Vector Group of Transformer

Introduction

Three phase transformer consists of three sets of primary windings, one for each phase, and three sets of secondary windings wound on the same iron core. Separate single-phase transformers can be used and externally interconnected to yield the same results as a 3-phase unit.

Vector Group of Transformer

The primary windings are connected in one of several ways. The two most common configurations are the delta, in which the polarity end of one winding is connected to the non-polarity end of the next, and the star, in which all three non-polarities (or polarity) ends are connected together. The secondary windings are connected similarly. This means that a 3-phase transformer can have its primary and secondary windings connected the same (delta-delta or star-star), or differently (delta-star or star-delta).

It's important to remember that the secondary voltage waveforms are in phase with the primary waveforms when the primary and secondary windings are connected the same way. This condition is called "***no phase shift***."

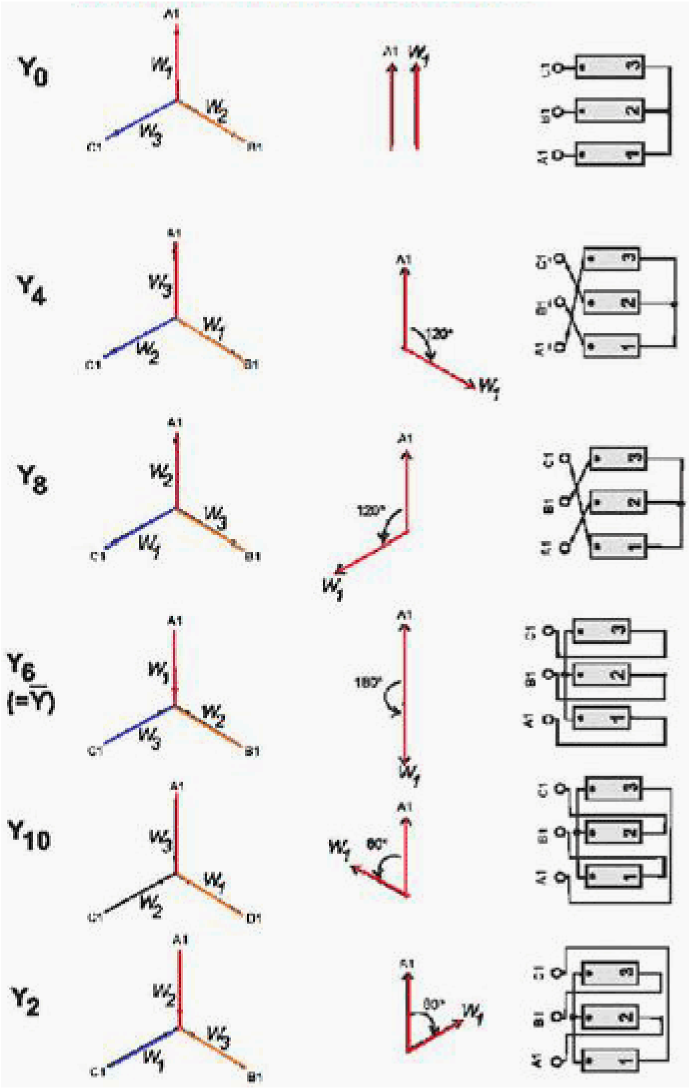
But when the primary and secondary windings are connected differently, the secondary voltage waveforms will differ from the corresponding primary voltage waveforms by 30 electrical degrees. This is called a 30 degree phase shift. When two transformers are connected in parallel, their phase shifts must be identical; if not, a short circuit will occur when the transformers are energized."

