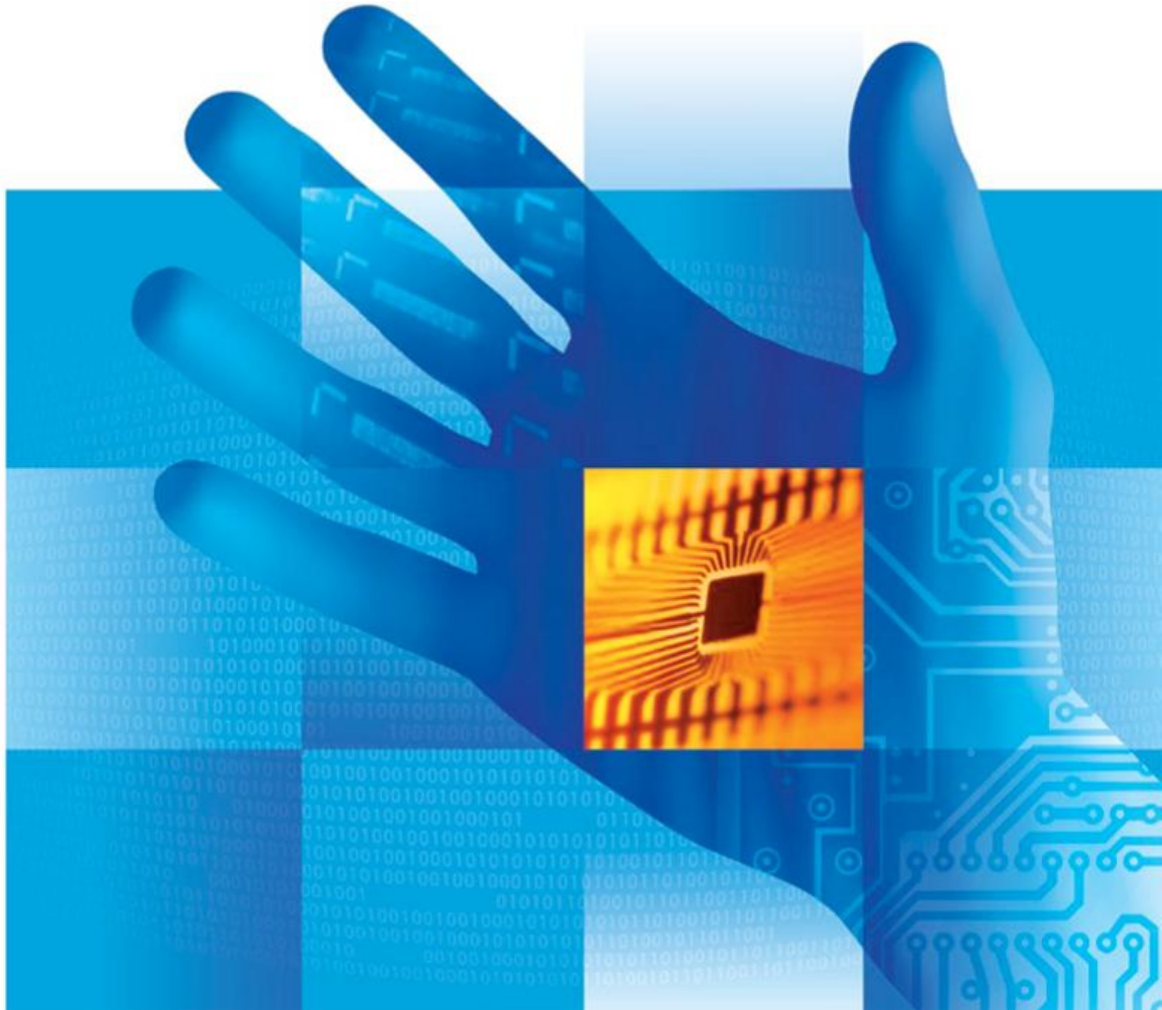
EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

9. TRANSFORMERS



Doc. Ing. Stanislav Kocman, Ph.D.

