EPFL

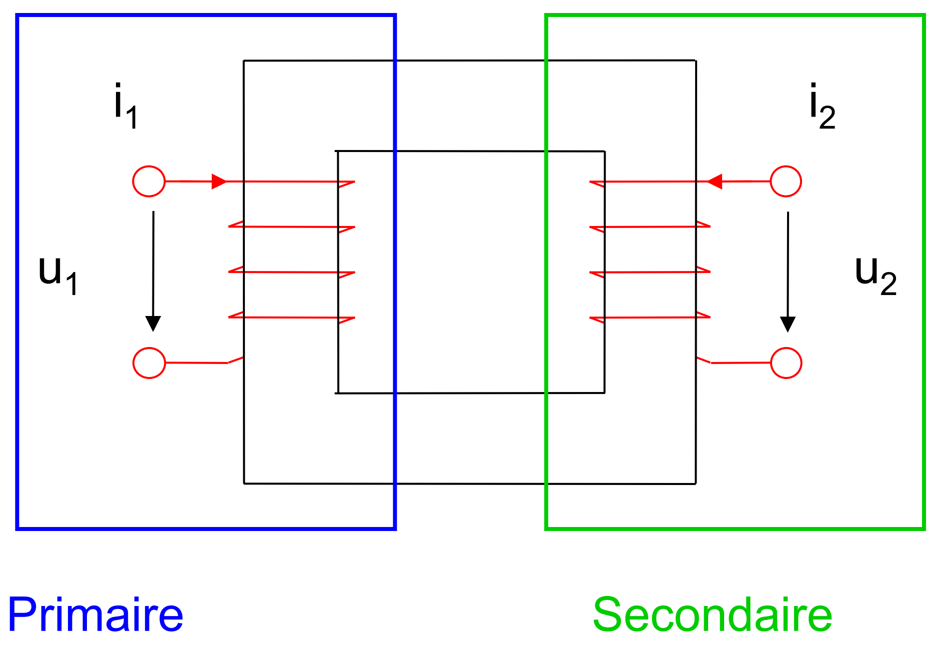
Transformateur monophasé

Actionneurs et systèmes électromagnétiques

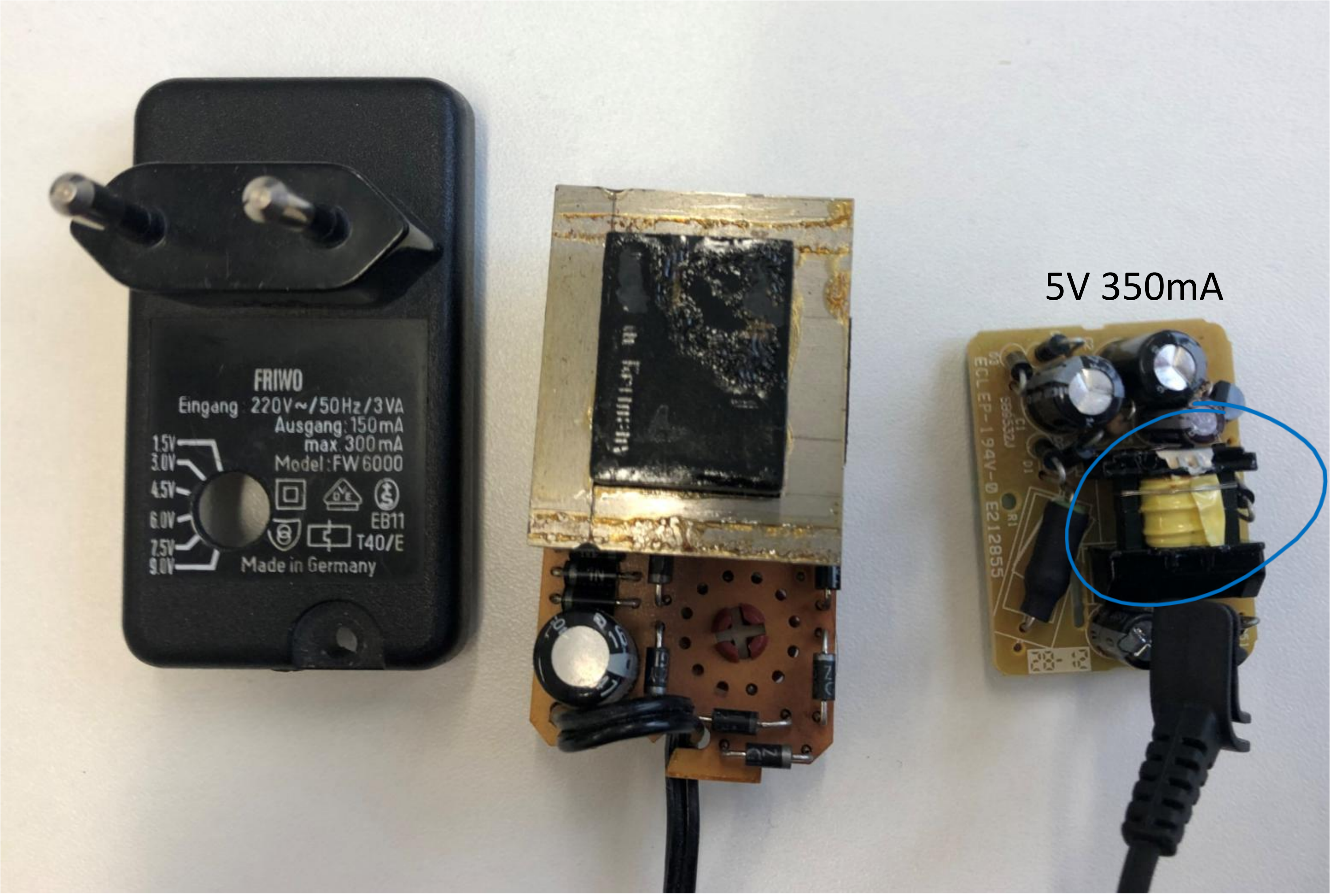
Fonctionnalité

$$L = N^2 \lambda = N^2 \cdot \frac{\mu \cdot S}{l}$$

