Three phase connection of Single-Phase Transformers

Introduction

The primary and secondary windings of three single-phase transformers can be connected in different configurations to meet specific 3-phase system requirements. For single-phase transformers with equal transformation ratio of the phase windings, the ratio of the line voltages and their phase relations depends on the winding connection. Based on the phase relation between primary and secondary voltages, the vector group of the transformer is determined. Identification of the transformer vector group is very important for connecting three phase transformers in parallel.

Aim

1. To connect three single-phase transformers in (a)Star/delta(Yd1, Yd11) (b)Star/Star(Yy6) and to obtain the no-load line voltage ratios and phase relations for each connection.
2. To observe the components in the magnetizing currents and induced voltages for different connections, with and without the neutral being connected.
3. To observe the zero sequence currents with balanced and un-balanced load, with and without a load neutral connection.

Theory

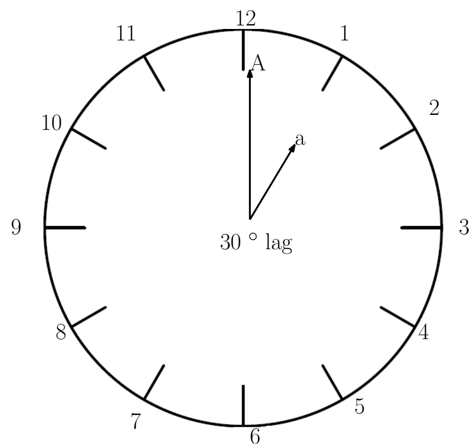

Figure 1: Clock convention

The vector group of a three phase transformer indicates the phase difference between the primary and secondary sides, introduced due to that particular configuration of transformer windings connection. In a vector group representation, first symbol in capital letters is for high voltage, second symbol in small letters is for low voltage and third symbol for phase displacement based on clock convention. The minute hand is used to represent the primary phase to neutral voltage and always shown to occupy the position 12. The hour hand represents the secondary phase to neutral voltage and may, depending upon phase shift, occupy position other than 12 as shown in figure 1.

Star/delta connection: Consider the system shown in figure 2-3. The primary windings are connected in star and the neutral point of the supply is available. The secondary windings are connected in delta. Let us consider that the secondary delta is not closed (say, one arm is open). From the three phase current expressions, it can be noted that the fundamental currents in the windings are phase shifted by 120 from each other, while the third harmonic currents are all in phase (co-phasal).

If the neutral of the primary star is connected to the supply neutral, since the source voltage to neutral is sinusoidal, the flux in the core will be sinusoidal but the exciting current will be non-sinusoidal. Next, consider the case when the neutral of the primary is kept isolated and the secondary continues to be open delta. The phase voltages are non-sinusoidal, containing the fundamental and third harmonic voltages.

Now, if the delta is closed, then the net third harmonic voltage will give rise to a third harmonic current which will circulate in the delta connected windings. This will partly provide the missing third harmonic component of the primary exciting current and consequently the flux and induced voltage will be closer to being sinusoidal.

