase to phase voltage will always be 1.732 times the phase voltage.

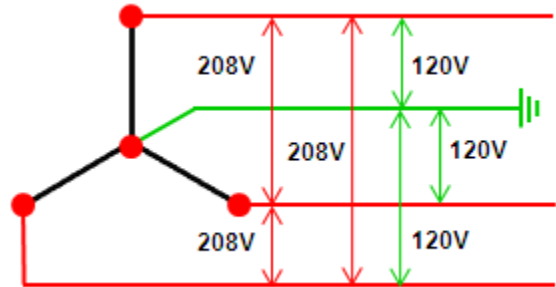
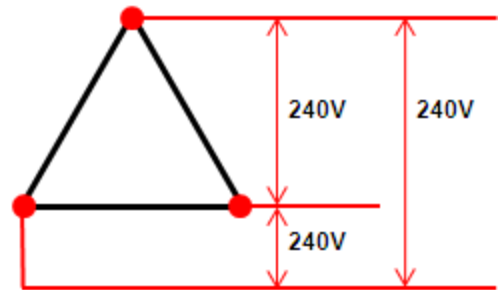


Figure 5 shows the secondary (output) side of a Delta connected three phase transformer. As in the Wye example, the individual phases produce 120 volts. In this example the phase to phase voltages are twice the individual phase voltages or 240 volts. Now, it may appear that the Delta is a more "efficient" design but, phase angle has a role here also. The phase to phase current in a Delta circuit is just 1.732 times the phase current while it is two times the phase current in a Wye circuit. This why the constant of 1.732 appears in the equations used to calculate wattage and other values in three phase circuits. It accounts for the phase angle effect on both voltage and current in the two different connections.



$$\text{Power (Watts)} = E \times I \times 1.732 \times \text{Power Factor}$$

Next month we will investigate three mutations of the common Delta secondary and how they can be problematic.

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