Principe

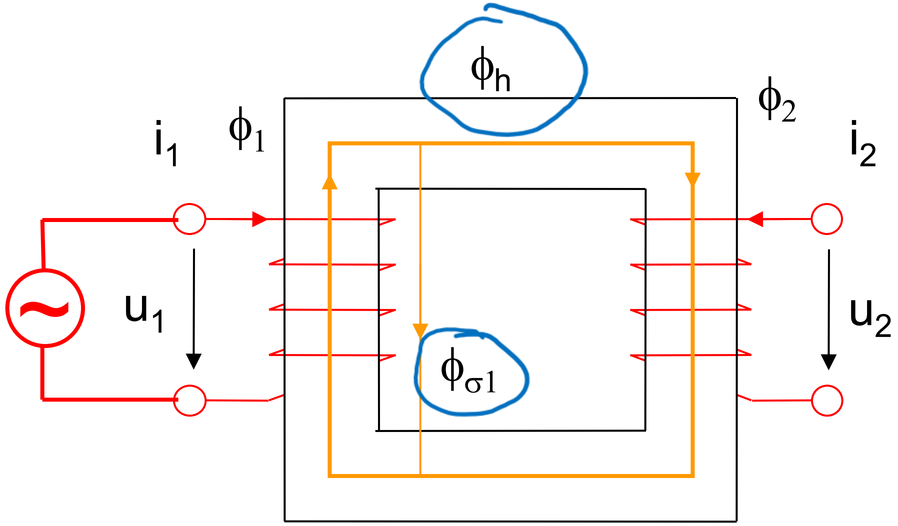


Evolution



5V 350mA
FRIWO
Eingang 220V~/50Hz/3VA
Ausgang: 150mA
max. 300mA
Model: FW 6000
1.5V
3.0V
4.5V
6.0V
7.5V
9.0V
EB11
T40/E
Made in Germany

