2.6 Three Phase Transformer Connections

Windings of a three phase transformer can be connected in various configurations as

(i) Star-star

(ii) Delta-delta

(iii) Star-delta

(iv) Delta-star

(v) Open delta

(vi) Scott connection.

These configurations are explained below.

Star-Star (Y-Y)

- Star-star connection is generally used for small, high-voltage transformers. Because of star connection, number of required turns/phase is reduced (as phase voltage in star connection is $1/\sqrt{3}$ times of line voltage only). Thus, the amount of insulation required is also reduced.
- The ratio of line voltages on the primary side and the secondary side is equal to the transformation ratio of the transformers.
- Line voltages on both sides are in phase with each other.
- This connection can be used only if the connected load is balanced.

Delta-Delta (Δ-Δ)

- This connection is generally used for large, low-voltage transformers. Number of required phase/turns is relatively greater than that for star-star connection.
- The ratio of line voltages on the primary and the secondary side is equal to the transformation ratio of the transformers.
- This connection can be used even for unbalanced loading.
- Another advantage of this type of connection is that even if one transformer is disabled, system can continue to operate in open delta connection but with reduced available capacity.

Star-Delta OR Wye-Delta (Y-Δ)

- The primary winding is star star (Y) connected with grounded neutral and the secondary winding is delta connected.
- This connection is mainly used in step down transformer at the substation end of the transmission line.
- The ratio of secondary to primary line voltage is $1/\sqrt{3}$ times the transformation ratio.
- There is 30° shift between the primary and secondary line voltages.

Delta-Star OR Delta-Wye (Δ-Y)