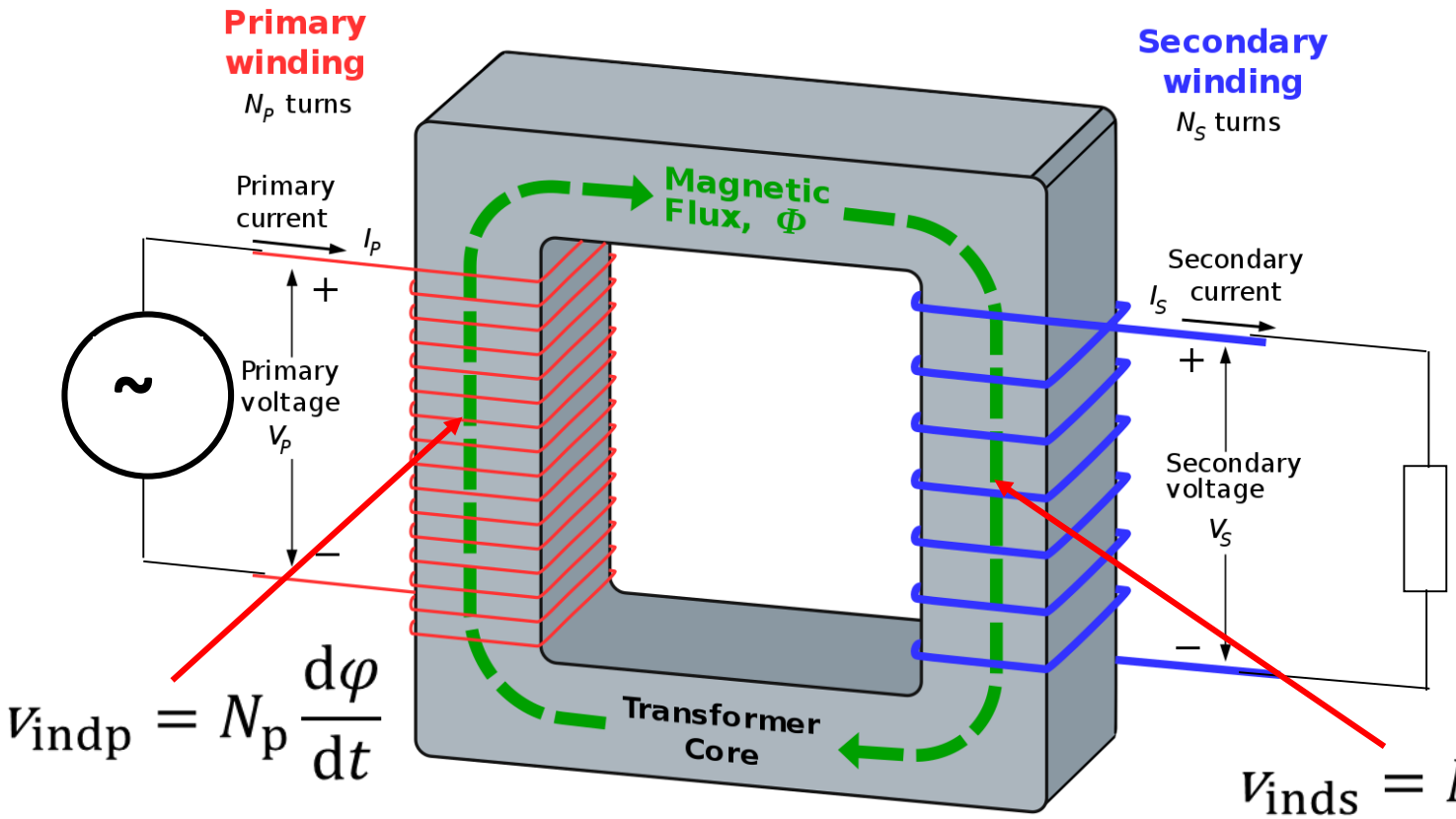
10. 3. 2018, Ostrava

LECTURE PLAN

- **principle of operation and construction of single-phase transformer**
- **transformer working conditions**
- **three-phase transformers: design, examples of connection, application**
- **autotransformer, instrument transformer**

Principle of operation and construction of single-phase transformer

Principle of operation



Transformer ratio

$$v_{\mathrm{indp}} = N_{\mathrm{p}} \frac{\mathrm{d}\varphi}{\mathrm{d}t} \longrightarrow \text{rms value: } V_{\mathrm{indp}} = 4{,}44 f_{\mathrm{p}} N_{\mathrm{p}} \varphi_m$$

$$v_{\mathrm{inds}} = N_{\mathrm{s}} \frac{\mathrm{d}\varphi}{\mathrm{d}t} \longrightarrow \text{rms value: } V_{\mathrm{inds}} = 4{,}44 f_{\mathrm{s}} N_{\mathrm{s}} \varphi_m$$

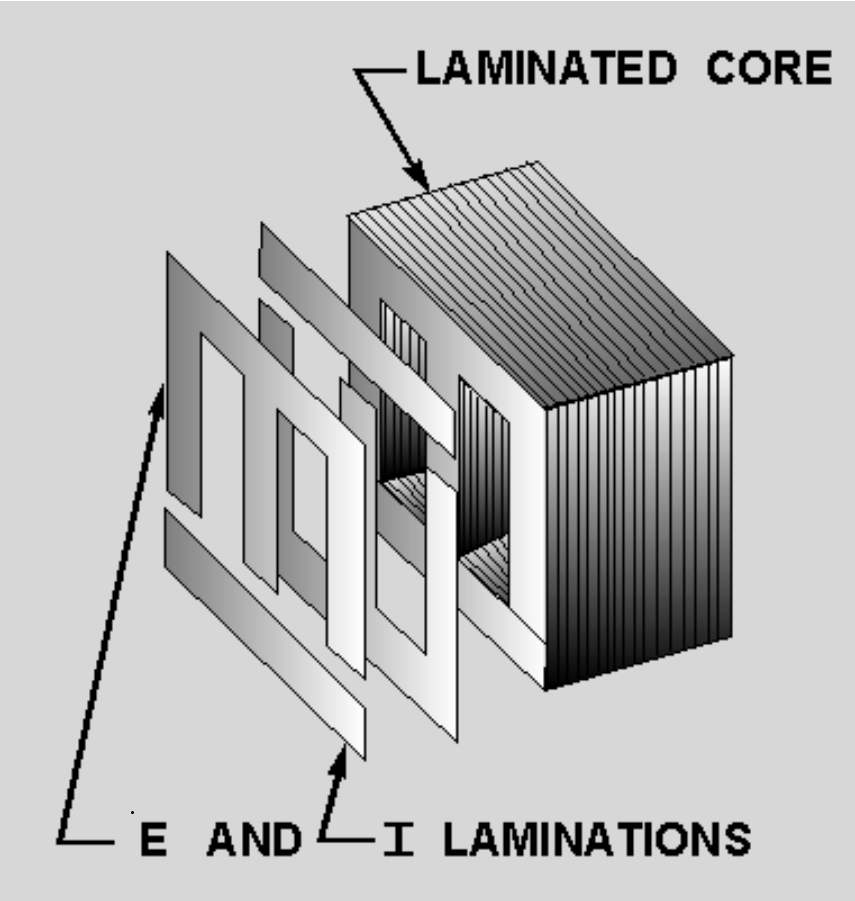
Transformer ratio (secondary winding open)

