

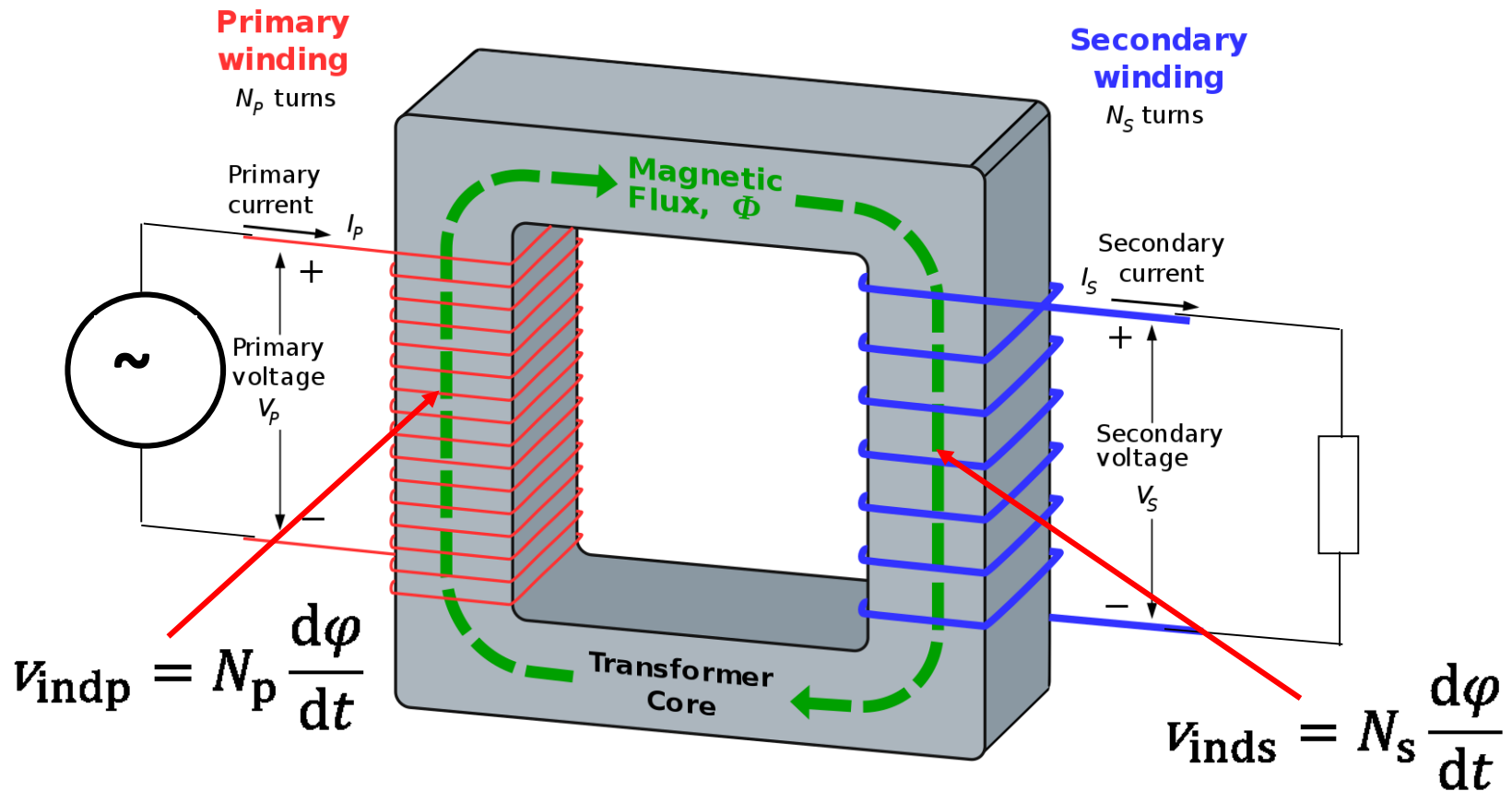
# **ELECTROTECHNICS**

## **TRANSFORMERS**

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# Principle of operation of single-phase transformer



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## Example 1

### Assignment

Single-phase transformer has primary voltage under no-load  $V_{P0}=3000$  V and secondary voltage  $V_{S0}=400$  V.

Primary winding has 1300 turns, cross-section of its core is  $S=80$  cm<sup>2</sup>, frequency 50 Hz. Calculate:

- a) Magnetic flux density in the transformer core
- b) Transformer ratio
- c) Number of secondary winding turns

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## Example 1

### Solution

Ad a) The voltage under no-load is at the real transformer very closed to the induced one, in the case of the ideal one are the same:

$$V_{P0} = V_{indP} = 4,44 \cdot f \cdot \Phi_m \cdot N_P = 4,44 \cdot f \cdot B_m \cdot S \cdot N_P$$

$$B_m = \frac{V_{indP}}{4,44 \cdot f \cdot S \cdot N_P} = \frac{3000}{4,44 \cdot 50 \cdot 80 \cdot 10^{-4} \cdot 1300} = 1,29 \text{ T}$$