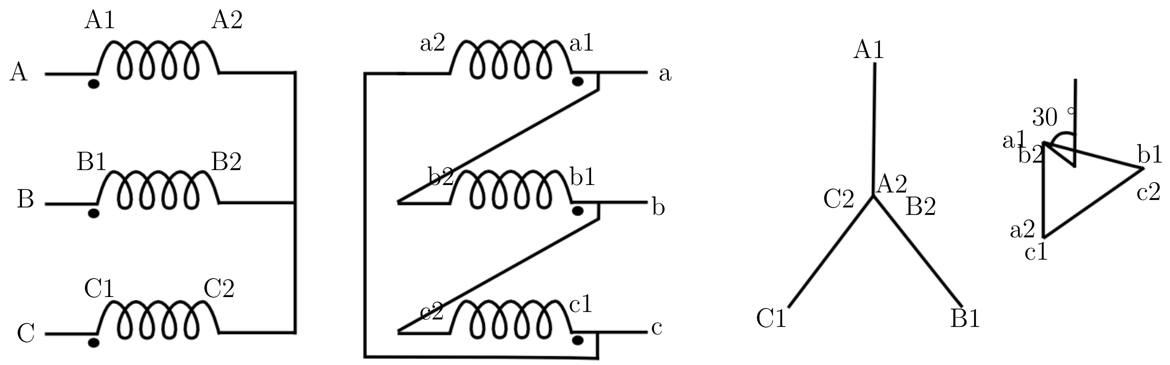

Figure 2: Star/delta (Yd11) connection and its phasor diagram

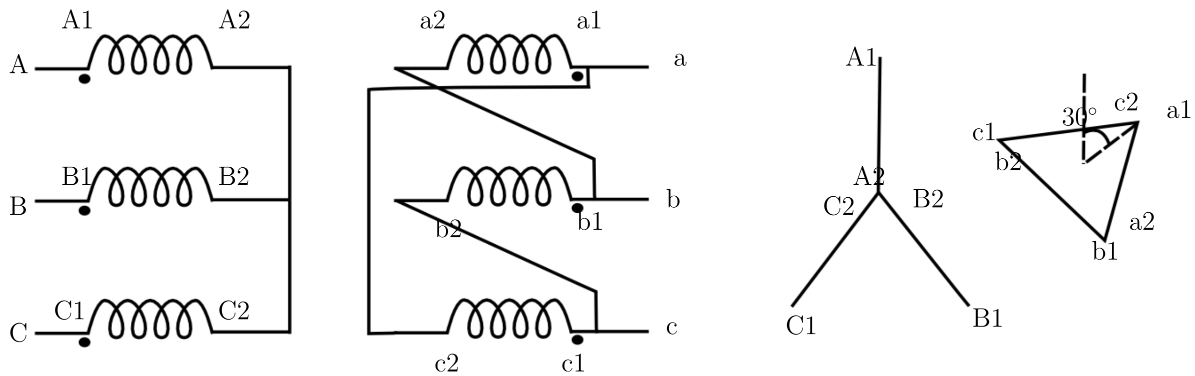

Figure 3: Star/delta (Yd1) connection and its phasor diagram

Star/star connection : See the system shown in figure 4. With no neutral connection, the triple frequency components of the excitation currents are suppressed, thereby causing large triple frequency components in the flux. Triple frequency component will be present in the phase voltages of both the windings, but these will not appear in the line voltages. With the neutral connection (4 wire system), the triple frequency components will disappear from the induced voltages in all the windings while the magnetizing currents of the primary will contain all the harmonics.

If a load is connected to the secondary side as shown in Fig. 5, and if unbalance is created for the load, we can observe the zero sequence currents depending on whether or not the neutrals are

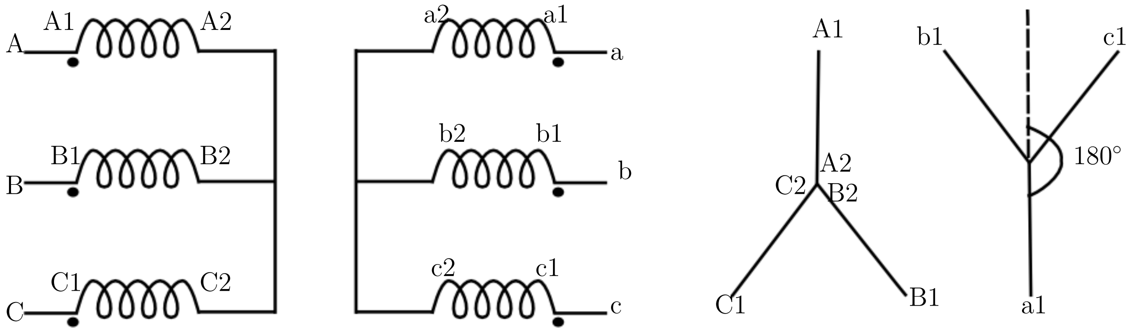

Figure 4: Star/Star (Yy6) connection and its phasor diagram

connected to the source neutral. For a star-star transformer with both neutrals connected to the source ground, as in Fig. 6, the phasor sum of three unbalanced phase currents is equal to three times the zero sequence current and it can flow in both the primary and secondary of the transformer. When the neutral of only one winding is grounded as shown in figure 7, the phase currents of the ungrounded winding must add up to zero. This implies that the zero sequence currents cannot exist in the winding that is not connected to the source neutral and hence the zero sequence currents cannot exist even in the transformer side with neutral connected to the source neutral. Note that $\frac{I_p}{I_s} \simeq \frac{N_s}{N_p}$ for each phase.

