1.5 Input Delta (Δ), Output Delta (Δ)

The connection diagram with input delta and output delta is shown in Figure 6. This type of transformer connection is used for a reliable power supply system. If one of the transformers is faulty, it can be removed and the whole system run in open-delta mode or V connection. The output power can still be supplied in this mode. The 58% of the rated can be supplied in open-delta mode. The voltage current relationship can be obtained in the same way.

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

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

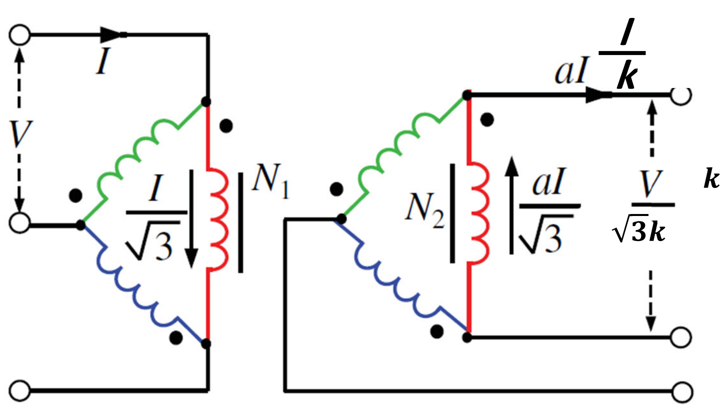

Fig.6 Delta-delta connection of three-phase transformer.

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

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

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

Line Voltage = Phase Voltage (because of delta connection)

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

1.6 Input Star (Y), Output Star (Y)

The connection diagram of star primary and star secondary is shown in Figure 7. This type of connection is not very commonly in use because of the problem with the exciting current (distorted current with harmonic content). 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.

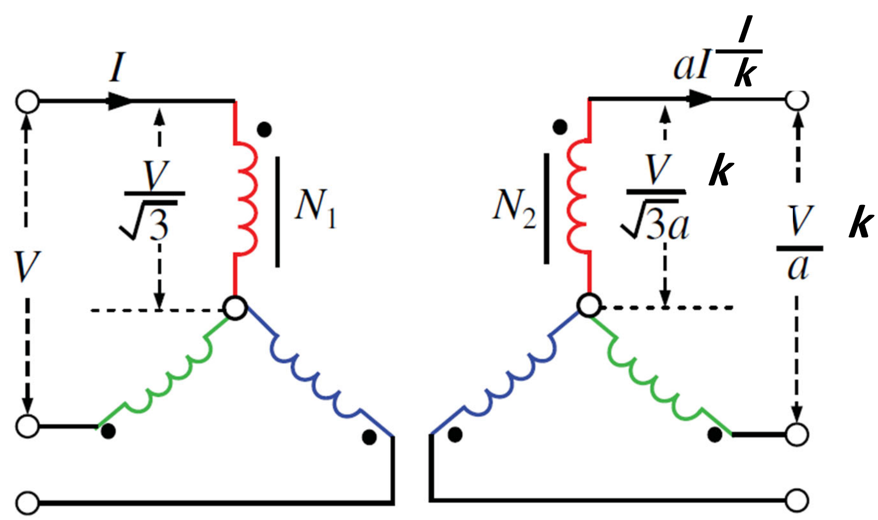


Fig.7 Star-star connection of three-phase transformer.

The phase voltage is transformed to the secondary phase voltage as

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

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

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

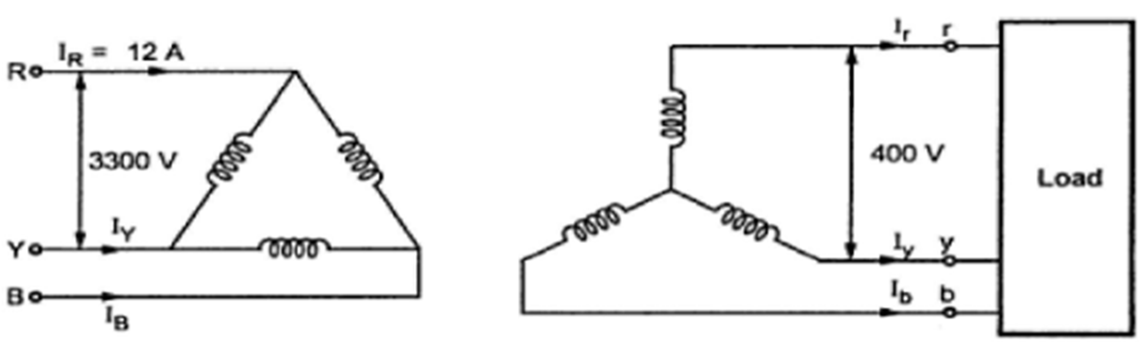
The secondary phase quantities are now transformed to the line quantities as;

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

Example 1: A three phase transformer has delta connected primary and a star connected secondary working on 50 Hz three phase supply. The line voltages of primary and secondary are 3300 V and 400 V respectively. The line current on the primary side is 12 A and secondary has a balanced load at 0.8 lagging p.f. Determine the secondary phase voltage line current and the output power.