Principe de fonctionnement



$$u_1 = R_1 i_1 + \frac{d\psi_1}{dt} = R_1 i_1 + N_1 \frac{d\phi_1}{dt}$$

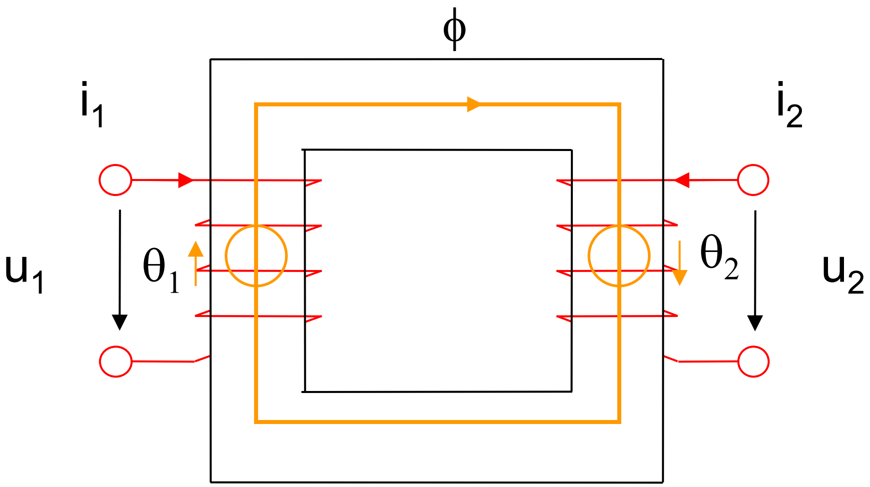
$$u_2 = R_2 i_2 + \frac{d\psi_2}{dt}$$

$$\psi_2 = L_{22} i_2 + L_{12} i_1$$

$$i_2 = 0$$

$$u_2 = \frac{d\psi_2}{dt} = \frac{d(L_{12} i_2)}{dt}$$

Transformateur Idéal



$\mu_{fer}=\infty$

Pas de pertes fer

$\rightarrow \quad \phi_1 = \phi_2 = \phi$

$R_1=R_2=0 \quad \rightarrow \quad u_1 = \dfrac{d\psi_1}{dt}, \quad u_2 = \dfrac{d\psi_2}{dt}$

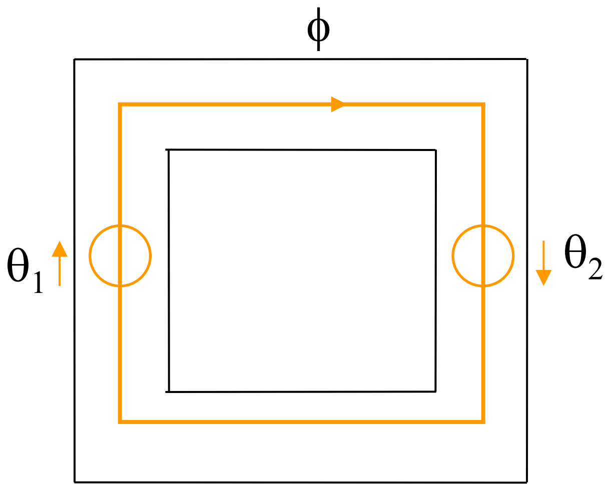
$$\psi_1 = N_1\phi_1 = N_1\phi \quad \rightarrow u_1 = \frac{d\psi_1}{dt} = N_1 \frac{d\phi}{dt}$$

$$\psi_2 = N_2\phi_2 = N_2\phi \quad \rightarrow u_2 = \frac{d\psi_2}{dt} = N_2 \frac{d\phi}{dt}$$