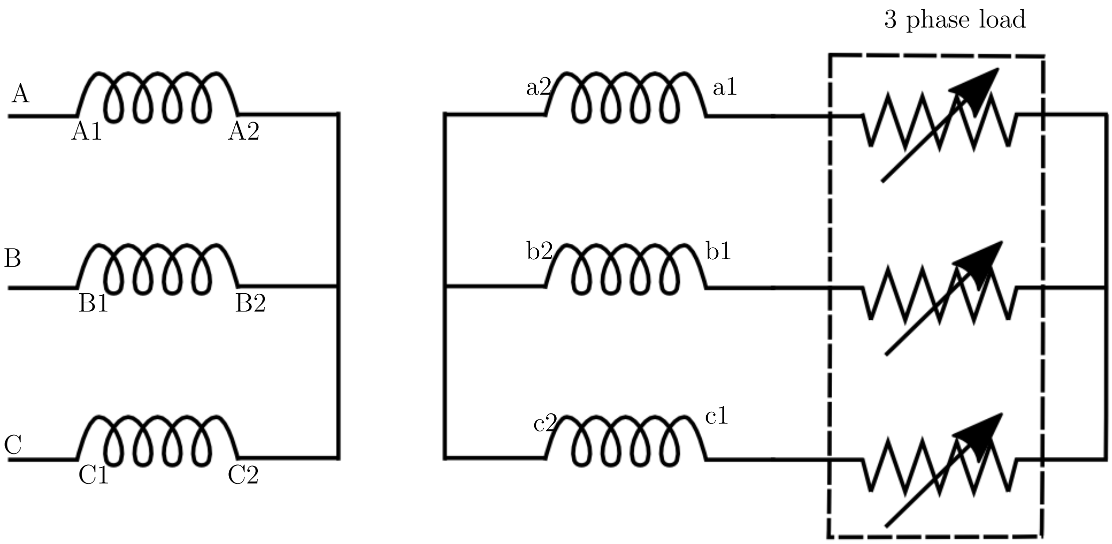

Figure 5: Zero sequence currents

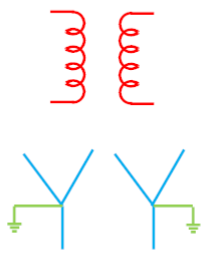

Figure 6: Yy transformer with both neutrals grounded

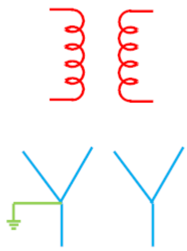

Figure 7: Yy transformer with only one neutral grounded

Procedure:

Using a Digital Storage Oscilloscope (DSO), observe the waveforms of the voltages and currents mentioned below for different connections. Using Fast Fourier Transform (FFT), find the percentages of 3rd, 5th and 7th harmonics with respect to the fundamental.

Star/delta(Yd1, Yd11)

(i) Line voltage, phase voltage and line current of the primary, when neutral is isolated and the secondary delta is open. (ii) Line voltage and phase voltage of the primary, line voltage of the secondary and the current flowing in the delta of the secondary when the primary neutral is still isolated but the secondary delta is closed. (iii) Now connect the primary neutral to the source neutral. Observe the line voltage, phase voltage , line current of the primary and current through the neutral-ground connection wire.

Star/Star(Yy6)

(i) Line voltage, phase voltage and line current of the primary when neutral is not grounded. (ii) Line voltage, phase voltage and line current of the primary when neutral is grounded. Also observe the current through the neutral-ground connection wire. (iii) Line voltage and phase voltage of the secondary with (a) primary neutral isolated and (b)primary neutral grounded.

Star/Star transformer with star connected load

(i) First connect both primary and secondary neutral to the source neutral and vary the load rheostat in any one phase to create unbalance. Observe the zero sequence currents in the neutral wire. (ii) Now remove the grounding on the secondary side and observe the phase to neutral voltage in unbalanced condition.

This document is prepared by *Neethu S.* (Research Scholar, 2014 batch).