Basic Idea of Winding

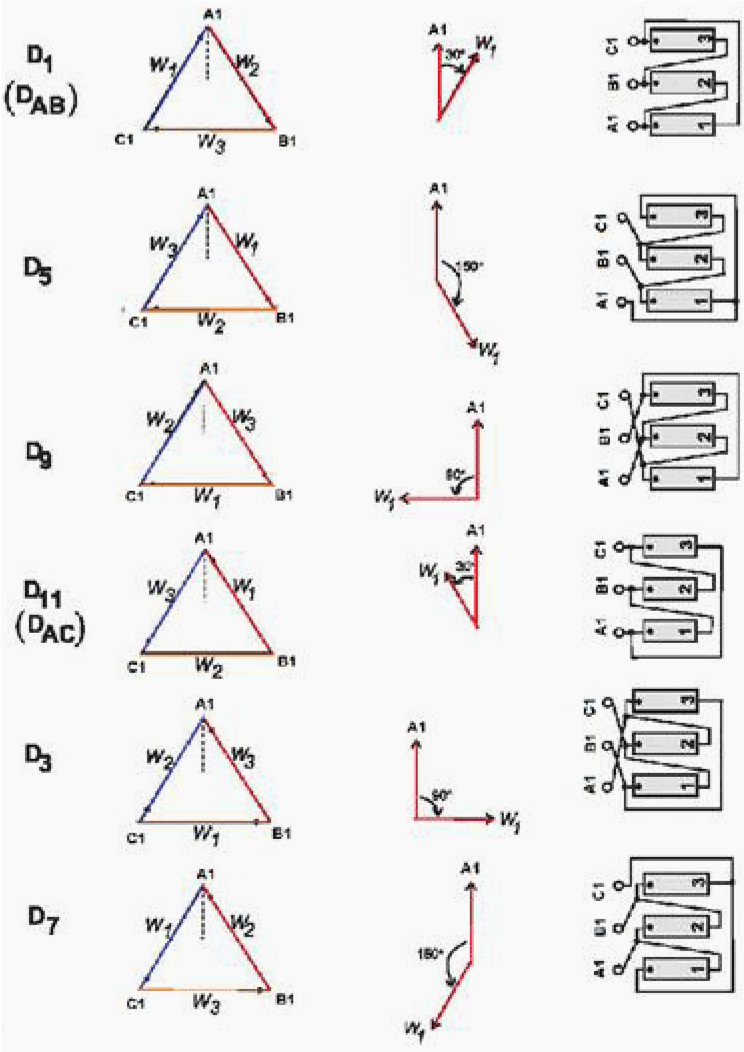
An ac voltage applied to a coil will induce a voltage in a second coil where the two are linked by a magnetic path. The phase relationship of the two voltages depends upon which ways round the coils are connected. The voltages will either be in-phase or displaced by 180 degree.

When 3 coils are used in a 3 phase transformer winding a number of options exist. The coil voltages can be in phase or displaced as above with the coils connected in star or delta and, in the case of a star winding, have the star point (neutral) brought out to an external terminal or not.

Six Ways to wire Star Winding:



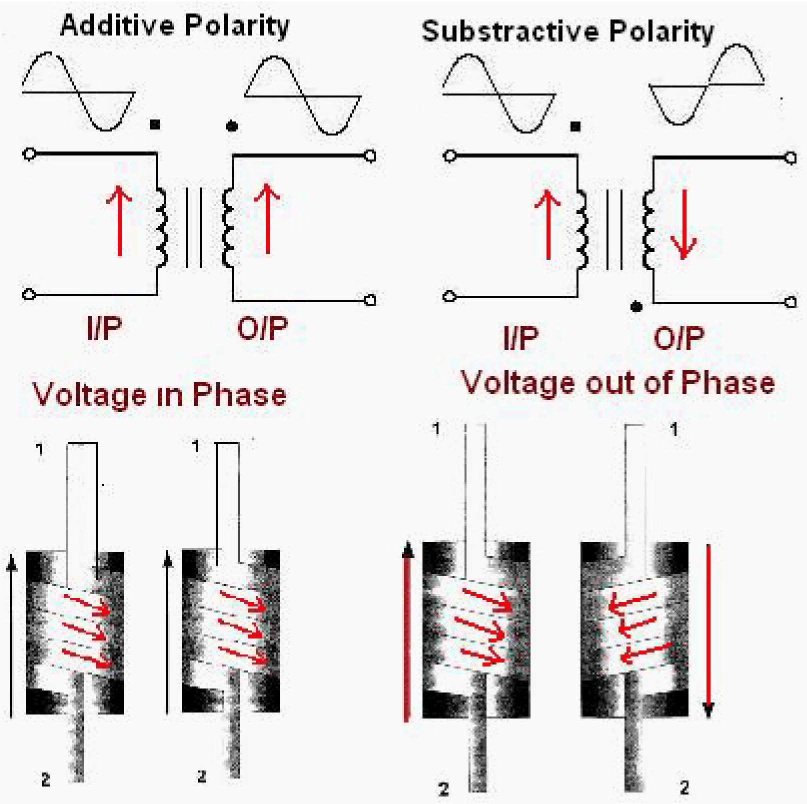
Six Ways to wire Delta Winding:



Polarity

An AC voltage applied to a coil will induce a voltage in a second coil where the two are linked by a magnetic path. The phase relationship of the two voltages depends upon which way round the coils are connected. The voltages will either be in-phase or displaced by 180 deg.

