

Application Note

How to Determine Transformer Vector Group

A vector group is the International Electrotechnical Commission (IEC) method of defining high voltage (HV) and low voltage (LV) winding configurations of three-phase transformers. The vector group also defines differences in phase angles between them. Transformer windings can be connected in several ways:

D: Delta, in which the end of one winding is connected to the beginning of the next winding. Each phase terminal connects to two windings, so the windings form a triangular configuration with the terminals on the points of the triangle.

Y: Wye (also called star), in which all three winding end terminals are connected together. Each individual phase terminal connects to one end of a winding, and the other end of each winding connects to a common central point. If the central point (also called neutral point) is accessible outside of the transformer, letter N is added to the marking (YN).

Z: Interconnected star (or zigzag), similar to a wye winding, but one winding is wound on two limbs, so the three legs are "bent" when the phase diagram is drawn. If the central point is accessible outside of the transformer, letter N is added to the marking (ZN).

III: Independent windings, which are not interconnected inside the transformer and must be connected externally.

In the IEC vector group code, each letter stands for one set of windings. The high-voltage (HV) winding is marked with an uppercase letter, followed by medium or low-voltage (LV) windings marked with a lowercase letter. The number following the letter codes indicates the difference in phase angle between the windings, with HV winding taken as a reference. This number is also called phase displacement, and can have values from 0 to 11. The phase displacement number multiplied with 30° gives the phase angle between the HV and LV windings. For example, a transformer with the vector group YNd5 has a wye-connected HV winding with neutral point accessible, and a delta-connected LV winding, while the phase angle of the LV winding lags the HV by 150° .

DV Power provides three-phase devices for testing a turns ratio (TRT series devices) and winding resistance (TWA series devices) of three-phase transformers. Since each vector group has a different internal design and connections, different testing sequences are used for different vector groups. Devices are equipped with algorithms that enable automated switching between these sequences, making testing of all three phases easy and quick. The only prerequisite for a successful test is to enter the proper vector group of the transformer under the test, so the device will use the proper algorithm. This is generally not a problem for IEC based transformers, since the vector group is stated on their nameplates. More complex approach may be needed when testing ANSI based transformers.

Transformers built to ANSI standards usually do not have a vector group shown on their nameplate and instead a vector diagram is given to show the relationship between the primary and other windings. Turning vector diagram into vector group is essential and necessary before making the test. It can be split into 2 parts.

1. Recognizing configurations of HV and LV windings. This is easier part and the Figure 1 can help in determining if the primary and/or secondary windings are connected in delta, wye, or interconnected star.