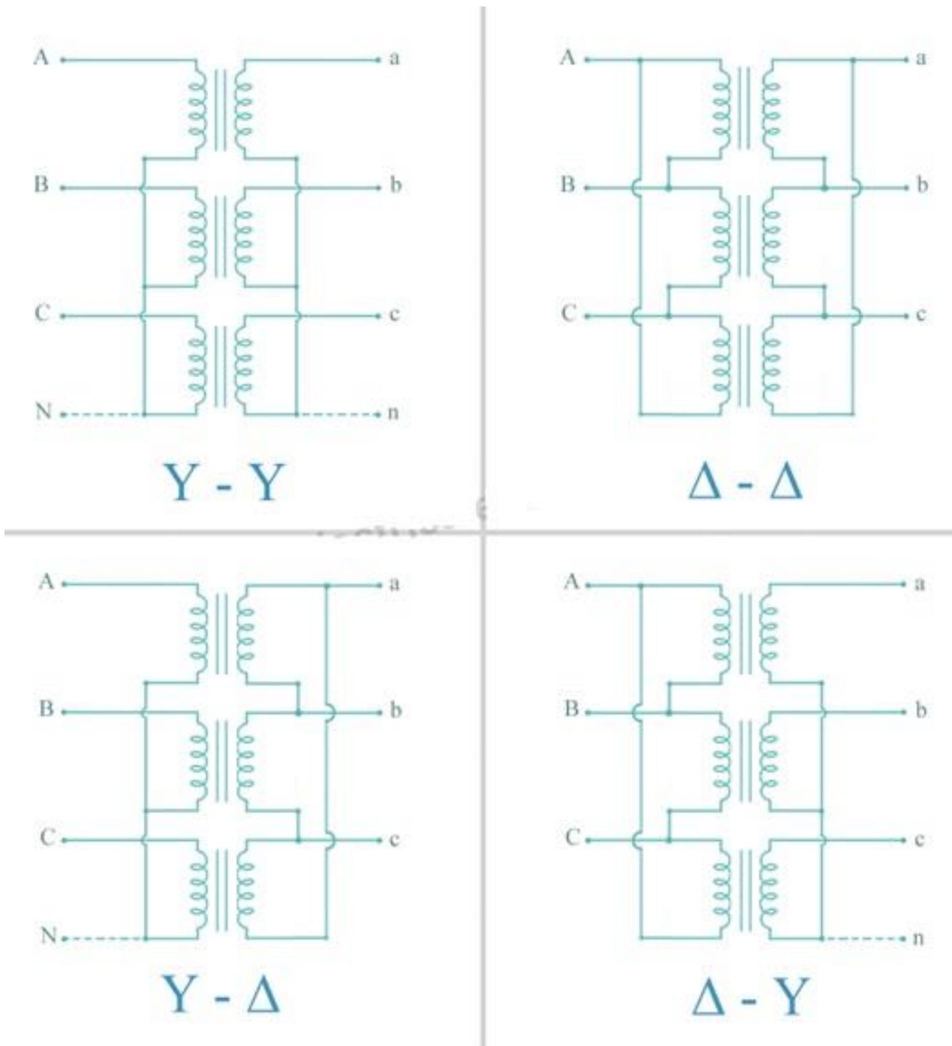

Figure 2.6.1 Three Phase Transformer Connections

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 168]*

- The primary winding is connected in delta and the secondary winding is connected in star with neutral grounded. Thus it can be used to provide 3-phase 4-wire service.
- This type of connection is mainly used in step-up transformer at the beginning of transmission line.
- The ratio of secodary to primary line voltage is √3 times the transformation ratio.
- There is 30° shift between the primary and secondary line voltages.

Above transformer connection configurations are shown in the following figure.

Open Delta (V-V) Connection

Two transformers are used and primary and secondary connections are made as shown in the figure below. Open delta connection can be used when one of the transformers in Δ-Δ bank is disabled and the service is to be continued until the faulty transformer is repaired or replaced. It can also be used for small three phase loads where installation of full three transformer bank is un-necessary. The total load carrying capacity of open delta connection is 57.7% than that would be for delta-delta connection.

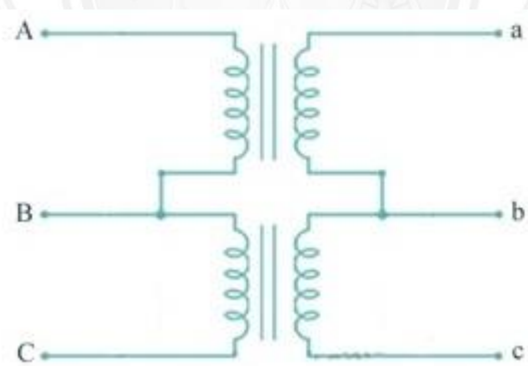

Figure 2.6.2 Open Delta (V-V) Connection

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 169]*

Scott (T-T) Connection

Two transformers are used in this type of connection. One of the transformers has center taps on both primary and secondary windings (which is called as main transformer). The other transformer is called as teaser transformer. Scott connection can also be used for three phase to two phase conversion. The connection is made as shown in the figure below.

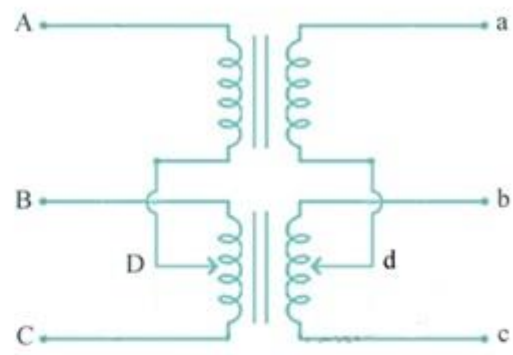

Figure 2.6.3 Scott (T-T) Connection

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 170]*

Transformer Phasing: The Dot Notation and Dot Convention

The Dot Notation

Generally, when we study about Transformers, we assume that the primary and secondary voltage and currents are in phase. But, such is not always the case. In Transformer, The phase relation between primary and secondary currents and voltages depends on how each winding is wrapped around the core.

