RESEARCH ARTICLE OPEN ACCESS

Vector Group of Transformers in KUWAIT Electrical Network

ABDELAZIZ BAKR MOHAMED KAMEL (1)
YASSER HASSAN ABDELAZIZ ELHADDAD (2)
Electrical Network Department (1) & Electrical Power Department (2)
High Institute of Energy, Public Authority of Applied Education and Training, KUWAIT

Date of Submission: 22-01-2021 Date of Acceptance: 06-02-2021

I. INTRODUCTION

Vector group of transformers considered to be the best method to show and explain the phase displacement between the High Voltage (HV) and Low Voltage (LV) sides. It also gets the winding configuration of HV and LV of three phase transformers.

The three phase transformers can be connected in several arrangements. They are divided into four main vector groups based on the phase angle difference between the windings. Phase difference is the angle by which the LV line leads the HV and it's measured in unit of 30° in anti-clock wise direction. The groups are as follows:

Group No.	Phase Displacement	Connection
Group 1	**No phase displacement**	**Yy0, Dd0, Dz0**
Group 2	**180° Phase displacement**	**Yy6, Dd6, Dz6**
Group 3	**-30° Phase displacement**	**Yd1, Dy1, Yz1**
Group 4	**30° Phase displacement**	**Yd11, Dy11, Yz11**

Table 1 – Group No. of Various Winding Designs.

Notes:
- Minus sign in the previous table indicates that LV lagging HV and Plus sign indicates that LV leads HV.
- The connection of **group 1** and **group 2** are vice-versa and can be obtained by reversing the connection.
- The connection of **group 3** and **group 4** are vice-versa and can be obtained by reversing the connection.

• **Advantages of Vector Group Method**

Vector group indicates what type of connection is made between two or more parallel transformers. It also indicates what is the phase difference between primary and secondary winding voltage. If vector group can't be obtained, then no-load current, iron losses, input and output voltage can't be determined properly.

On the other hand, when connecting two different transformers in parallel, it's a must that the two transformers have the same vector group to avoid large circulating current flow between them.

Connecting Transformers in Parallel

When connecting two or more transformers in parallel to achieve more power transfer, there are some requirements must be taken into considerations.

1- The parallel transformers must have the same capacity.
2- Same voltage ratio.
3- Same impedance ratio (Z%).
4- Have the same frequency.
5- Also, have the same polarity.
6- All parallel transformers must have the same vector group (as explained in next sections).

II. WINDING DESIGN CONSIDERATIONS

The three-phase transformer consists of three winding connected in several ways. When AC current flows through a phase, a magnetic flux will be produced, hence, a voltage will be on each turn of the winding. Using a magnetic path between primary and secondary winding, a voltage also will be produced on the other side.

The phase relationship of the two voltages depends upon which ways round the coils are connected. The voltages can be in-phase or displaced by a unit of 30°.

- There are six ways to wire Star and Delta Winding as follows:

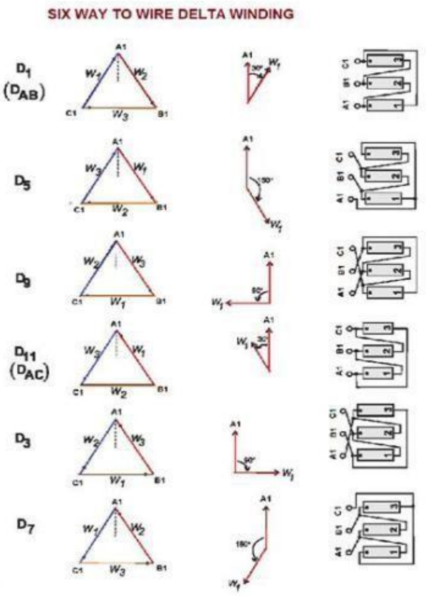

Figure 1 – Various ways to wire Delta winding.

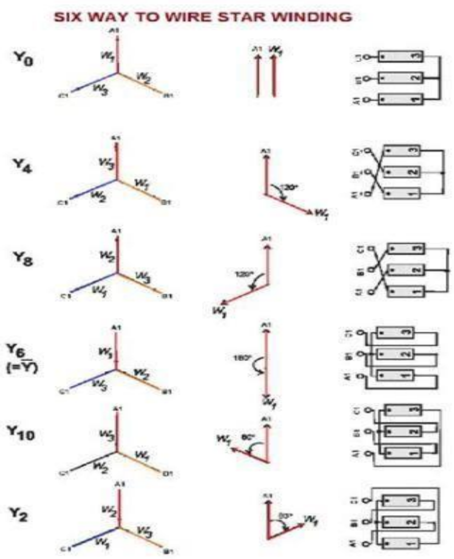

Figure 2 – Various ways to wire Star winding.