When 3 coils are used in a 3 phase transformer winding a number of options exist. The coil voltages can be in phase or displaced as above with the coils connected in star or delta and, in the case of a star winding, have the star point (neutral) brought out to an external terminal or not.



When Pair of Coil of Transformer have same direction than voltage induced in both coil are in same direction from one end to other end. When two coil have opposite winding direction than Voltage induced in both coil are in opposite direction.

Winding connection designations

First Symbol: for **High Voltage**: Always capital letters.

D=Delta, S=Star, Z=Interconnected star, N=Neutral

Second Symbol: for Low voltage: Always Small letters.

d=Delta, s=Star, z=Interconnected star, n=Neutral.

Third Symbol: Phase displacement expressed as the clock hour number (1,6,11)

Example – Dyn11

Transformer has a delta connected primary winding (**D**) a star connected secondary (**y**) with the star point brought out (**n**) and a phase shift of 30 deg leading (**11**).

The point of confusion is occurring in notation in a step-up transformer. As the ***IEC60076-1*** standard has stated, the notation is HV-LV in sequence. For example, a step-up transformer with a delta-connected primary, and star-connected secondary, is not written as 'dY11', but 'Yd11'. The 11 indicates the LV winding leads the HV by 30 degrees.

Transformers built to ANSI standards usually do not have the vector group shown on their nameplate and instead a vector diagram is given to show the relationship between the primary and other windings.

Vector Group of Transformer

The three phase transformer windings can be connected several ways. Based on the windings' connection, the vector group of the transformer is determined.

The transformer vector group is indicated on the Name Plate of transformer by the manufacturer. The vector group indicates the phase difference between the primary and secondary sides, introduced due to that particular configuration of transformer windings connection.

The Determination of vector group of transformers is especially important before connecting two or more transformers in parallel. If two transformers of different vector groups are connected in parallel, then phase difference exist between the secondary of the transformers and large circulating current flows between the two transformers which is very detrimental.

Phase Displacement between HV and LV Windings

The vector for the high voltage winding is taken as the reference vector. Displacement of the vectors of other windings from the reference vector, with anticlockwise rotation, is represented by the use of clock hour figure.

IS: 2026 (Part 1V)-1977 gives 26 sets of connections star-star, star-delta, and star zigzag, delta-delta, delta star, delta-zigzag, zigzag star, zigzag-delta. Displacement of the low voltage winding vector varies from zero to -330° in steps of -30°, depending on the method of connections.

Hardly any power system adopts such a large variety of connections. Some of the commonly used connections with phase displacement of 0, -300, -180″ and -330° (clock-hour setting 0, 1, 6 and 11).

Symbol for the high voltage winding comes first, followed by the symbols of windings in diminishing sequence of voltage. For example, a 220/66/11 kV Transformer connected star, star and delta and vectors of 66 and 11 kV windings having phase displacement of 0° and -330° with the reference (220 kV) vector will be represented As **Yy0 – Yd11**.

The digits (0, 1, 11 etc) relate to the phase displacement between the HV and LV windings using a clock face notation. The phasor representing the HV winding is taken as reference and set at 12 o'clock. Phase rotation is always anti-clockwise. (International adopted).

Use the hour indicator as the indicating phase displacement angle. Because there are 12 hours on a clock, and a circle consists out of 360°, each hour represents 30°.Thus 1 = 30°, 2 = 60°, 3 = 90°, 6 = 180° and 12 = 0° or 360°.

The minute hand is set on 12 o'clock and replaces the line to neutral voltage (sometimes imaginary) of the HV winding. This position is always the reference point.

