5.3 Three-Phase Transformer Construction

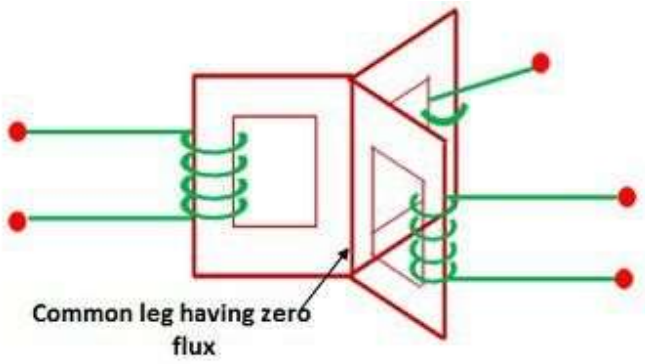
A three phase transformer is used to transfer a large amount of power. The three phase transformer is required to step-up and step-down the voltages at various stages of a power system network. The three phase transformer is constructed in two ways.

1. Three separate single phase transformer is suitably connected for three phase operation.
2. A single three-phase transformer in which the cores and windings for all the three phases are merged into a single structure.

The three single-phase transformer can be used as a three-phase transformer when their primary and secondary winding are connected to each other. The three phase transformer supply has many advantages as compared to three single phase units like it requires very less space and also very lighter smaller and cheaper in size. The three phase transformer is mainly classified into two types, i.e., the core type transformer and the shell type transformer.

Core Type Three Phase Transformer

Consider a three single phase core type transformer positioned at 120° to each other as shown in the figure below. If the balanced three-phase sinusoidal voltages are applied to the windings, the fluxes φ_a, φ_b and φ_c will also be sinusoidal and balanced. If the three legs carrying these fluxes are combined, the total flux in the merged leg becomes zero. This leg can, therefore, be removed because it carries the no flux. This structure is not convenient for the core.



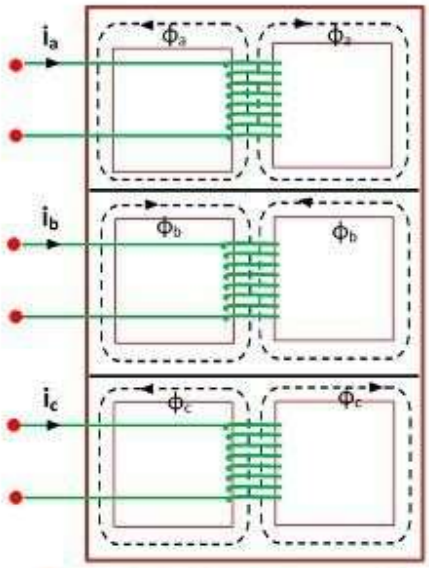
Three Single Phase Core in Contact With Another

The core of the three phase transformer is usually made up of three limbs in the same plane. This can be built using stack lamination. The each leg of this core carries the low voltage and high voltage winding. The low voltage windings are insulated from the core than the high voltage windings.

The low windings are placed next to the core with suitable insulation between the core and the low voltage windings. The high voltage windings are placed over the low voltage windings with suitable insulation between them. The magnetic paths of the leg a and c are greater than that of leg b, the construction is not symmetrical, and there is a resultant imbalance in the magnetizing current.

Shell type Three Phase Transformer

The shell type 3-phase transformer can be constructed by stacking three single phase shell transformer as shown in the figure below. The winding direction of the central unit b is made opposite to that of units a and c. If the system is balanced with phase sequence a-b-c, the flux will also be balanced.



3-Phase Shell Type Transformer

Circuit Globe

The magnitude of this combined flux is equal to the magnitude of each of its components. The cross section area of the combined yoke is same as that of the outer leg and top and bottom section of the yoke. The imbalance in the magnetic path has very little effect on the performance of the three shell-type transformers. The windings of the shell type three phase transformer are either connected in delta or star as desired.

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

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/√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/√3 times the transformation ratio.
- There is 30° shift between the primary and secondary line voltages.