• Winding Connection Designations

Vector group of any transformer can be obtained from its nameplate.
The winding connection could be writing as follows:

- **HV** winding: Y, D or Z (Upper case).
- **LV** winding: y, d or z (Lowe case).

Where:

1- Y or y indicates a Star connection.
2- D or d indicates a Delta connection.
3- Z or z indicates a Zigzag connection.
4- N or n indicates that a neutral point is brought out.

Phase Displacement:

The digits (0, 1, 11, etc.) relate to the phase displacement between HV and LV winding using clock face notation as follows;

- Digit **0** means that LV phasor is in phase with HV phasor.
- Digit **1** means that LV phasor lagging HV phasor by 30°.
- Digit **11** means that LV phasor lagging HV phasor by 330° or leads by 30°.

For example, suppose a transformer having **Dyn11** group. It means:
D – Primary DELTA connection.
y - Secondary STAR connection.
n – Neutral point available in STAR connection (Secondary).
11 – 30-degree lead.

Different Transformers Connections Analysis in KUWAIT Network

In this section, vector group of **KUWAIT** Network transformers will be handled and analyzed.

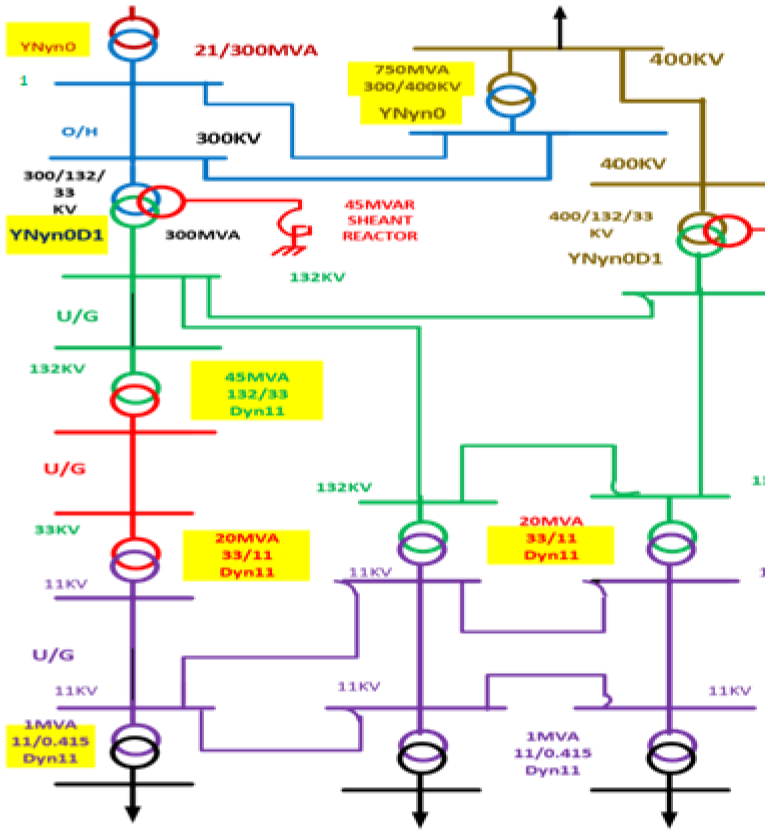

Figure 3 – Transformer Distribution through Electrical Network.

All Step Down Tr. In Primary S/S in Kuwait:

Voltages	Vector group	Capacity
400/275/33 KV	YNyn0D1	750 MVA
400/132/33 KV	YNyn0D1	300 MVA
275/132/33 KV	YNyn0D1	300 MVA
132/33 KV	Dyn11	45 MVA 75 MVA
132/11 KV	Dzn10	30 MVA
33/11 KV	Dyn11	20 MVA 15 MVA

Figure 4 – All step-down transformers in **KUWAIT** electrical network.

As shown in the previous figure;

For Extra High Voltage Level (400KV&300KV):

It's Noticed that Vector group of the Step-down transformer is **YNyn0D1**. It indicates that Primary windings are wired as **STAR** connection with neutral point (N).

On the other hand, the secondary windings are wired as **STAR** connection with neutral point included also. The phase displacement is **0**, and this means there is no phase difference between primary and secondary voltage phasors. This connection has many advantages as follows;

1- Mainly used for large system tie-up Transformer (**400KV**).

2- Most economical connection in HV power system to interconnect between two delta systems and to provide neutral for grounding both of them.

3- In This Transformers. Insulation cost is highly reduced. Neutral wire can permit mixed loading.

4- The tertiary transformer used for cancelling the 3rd harmonics.