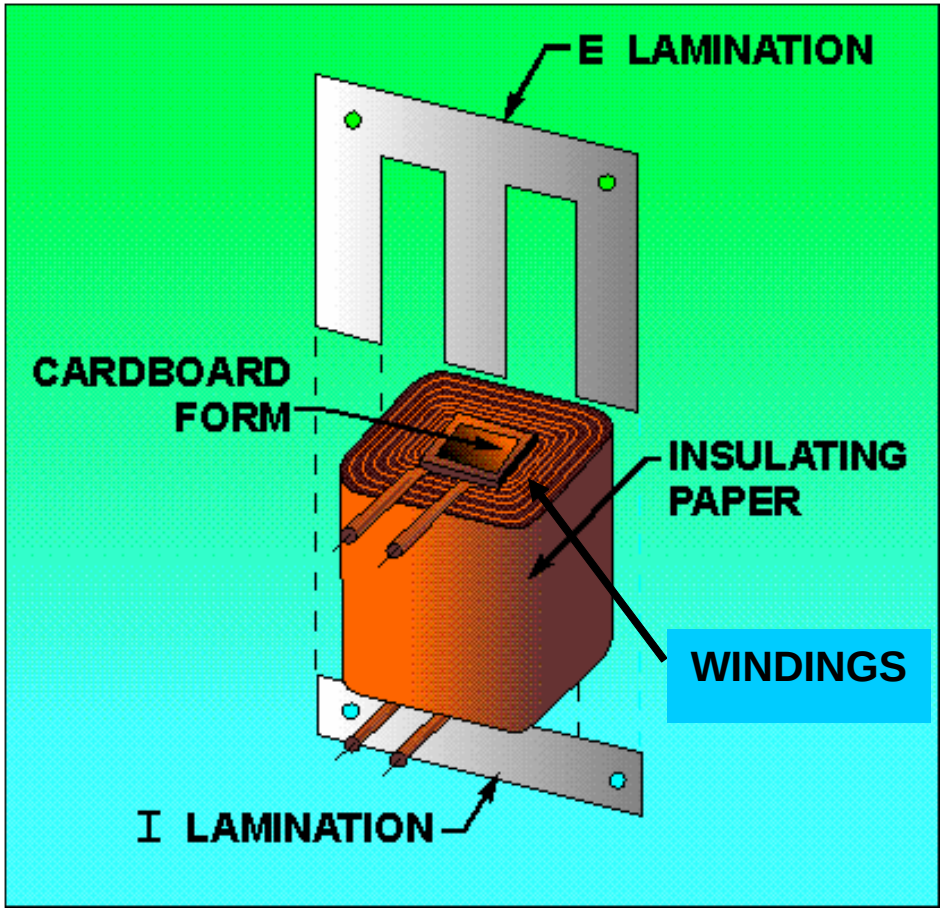
$$\frac{V_{\mathrm{indp}}}{V_{\mathrm{inds}}} = \frac{N_{\mathrm{p}}}{N_{\mathrm{s}}} = K$$

Transformer ratio (secondary winding closed) for ideal transformer

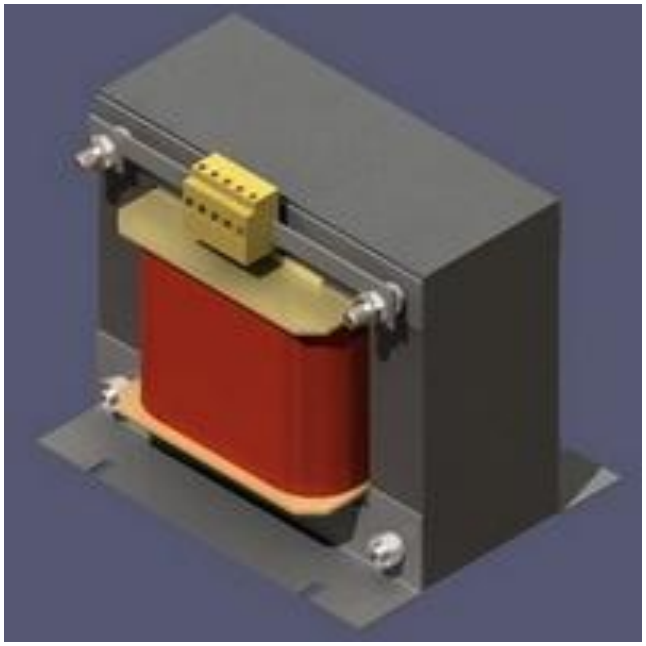
$$S_{\mathrm{p}} = S_{\mathrm{s}} = V_{\mathrm{p}} I_{\mathrm{p}} = V_{\mathrm{s}} I_{\mathrm{s}} = \frac{V_{\mathrm{p}}}{V_{\mathrm{s}}} = \frac{I_{\mathrm{s}}}{I_{\mathrm{p}}} = K$$

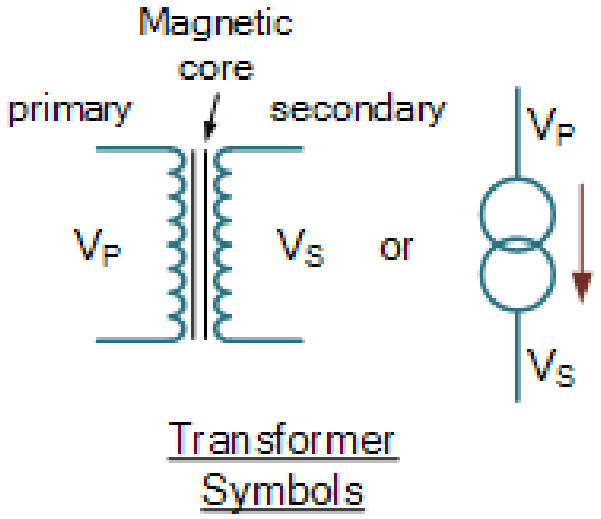
Construction of single-phase transformer





