Ministry of Higher Education
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تكنولوجيا الكهرباء

Electrical Technology

Lecture 6

Lecture Name: TRANSFORMER

By

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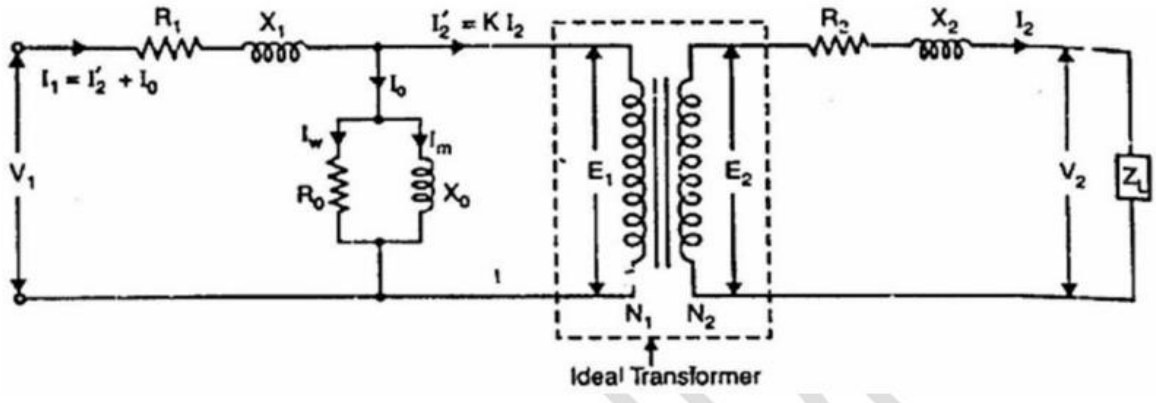
Equivalent Circuit of Transformer

(حفظThe equivalent circuit of transformer is shown in the figure)



Where:

R1: primary winding resistance

R2: secondary winding resistance

X1: leakage reactance of primary winding

X2: leakage reactance of the secondary winding

Ro: represents the core losses (hysteresis and eddy current losses)

Xo: represents magnetizing reactance of the core

Im: magnetizing current (to create magnetic flux in the core)

Iw: active current (required to supply the core losses)

Io = no load primary current

<u>NOTE1</u>: Parallel circuit R0 - X0 is the no-load equivalent circuit of the transformer or called exciting circuit

No load Components

The no-load primary current I_o has two components, namely I_m and I_w.

Where I_m = magnetizing component = $I_o \sin \varphi_o$
and I_w = core-loss component = $I_o \cos \varphi_o$.

- **I_w supplies for the no-load losses and is assumed to flow through the no-load resistance which is also known as core-loss resistance (R_o).**
- **The magnetizing component, I_m is assumed to be flowing through a reactance which is known as magnetizing reactance, X_o.**
- **The parallel combination of R_o and X_o is also known as the exciting circuit.**

From the **equivalent circuit of transformer**,

$R_o = V_1/I_w$ and $X_o = V_1/I_m$.

<u>NOTE2</u>:

The equivalent circuit has created two normal electrical circuits separated only by an ideal transformer whose function is to change values according to the equation:

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I'_2}{I_2}$$

<u>NOTE3:</u>

If ZL is the external load across the secondary circuit, voltage E2 induced in the secondary by mutual flux will produce a secondary current I2, hence

$$V_2 = E_2 - I_2(R_2 + jX_2) = E_2 - I_2 Z_2$$

Similarly supply voltage can be given as:

$$V_1 = -E_1 + I_1(R_1 + jX_1) = -E_1 + I_1 Z_1$$

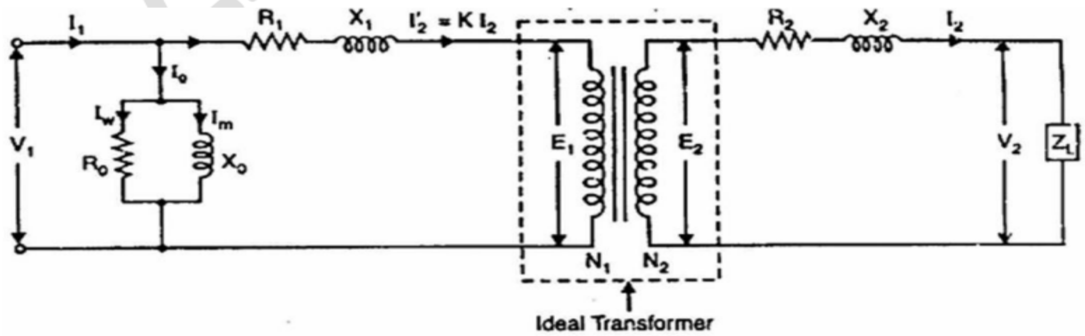
NOTE4:

When the transformer is loaded to carry the secondary current I2, the primary current consists of two components: ► I_0 to provide magnetizing current and the current required to supply the core losses.

