Ministry of Higher Education
and Scientific Research
Al- Mustaqbal University College
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تكنولوجيا الكهرباء

Electrical Technology

Lecture 5

Lecture Name: TRANSFORMER

By

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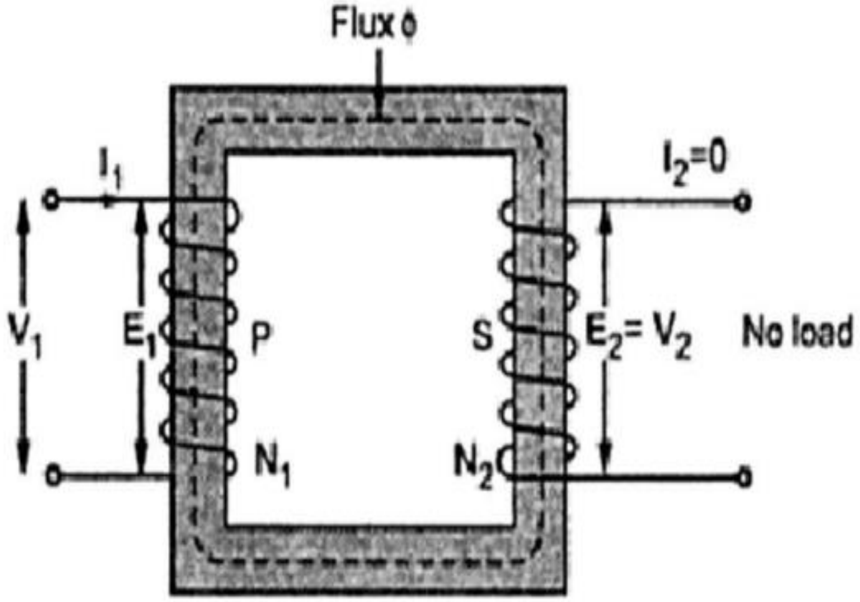
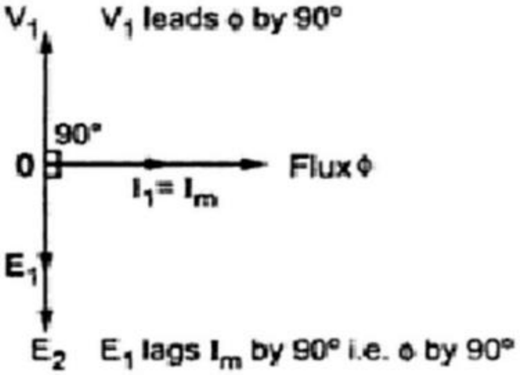
Ideal Transformer on No Load

For no load I2 =0. I1 is just necessary to produce flux in the core, which is called magnetizing current denoted as Im.

Im is very small Hence E1 and E2 are in antiphase with V1 but equal in magnitude and E1 and E2 are in phase.



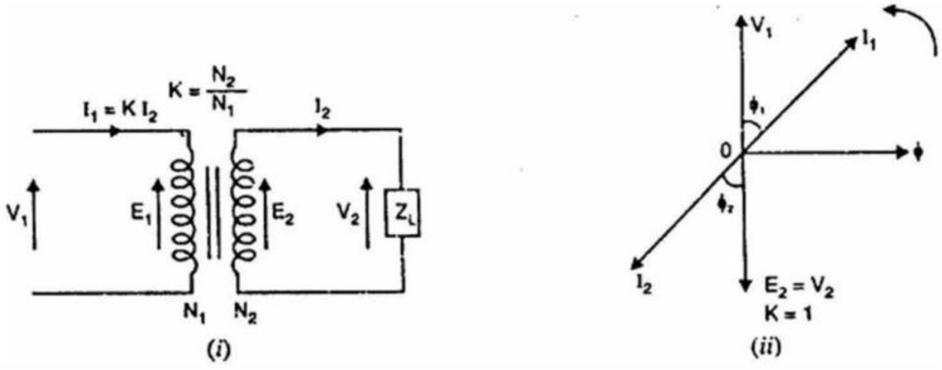
This can be illustrated in the phase diagram as shown below:



Phasor diagram for ideal transformer on no load

Ideal Transformer on Load

Let us connect a load ZL across the secondary of an ideal transformer as shown in Figure below: The secondary emf E2 will cause a current I2 to flow through the load:



$$I_2 = \frac{E_2}{Z_L} = \frac{V_2}{Z_L}$$

PRACTICAL TRANSFORMER

A differs from the ideal transformer in many respects. The practical transformer has

(i) iron losses

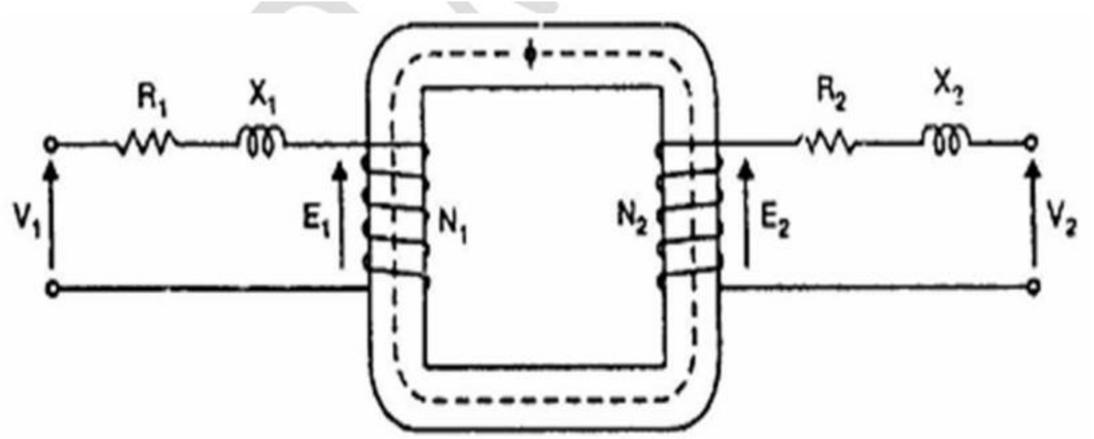
(ii) winding resistances and

(iii) magnetic leakage, giving rise to leakage reactance.

(i) Iron losses. Since the iron core is subjected to alternating flux, there occurs eddy current and hysteresis loss in it.

(ii) Winding resistances. Since the windings consist of copper conductors, it immediately follows that both primary and secondary will have winding resistance.

The primary resistance R1 and secondary resistance R2 act in series with the respective windings as shown below:



(iii) Leakage reactance. Both primary and secondary currents produce flux. The flux Φ which links both the windings is the useful flux However, primary current would produce some flux Φ which would not link the secondary winding and is called mutual flux.