$$\rightarrow \frac{d\phi}{dt} = \frac{U_1}{N_1} = \frac{U_2}{N_2}$$

$$\frac{U_1}{U_2} = \frac{N_1}{N_2}$$

Transformateur Idéal



$\mu_{fer} = \infty$

Pas de pertes fer $\rightarrow$ $\theta_1 + \theta_2 = 0$

$$\frac{u_1}{u_2} = \frac{N_1}{N_2}$$

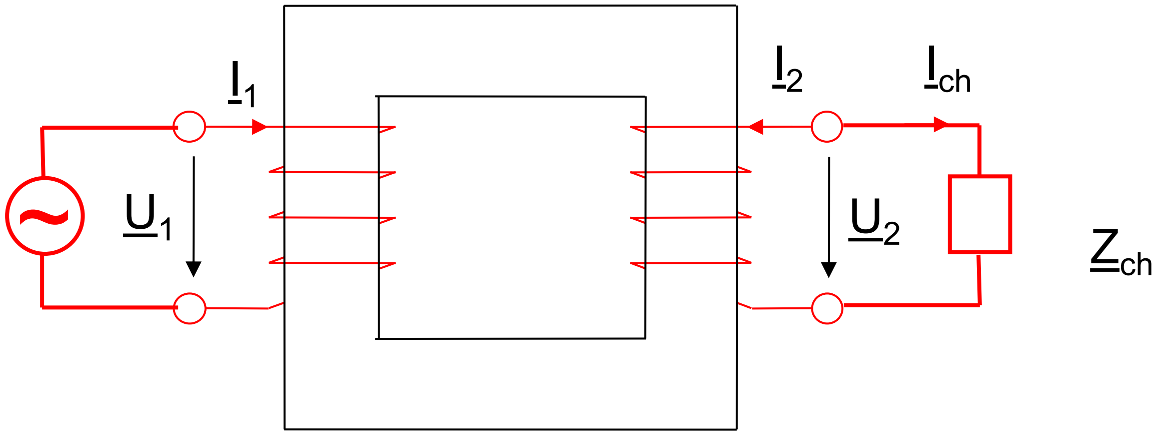
$$\frac{N_1}{N_2} = m \quad \text{rapport de transformation}$$

$$N_1 \cdot i_1 + N_2 \cdot i_2 = 0$$

$$N_1 i_1 = -N_2 i_2 \qquad -\frac{i_1}{i_2} = \frac{N_2}{N_1}$$

$$m = \frac{U_1}{U_2} = -\frac{i_2}{i_1}$$

Alimentation sinusoïdale

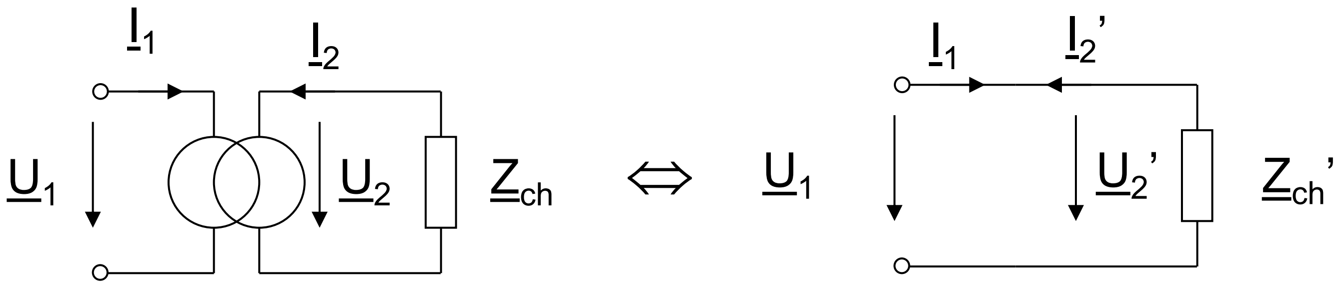


$$\frac{N_1}{N_2} = \frac{u_1}{u_2} = -\frac{i_2}{i_1} = \ddot{u} \longrightarrow \frac{N_1}{N_2} = \frac{\underline{U}_1}{\underline{U}_2} = -\frac{\underline{I}_2}{\underline{I}_1} = \ddot{u}$$

