Basic Electrical Engineering KEE101/201

Department of Engineering

Uttar Pradesh Textile Technology Institute

Session 2019-20

Semester-II

Faculty: Dr Indra Prakash Mishra

Ideal Vs Practical Transformer

- Coil resistance is zero (Lossless)
- Core material has infinite permeability
- No flux Leakages (All flux is linked with the core)
- No eddy current losses, No Hysteresis Losses.

- Coil resistance is present though it is low.
- Core material has finite permeability
- Some Flux Leakages occur through air. Represented by Leakage reactance.
- Eddy current and Hysteresis Losses are present. (core or Fixed Losses)

Ideal Transformer on Load

- $V_1 = Applied\ ac\ Voltage(RMS)$
- $E_1 = 4.44 f \phi_m N_1$
- $E_2 = 4.44 f \phi_m N_2$
- $E_1 = Induced\ Voltage\ in\ Primary(RMS)$
- $E_2 = Induced\ Voltage\ in\ Secondary(RMS)$
- $V_2 = Terminal\ ac\ secondary\ Voltage(RMS)$
- $\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{V_1}{V_2}$

Ideal Transformer on Load

- *Excitation current is zero for primary Ni*
- $I_2 = Secondary\ current\ when\ load\ is\ connected$
- $N_2 I_2 = Secondary\ mmf$
- $N_1 I_1 = Primary\ counter\ mmf$
- $N_2 I_2 = N_1 I_1$
- $\frac{N_1}{N_2} = \frac{I_2}{I_1}$

