

# UTILISATION OF ELECTRICAL ENERGY



## Transformers and Induction Motors

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Cover image (Carroll & Meynel, 2013)

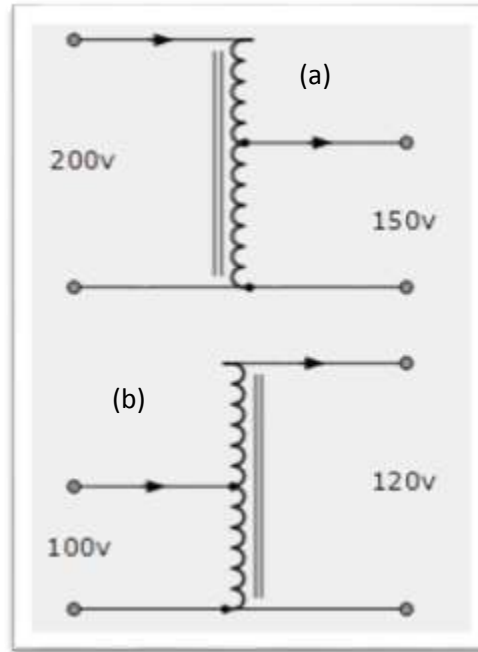


Figure 9: Auto transformer step-down and step-up configuration

If the tapped point is connected to the supply (see Figure 9(b)), and the secondary is connected to the full windings, the secondary voltage will be greater than the supply voltage (step-up).

In an auto transformer, the primary and secondary circuits are electrically connected. Unlike dual wound transformers, which are electrically isolated from each other. As Figure 9 shows both sides share a common earth.

If the secondary is open circuit current flow through the primary results in the full supply voltage at the secondary output. A short circuit in the secondary results in a high primary current, which may damage the transformer.

Due to these potential problems auto transformers are generally used where the primary and secondary voltages are almost equal, e.g. starting induction motors and voltage regulation of transmission lines.

The auto transformer is generally more efficient and cheaper to manufacture than the equivalent rated dual wound transformer.

## 1.5 Transformer Construction

### 1.5.1 Shell and Core

The windings are wrapped around a cardboard former. There will be one layer of primary windings then (optionally a layer of paper or cloth insulation then) a layer of secondary windings. This process is repeated until desired number of turns is achieved for both sets of windings. The wires used in the windings look "bare", but they are in fact coated in varnish for insulation. Whichever set of windings carries the highest current, will use thicker wire.

The core of a transformer is made from insulated, laminated, cold-rolled, grain-oriented (GO) silicon steel. This provides high permeability whilst reducing losses due to Eddy currents.

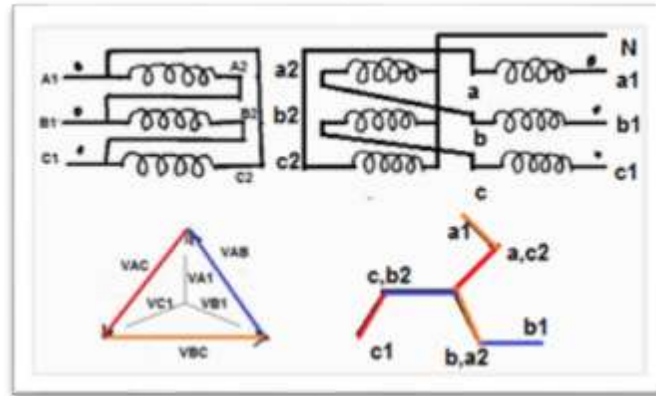


Figure 25: Dz connections (Parmar, 2012)

Table 15: Transformer name plate notation

Phase Shift	Transformer Configuration
0°	Yy0, Dd0, Dz0
30° lag	Yd1, Dy1, Yz1
60° lag	Dd2, Dz2
120° lag	Dd4, Dz4
150° lag	Yd5, Dy5, Yz5
180° lag	Yy6, Dd6, Dz6
150° lead	Yd7, Dy7, Yz7
120° lead	Dd8, Dz8
60° lead	Dd10, Dz10
30° lead	Yd11, Dy11, Yz11

Yd6 indicates Star primary (HV), delta secondary (LV), 6 o'clock

4.2 11000/3300 (Yy) and 3300/415 (Dy) Transformers

(Q4b)