$$\frac{\underline{U}_1}{\underline{I}_1} = \frac{\frac{N_1}{N_2} \cdot \underline{U}_2}{\frac{N_2}{N_1} \cdot (-\underline{I}_2)} = \left(\frac{N_1}{N_2}\right)^2 \frac{\underline{U}_2}{-\underline{I}_2} = \ddot{u}^2 \frac{\underline{U}_2}{\underline{I}_{ch}} = \ddot{u}^2 \underline{Z}_{ch}$$

Grandeurs rapportées

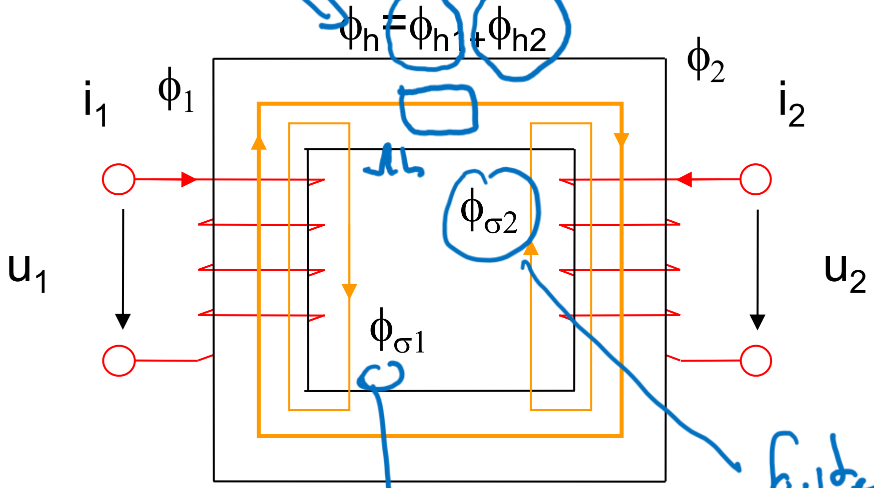
Tension secondaire rapportée au primaire	$\underline{U}_2' = \ddot{u}\underline{U}_2$
Courant secondaire rapportée au primaire	$\underline{I}_2' = \dfrac{\underline{I}_2}{\ddot{u}}$
Impédance secondaire rapportée au primaire	$\underline{Z}_{ch}' = \ddot{u}^2 \underline{Z}_{ch}$



Dans un transformateur idéal $\underline{I}_2' = -\underline{I}_1$ et $\underline{U}_2' = \underline{U}_1$

Transformateur réel: Flux

champ principal



fuites secondaire

fuite primaire

$$\phi_1 = \phi_{\sigma 1} + \phi_h$$

$$\phi_2 = \phi_{\sigma 2} + \phi_h$$

propre 1

fuites 1

$$\Phi_1 = \Phi_{h1} + \Phi_{\sigma_1} + \Phi_{h2}$$

"mesuré" dans 1 — champ principal 1 — champ principal 2

~~$\mu_{fer}=\infty$~~

Pas de pertes fer

~~$R_1=R_2=0$~~

Pas de saturation =>

$$\phi_h = \phi_{h1} + \phi_{h2}$$

Avec:

$$\phi_{h1} = \Lambda_h N_1 i_1$$

Θ_1

$$\phi_{h2} = \Lambda_h N_2 i_2$$

$$\phi_h = \Lambda_h (N_1 i_1 + N_2 i_2)$$

Inductances

$$\phi_h = \Lambda_h (N_1 i_1 + N_2 i_2)$$
$$\psi_1 = N_1 \phi_1 = N_1 \phi_{\sigma 1} + N_1 \phi_h$$
$$\psi_2 = N_2 \phi_2 = N_2 \phi_{\sigma 2} + N_2 \phi_h$$