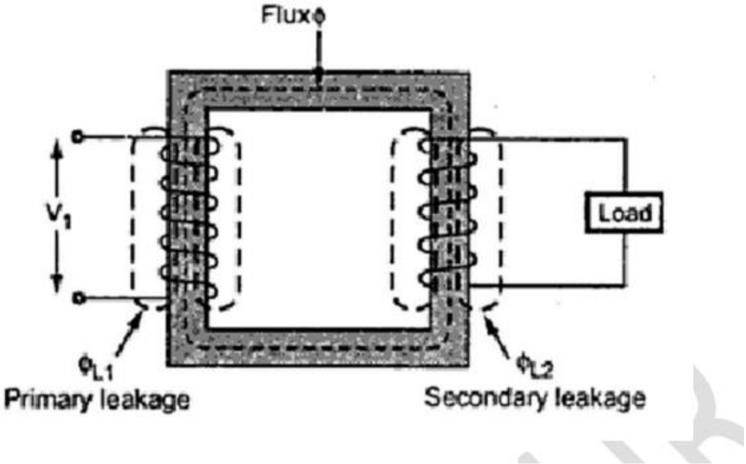
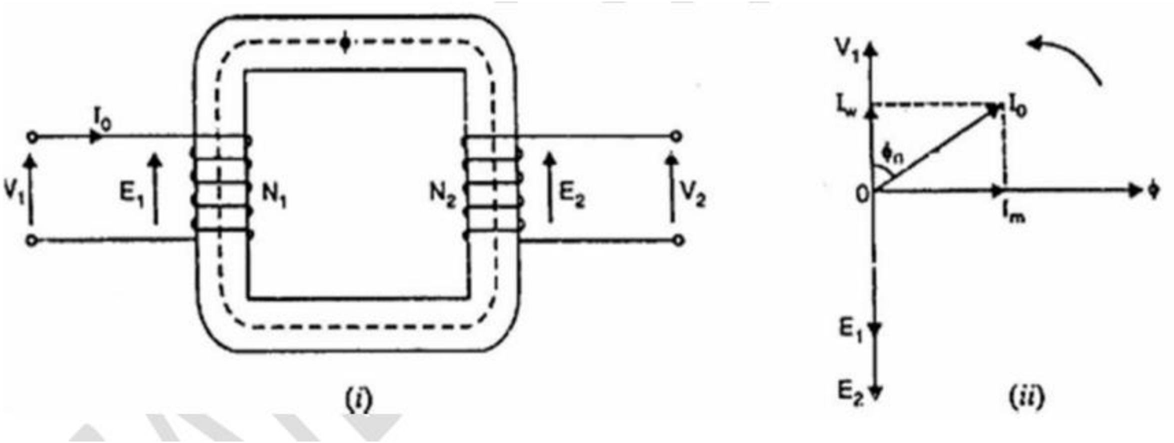


Figure : Leakage reactance

Practical Transformer on No Load

Consider the figure below:



(i) (ii)

The primary will draw a small current I0 to supply (i) the iron losses and (ii) a very small amount of copper loss in the primary.

The no-load primary current I0 can be resolved into two rectangular components:

(i) The component I_W in phase with the applied voltage V_1. This is known as active or working or iron loss component and supplies the iron loss and a very small primary copper loss.

$$I_W = I_0 \cos \phi_0$$

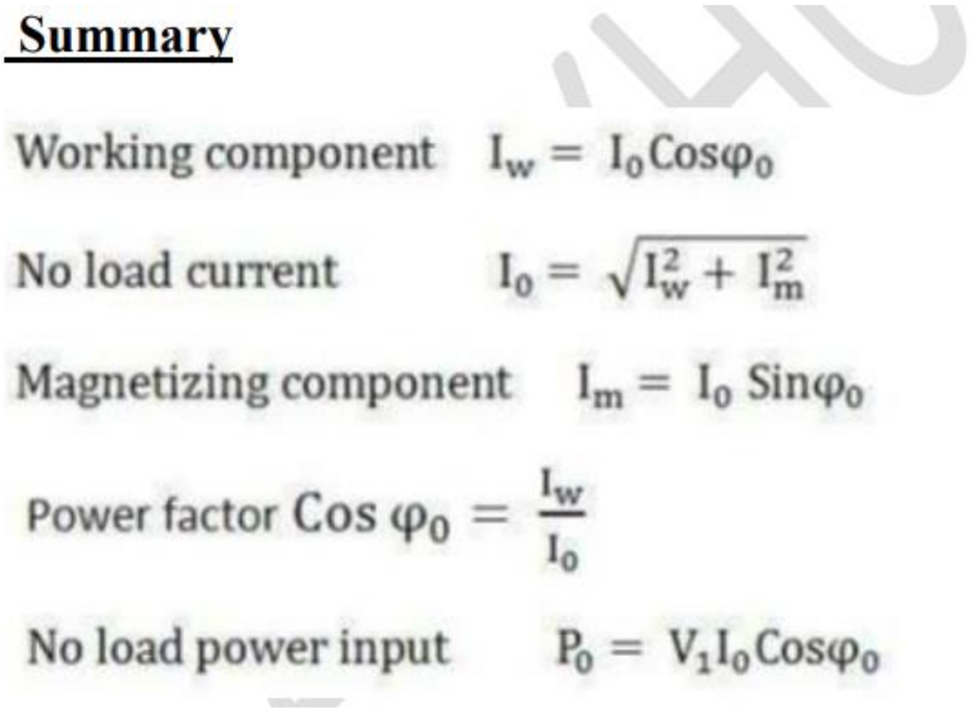
(ii) The component I_m lagging behind V_1 by 90° and is known as magnetizing component. It is this component which produces the mutual flux ϕ in the core.