► primary current I'_2 (= K I_2) required to supply the load connected to the secondary

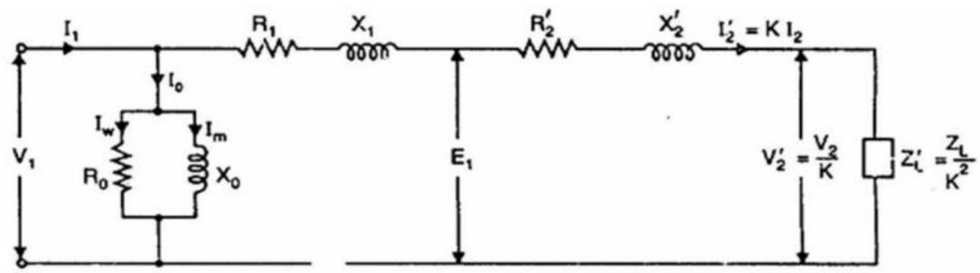
Simplified Equivalent Circuit of a Loaded Transformer(حفظ)

If I_0 of a transformer is small as compared to the rated primary current I_1, voltage drops in R_1 and X_1 due to I_0 are negligible. Hence, the exact equivalent, circuit can be simplified by transferring the shunt circuit R_0 - X_0 to the input terminals as shown below:

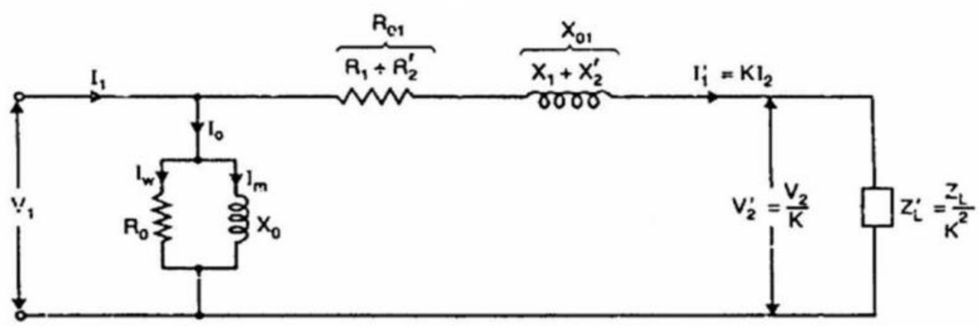


If all the secondary quantities are referred to the primary, we can get the

simplified equivalent circuit of the transformer referred to the primary as shown below(حفظ)



(i)



From the above circuit:

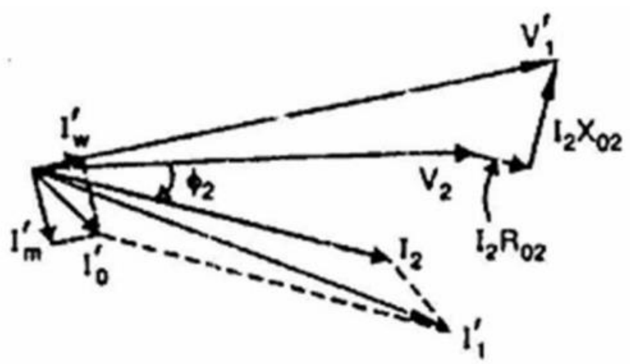
$R'_1 = K^2 R_1$; $X'_1 = K^2 X_1$; $V'_2 = K\ V_1$; $I'_1 = \frac{I_1}{K}$

$$Z_{02} = R_{02} + j\,X_{02}$$

Where $R_{02} = R_2 + R'_1$; $X_{02} = X_2 + X'_1$

Hence the phasor diagram can be obtained as:

Based



Based on the above phasor diagram we can notice the following:

- The referred value of load voltage V_2 is chosen as the reference phasor.
- I_2 is lagging V_2 by phase angleθ_2.
- $I_2\ R_{02}$ is in phase with I_2 and the voltage drop $I_2\ X_{02}$, leads I_2 by 90°.
- I'_W is in phase with V'_1 while I'_m lags behind V'_1 by 90°.
- The phasor sum of I'_W and I'm is I'_0.
- The phasor sum of I'_0 and I_2 is the input current I'_1.

Exp: A transformer has 1200 primary turns and 200 secondary turns. The primary and secondary resistances are 0.2 Ω and 0.02 Ω respectively and the corresponding leakage reactance are 1.2 Ω and 0.05 Ω respectively. Calculate (a) the equivalent resistance, reactance and impedance referred to the primary winding, and (b) the phase angle of the impedance

(a) **Equivalent resistance,** $R_e = R_1 + R_2\left(\frac{V_1}{V_2}\right)^2 = 0.2 + 0.02\left(\frac{1200}{200}\right)^2$ = **0.92 Ω**

Equivalent reactance, $X_e = X_1 + X_2\left(\frac{V_1}{V_2}\right)^2 = 1.2 + 0.05\left(\frac{1200}{200}\right)^2$ = **3.0 Ω**

Equivalent impedance, $Z_e = \sqrt{R_e^{\,2} + X_e^{\,2}} = \sqrt{0.92^2 + 3.0^2}$ **= 3.138 Ω** or **3.14 Ω**

(b) $\cos\phi_e = \frac{R_e}{Z_e} = \frac{0.92}{3.138}$ and **phase angle of impedance,** $\phi_e = \cos^{-1}\left(\frac{0.92}{3.138}\right) =$ **72.95°**