1 What is a three phase transformers

Three-phase transformers are passive machines that pass electrical energy between circuits. In the secondary circuit, a magnetic flux induces an electromotive force (emf), thus stepping up (increase) or stepping down (decrease) voltages without altering the frequency. There are different kinds of electrical systems, and therefore transformers have to operate alongside compatible systems. A three-phase transformer works with a three-phase AC (alternating current) electrical system to provide consumers with stable and device-safe electricity. Depending on the industry or application, the size, design, volt-ampere rating, and load-bearing capabilities of the three-phase transformer will differ.

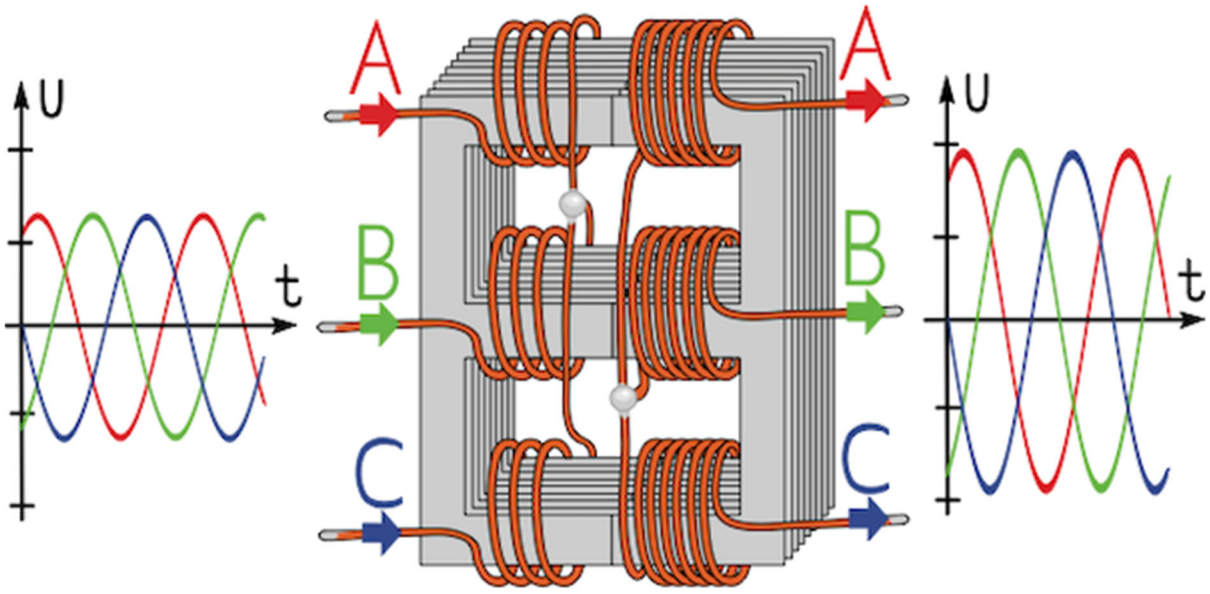
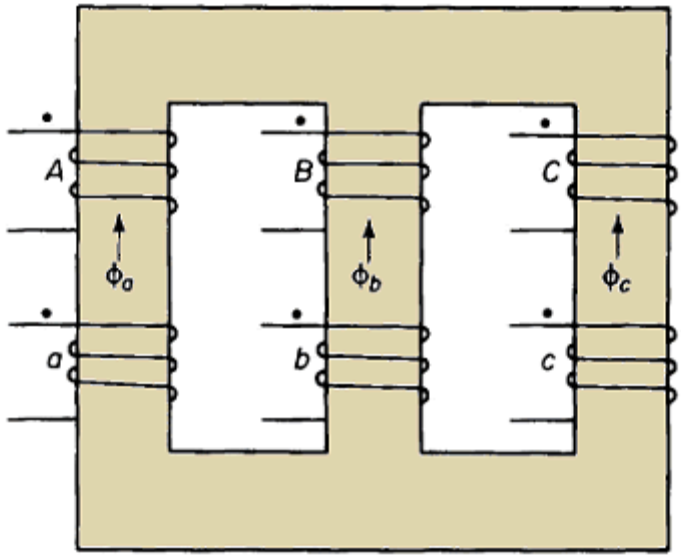


Fig.1 A three-phase transformer having three sets of windings on both primary and secondary sides

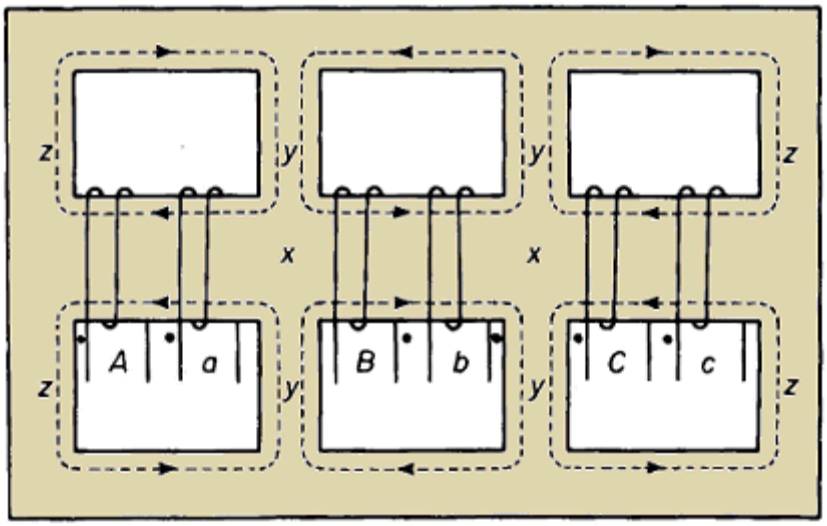
Construction of a Three Phase Transformer