Inductances de fuite

$$L_{\sigma 1} = \frac{N_1 \phi_{\sigma 1}}{i_1} = N_1^2 \Lambda_{\sigma 1}$$
$$L_{\sigma 2} = \frac{N_2 \phi_{\sigma 2}}{i_2} = N_2^2 \Lambda_{\sigma 2}$$

Inductances principales

$$L_{h1} = \frac{N_1 \phi_{h1}}{i_1} = N_1^2 \Lambda_h$$
$$L_{h2} = \frac{N_2 \phi_{h2}}{i_2} = N_2^2 \Lambda_h \qquad L_{12} = \frac{N_1 \phi_{h2}}{i_2} = N_1 N_2 \Lambda_{h1}$$

$$L = \frac{\psi_\beta}{i_\alpha}$$ (ψ_β mesuré, i_α crée)

$$L_{12} = \frac{\psi_{1\beta}}{i_{2\alpha}}$$ (mesuré, créé)

Equations de tension induite

$$U_1 = R_1 i_1 + \frac{d\psi_1}{dt} \qquad \psi_1 = N_1 (\phi_{\sigma 1} + \phi_h)$$
$$U_1 = R_1 i_1 + N_1 \left(\frac{d\phi_{\sigma 1}}{dt} + \frac{d\phi_h}{dt} \right)$$
$$U_1 = R_1 i_1 + N_1 \frac{L_{\sigma 1}}{N_1} \frac{di_1}{dt} + N_1 \frac{d\phi_h}{dt}$$
$$U_1 = R_1 i_1 + L_{\sigma 1} \cdot \frac{di_1}{dt} + N_1^2 \Lambda_h \frac{di_1}{dt} + N_1 N_2 \Lambda_h \frac{di_2}{dt}$$
$$U_1 = R_1 i_1 + L_{\sigma 1} \frac{di_1}{dt} + L_{h1} \left(\frac{di_1}{dt} + \frac{N_2}{N_1} \frac{di_2}{dt} \right)$$

Equations de tension en grandeurs rapportées

$$\ddot{u} = \frac{N_1}{N_2}$$

$$u_2' = \ddot{u}\, u_2$$

$$i_2' = \frac{i_2}{\ddot{u}}$$

$$R_2' = \ddot{u}^2 R_2$$

$$L_{\sigma 2}' = \ddot{u}^2 L_{\sigma 2}$$

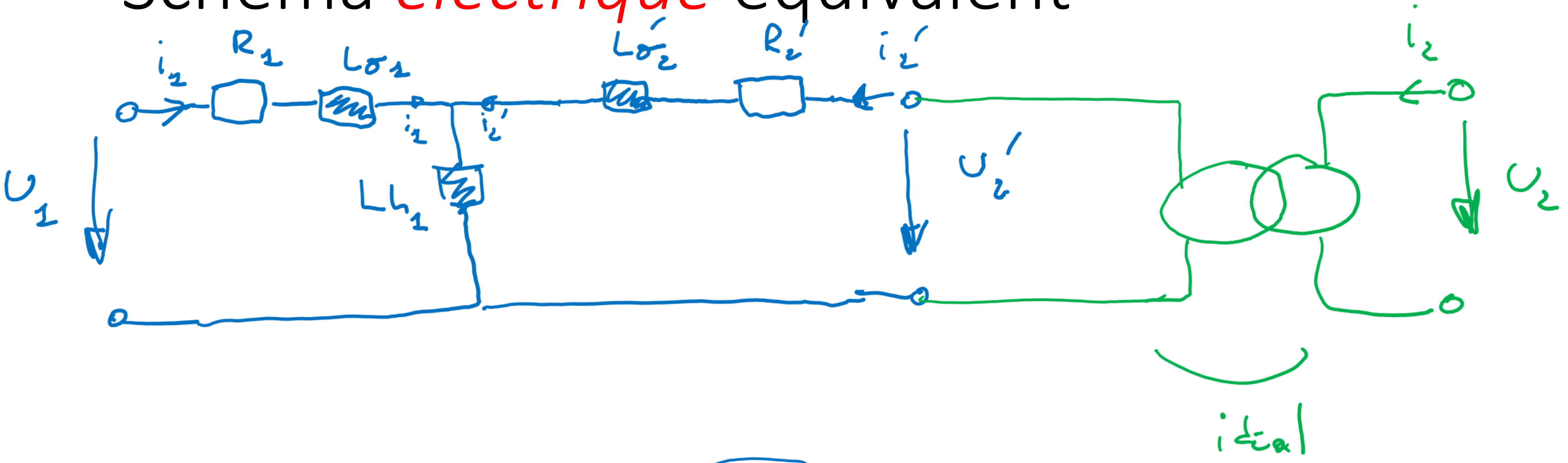
$$L_{h2}' = \ddot{u}^2 L_{h2} = L_{h1}$$

