The autotransformer

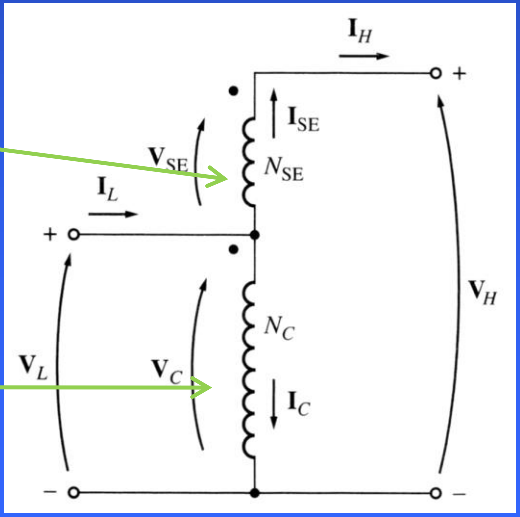
Sometimes, it is desirable to change the voltage by a small amount (for instance, when the consumer is far away from the generator and it is needed to raise the voltage to compensate for voltage drops).

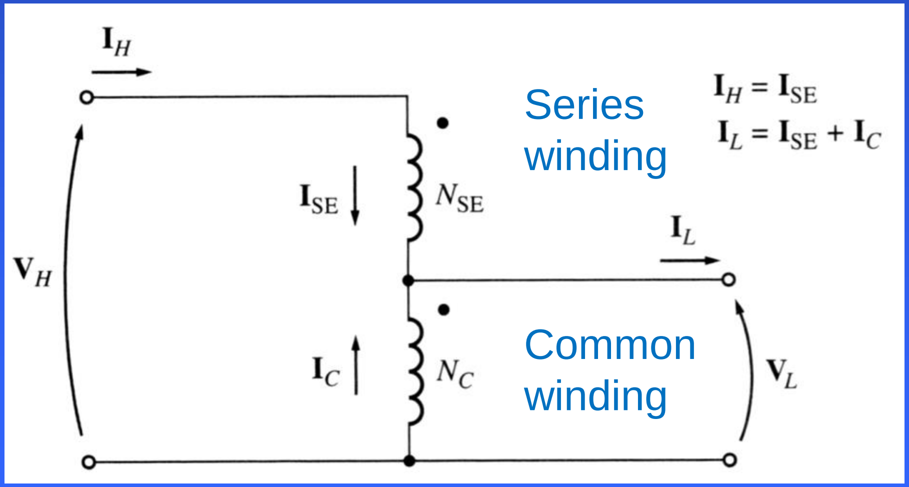
In such situations, it would be expensive to wind a transformer with two windings of approximately equal number of turns. An autotransformer (a transformer with only one winding) is used instead.

Diagrams of step-up and step-down autotransformers:

Series winding

Common winding





Output (up) or input (down) voltage is a sum of voltages across common and series windings.

The autotransformer

Since the autotransformer's coils are physically connected, a different terminology is used for autotransformers:

The voltage across the common winding is called a common voltage V_C, and the current through this coil is called a common current I_C. The voltage across the series winding is called a series voltage V_{SE}, and the current through that coil is called a series current I_{SE}.

The voltage and current on the low-voltage side are called V_L and I_L; the voltage and current on the high-voltage side are called V_H and I_H.

For the autotransformers:

$$\frac{V_C}{V_{SE}} = \frac{N_C}{N_{SE}} \qquad (4.68.1)$$

$$N_C I_C = N_{SE} I_{SE} \qquad (4.68.2)$$

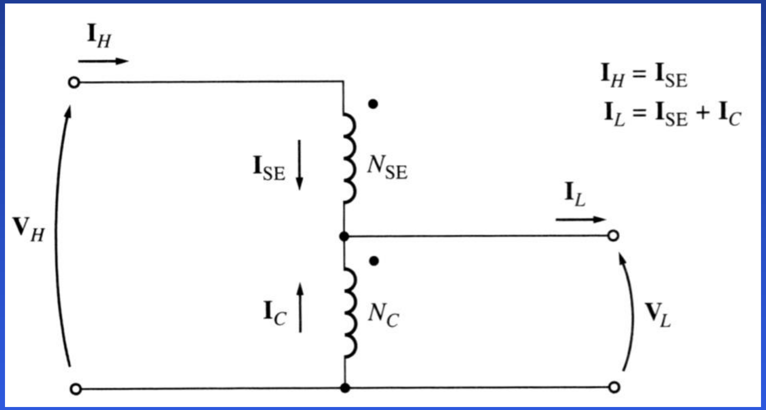
$$V_L = V_C \qquad I_L = I_C + I_{SE} \qquad (4.68.3)$$

$$V_H = V_C + V_{SE} \qquad I_H = I_{SE} \qquad (4.68.4)$$

Voltage and Current relationships in an Autotransformer

Combining (4.68.1) through (4.68.4), for the high-side voltage, we arrive at

$$V_H = V_C + \frac{N_{SE}}{N_C} V_C = V_L + \frac{N_{SE}}{N_C} V_L \quad (4.69.1)$$



Therefore:

$$\frac{V_L}{V_H} = \frac{N_C}{N_C + N_{SE}} \quad (4.69.2)$$

The current relationship will be:

$$I_L = I_{SE} + \frac{N_{SE}}{N_C} I_{SE} = I_H + \frac{N_{SE}}{N_C} I_H \quad (4.69.3)$$

Therefore:

$$\frac{I_L}{I_H} = \frac{N_C + N_{SE}}{N_C} \quad (4.69.4)$$

The apparent power advantage

Not all the power traveling from the primary to the secondary winding of the autotransformer goes through the windings. As a result, an autotransformer can handle much power than the conventional transformer (with the same windings).

Considering a step-up autotransformer, the apparent input and output powers are:

$$S_{in} = V_L I_L \tag{4.70.1}$$

$$S_{out} = V_H I_H \tag{4.70.2}$$

It is easy to show that

$$S_{in} = S_{out} = S_{IO} \tag{4.70.3}$$

where S_{IO} is the input and output apparent powers of the autotransformer. However, the apparent power in the autotransformer's winding is

$$S_W = V_C I_C = V_{SE} I_{SE} \tag{4.70.4}$$

Which is:

$$S_W = V_L\left(I_L - I_H\right) = V_L I_L - V_L I_H$$

$$= V_L I_L - V_L I_L \frac{N_C}{N_{SE} + N_C} = S_{IO} \frac{N_{SE}}{N_{SE} + N_C} \tag{4.70.5}$$

The apparent power advantage

Therefore, the ratio of the apparent power in the primary and secondary of the autotransformer to the apparent power **actually** traveling through its windings is

$$\frac{S_{IO}}{S_W} = \frac{N_{SE} + N_C}{N_{SE}} \qquad (4.71.1)$$

The last equation described the apparent power rating advantage of an autotransformer over a conventional transformer.

S_W is the apparent power actually passing through the windings. The rest passes from primary to secondary parts without being coupled through the windings.

Note that the smaller the series winding, the greater the advantage!