Construction and symbol of single-phase transformer

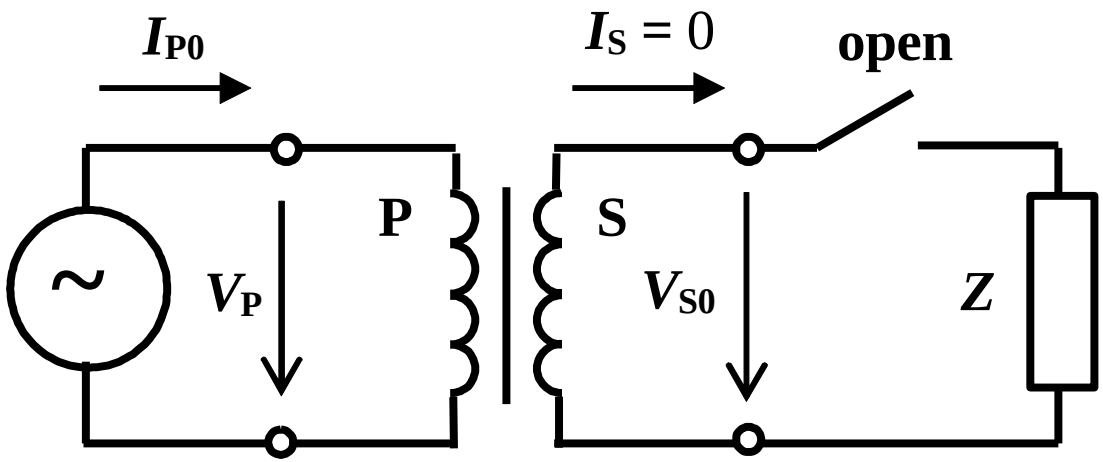




Transformer Symbols

Transformer operating conditions

Transformer under no-load

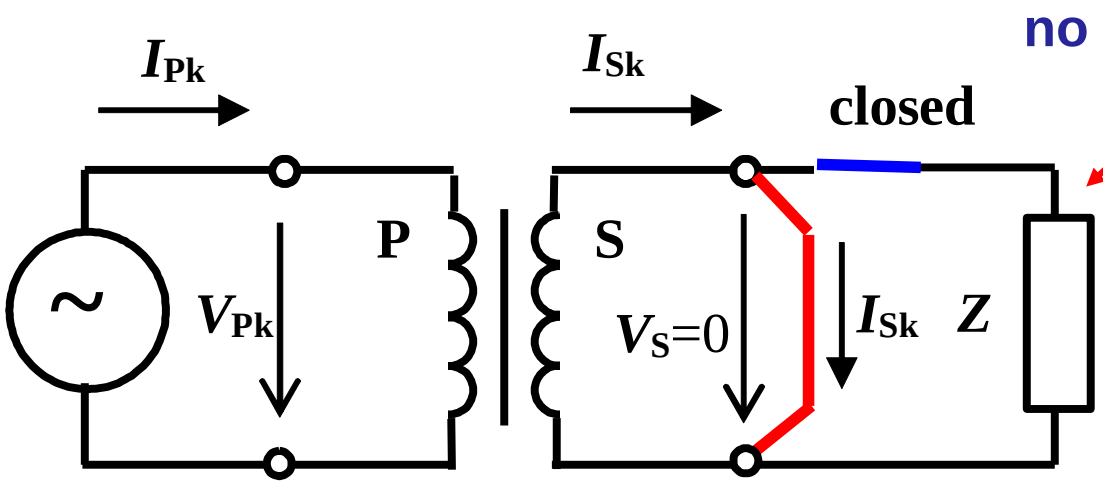


$$P_{P0} = \Delta P_{fe} + R_P I_{P0}^2 \cong \Delta P_{fe}$$

$$P_S = 0$$

losses in magnetic core

Transformer short-circuit test



$$I_{Pk} = I_{Pn} \rightarrow V_P = V_{Pk}$$

percentage impedance

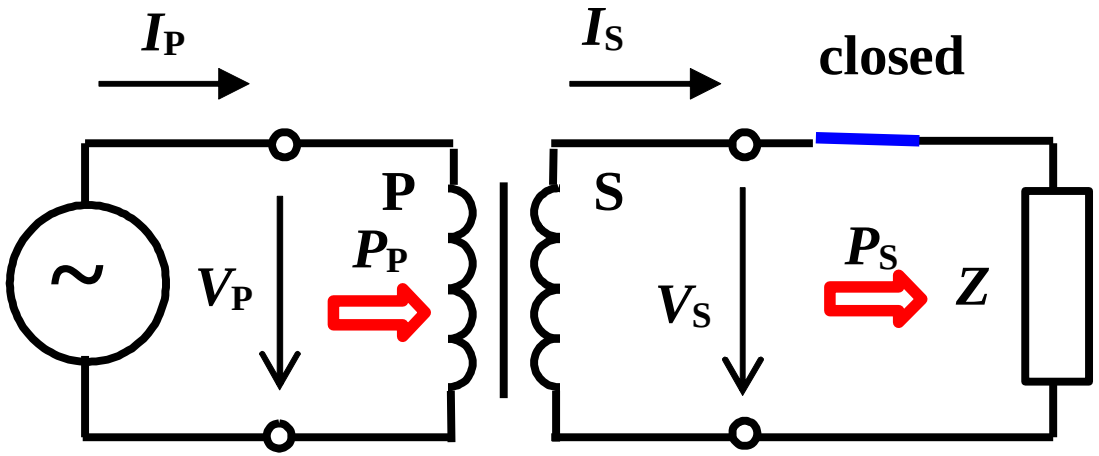
$$P_K = \Delta P_j + \Delta P_d \cong \Delta P_j$$