$$u_1 = R_1 i_1 + L_{\sigma 1}\frac{di_1}{dt} + L_{h1}\left(\frac{di_1}{dt} + \frac{N_2}{N_1}\frac{di_2}{dt}\right)$$

$$U_1 = R_1 i_1 + L_{\sigma 1}\frac{di_1}{dt} + L_{h1}\left(\frac{di_1}{dt} + \frac{di_2'}{dt}\right)$$

$$U_2' = R_2' i_2' + L_{\sigma 2}'\frac{di_2'}{dt} + L_{h1}\left(\frac{di_1}{dt} + \frac{di_2'}{dt}\right)$$

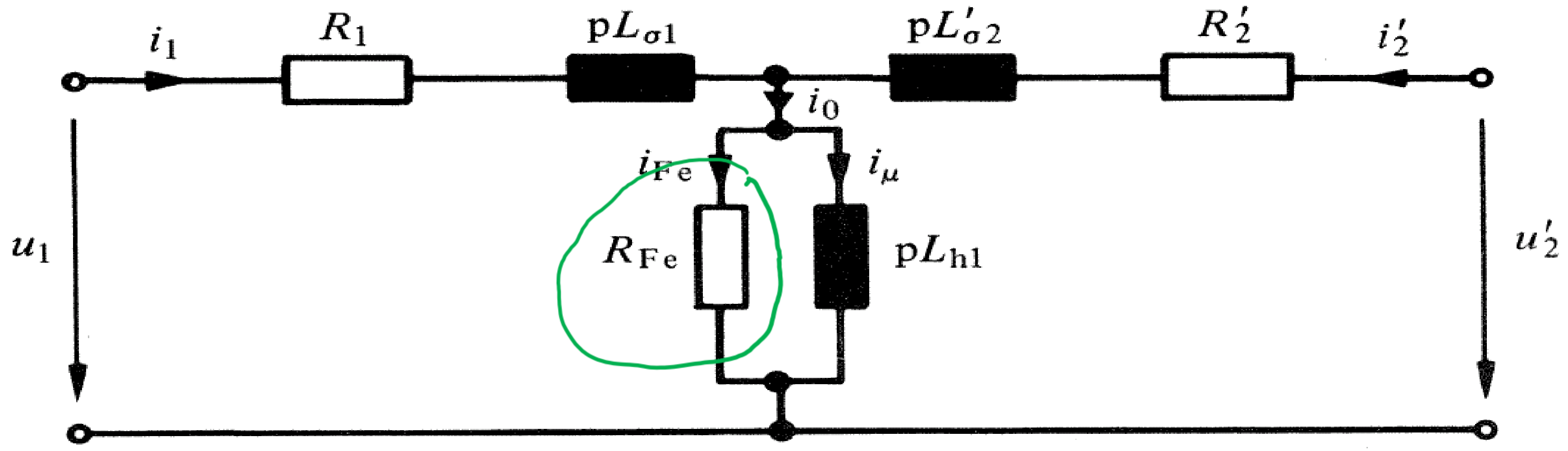
Schéma électrique équivalent



$$u_1 = R_1 i_1 + L_{\sigma 1}\frac{di_1}{dt} + L_{h1}\left(\frac{di_1}{dt} + \frac{di_2'}{dt}\right)$$