The voltage level was **300KV** years ago, but currently **400KV** has been applied directly with

132KV. And to avoid vector group mismatch with the **LV** side, **YNyn0D1** is used for the following reasons:

1- The voltage produced will be $V_{ph} = \frac{V_L}{\sqrt{3}}$ so, the insulation cost will be reduced.

2- Due to voltage reduction, the number of turns used to produce voltage will be reduced than in Delta connection.

3- In case of the presence of short-circuit in Star connection, we can operate the transformer on single-phase only.

4- A Delta winding has been added to eliminate 3rd harmonic.

5- On the other hand, this vector group has no phase displacement, so it facilitates electrical wiring with Gulf countries and connect with **132KV** directly.

For Extra High Voltage Level 300/132/33KV:

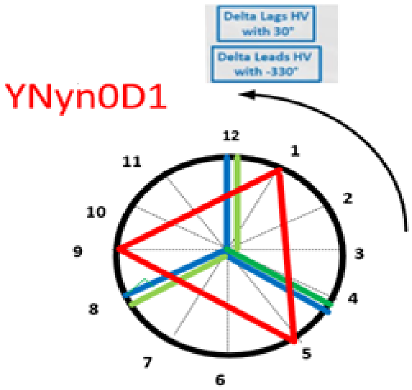

Figure 5 – Clock notation for **YNyn0D1** Transformer

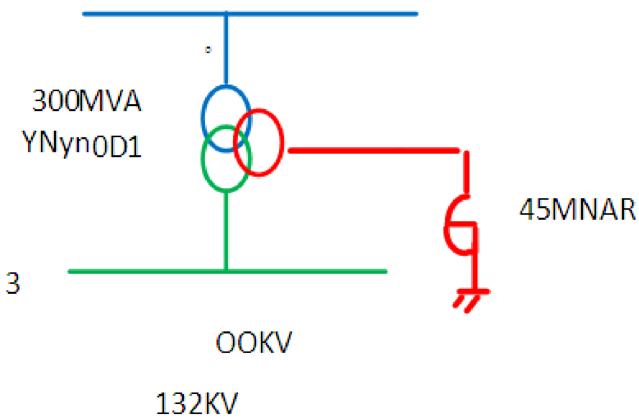

Figure 6 – Network diagram

On the other hand, the main advantage of used thee winding transformer is that when any fault and short circuit is occurred on primary and secondary side. a large unbalance of phase voltage may be produced, which is compensated by large tertiary winding circulating currents.

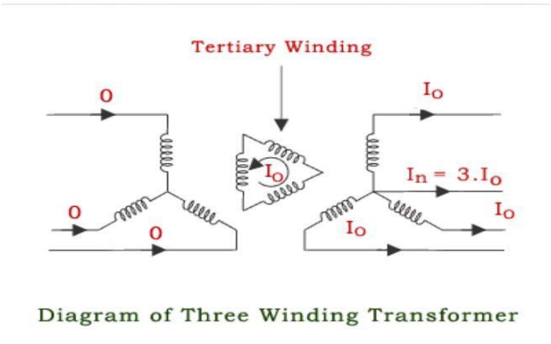

Figure 7 – Diagram of three-winding transformer.

Third winding is also known as stabilizing winding. Because, A Delta connected tertiary winding reduced the impedance offered to zero sequence current. So large earth fault current flows for proper operations of protective devices. When the load is unbalanced, tertiary winding reduced third harmonic voltage and limits the unbalanced voltage.

At High 132/33KV Level:

Vector group of the transformer used in this voltage level is **Dyn11.**

The specifications of this vector group as follows:

HV windings are wired as Delta connection.

LV windings are wired as Star connection with Neutral point included.

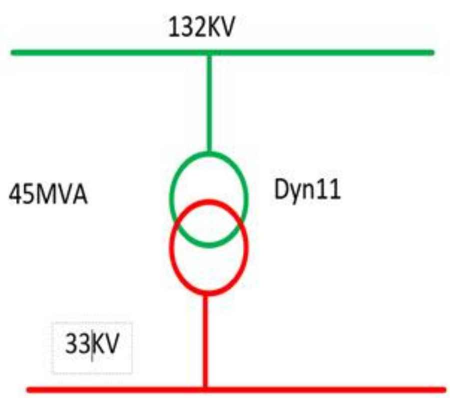

Figure 8 – Network diagram

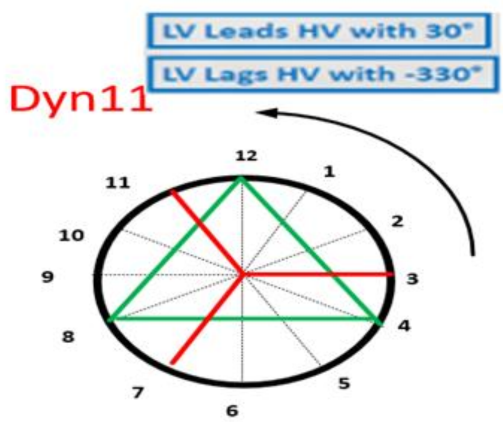

Figure 9 – Clock Notation **Dyn11**

There is a phase displacement of **+30** degree between **HV** and **LV** phasors. This type of vector group considered to be common configuration for distribution transformers. The delta winding carries third harmonics and stabilizes star point potential. A delta-Star connection is used for step-up generating stations.

