Three-Phase Transformers

Introduction

Modern large transformers are usually of the three-phase core type, shown in Figure 1. Three similar limbs are connected by top and bottom yokes, where each limb has primary and secondary windings arranged concentrically. The windings may be connected star–delta, delta–star, star–star or delta–delta, depending upon the conditions under which the transformer is to be used.

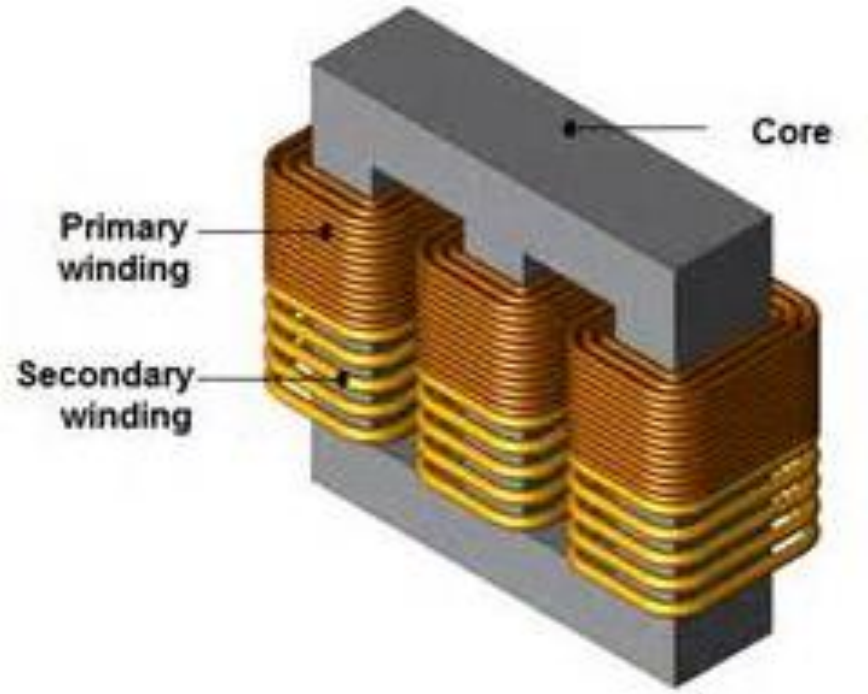

Figure 1. Three-Phase core-type transformer

Example

A three-phase transformer has 400 turns on the primary and 40 turns on the secondary. If the supply line voltage is 3 kV. Find the secondary line voltage on no load when the windings are connected

(a) star–delta,

(b) delta–star.

Answer

(a) $\text{Primary phase voltage} = \dfrac{3000}{\sqrt{3}} = 1732 \text{ V}$

$\therefore \text{ Secondary phase voltage} = 1732 \times \dfrac{40}{400} = 173.2 \text{ V} = \text{secondary line voltage}$

(b) Primary phase voltage = 3000 V

$\therefore$ Secondary phase voltage = $3000 \times \frac{40}{400} = 300$ V

$\therefore$ Secondary line voltage = $300 \times \sqrt{3} = 591.6$ V

Application notes for three-phase transformers

Transformer insulation voltage limit

We would normally wish to keep the voltage across the primary and secondary windings as low as possible to minimise insulation requirements. This is a bigger issue on the side of the transformer with the higher voltage, often called the high tension (HT) side. Therefore, it is advantageous to have only the phase voltage across the windings on the HT side.

For step up applications: Use ΔY connection

For step down applications: Use YΔ connection

Grounded secondary

In some situations, it is desirable for safety reasons to have a grounded neutral point connection on the Secondary windings. This therefore requires either the YY or ΔY connection:

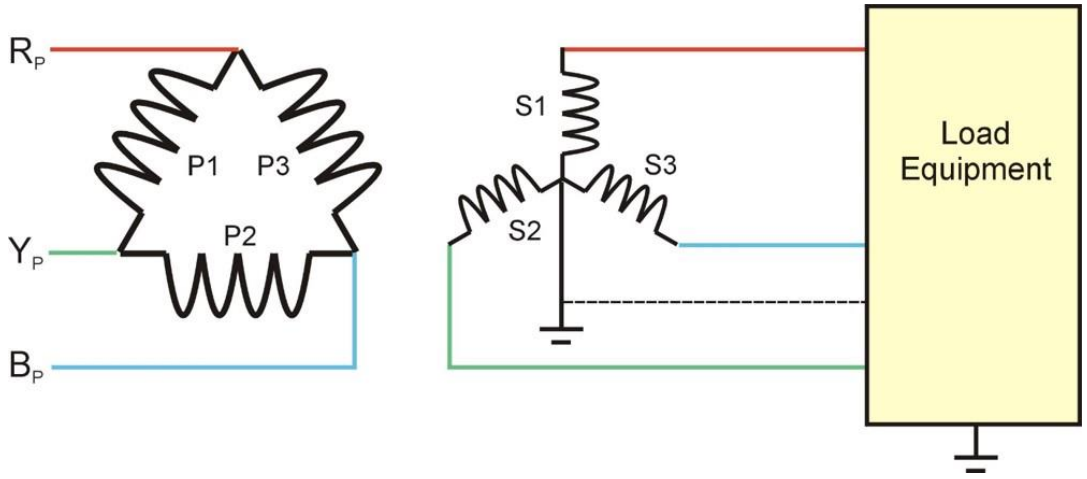

Figure 2. Delta-Wye three-phase transformer with a grounded secondary

Open delta configuration

If 3 single phase transformers are connected as ΔΔ and one of them becomes defective, and has to be removed, it is possible to feed the 3-phase load on a temporary basis with the two remaining transformers (an advantage of ΔΔ) (Figure 3). When operating in Open Delta the three-phase transformers must be de-rated to 57.7% of their nominal rating. For example, if each transformer is rated at 50kVA then the maximum 3 phase load must not exceed 86.7kVA.

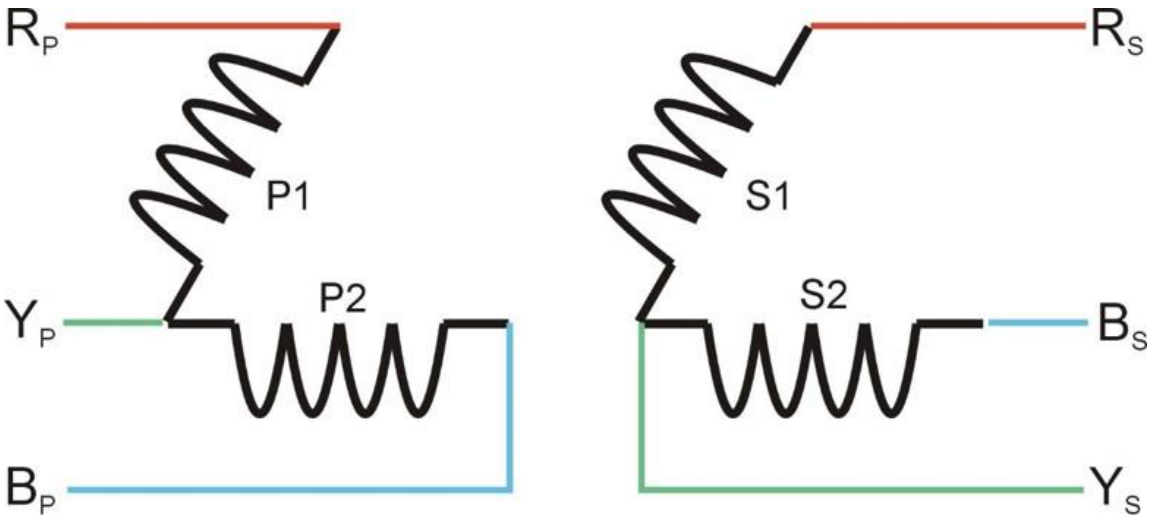

Figure 3. Open delta configuration

Bibliography

1. Theodore Wildi “Electrical Machines, Drives, and Power Systems” 2nd Edition, Prentice-Hall (1981). Chapter 10.
2. https://studyelectrical.com/2019/11/open-delta-v-v-connection-of-transformers.html