Three-phase transformers can be categorized depending on their construction. There are two types of 3-phase transformers: the core-type with primary and

secondary windings wound on one core and the shell-type transformer that combines three 1-phase transformers.



(a)



(b)

Fig.2 Types of three phase transformer (a) Core type (b) Shell type.

1.1 Core-type

In core-type three-phase transformers, the core has three limbs within the same plane. Each limb contains primary and secondary windings, and these windings are evenly split among the three limbs. It's not uncommon to hear of high voltage (HV) and low voltage (LV) windings.

As a low voltage winding is easier to insulate, these windings are closer to the core than the higher voltage coils. The latter windings wrap around the former, with insulative material between them. This construction has the windings magnetically linked with one another, with one winding using the other pair of limbs as return paths for its magnetic flux (see Figure 2(a)).

1.2 Shell-type

The shell-type 3-phase transformer is three separate 1-phase transformers. The three phases of this transformer have their magnetic fields virtually independent, and this transformer's core has five limbs as seen in Figure 2 (b).

The HV and LV windings exist around the three main limbs. Like the core-type 3-phase device, the low voltage coil is nearest the core. The two outermost limbs serve as the flux's return paths.

Magnetic flux divides in two as the field approaches the yoke. It's common for the outer limbs and the yoke to be half the size of the main limbs. You can decrease the transformer's height by reducing the yoke's size.

Three Phase Transformer Connections

A *three phase transformer* or 3φ transformer can be constructed either by connecting together three single-phase transformers, thereby forming a so-called three phase transformer bank, or by using one pre-assembled and balanced three phase

transformer which consists of three pairs of single phase windings mounted onto one single laminated core.

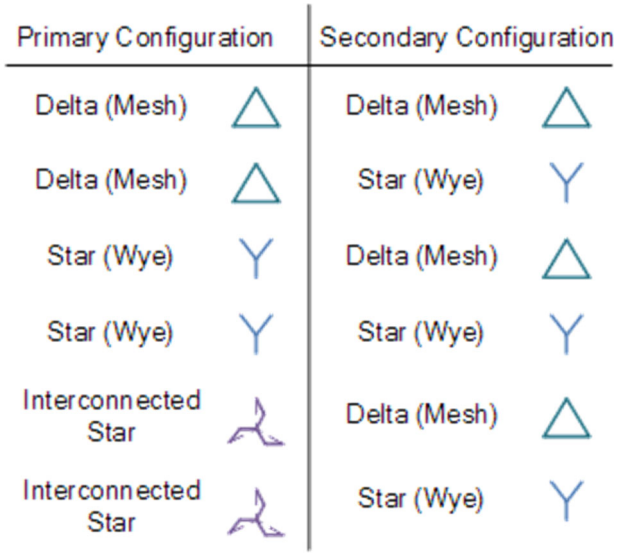


Fig.3 Symbols of winding connections.

The advantages of building a single three phase transformer is that for the same kVA rating it will be smaller, cheaper and lighter than three individual single phase transformers connected together because the copper and iron core are used more effectively. The methods of connecting the primary and secondary windings are the same, whether using just one **Three Phase Transformer** or three separate *Single Phase Transformers.*

The possible connections that will be reviewed in this section are:

- *Input star (Y), output delta (Δ)*
- *Input delta (Δ), output star (Y)*
- *Input delta (Δ), output delta (Δ)*
- *Input star (Y), output star (Y).*

1.3 Input (Y), Output (Δ)

The connection diagram with primary as star and secondary as delta is shown in Figure 4. This type of connection is mostly used in step-down applications. The high-voltage side (star connected) can be grounded, which is desirable. Given the primary line voltage, V and line current I and turn ratio k = N_2/N_1. The phase voltage of the primary side is given as $V/\sqrt{3}$ and the phase current is same as the line current.