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## Example 1

### Solution

**ad b)**

$$K = \frac{V_{indP}}{V_{indS}} = \frac{3000}{400} = 7,5$$

**ad c)**

$$K = \frac{V_{indP}}{V_{indS}} = \frac{N_P}{N_S} \rightarrow N_S = N_P \cdot \frac{V_{indS}}{V_{indP}} = 1300 \cdot \frac{400}{3000} = 174$$

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## Example 2

### Assignment

Single-phase transformer of the nominal power  $S_n = 3$  kVA, nominal primary voltage  $V_{Pn} = 1000$  V, nominal secondary voltage  $V_{Sn} = 230$  V, frequency 50 Hz, has number of primary turns  $N_p = 700$  and cross-section of its core  $S = 46$  cm<sup>2</sup>. Calculate ratio, number of secondary winding turns, magnetic flux density in the transformer core and currents in the primary and secondary. Transformer losses are neglected (=ideal transformer).

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## Example 2

### Solution

Ratio:

$$K = \frac{V_{Pn}}{V_{Sn}} = \frac{1000}{230} = 4,34$$

Number of secondary winding turns:

$$K = \frac{V_{Pn}}{V_{Sn}} = \frac{N_P}{N_S} \rightarrow N_S = \frac{N_P}{K} = \frac{700}{4,34} = 162$$

Magnetic flux density in core:

$$B_m = \frac{V_{Pn}}{4,44 \cdot f \cdot S \cdot N_P} = \frac{1000}{4,44 \cdot 50 \cdot 46 \cdot 10^{-4} \cdot 700} = 1,4 \text{ T}$$

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## Example 2

### Solution

Current in the primary:

$$S_{Pn} = V_{Pn} \cdot I_{Pn} \rightarrow I_{Pn} = \frac{S_{Pn}}{V_{Pn}} = \frac{5000}{1000} = 5 \text{ A}$$

Current in the secondary:

$$S_{Sn} = S_{Pn} = V_{Sn} \cdot I_{Sn} \rightarrow I_{Sn} = \frac{S_{Sn}}{V_{Sn}} = \frac{5000}{230} = 21,74 \text{ A}$$

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## Example 3

### Assignment

How large magnetic flux  $\phi_m$  is in the magnetic core with the cross-section of  $S=15 \text{ cm}^2$  at magnetic flux density  $B_m=1,1 \text{ T}$ ? How large voltage will be induced into one turn of the secondary winding and how many turns it must have to get the ratio of 230/50 V? Transformer losses are neglected (=ideal transformer).

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## Example 3

### Solution

**Magnetic flux in core:**

$$\Phi_m = B_m \cdot S = 1,1 \cdot 15 \cdot 10^{-4} = 1,65 \cdot 10^{-3} \text{ Wb}$$

**Induced voltage into one turn:**

$$V_{indS1} = V_{S1} = 4,44 \cdot f \cdot \Phi_m = 4,44 \cdot 50 \cdot 1,65 \cdot 10^{-3} = 0,366 \text{ V}$$

**Number of secondary winding turns:**

$$V_S = 4,44 \cdot f \cdot \Phi_m \cdot N_S = V_{S1} \cdot N_S \rightarrow N_S = \frac{V_S}{V_{S1}} = \frac{50}{0,366} = 137$$