At Medium 33/11KV Level:
Vector group of the transformer used in this voltage level is **Dyn11.** The high voltage winding is wired as Delta and the low voltage winding is wired as Star with Neutral point. The Phase Displacement of this vector group is **+30** degree. As shown in the following figure.

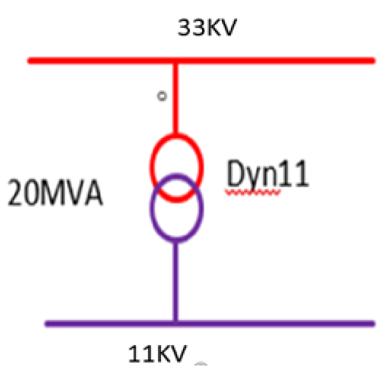

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Figure 10 – Network diagram **Dyn11.**

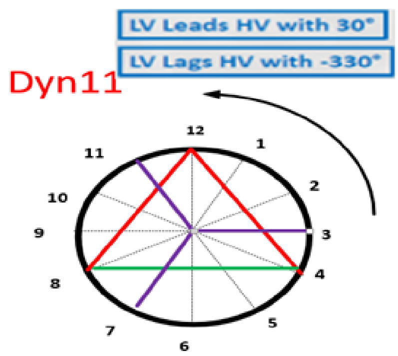

Figure 11 – Clock Notation

At High 132/11KV Level:
In this section, a new vector group of **132/11KV** will be illustrated. It's concluded from the **132/33KV** and **33/11KV** levels that the phase displacement is $\mathbf{30° + 30° = 60°}$**.** And there is no way to connect the transformer as **Dy** as in **33/11KV,** so we can overcome this problem by using **zigzag** of a vector group of **Dzn10** in addition, reducing the 3rd harmonics.

The primary winding will be **Delta** connection, and the secondary winding will be **Zigzag** with a phase displacement of +60 degree.

ISSN: 2248-9622, Vol. 11, Issue 2, (Series-I) February 2021, pp. 26-31

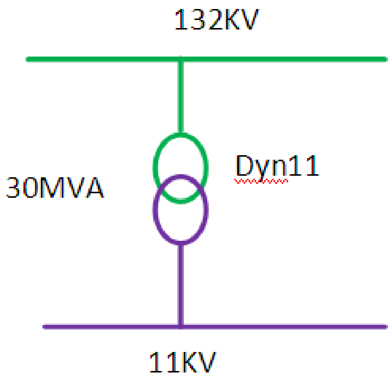

Figure 12 – Network diagram
Dzn10

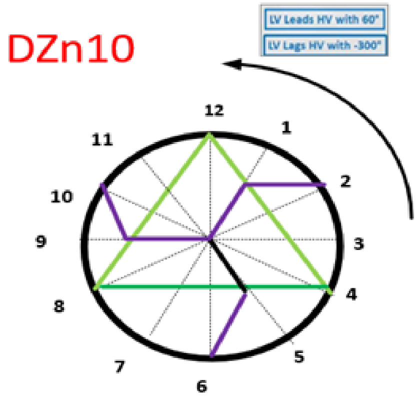

Figure 13 – Clock Notation

III. CONCLUSION

We can conclude from the previous section that **33/11KV** stage can be cancelled and could be substituted with **132/11KV** directly due to the high cost of operation of the power planets, also, the residential loads are very nearby, and **33KV** stage needed in the long-distance loads.

As a result, we can cancel **33/11KV** stage and we will use **132/11KV Dzn10** as explained in the previous section.

- **At Medium Voltage Stage**

The vector group used in this stage is **Dyn11** to avoid 3rd harmonic.

- **At 132/11KV stage**

The vector group applied is **Dzn10**, to avoid the phase displacement of **60** degree and eliminate the **3rd** harmonic.

- **For Linking Network with Gulf Countries**

Auto transformers used in this stage have a vector group of **Yy0** to get rid of any phase displacement between the high and low voltage sides.

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Abdelaziz Bakr Mohamed Kamel, et. al. “Vector Group of Transformers in KUWAIT Electrical Network.” *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (2), 2021, pp 26-31.