$$u_2' = R_2' i_2' + L_{\sigma 2}'\frac{di_2'}{dt} + L_{h1}\left(\frac{di_1}{dt} + \frac{di_2'}{dt}\right)$$

Pertes fer



Régime permanent (sinus)

$$\underline{U}_1 = R_1\underline{I}_1 + j\omega L_{\sigma 1}\underline{I}_1 + j\omega L_{h1}\left(\underline{I}_1 + \underline{I}_2'\right)$$

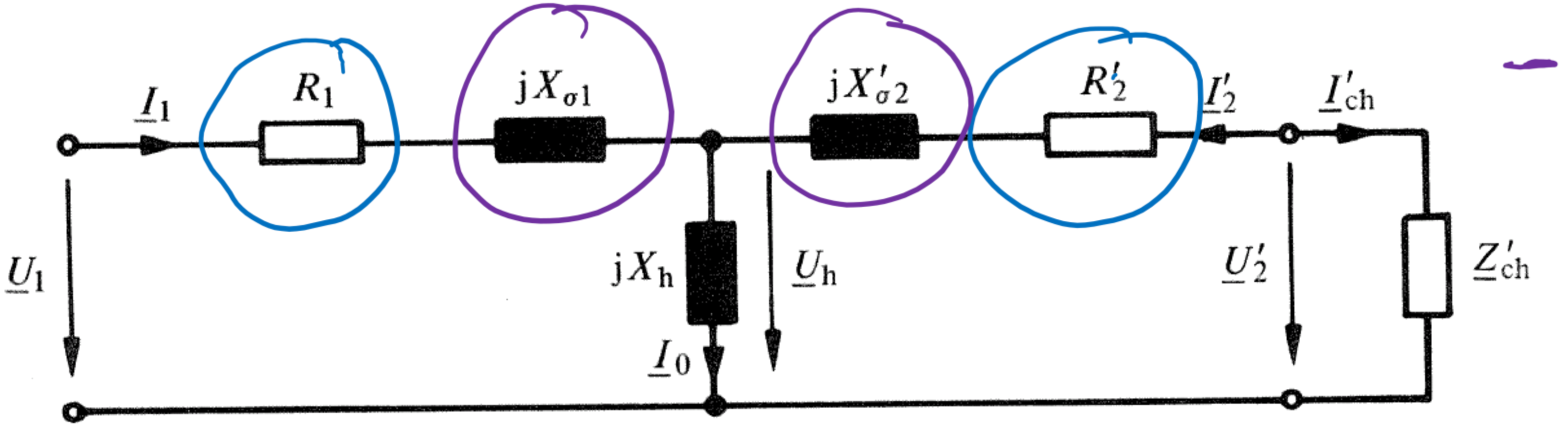
$$= R_1\underline{I}_1 + jX_{\sigma 1}\underline{I}_1 + jX_h\left(\underline{I}_1 + \underline{I}_2'\right)$$

$$\underline{U}_2' = R_2'\underline{I}_2' + j\omega L_{\sigma 2}'\underline{I}_2' + j\omega L_{h1}\left(\underline{I}_1 + \underline{I}_2'\right)$$

$$R_2'\underline{I}_2' + jX_{\sigma 2}'\underline{I}_2' + jX_h\left(\underline{I}_1 + \underline{I}_2'\right)$$

– perdas

– fugas



$X_h = \omega L_h$