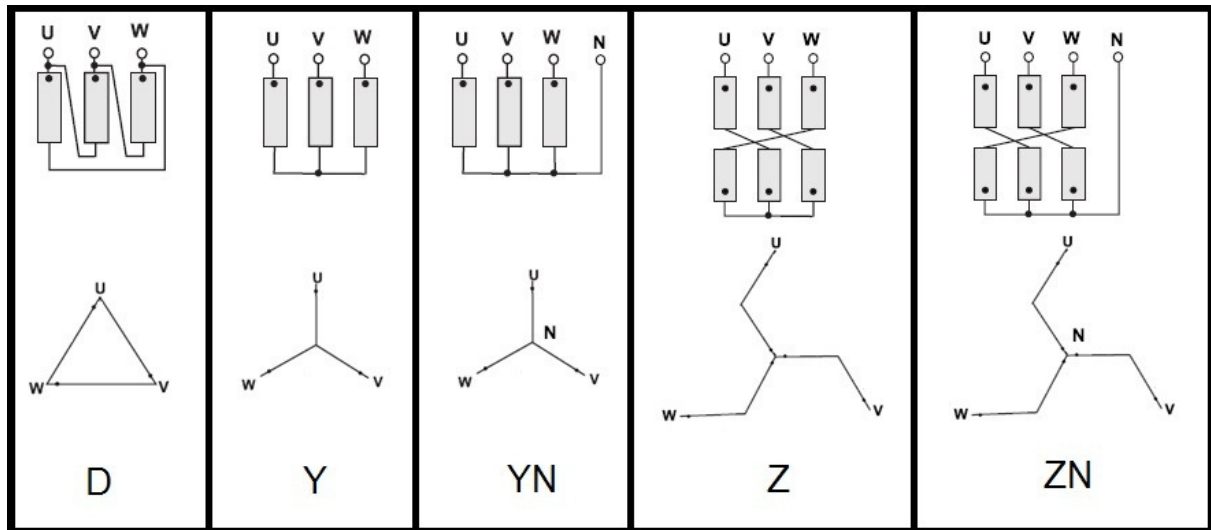


Figure 1: Diagram of different winding connections

NOTE: U, V, W, and N are phase labels. In different parts of the world, different labels might be used, such as A, B, C, N in Australia, or H1, H2, H3, H0 (X1, X2, X3, X0) in USA and Canada, etc.

2. Determining phase displacement between HV and LV windings. The phase angle between HV and LV windings is detected from the nameplate vector diagram. It is actually the angle between corresponding phasors on HV and LV side (H1 and X1). Once the phase angle is defined, the phase displacement number is simply calculated by dividing the phase angle by 30°.

Let's take a look at the example below. Figure 2 illustrates a typical transformer nameplate with ANSI markings. The vector diagram is marked with red rectangle and zoomed in on the right-hand part of the figure, for better visibility. Comparing to the Figure 1, it can be seen that HV windings are connected in delta (D), while LV windings are connected in wye with neutral point accessible (yn).

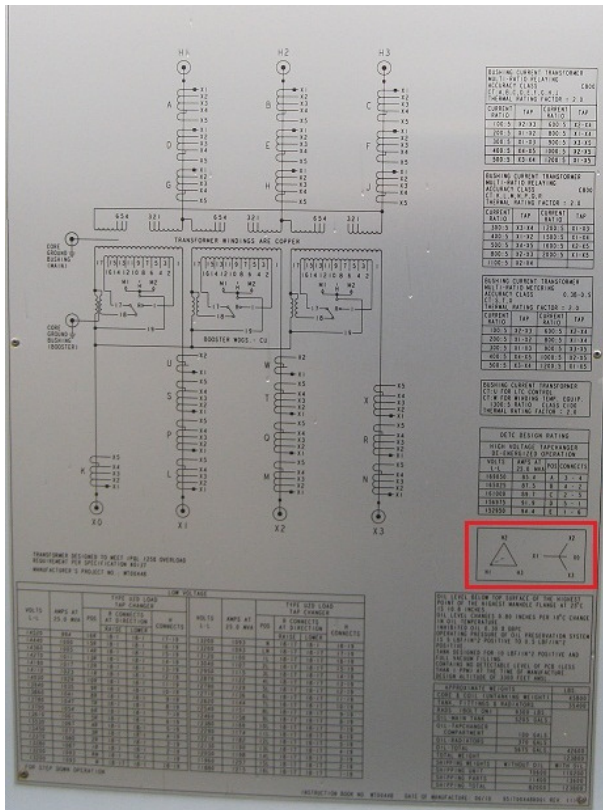
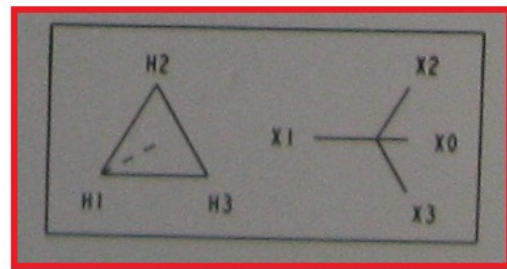
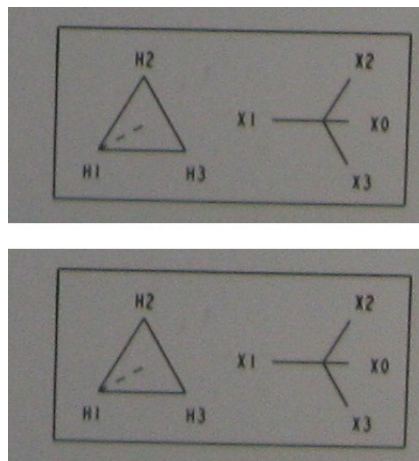


Figure 2:
Example of a nameplate with vector diagram instead of vector group



The angle between H1 (dotted line) and X1 is 30°, as illustrated in the Figure 3. The phase displacement number is therefore $30^\circ/30^\circ=1$. The vector group of this transformer is Dyn1.

