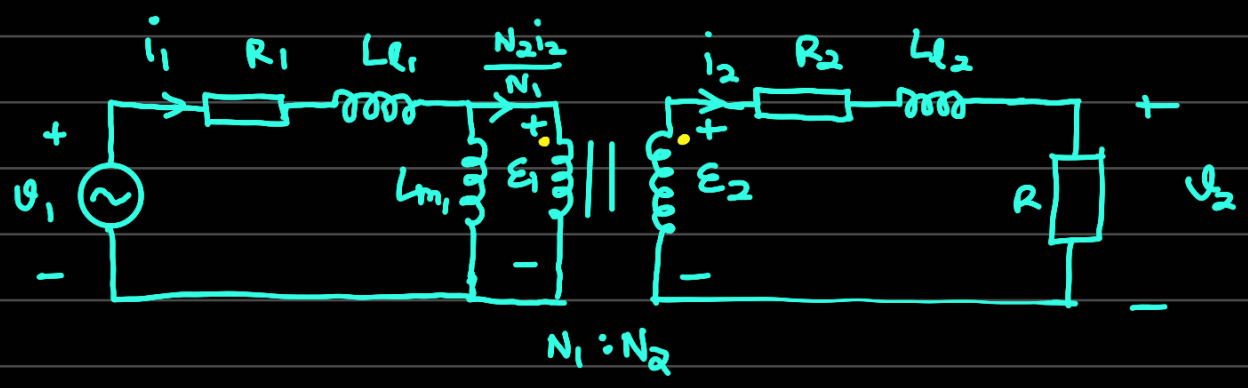
Day - 19

→ **Transformers:**



Steady-state equivalent circuit of transformer.

$$\psi_1 = N_1 \phi_1 = N_1 (\phi_{L_1} + \phi_m)$$

$$= N_1 \phi_{L_1} + N_1 \phi_m$$

$$= L\ell_1 i_1 + N_1 \left(\frac{N_1 i_1 - N_2 i_2}{\mathcal{R}_c} \right)$$

$$= \left(L\ell_1 + \frac{N_1^2}{\mathcal{R}_c} \right) i_1 - \frac{N_1 N_2}{\mathcal{R}_c} i_2$$

$$= (L\ell_1 + \underbrace{L_{m_1}}_{L_{m_1}}) i_1 - L_{12} i_2$$

$(L\ell_1 + L_{m_1})$: Self-inductance of coil 1 (L_{11})

L_{12} : mutual inductance between coils 1 and 2.

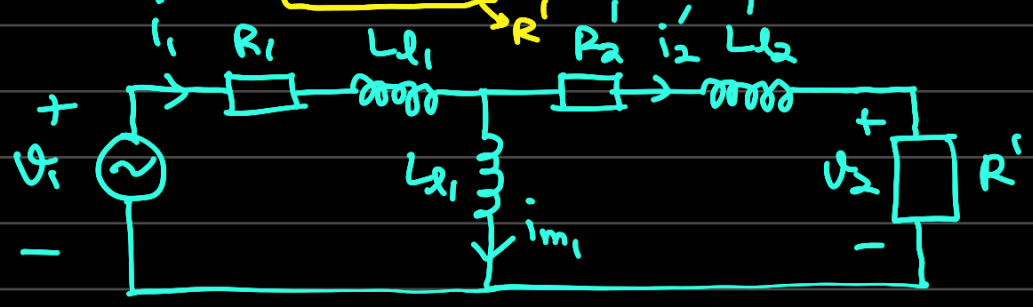
$$\psi_2 = (L\ell_2 + L_{m_2}) i_2 - L_{21} i_1$$

$$\mathcal{E}_2 = i_2 R_2 + L\ell_2 \frac{di_2}{dt} + i_2 R$$

$$\frac{N_2}{N_1} \mathcal{E}_1 = \frac{N_1}{N_2} i_2' R_2 + L\ell_2 \frac{N_1}{N_2} \frac{di_2'}{dt} + \frac{N_1}{N_2} i_2' R$$

$$\Rightarrow e_1 = \left(\frac{N_1}{N_2}\right)^2 R_2 i_2' + \left(\frac{N_1}{N_2}\right)^2 L_{l_2} \frac{di_2'}{dt} + \left(\frac{N_1}{N_2}\right)^2 R i_2'$$

R_2' , L_{l_2}' , R'

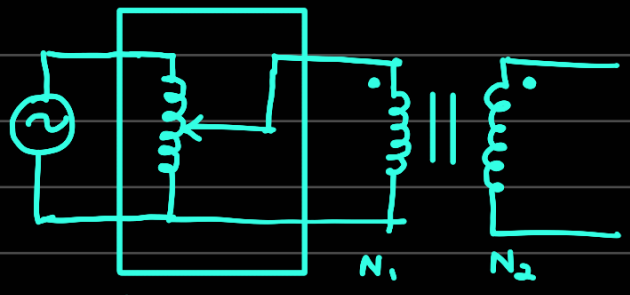


$$\left(i_2' = \frac{N_2 i_2}{N_1}\right)$$

we performed power-invariant transformation

→ **Open Circuit Test :**

2ndary winding is open (the no-load case)