Delta-Star OR Delta-Wye (Δ-Y)

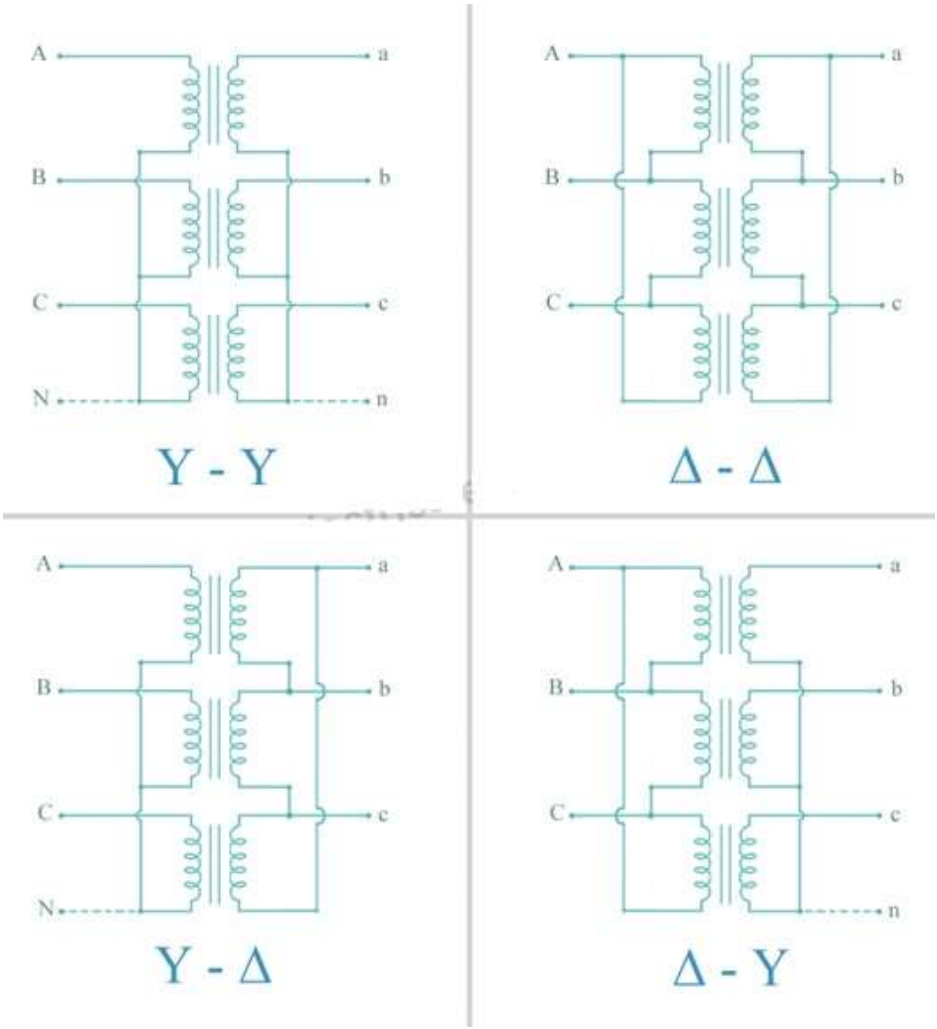


Figure 5.3.1 Three Phase Transformer Connections

[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.

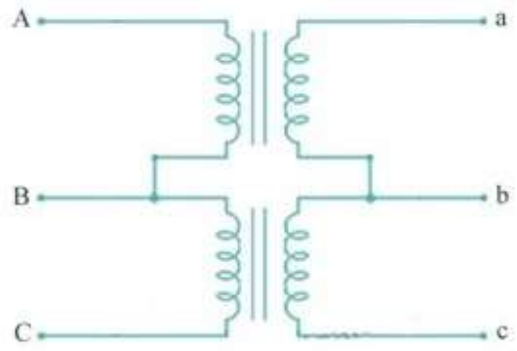


Figure 5.3.2 Open Delta (V-V) Connection

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