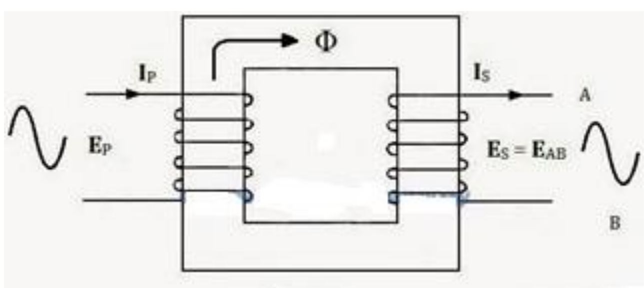

Figure 2.6.4 (a) Primary and Secondary voltage in Phase

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 172]*

Refer to fig (1) and (2), you may see that the primary sides of both transformers are identical i.e. primary windings of both transformers wrapped in the same direction around the core.

But in fig (2) you may notice that the secondary winding is wound around the core in the opposite direction from the secondary winding in fig (1).

Consequently, the voltage induced in the Secondary winding in fig (2) is 180° out of phase as compared with the induced voltage in secondary in fig (1) and the direction of secondary current (I_S) is opposite from the primary current (I_P)

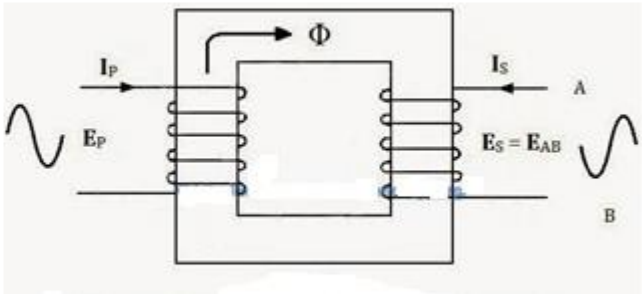

Figure 2.6.4 (b) Primary and Secondary voltage 180° out of Phase

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 173]*

So we see that

1. The primary and secondary voltage and current are in phase in fig (1)
2. The primary and secondary voltage and current are 180° out of phase in fig (2)

Dot Convention

To eliminate any confusion in the phase relation between primary and secondary voltage and current, a dot convention has been adopted for transformer schematic diagrams. Dots are placed on the top of primary and secondary terminals as shown in fig (3) and (4)

In fig (3), we see that dots are placed at the top in both primary and secondary terminals. It shows that the primary and secondary current and voltages are in phase. Moreover, the primary and secondary voltages (V_P and V_S) have similar sine wave, also the primary and secondary (I_P and I_S) currents are same in direction.

The story is opposite in fig (4). We can see that one dot is positioned at the top in primary terminal and the other one (dot) is placed at bottom of secondary terminal. It shows that the primary and secondary current and voltages are 180° out of phase. In addition, the primary and secondary voltages (V_P and V_S) sine waves are opposite to each other. Also the primary and secondary currents ($I_P$and I_S) are opposite in direction.

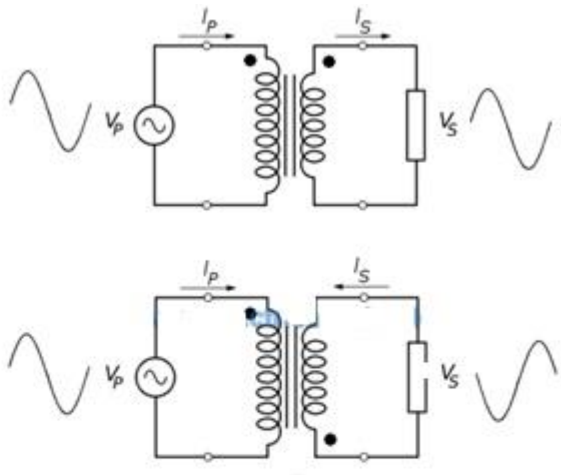

Figure 2.6.5 Phase relation between primary and secondary voltages and currents

[Source: "'Electric Machinery Fundamentals" by Stephen J. Chapman, *Page: 175]*