Example

Digit 0 =0° that the LV phasor is in phase with the HV phasor
Digit 1 =30° lagging (LV lags HV with 30°) because rotation is anti-clockwise.
Digit 11 = 330° lagging or 30° leading (LV leads HV with 30°)
Digit 5 = 150° lagging (LV lags HV with 150°)
Digit 6 = 180° lagging (LV lags HV with 180°)

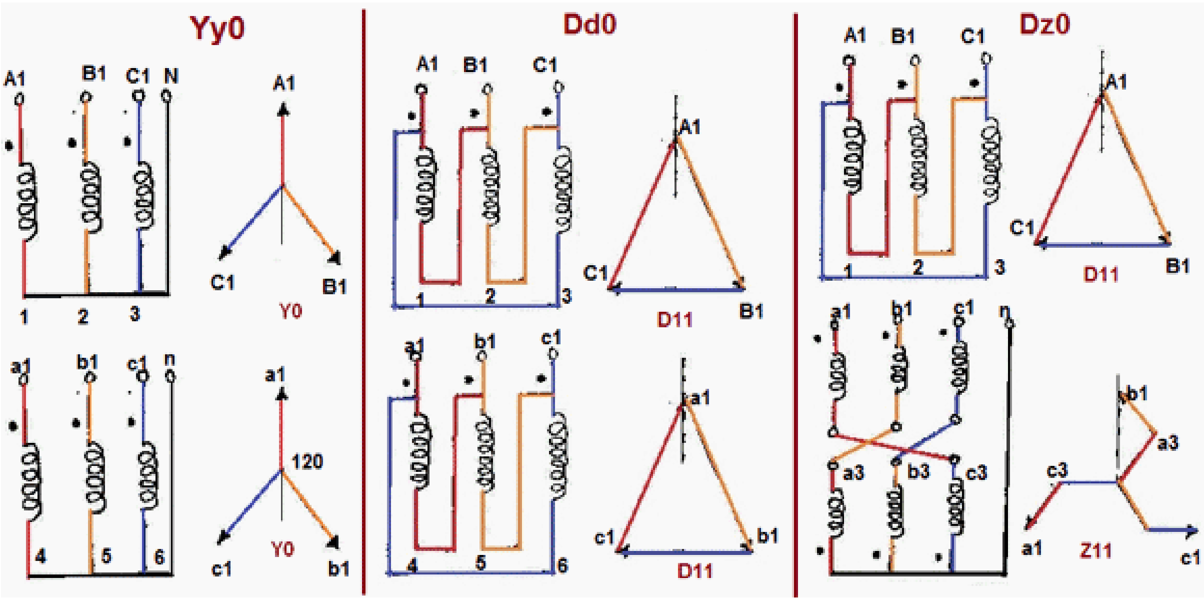
When transformers are operated in parallel it is important that any phase shift is the same through each. Paralleling typically occurs when transformers are located at one site and connected to a common bus bar (banked) or located at different sites with the secondary terminals connected via distribution or transmission circuits consisting of cables and overhead lines.

Phase Shift (Deg)	Connection		
0	Yy0	Dd0	Dz0
30 lag	Yd1	Dy1	Yz1
60 lag	Dd2	Dz2	
120 lag	Dd4	Dz4	
150 lag	Yd5	Dy5	Yz5
180 lag	Yy6	Dd6	Dz6
150 lead	Yd7	Dy7	Yz7
120 lead	Dd8	Dz8	
60 lead	Dd10	Dz10	
30 lead	Yd11	Dy11	Yz11