$$I_m = I_0 \sin \phi_0$$

Clearly, I_0 is phasor sum of I_m and I_W,

$$\therefore \quad I_0 = \sqrt{I_m^2 + I_W^2}$$

No load p.f., $\cos\phi_0 = \dfrac{I_W}{I_0}$



Summary

Working component $I_w = I_0 \cos\varphi_0$

No load current $I_0 = \sqrt{I_w^2 + I_m^2}$

Magnetizing component $I_m = I_0 \sin\varphi_0$

Power factor $\cos\varphi_0 = \frac{I_w}{I_0}$

No load power input $P_0 = V_1 I_0 \cos\varphi_0$

Exp.

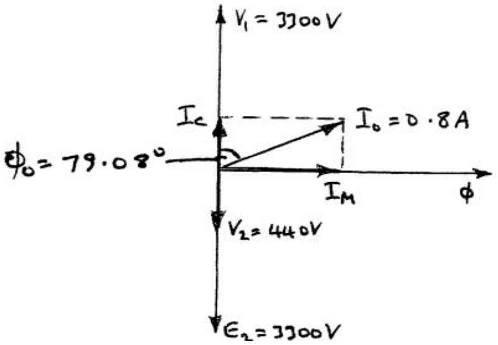
A 3300 V/440 V, single-phase transformer takes a no-load current of 0.8 A and the iron loss is 500 W. Draw the no-load phasor diagram and determine the values of the magnetizing and core loss components of the no-load current.

$V_1 = 3300\,V$, $V_2 = 440\,V$ and $I_O = 0.8A$

Core or iron loss $= 500 = V_1 I_O \cos\phi_O$ i.e. $500 = (3300)(0.8)\cos\phi_O$

from which, $\cos\phi_O = \dfrac{500}{(3300)(0.8)} = 0.1894$ and $\phi_O = \cos^{-1} 0.1894 = 79.08°$

The no-load phasor diagram is shown below.



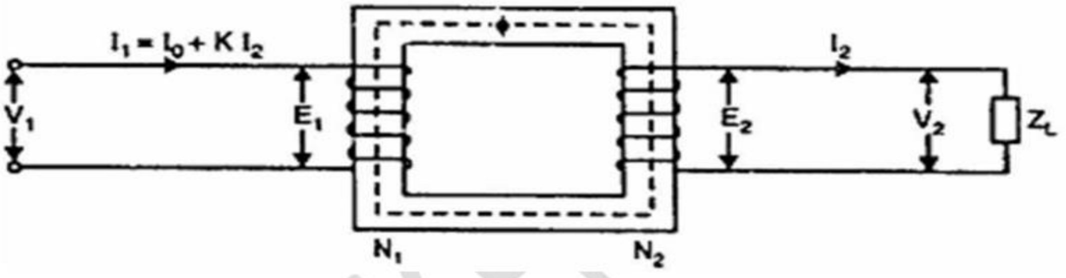
Magnetizing component, $I_M = I_O \sin\phi_O = 0.8 \sin 79.08°$ $=$ **0.786 A**