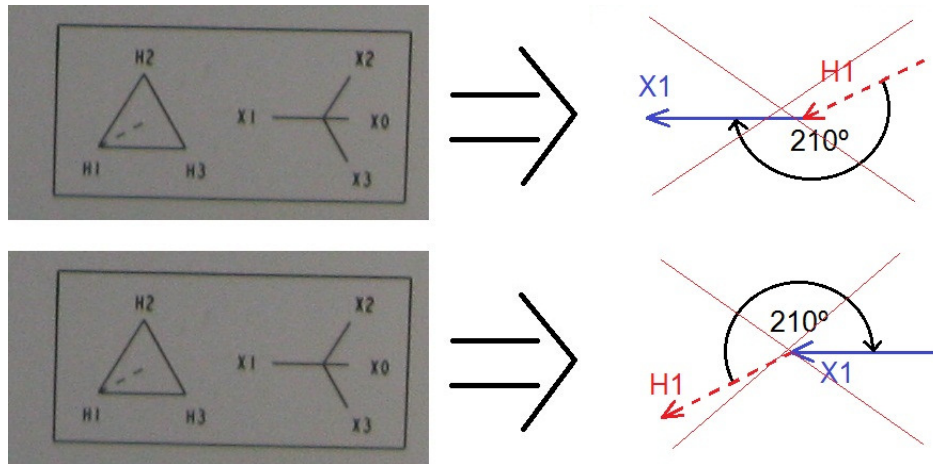
Figure 3:
The correct way of determining angle between H1 and X1



Note that when determining the angle between H1 and X1, the rotation must be clockwise. Going counterclockwise between H1 and X1 can give wrong phase angle, and therefore wrong phase displacement number, which leads to wrong vector group and possibly to wrong test results.

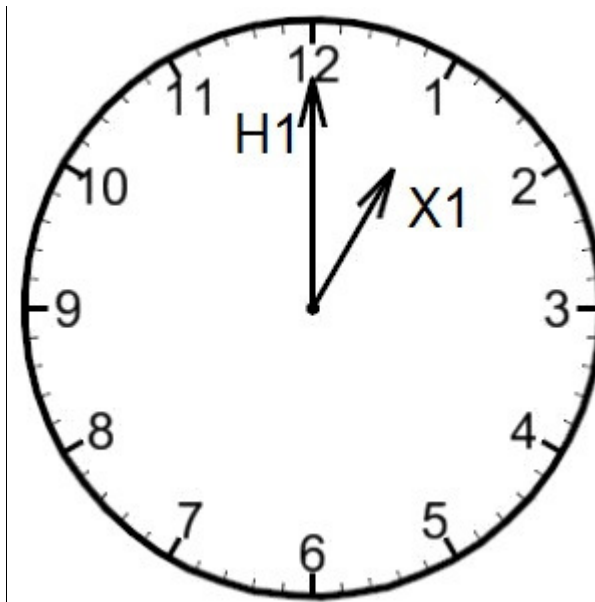
The tip of one vector must not be brought to common point with the origin of the other vector, and vice versa. The Figure 4 shows incorrect ways of determining the angle between H1 and X1.

Figure 4:
The incorrect way of determining angle between H1 and X1



Another way to define the phase displacement is to consider H1 and X1 as clock's hands: H1 is the minute's hand, X1 is the hour's hand. In this case, they form 1 o'clock, which means the phase displacement number is 1 (Figure 5).

Figure 5:
1 o'clock formed by H1 and X1



NOTE: The table with all vector groups and their corresponding vector diagrams can be found at the end of User Guides for TRT and TWA series devices.

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