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## Example 4

### Assignment

**Three-phase transformer in the connection Yy0 has these parameters:**

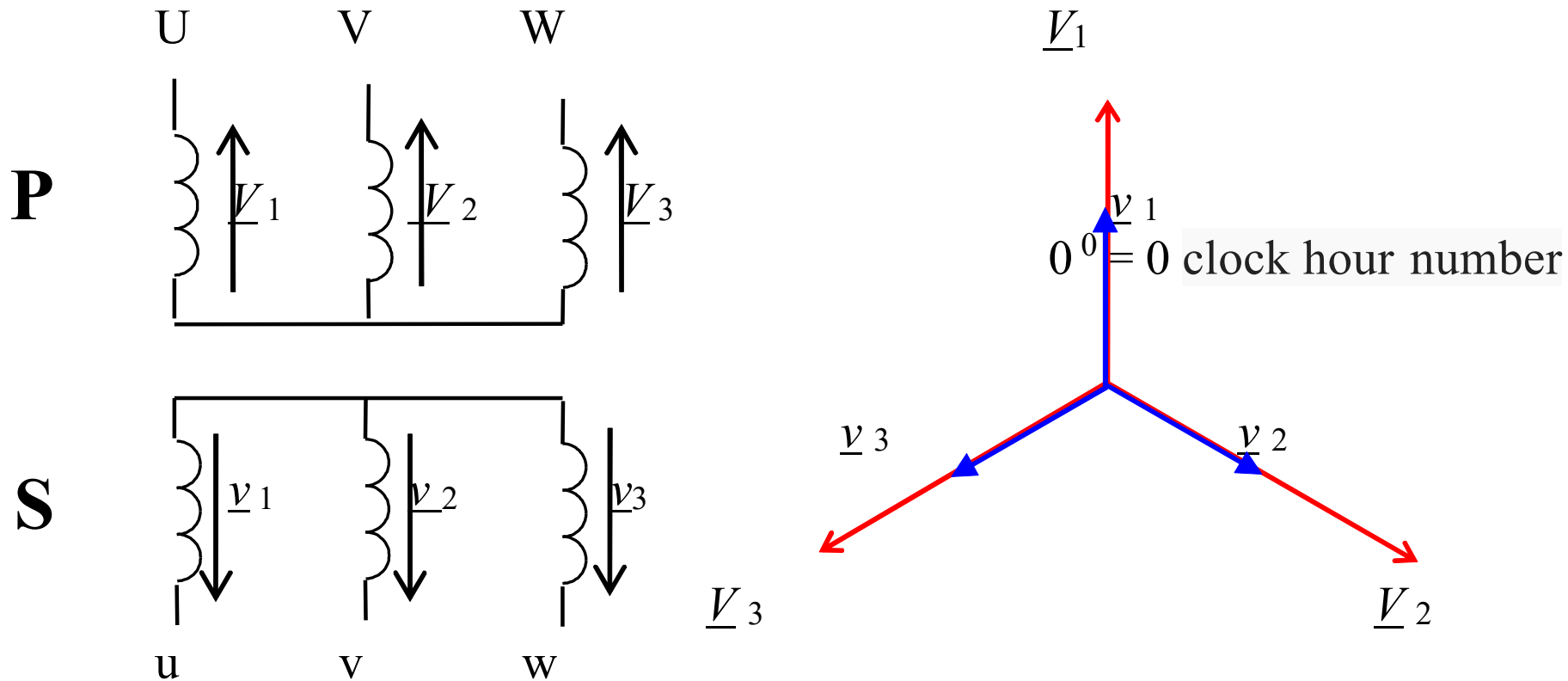
- **nominal power  $S_n = 630$  kVA**
- **nominal primary voltage  $V_{pn} = 3000$  V**
- **nominal secondary voltage  $V_{sn} = 525$  V**

**Calculate nominal currents and impedances in the primary and secondary windings. Losses are neglected.**

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## Example 4

### Connection Yy0



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## Example 4

### Solution

Nominal current in the primary:

$$I_{PN} = \frac{S_{PN}}{\sqrt{3} \cdot V_{PN}} = \frac{630 \cdot 10^3}{\sqrt{3} \cdot 3000} = 121,2 \text{ A}$$

Nominal current in the secondary:

$$I_{SN} = \frac{S_{SN}}{\sqrt{3} \cdot V_{SN}} = \frac{630 \cdot 10^3}{\sqrt{3} \cdot 525} = 693 \text{ A}$$

Nominal impedance in the primary:

$$Z_{PN} = \frac{V_{PfN}}{I_{PfN}} = \frac{V_{PN}}{\sqrt{3} \cdot I_{PN}} = \frac{3000}{\sqrt{3} \cdot 121,2} = 14,3 \text{ } \Omega$$

Nominal impedance in the secondary:

$$Z_{SN} = \frac{V_{SfN}}{I_{SfN}} = \frac{V_{SN}}{\sqrt{3} \cdot I_{SN}} = \frac{525}{\sqrt{3} \cdot 693} = 0,43 \text{ } \Omega$$

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## Example 5

### Assignment

Three-phase transformer in the connection Yy0 has these parameters:

- nominal power  $S_n = 1000$  kVA
- nominal primary voltage  $V_{pn} = 35$  kV
- ratio  $K = 5,56$
- number of primary winding turns  $N_p = 1600$
- percentage current under no-load  $i_0 = 5,5$  %
- percentage impedance  $z_{pU} = 5,5$  %

Calculate number of turns and nominal voltage of secondary winding, current under no-load and short-circuit voltage. Losses are neglected.

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## Example 5

### Solution

Number of secondary winding turns:

$$K = \frac{N_P}{N_S} \rightarrow N_S = \frac{N_P}{K} = \frac{1600}{5,56} = 287$$

Nominal voltage in the secondary:

$$V_{SN} = \frac{V_{PN}}{K} = \frac{35 \cdot 10^3}{5,56} = 6,3 \cdot 10^3 \text{ V}$$

Current under no-load :

$$i_0 = \frac{I_{P0}}{I_{PN}} \cdot 100 \rightarrow I_{P0} = \frac{i_0 \cdot I_{PN}}{100} = \frac{5,5 \cdot 16,5}{100} = 0,91 \text{ A}$$

Nominal current in the primary:

$$I_{PN} = \frac{S_{PN}}{\sqrt{3} \cdot V_{PN}} = \frac{1000 \cdot 10^3}{\sqrt{3} \cdot 35 \cdot 10^3} = 16,5 \text{ A}$$

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## Example 5

### Solution

Short-circuit voltage:

$$z_{PU} = \frac{V_{PK}}{V_{PN}} \cdot 100 \rightarrow V_{PK} = \frac{z_{PU} \cdot V_{PN}}{100} = \frac{5,5 \cdot 35 \cdot 10^3}{100} = 1,93 \cdot 10^3 \text{ V}$$