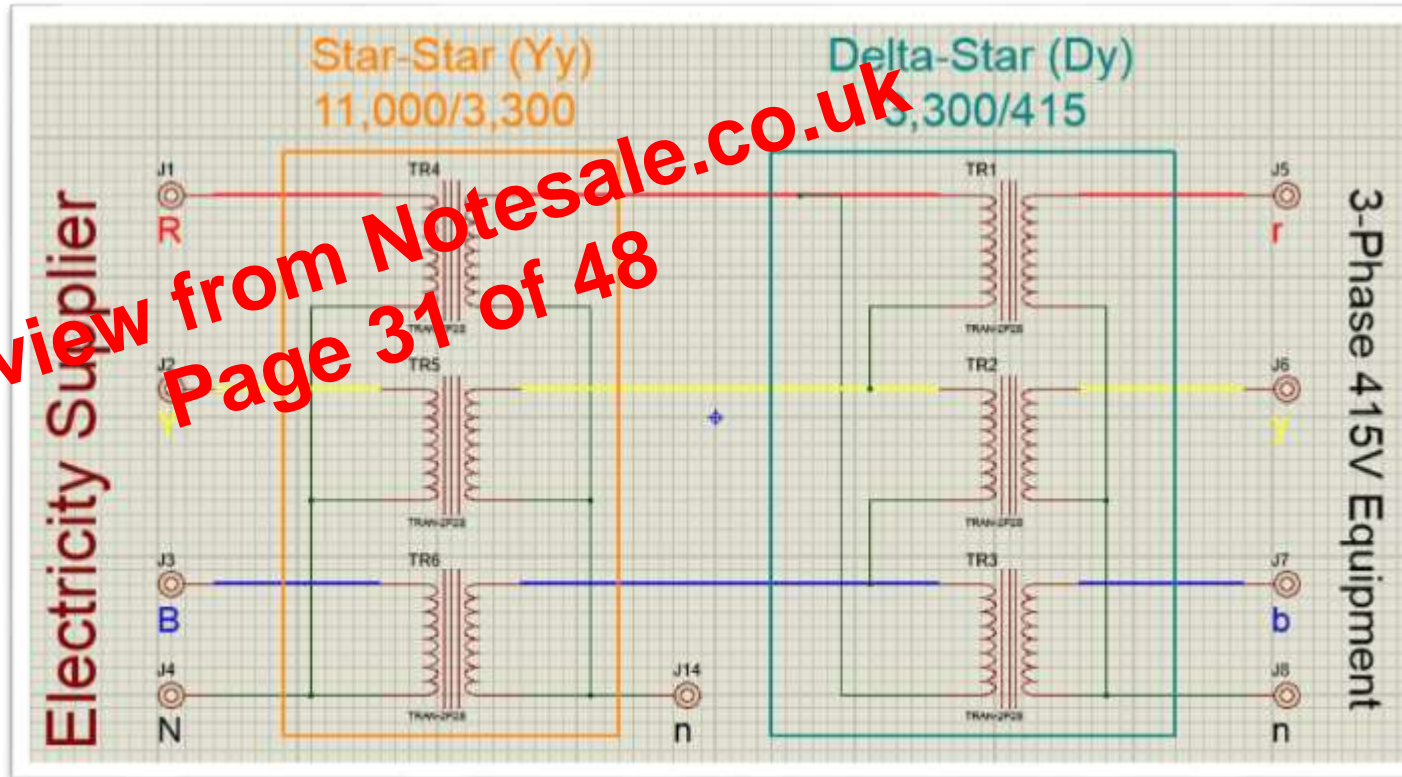


Figure 26: Circuit diagram (Proteus) of two transformers

Note: Figure 26 is using colours from pre 2004 IEE regulations.

## 4.2.2 Star-Star (Yy) 11000/3300

Table 18: Star-Star calculations

Star (y) 3,300V Secondary	Star (Y) 11,000V Primary
$V_{S-Line} = 3,300 \text{ V}$ $V_{S-Phase} = \frac{3,300}{\sqrt{3}} = 1,905.255888 \text{ V}$ $V_{S-Phase} = 1905.3 \text{ V (1dp)}$	$V_{P-Line} = 11,000 \text{ V}$ $V_{P-Phase} = \frac{11,000}{\sqrt{3}} = 6,350.852961 \text{ V}$ $V_{P-Phase} = 6350.9 \text{ V (1dp)}$
From the 3300/415 transformer above: $I_{P-Line} = 100.6060606 \text{ A}$	
$\therefore I_{S-Line} = I_{S-Phase} = 100.61 \text{ A (2dp)}$	$I_{P-Line} = I_{P-Phase} = ? \text{ see below}$
$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{11,000}{3,300} = \frac{10}{3} = 3.333333333$ $\frac{N_P}{N_S} = 3.33 \text{ (2dp)}$	$\therefore N_P : N_S = 3.33 : 1$
$\frac{N_P}{N_S} = \frac{I_S}{I_P} = \frac{10}{3}$ $I_P = I_S \times \frac{N_S}{N_P} = 100.6060606 \times \frac{10}{3}$ $I_P = \frac{332}{11} = 30.18181818 \text{ A}$ $I_P = 30.18 \text{ A (2dp)}$	$\therefore I_{P-Line} = I_{P-Phase} = 30.18 \text{ A (2dp)}$

## 5.2 Wound Rotor (Slip Ring) Induction Motor

(Q5aii)

### 5.2.1 Construction

The stator of the wound rotor IM is manufactured in the same manner as the squirrel cage IM. The difference is in the construction of the rotor. The body of the rotor is made from laminated silicon steel. The laminations have cut outs which contain the three phase windings. The windings are connected in a star configuration. The open ends of the star are connected to separate slip rings as shown in Figure 29.



Figure 29: Rotor of a slip ring IM (DPS, 2010)