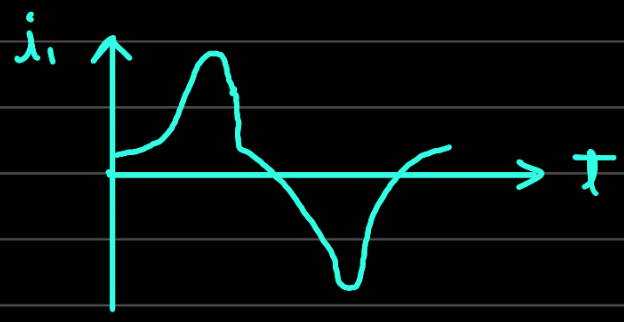
1 kVA
200/100 V

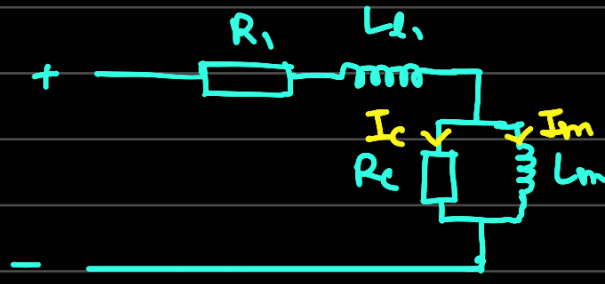
1ph Auto-transformer

single phase

- Apply rated voltage to transformer

we can't directly apply rated voltage to transformer → leads to flow of inrush current, which affects the lifetime of the device. That is why autotransformer is used.





$i_1(t) = I_c \sin\omega t + I_m \cos\omega t$

$\phi_1(t) = V_m \sin\omega t$

[R_1 and L_{l_1} may be neglected]

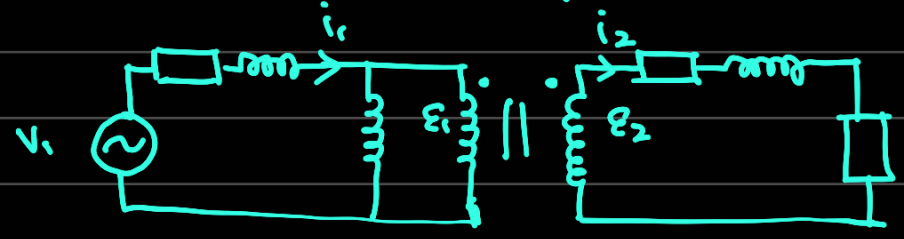
$$R_c = \frac{V_m}{I_c}, \quad L_m = \frac{V_m}{2\pi f I_m}$$

we can calculate core loss, shunt parameters.

$$\text{Core loss } (P_c) = \frac{V_m I_c}{2}$$

Standard wire gauge (SWG) ↑ ⇒ Thickness ↓

☆ i_1 has peaky nature under no-load condition But when load is applied:



V_1 is sinusoidal ⇒ ε_1 is sinusoidal

($\because V_1 \simeq \frac{d\psi}{dt}$)

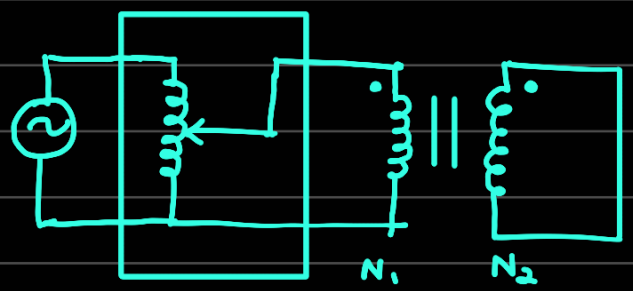
⇒ ε_2 is sinusoidal

⇒ i_2 is sinusoidal (only R-L components in secondary ckt.)

But $i_1 \sim \frac{N_1}{N_2} i_2$

$\Rightarrow$ i_1 is sinusoidal

→ **Short-circuit Test :**

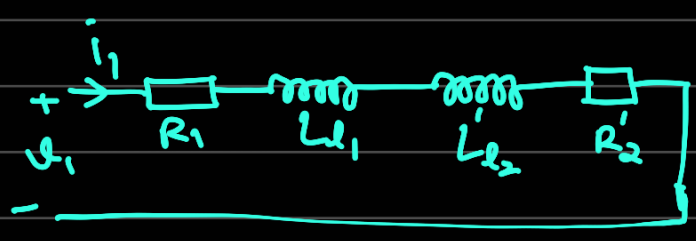


← Be careful! High current! don't apply rated voltage!

1ph Auto-transformer

single phase

- Apply low voltage so that rated current flows in the circuit.
- Since $V_m \downarrow \Rightarrow \phi_m \downarrow \Rightarrow$ core loss $\downarrow \Rightarrow I_{nl} \downarrow$ (no load)



$$v_1(t) = V_m \sin\omega t$$

$$i_1(t) = I_1 \sin(\omega t - \theta)$$

$$= I_1 \cos\theta \sin\omega t - I_1 \sin\theta \cos\omega t$$

$$\frac{V_m \angle 0^\circ}{I_1 \angle -\theta} = R_1 + R_2' + j(X_{l_1} + X'_{l_2})$$

$$\Rightarrow R_1 + R_2 = \frac{V_m}{I_1 \cos\theta}, \quad X_{l_1} + X'_{l_2} = \frac{V_m}{I_1 \sin\theta}$$