losses in windings

$$\Delta P_{jn} = R_P I_{Pn}^2 + R_S I_{Sn}^2$$

$$z_{pu} = \frac{V_{Pk}}{V_{Pn}} \cdot 100 = \frac{I_{Pn}}{I_{PSC}} \cdot 100$$

Transformer under load



power efficiency ← $\eta = \frac{P_S}{P_P}$

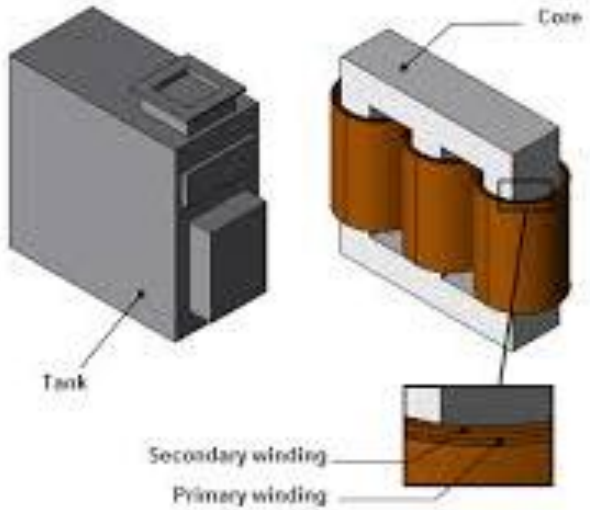
total losses ← $\Delta P = P_P - P_S \rightarrow \eta = \frac{P_P - \Delta P}{P_P}$

