M-I-C-K-E-Wye

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When setting out to monitor three phase power systems, one of the first factors (after safety, of course) is to determine if the circuit is a wye or delta configuration. The primary and secondary sides of transformers are often different wiring configurations, as can be the loads from the source. This affects not only how you would connect the voltage and current probes, but also what you will see in the data.

A "wye" circuit is so named because the three phase elements or legs of the load or source are interconnected in the same of a letter 'Y'. This configuration is sometimes referred to as a star. The connections are usually made between the outer point on each leg (the phase conductor) and the common center point. Though not always, this common center point is often connected to the grounded conductor, called the "neutral". The word "neutral" is very misleading in today's electrical distribution systems, since significant current is often found to be flowing in the neutral due to unbalanced loads or sources, as well as harmonic currents that don't cancel out (referred to as the "triplen" or zero sequence currents of the 3rd, 6th, 9th, 12th, ... harmonics). Connections may also be made from leg-to-leg or phase-to-phase on a wye, if that is how the loads are connected.

A "delta" circuit looks like the delta symbol, which is an equal-sided triangle. There are numerous variations of the delta circuit, such as: grounded deltas (one corner of the triangle is connected to a grounded conductor); open-leg delta (only two elements instead of three are used); or, crazy-leg (where one leg is center-tapped to produce two voltages that 180 degrees out of phase from each other).

A significant difference between a delta and wye circuit is relative to the current flow. Looking at a typical wye connected load, the current flowing down a phase conductor flows through one leg or element of the load into the center conductor or neutral and back to the source. This holds for each of the three phases. In a balanced circuit with no harmonics, the 120 degree phase shift of each current results in a canceling effect in the neutral, and no current flow. The measured phase shift between the voltage and current is an indication of the power factor of that leg.

In a delta circuit, the current coming down the phase conductor will divide between the two legs that are connected at each corner. If the impedances of each leg were identical, then the current would divide evenly. Since this is often not the case, the ratio may not be known. If the load were purely resistive, there will be a 30 degree phase shift between the voltage (which is measured phase-to-phase or across two legs) and current. Therefore, any power factor calculation on an individual phase would be altered by this inherent phase shift. Often only the three phase power factor is of any value.

In the past, it was possible to use a simple formula for converting between "equivalent" delta and wye circuits. The voltage in the delta circuit (measure phase-to-phase) would be larger than the phase-to-neutral voltage of the wye circuit by the square root of three. Similarly, the current in wye phase would be larger than the delta circuit by the square root of three. These relationships aren't valid with imbalances or harmonics present.

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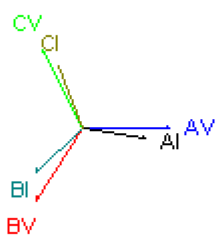
In the world of power quality, these factors about the type of circuit are important when selecting a monitor, connecting the monitor, and analyzing the data from it. For example, if the monitor does not have differential inputs on the voltage input channels, it is probably designed to monitor the voltage phases with reference to the "neutral" voltage input. However, a delta circuit may not be referenced or connected to any grounded conductor. The voltage waveforms and measurements will be made with relative to this "pseudo neutral", which is not how the loads are connected. This means that what the monitor is seeing is not what the load is seeing, which is what really matters. For example, if a rapid reduction of equal magnitude of the voltage occurs on two phases relative to the neutral, the load connected across those phases would not have experienced any disturbance. Conversely, if a disturbance occurs that causes change or shift in the 120 degree phase relationship between two phases, the voltage measured between each of the phases and the pseudo neutral may remain the same (indicating that nothing has happened), yet the voltage between the two phases that is powering the load may be sharply reduced. Therefore, it is important that the monitoring be done in a manner consistent with how the loads are connected.

In next month's issue, we will look at how a disturbance that happens on the primary side of a delta-wye transformer would look on the secondary side, along with other combinations that can produce some interesting results.

Phasor diagram for a wye circuit



Normalized to AV
AV=0°, BV=239°,
CV=117°,
AI=351°, BI=226°,
CI=110°

Phasor diagram for delta circuit

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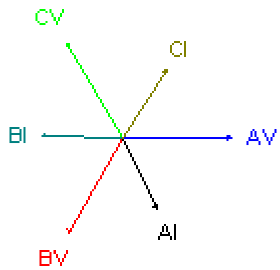

Normalized to AV
AV=0°, BV=241°, CV=121°,
AI=297°, BI=179°, CI=57°

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