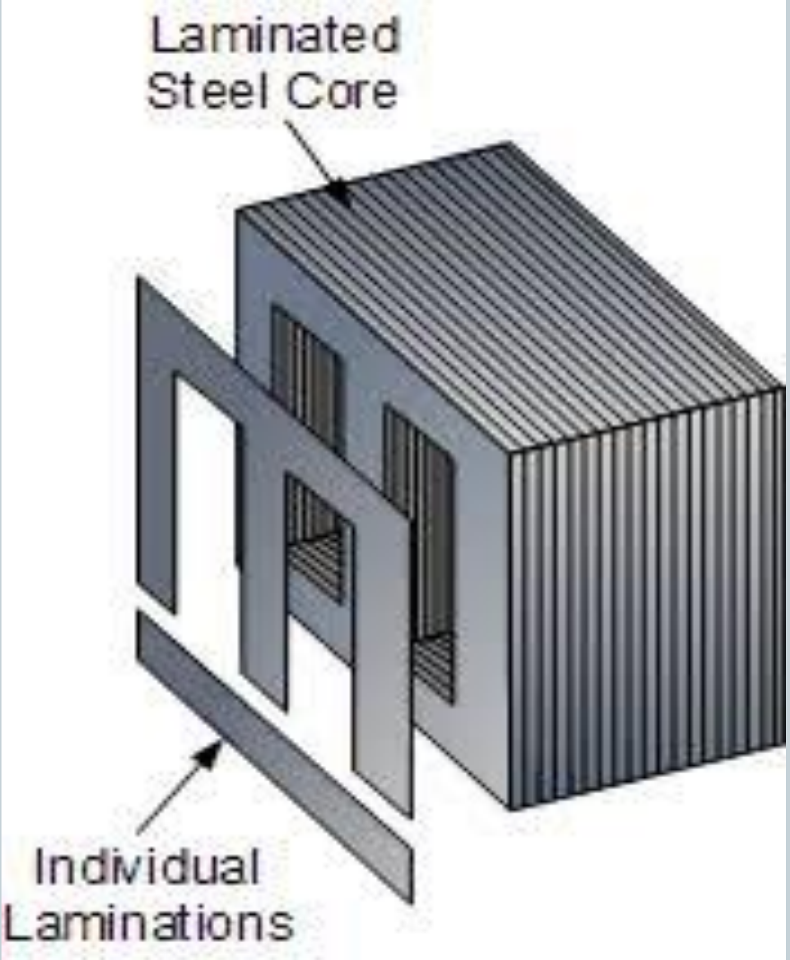
Ideal Vs Practical Transformer

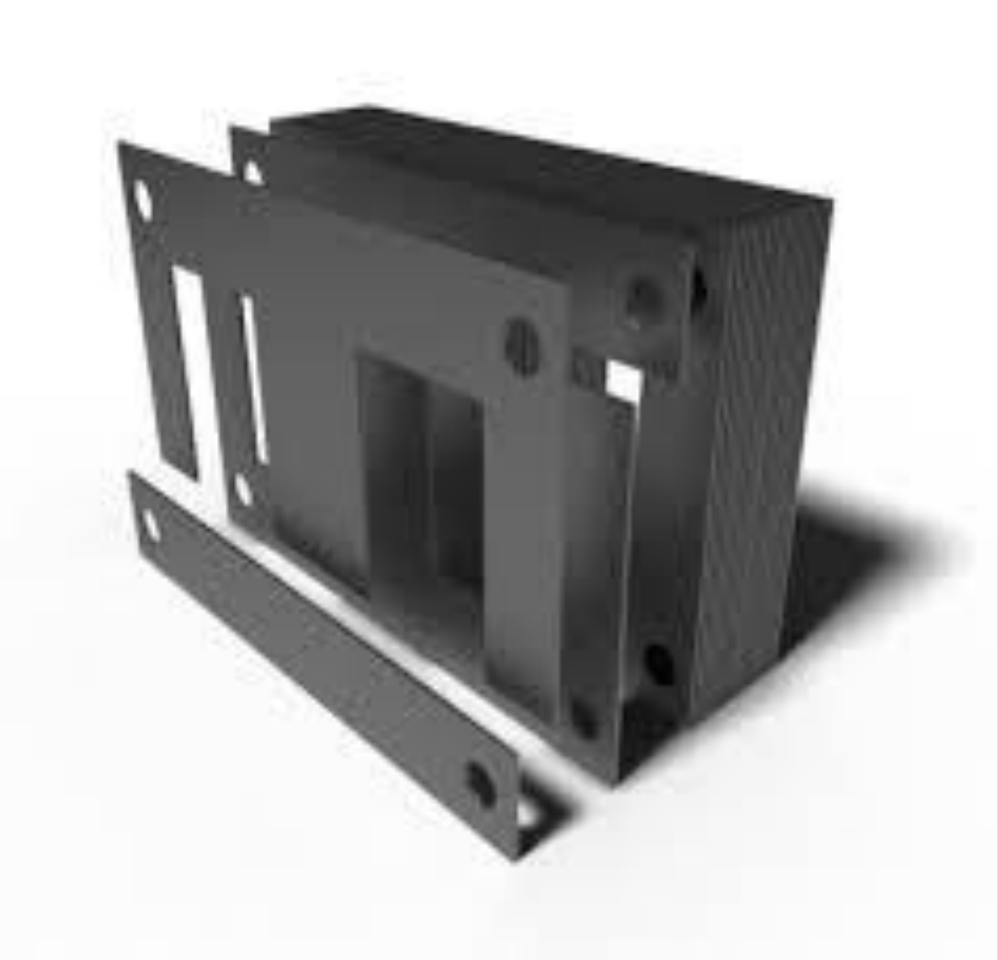
- Coil resistance is zero (Lossless)
- Core material has infinite permeability
- No flux Leakages (All flux is linked with the core)
- No eddy current losses, No Hysteresis Losses.

- Coil resistance is present though it is low.
- Core material has finite permeability
- Some Flux Leakages occur through air. Represented by Leakage reactance.
- Eddy current and Hysteresis Losses are present. (core or Fixed Losses)