$$\Delta P = \Delta P_{fe} + \Delta P_j$$

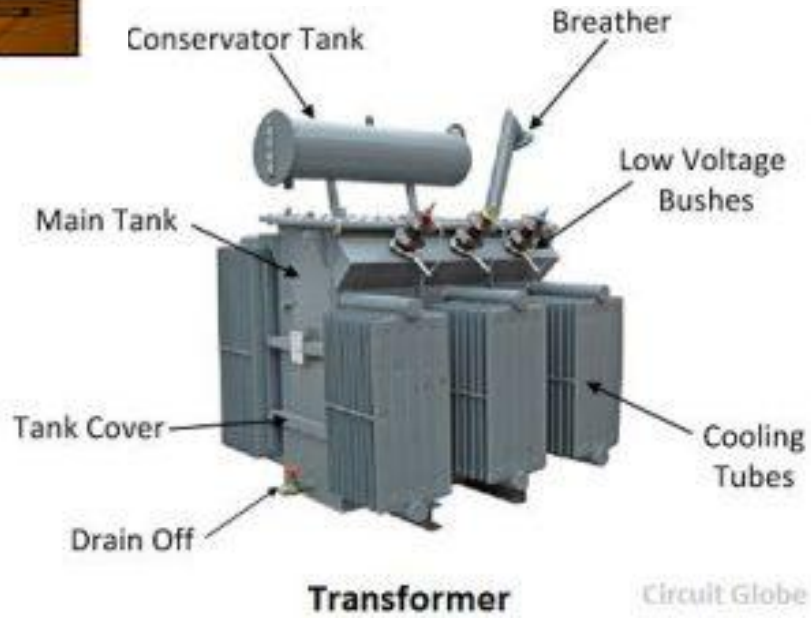
$$P_P = V_P I_P \cos\varphi_P$$

Three-phase transformers

Design







Design, transformer station





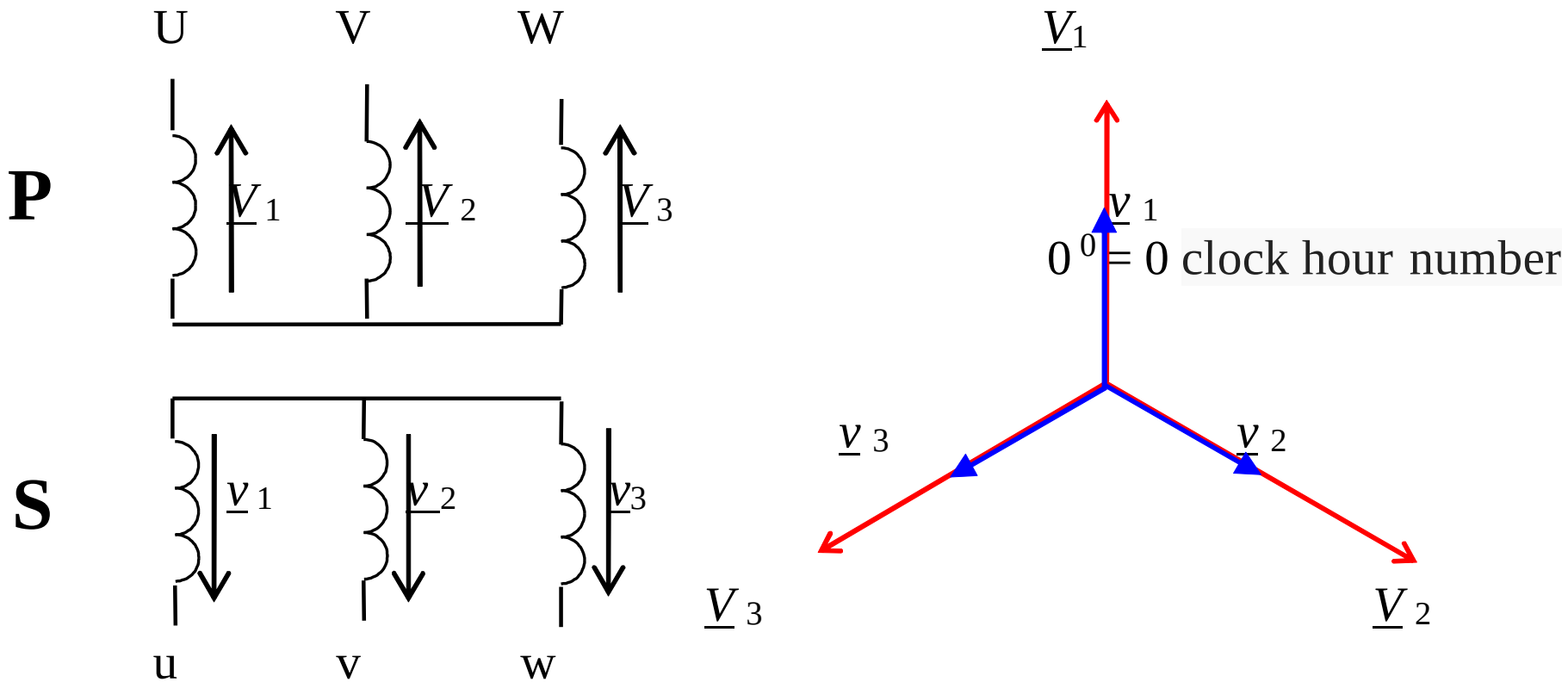


Three-phase transformers

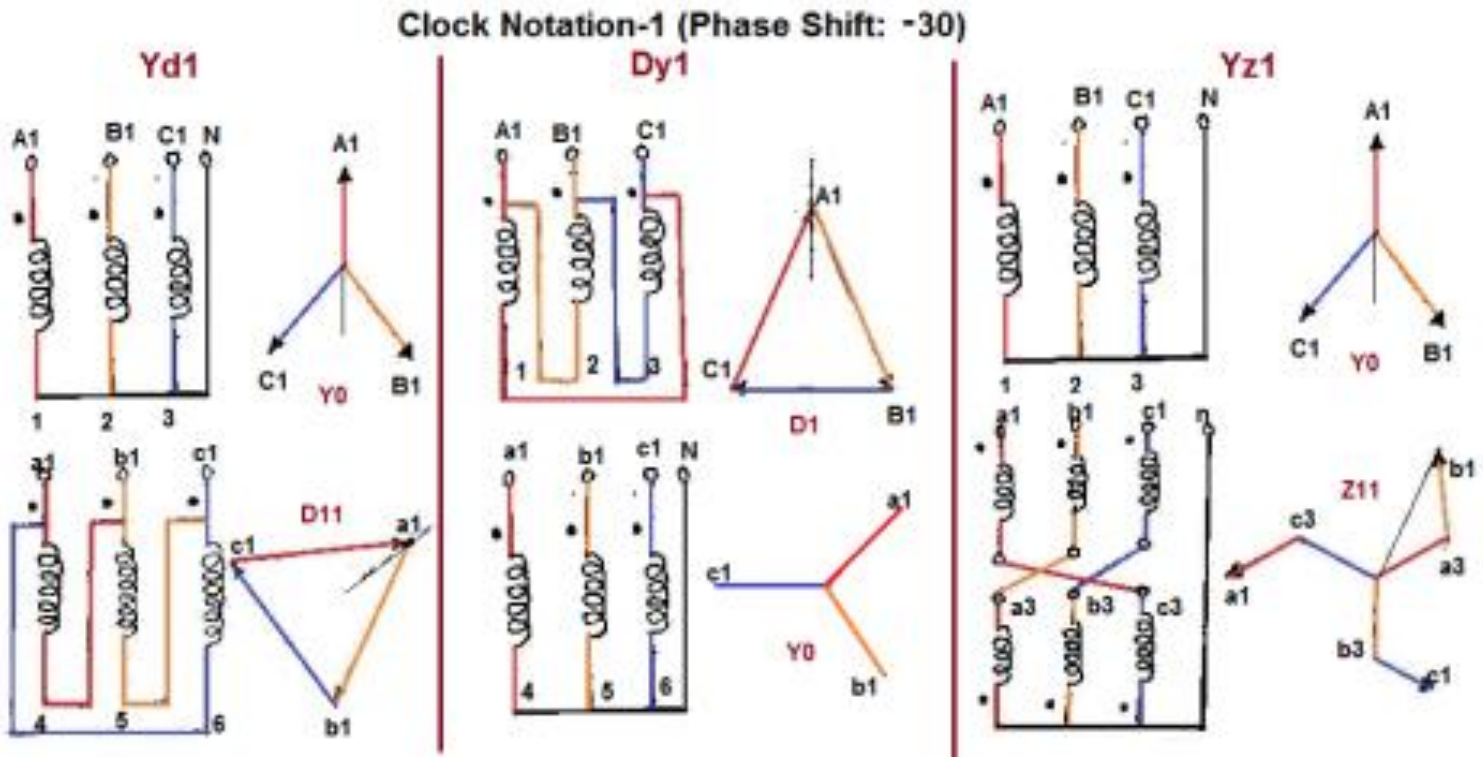
Examples of connection

- **Primary winding: HV (delta: D, wye (star): Y)**
- **Secondary winding: LV (delta: d, wye (star): y, zigzag: z)**
- **Often used connection:**
  - **Yy0**
  - **Yz1**
  - **Dy1**
  - **Yd1**