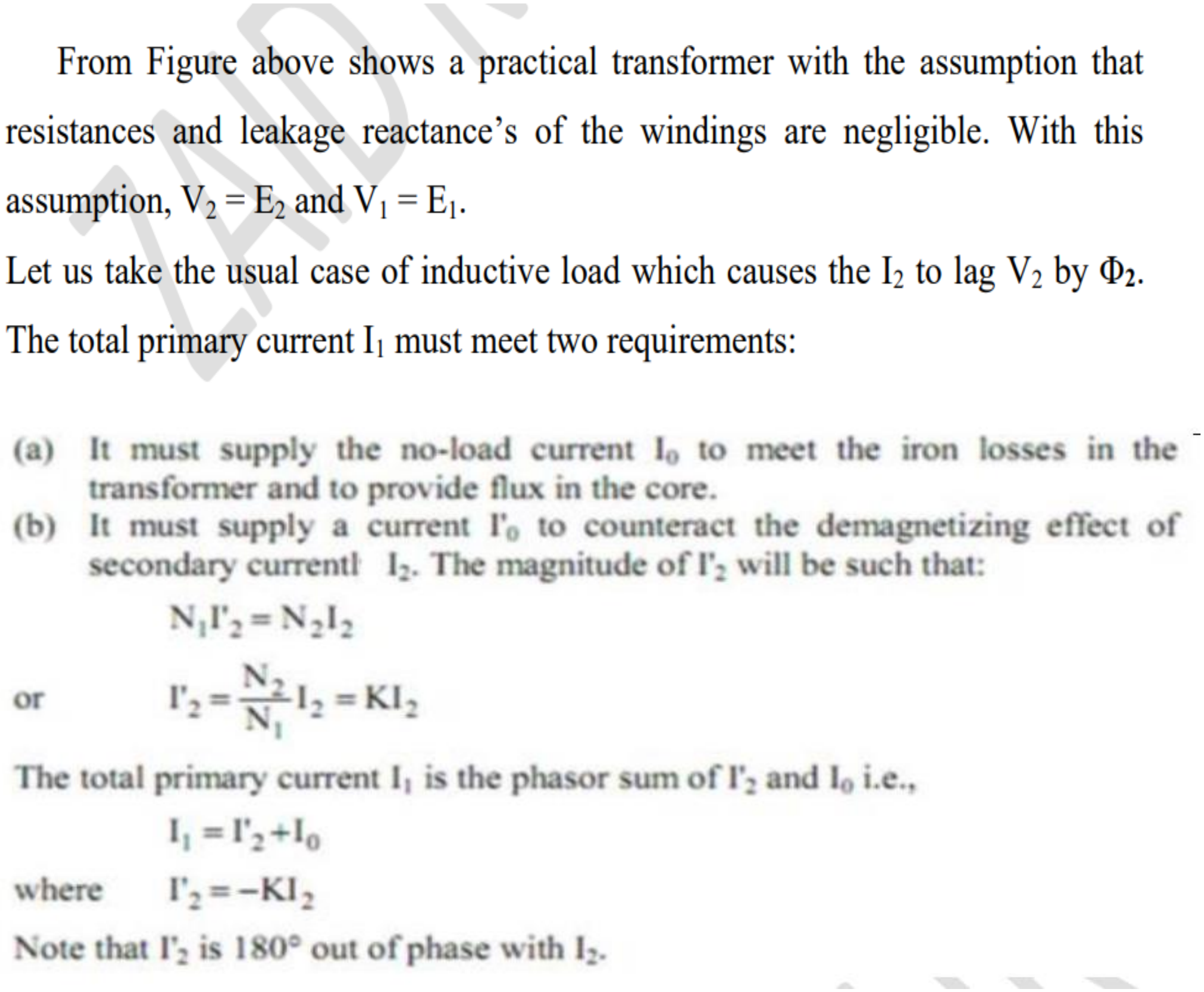
Core loss component, $I_C = I_O \cos\phi_O = 0.8(0.1894)$ $=$ **0.152 A**

Practical Transformer on Load

We shall consider two cases (i) when such a transformer is assumed to have no winding resistance and leakage flux (ii) when the transformer has winding resistance and leakage flux.

No winding resistance and leakage flux





From Figure above shows a practical transformer with the assumption that resistances and leakage reactance's of the windings are negligible. With this assumption, $V_2 = E_2$ and $V_1 = E_1$.

Let us take the usual case of inductive load which causes the I_2 to lag V_2 by Φ_2.

The total primary current I_1 must meet two requirements:

(a) It must supply the no-load current I_0 to meet the iron losses in the transformer and to provide flux in the core.