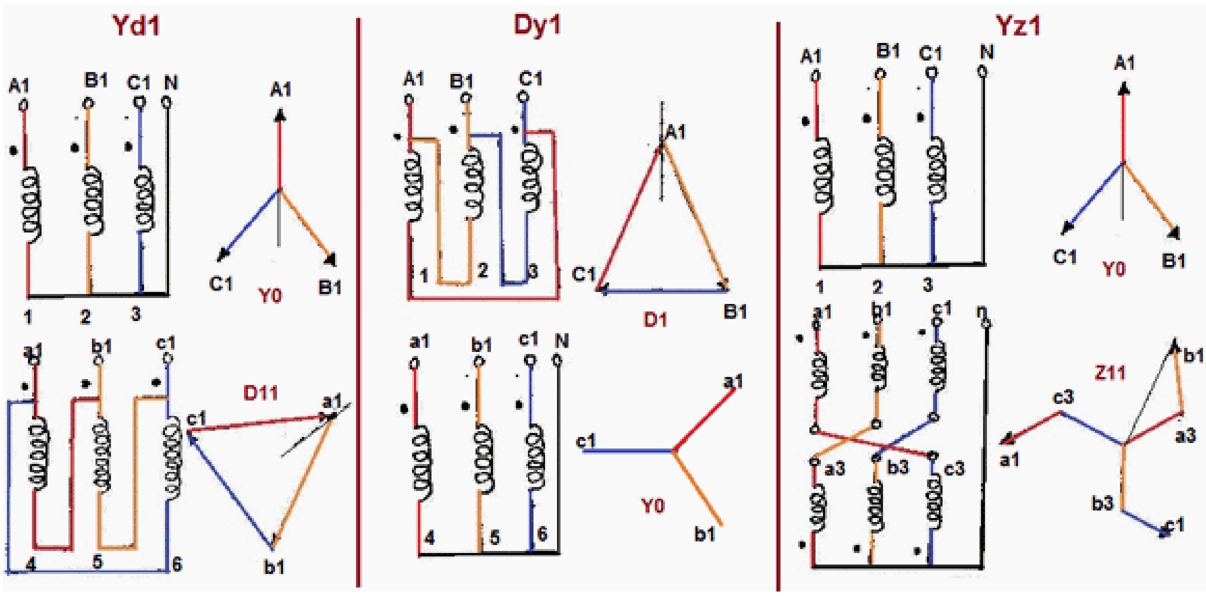
The phase-bushings on a three phase transformer are marked either ABC, UVW or 123 (HV-side capital, LV-side small letters). Two winding, three phase transformers can be divided into four main categories

Group	O'clock	TC
Group I	0 o'clock, 0°	delta/delta, star/star
Group II	6 o'clock, 180°	delta/delta, star/star
Group III	1 o'clock, -30°	star/delta, delta/star
Group IV	11 o'clock, +30°	star/delta, delta/star
Minus indicates LV lagging HV, plus indicates LV leading HV		

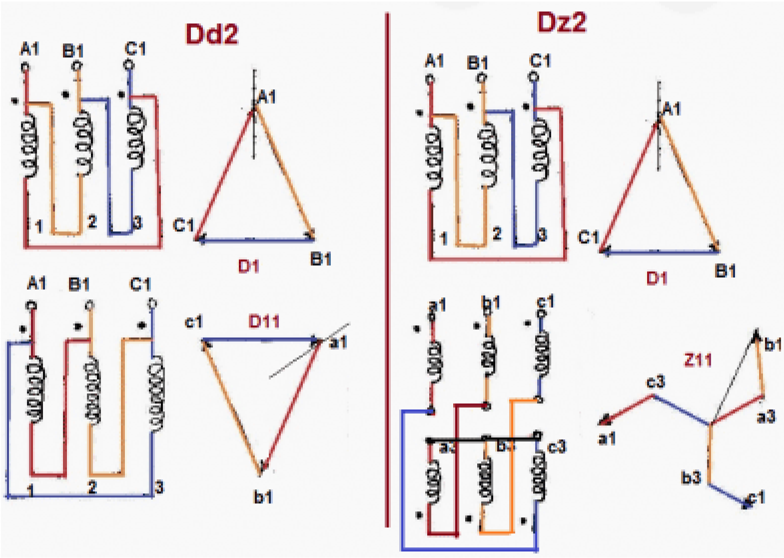
Clock Notation 0 (Phase Shift 0)



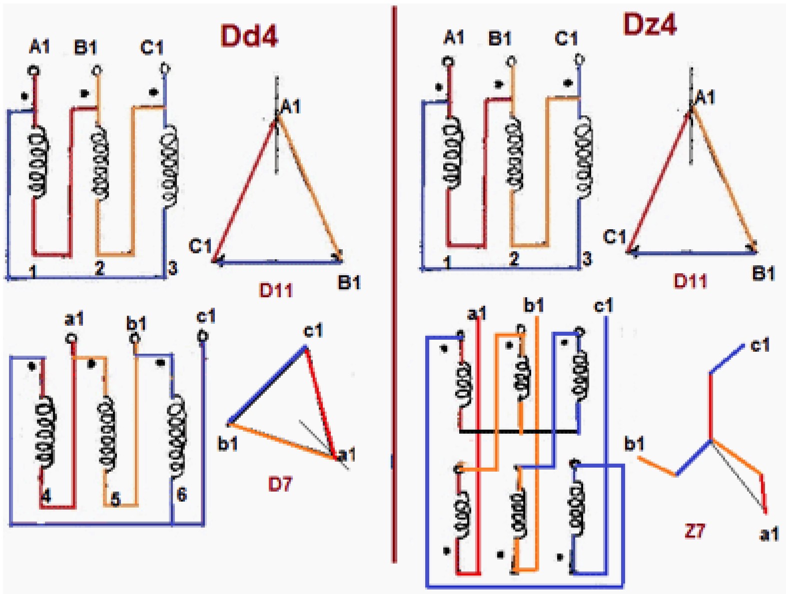
Clock Notation 1 (Phase Shift -30)