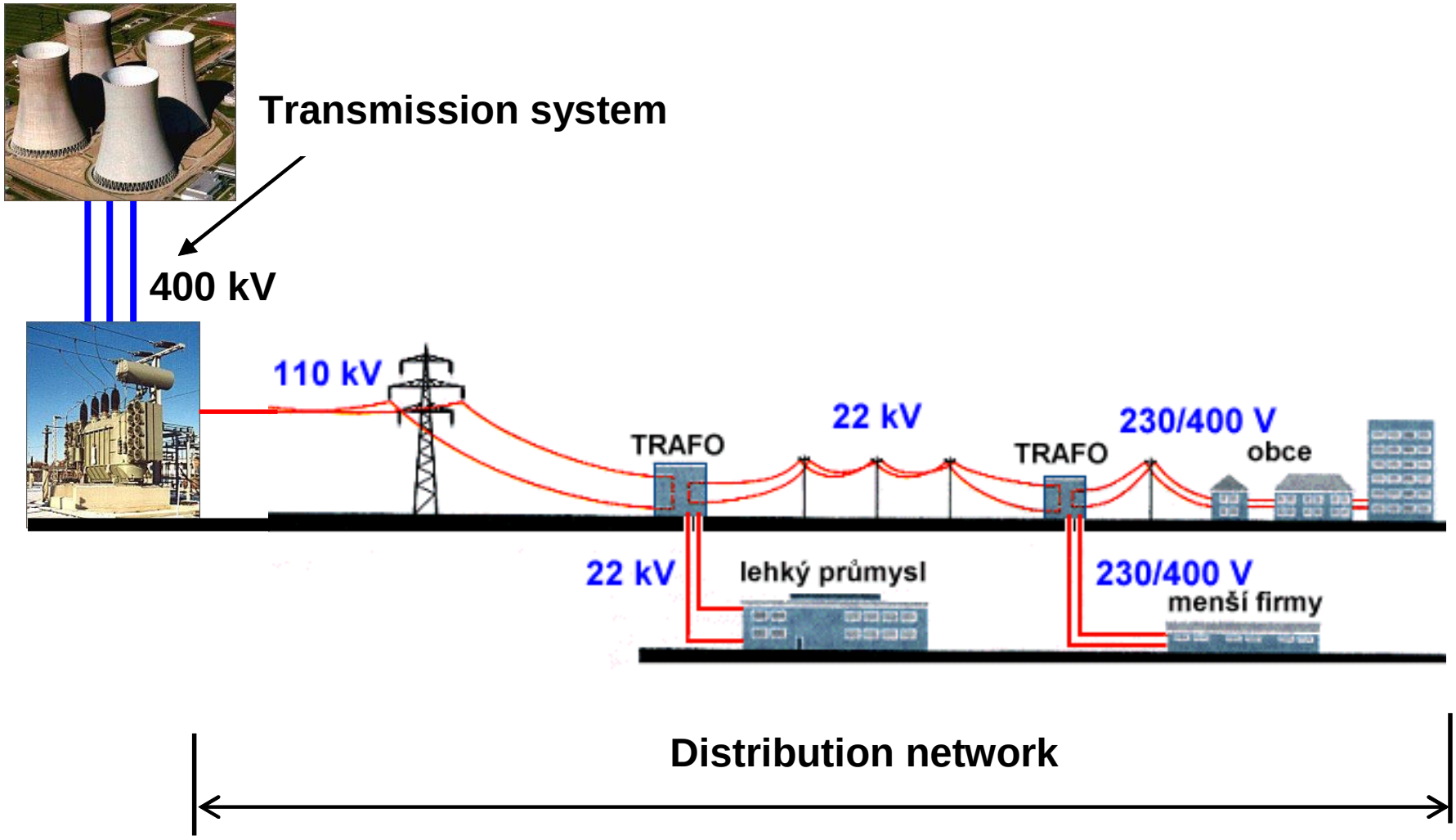
Yy0 connection



Other connections

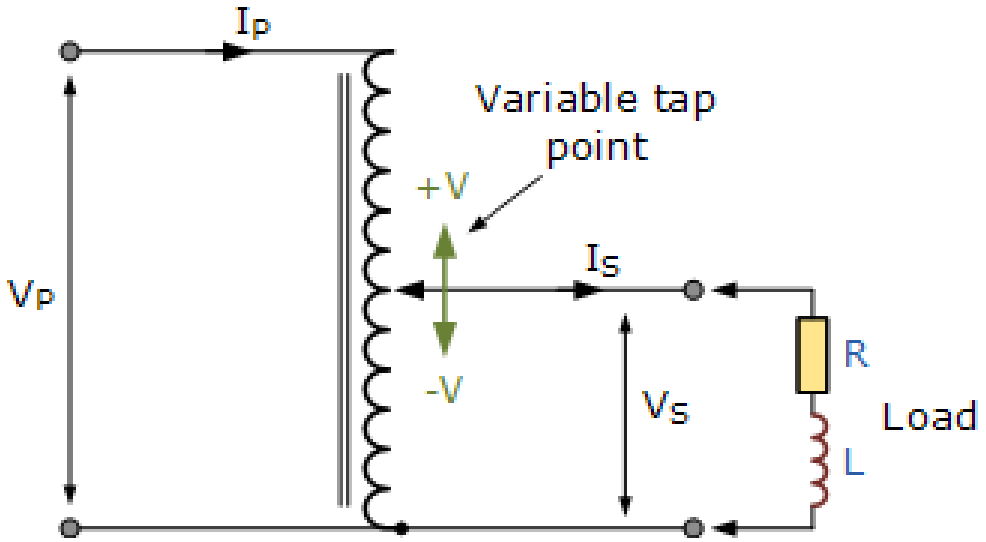


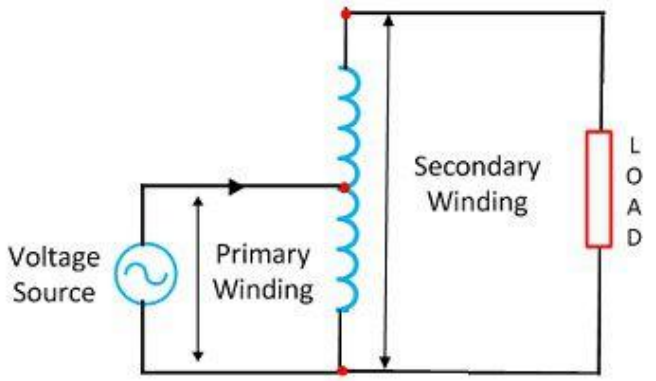
Application

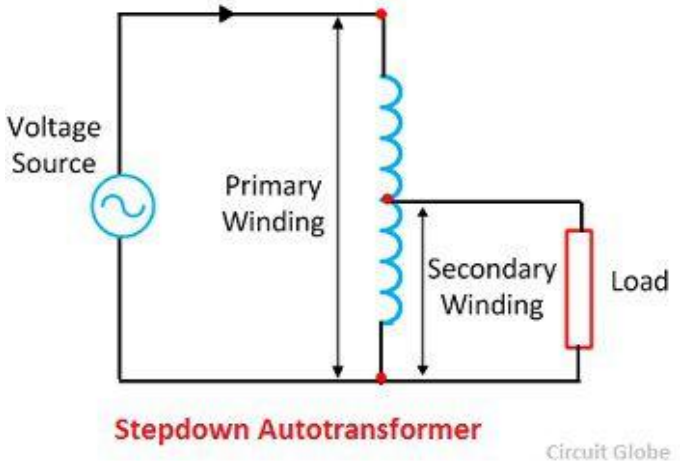


Autotransformer

- **Transformer with one winding (smaller, more economic, cheaper, infinitely adjustable output voltage)**