(b) It must supply a current I'_0 to counteract the demagnetizing effect of secondary currentl I_2. The magnitude of I'_2 will be such that:

$$N_1 I'_2 = N_2 I_2$$

or $$I'_2 = \frac{N_2}{N_1} I_2 = K I_2$$

The total primary current I_1 is the phasor sum of I'_2 and I_0 i.e.,

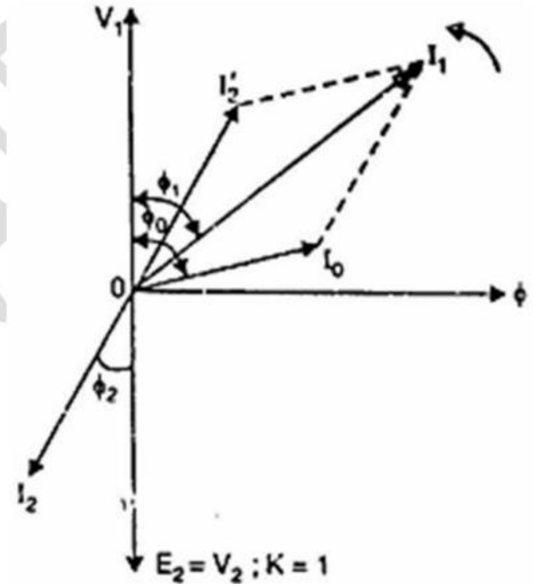
$$I_1 = I'_2 + I_0$$

where $$I'_2 = -K I_2$$

Note that I'_2 is 180° out of phase with I_2.

Phasor Diagram:

Both E1 and E2 lag behind the mutual flux Φ by 90°. The current I'2 represents the primary current to neutralize the demagnetizing effect of secondary current I2. Now I'2 = K I2 and is antiphase with I2. I0 is the no-load current of the transformer. The phasor sum of I'2 and I0 gives the total primary current I1. Note that in drawing the phasor diagram, the value of K is assumed to be unity so that primary phasors are equal to secondary phasors.



Transformer with resistance and leakage reactance The total primary current I1 must meet two requirements:

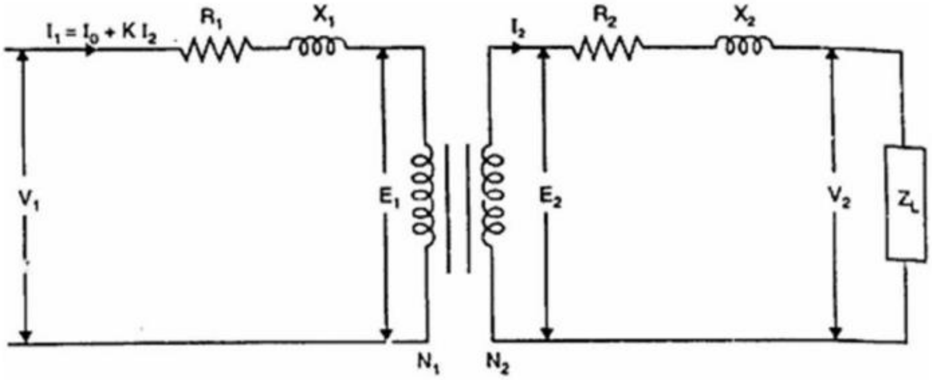
(a) It must supply the no-load current I_0 to meet the iron losses in the transformer and to provide flux in the core.