Solution

$V_{L1} = 3300\,V\,, \quad I_{L1} = 12\,A\,, \qquad$ Secondary power factor $= 0.8$



Primary side　　　Secondary side

Primary side : $\qquad V_{P1} = V_{L1} = \mathbf{3300\,V}$

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Secondary side : $V_{P2} = {V_{L2}}/{\sqrt{3}} = {400}/{\sqrt{3}} = \mathbf{230.94\ V}$

$$k = \frac{V_{P2}}{V_{P1}} = \frac{230.94}{3300} = \mathbf{0.0699}$$

Primary side : $I_{P1} = {I_{L1}}/{\sqrt{3}} = {12}/{\sqrt{3}} = \mathbf{6.928\ A}$

Secondary side :

$$k = \frac{I_{P1}}{I_{P2}} \Rightarrow I_{P2} = \frac{I_{P1}}{k} = \frac{6.928}{0.0699} = \mathbf{99.11\ A}$$

Since secondary is connected in star

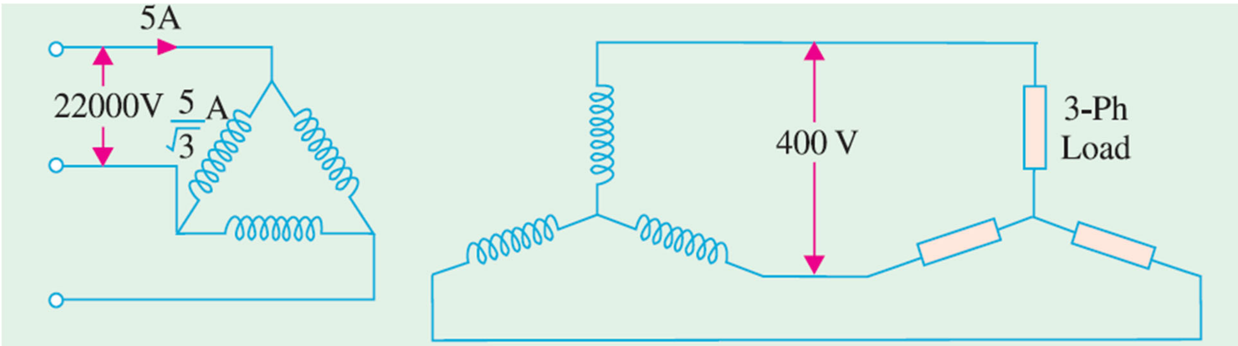
$$I_{P2} = I_{L2} = \mathbf{99.11\ A}$$

Power output = $\sqrt{3}\, V_{L2} I_{L2} \cos\phi_L = \sqrt{3} \times 400 \times 99.11 \times 0.8 = \mathbf{54.94\ kW}$

Example 2: A 3-phase, 50-Hz transformer has a delta-connected primary and star-connected secondary, the line voltages being 22,000 V and 400 V respectively. The secondary has a star connected balanced load at 0.8 power factor lagging. The line current on the primary side is 5 A. Determine the current in each coil of the primary and in each secondary line. What is the output of the transformer in kW?

Solution

It should be noted that in three-phase transformers, the *phase* transformation ratio is equal to the turn ratio but the terminal or line voltages depend upon the method of connection employed.



V_{P1} = **22,000 V** , V_{P2} = **400 /$\sqrt{3}$ V**

$k = V_{P2}/V_{P1} = 400/(22000 \times \sqrt{3}) = \mathbf{1/55\sqrt{3}}$

I_{P1}=**5/$\sqrt{3}$ A** , $k = I_{P1}/I_{P2} \Rightarrow I_{P2} = I_{P1}/k = \dfrac{\frac{5}{\sqrt{3}}}{\frac{1}{55\sqrt{3}}}$ = **275 A**

$P_{out} = \sqrt{3}\, V_{L2} I_{L2} \cos\phi_L = \sqrt{3} \times 400 \times 275 \times 0.8 = \mathbf{15.24\ kW}$

1.7 Single phase transformer vs three phase transformer

Following are the main differences between a 1-phase and a 3-phase transformer.

No	Single Phase Transformer	Three Phase Transformer
1	Single-phase transformer has only one primary winding and one secondary winding.	Three-phase transformer has three-primary windings and three secondary windings.
2	Single-phase transformer has two input terminals and two output terminals	In case of three-phase transformer, there are three input terminals for line wires and one terminal is for neutral (depending upon the type of primary winding connection), and similarly, at the output, three line terminals and one neutral terminal be provided, again the

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		presence of neutral terminal depends upon the type of secondary winding connection.
3	The size of a single-phase transformer is small.	A three-phase transformer is relatively larger in size.
4	A single-phase transformer cannot be used for supplying a three-phase load.	A three-phase transformer can be used to supply both 1-phase and 3-phase loads.
5	No specific winding configuration exists in case of a single-phase transformer.	The primary and secondary windings may be configured as follows. Delta – Delta (Δ-Δ) Delta – Star (Δ-Y) Star – Star (Y-Y) Star Delta (Y-Δ)
6	It costs less.	Cost is little bit higher
7	Single-phase transformers are used for small loads such as to supply single-domestic loads like pumps and lightings, etc., used in various electronic devices like in TVs, mobile chargers, etc. for voltage regulation, in home inverters for stepping up voltage, etc.	Three-phase transformers are used for supplying high power single-phase as well as three-phase loads as induction motors, etc. Also used in power systems for power transmission and distribution

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