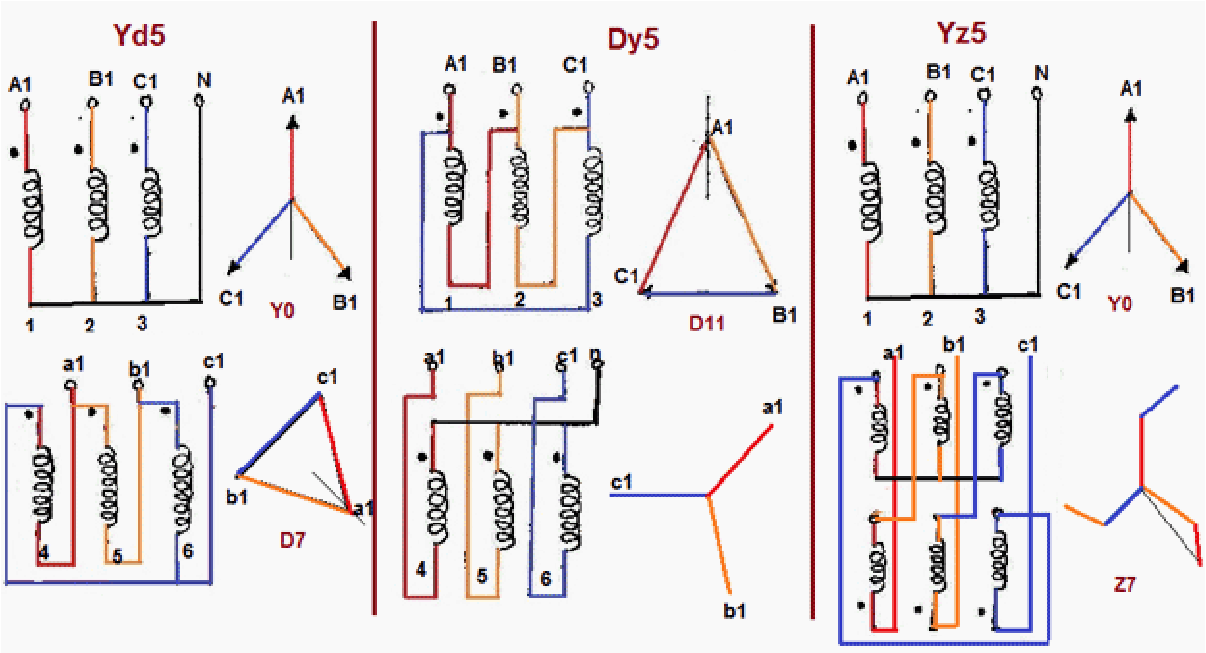
Clock Notation 2 (Phase Shift -60)