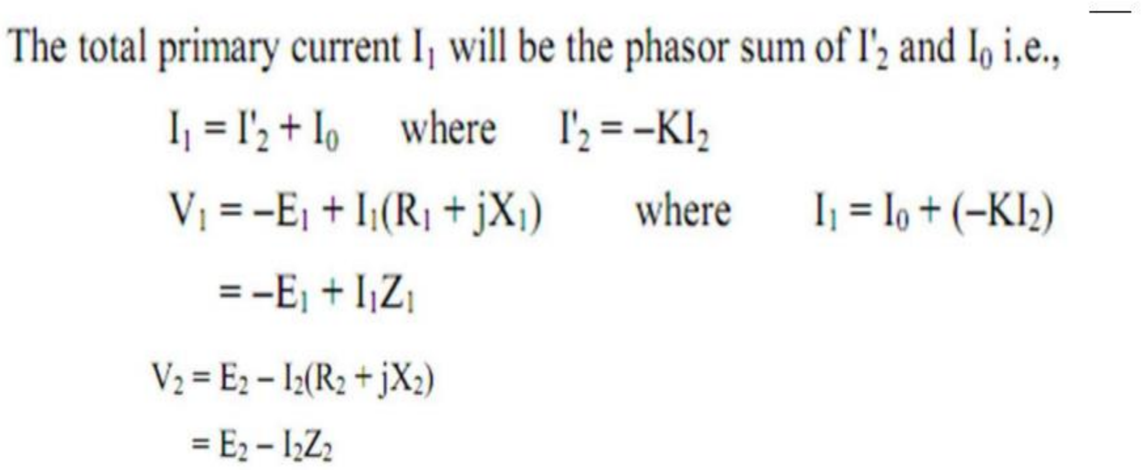
(b) It must supply a current I'_2 to counteract the demagnetizing effect of secondary current I_2. The magnitude of I'_2 will be such that:

$$N_1 I'_2 = N_2 I_2$$

or

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





The total primary current I_1 will be the phasor sum of I'_2 and I_0 i.e.,

$$I_1 = I'_2 + I_0 \quad \text{where} \quad I'_2 = -KI_2$$

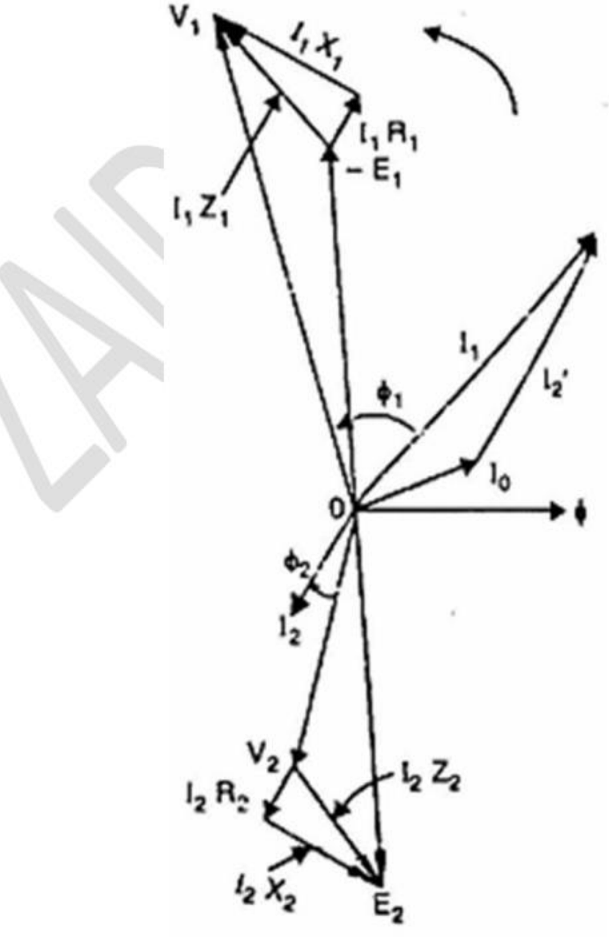
$$V_1 = -E_1 + I_1(R_1 + jX_1) \quad \text{where} \quad I_1 = I_0 + (-KI_2)$$

$$= -E_1 + I_1Z_1$$

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

$$= E_2 - I_2Z_2$$

Phasor Diagram Note that counter emf that opposes the applied voltage V1 is -E1. Therefore, if we add I1R1 (in phase with I1) and I1 X1 (90° ahead of I1) to -E1, we get the applied primary voltage V1. The phasor E2 represents the induced emf in the secondary by the mutual flux. The secondary terminal voltage V2 will be what is left over after subtracting I2R2 and I2X2 from E2.


V_1
I_1X_1
I_1R_1
$-E_1$
I_1Z_1
I_1
I_2'
ϕ_1
I_0
0
ϕ
ϕ_2
I_2
V_2
I_2R_2
I_2Z_2
I_2X_2
E_2