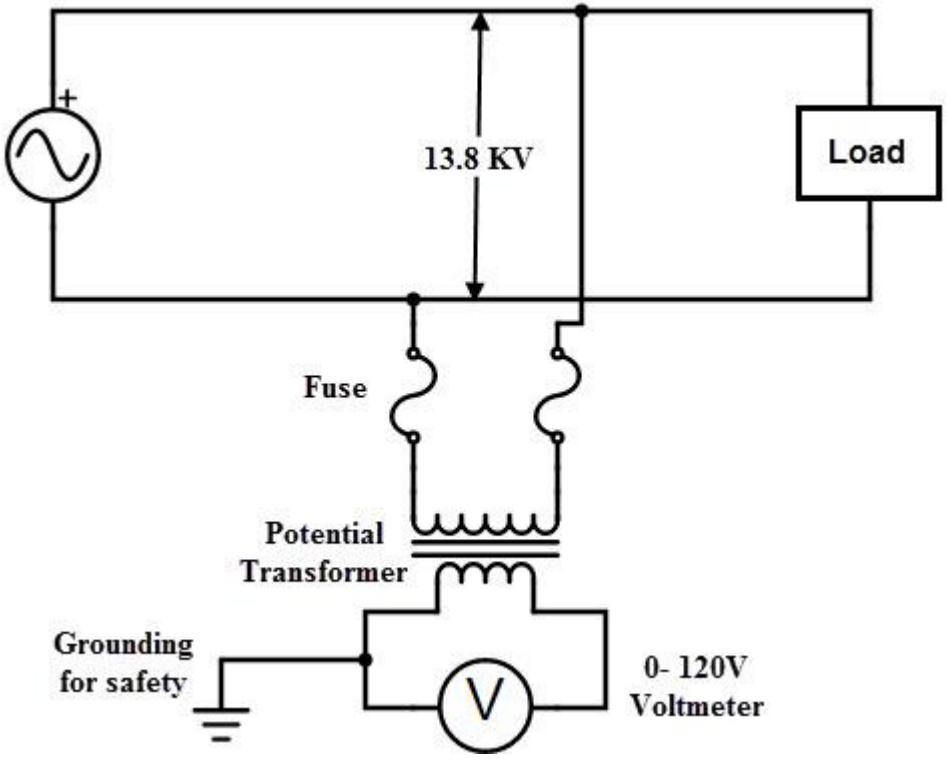






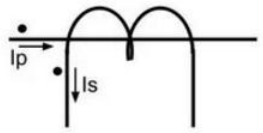
Instrument transformer

- Voltage (=potential) transformer
  - for measuring in HV circuits
  - output voltage 100 V, 110 V

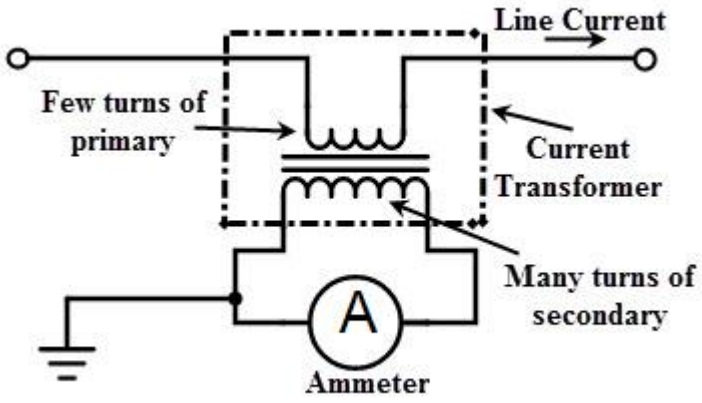


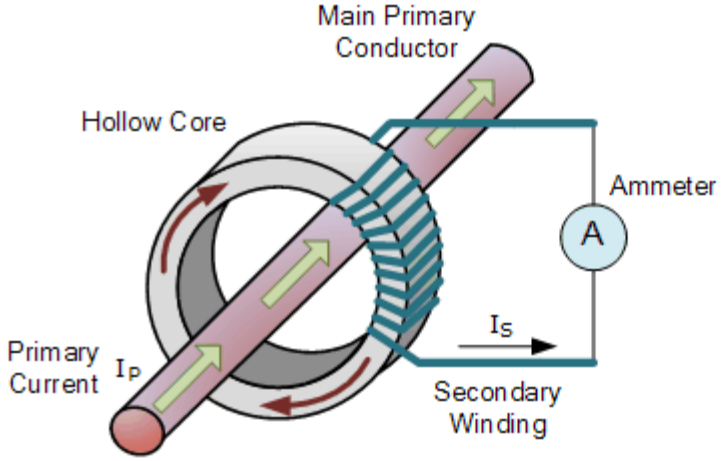
Instrument transformer

- Current transformer
  - for measuring high currents in LV circuits
  - for measuring currents in HV circuits
  - output current 5 A, 1 A

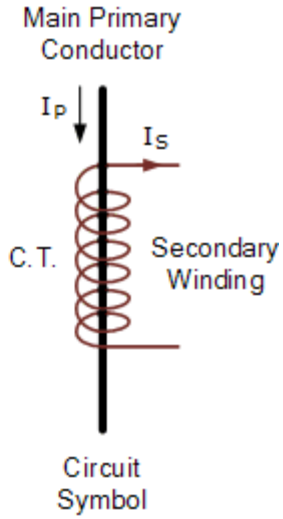


Symbol of CT





Construction



Circuit Symbol