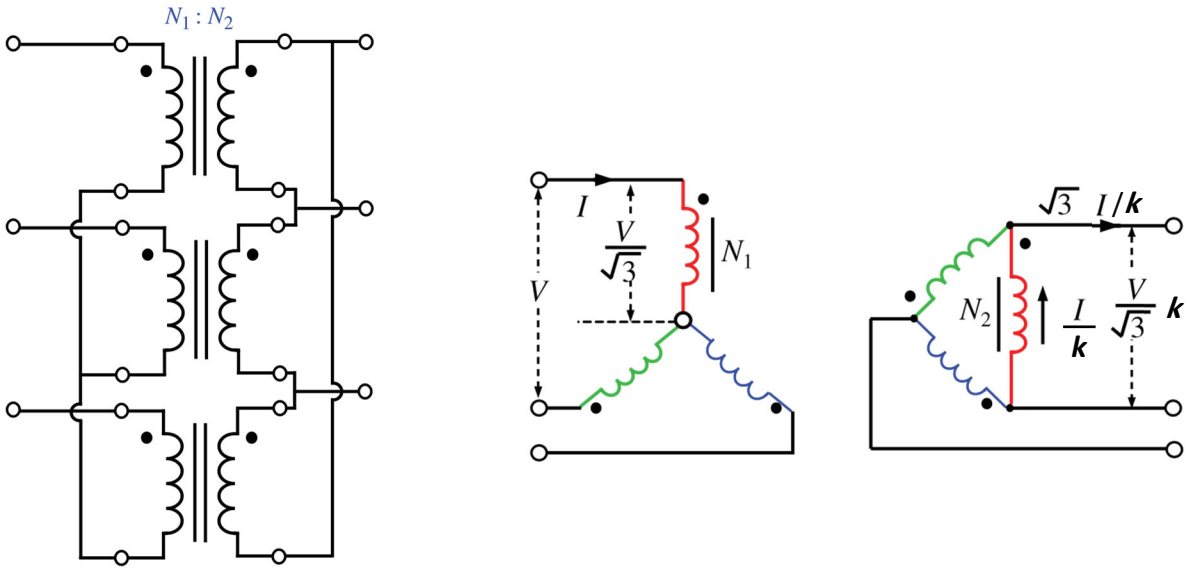


Fig.4 Star-delta three-phase transformer connection.

The phase voltage is transformed to the secondary phase voltage as:-

$$\frac{V_{P2}}{V_{P1}} = k \quad \Rightarrow \quad \frac{V_{P2}}{V/\sqrt{3}} = k \quad \Rightarrow \quad V_{P2} = k\frac{V}{\sqrt{3}}$$

The primary side phase current is transformed to the secondary side phase current as:

$$\frac{I_{P1}}{I_{P2}} = k \quad \Rightarrow \quad \frac{I}{I_{P2}} = k \quad \Rightarrow \quad I_{P2} = \frac{I}{k}$$

The secondary phase quantities are now transformed to the line quantities as:

Line Voltage = Phase Voltage (because of delta connection)

$$V_{L2} = V_{P2} = k\frac{V}{\sqrt{3}} \quad , \quad I_{L2} = \sqrt{3}I_{P2} = \sqrt{3}\frac{I}{k}$$

1.4 Input Delta (Δ), Output Star (Y)

The connection diagram with input delta and output star is shown in Figure 5. This type of transformer connection is used for step-down applications. Given the primary line voltage, V and line current I and turn ratio k = N_2/N_1. The phase voltage of the primary side is the same as line voltage (delta connection) and the phase current is $I/\sqrt{3}$. The phase voltage is transformed to the secondary phase voltage as:-

$$\frac{V_{P2}}{V_{P1}} = k \quad \Longrightarrow \quad \frac{V_{P2}}{V} = k \quad \Longrightarrow \quad V_{P2} = kV$$

The primary side phase current is transformed to the secondary side phase current as

$$\frac{I_{P1}}{I_{P2}} = k \quad \Longrightarrow \quad \frac{I/\sqrt{3}}{I_{P2}} = k \quad \Longrightarrow \quad I_{P2} = \frac{I}{k\sqrt{3}}$$

The secondary phase quantities are now transformed to the line quantities as

Line Current = Phase Current (because of delta connection)

$$V_{L2} = \sqrt{3}V_{P2} = \sqrt{3}\,kV \quad , \quad I_{L2} = I_{P2} = \frac{I}{k\sqrt{3}}$$

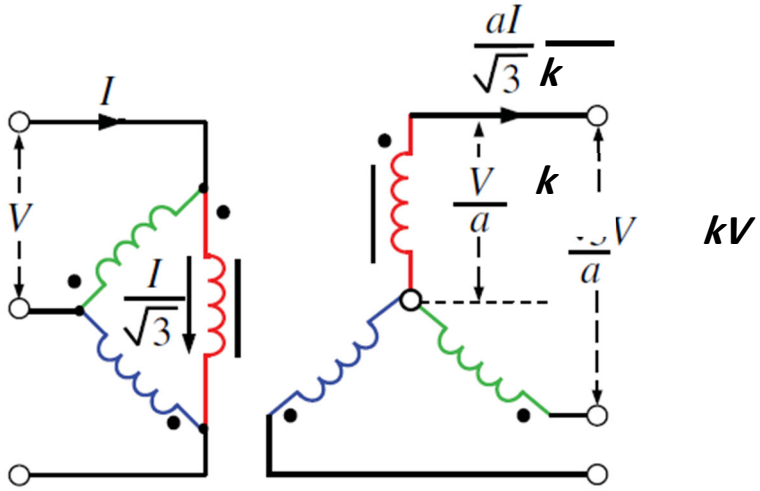


Fig.5 Delta-star connection of three-phase transformer