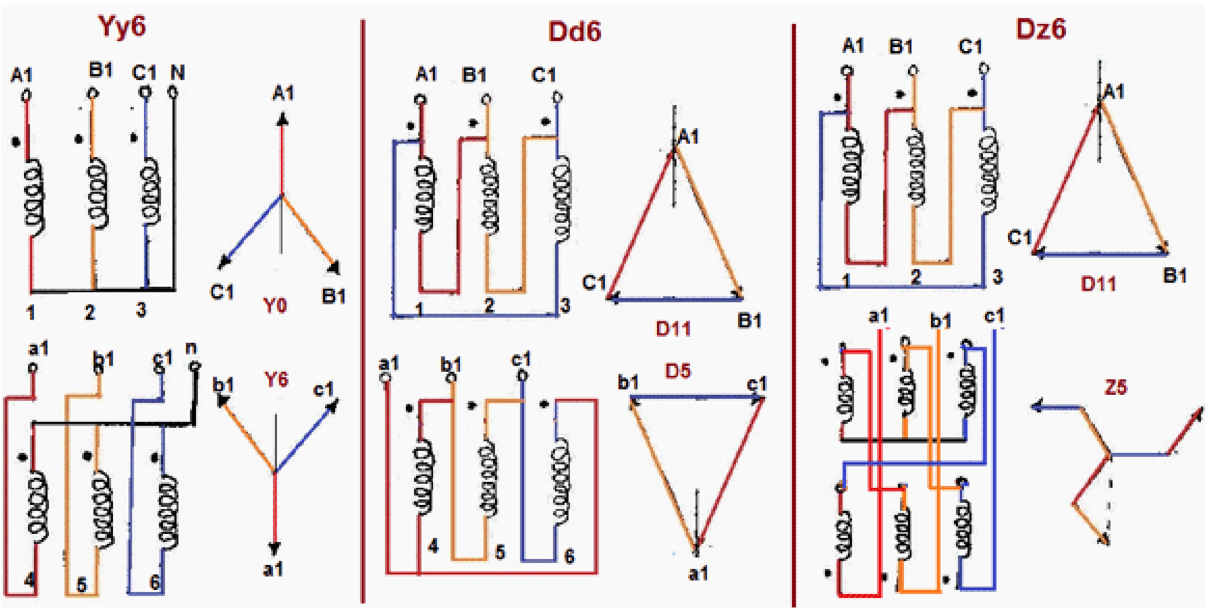
Clock Notation 4 (Phase Displacement -120)



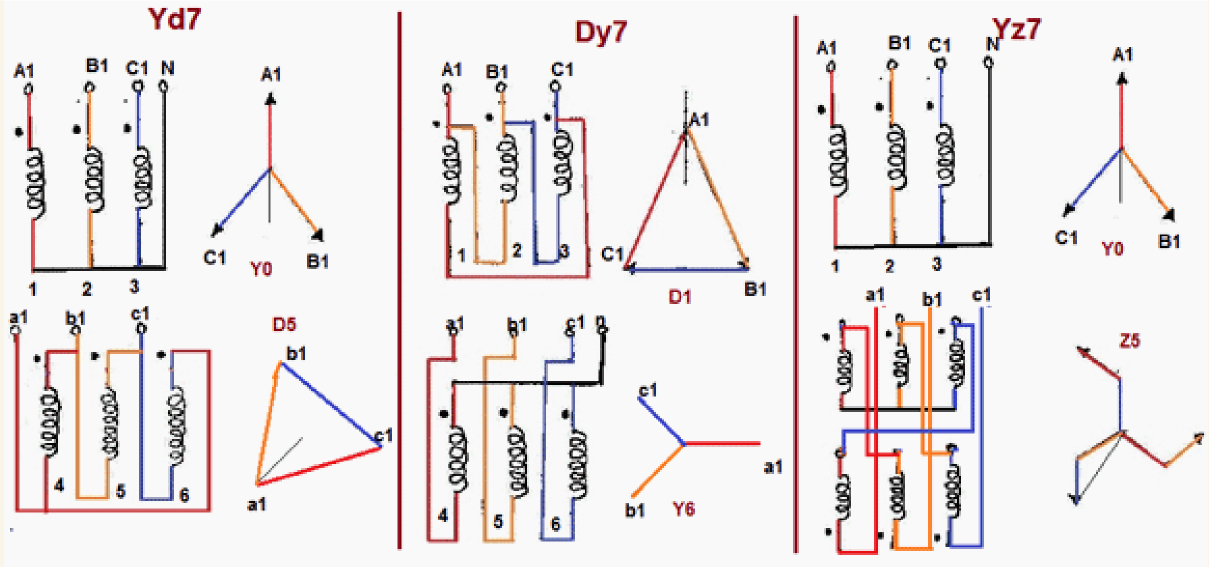
Clock Notation 5 (Phase Displacement -150)



Clock Notation 6 (Phase Shift +180)



Clock Notation 7 (Phase Shift +150)



Clock Notation 11 (Phase Shift +30)