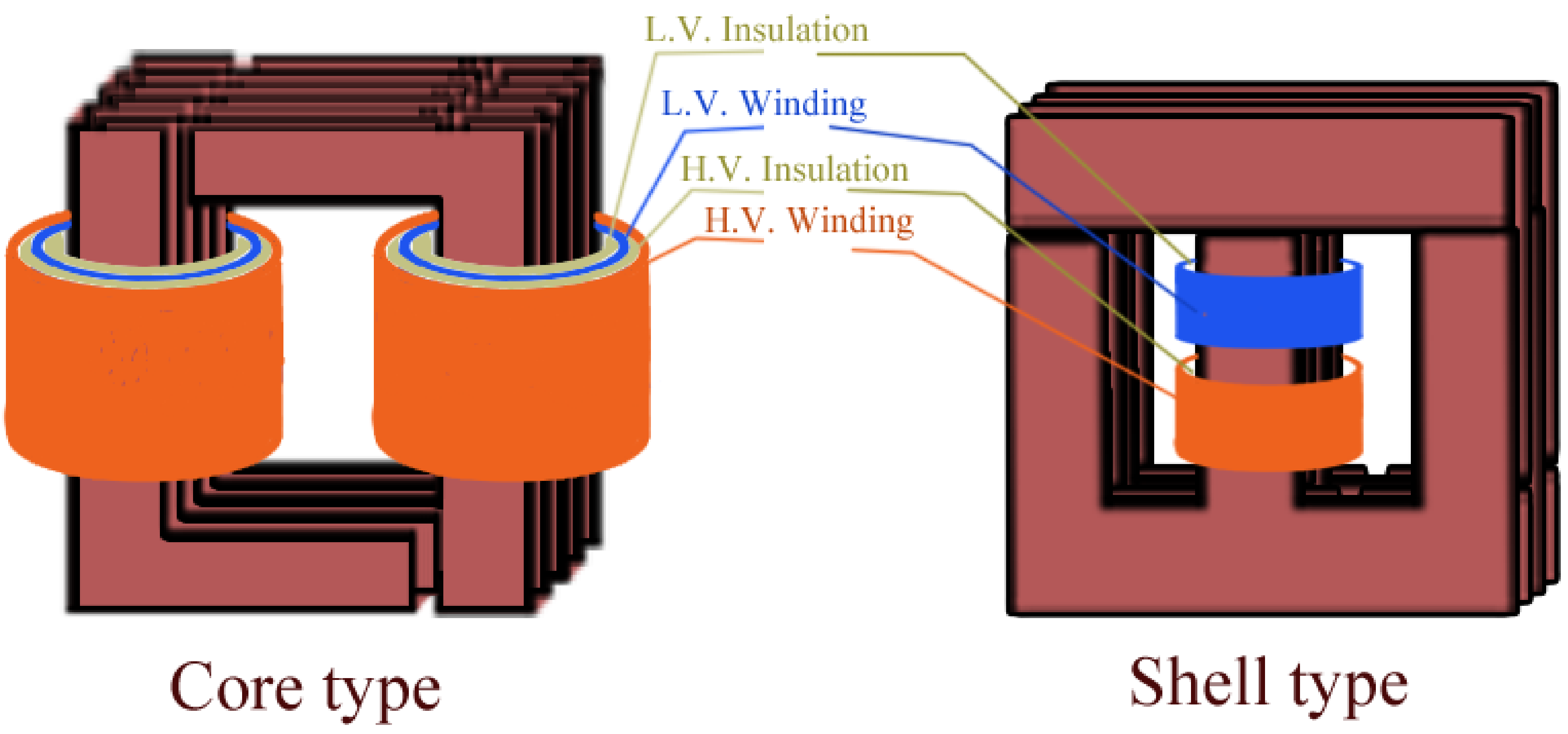
Practical 1-Phase Transformer: Construction

Transformer: Construction





Transformer: Construction



Transformer: Important Parts

- Core
  - Core Type
  - Shell Type
- Winding
  - LV (Low Voltage) Winding
  - HV(High Voltage) Winding
- Insulation
  - Major Insulation
  - Minor Insulation
- Protection

Windings on side limbs Enclose the core

Core Encloses the Windings on Central Limb

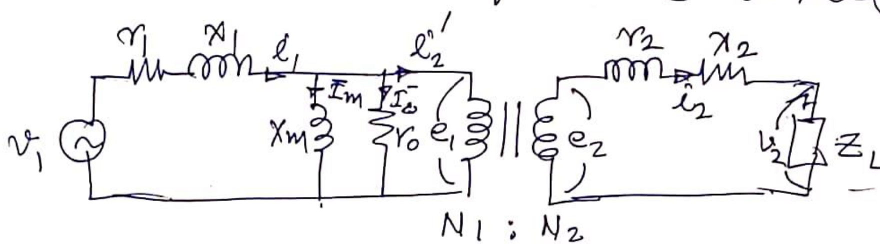
Thick Wire More current to carry

Thin Wire, Less Current

Between Windings and Container

Between winding turns and Layers

Ideal Transformer Vs Practical



x_m = magnetizing reactance to account for $\bar{I}_m$ (i_m) - the magnetizing current when some finite reluctance will be there in core of a practical transformer

r_0 = Core loss resistor to account for the losses in eddy current and hysteresis loss. (current i_0 is there).

$$\bar{I}_M + \bar{I}_0 = \bar{I}_e$$

$$\bar{V}_1 = r_1 \bar{I}_1 + j X_1 \bar{I}_1 + \bar{E}_1$$

$$\bar{E}_2 = r_2 \bar{I}_2 + j X_2 \bar{I}_2 + \bar{V}_2$$

$$\bar{V}_2 = I_2 Z_L$$

$$\bar{I}_1 = \bar{I}_2' + \bar{I}_e$$

$$\bar{I}_m = E_1 / jX_m$$

$$\bar{I}_0 = \frac{E_1}{r_0}$$

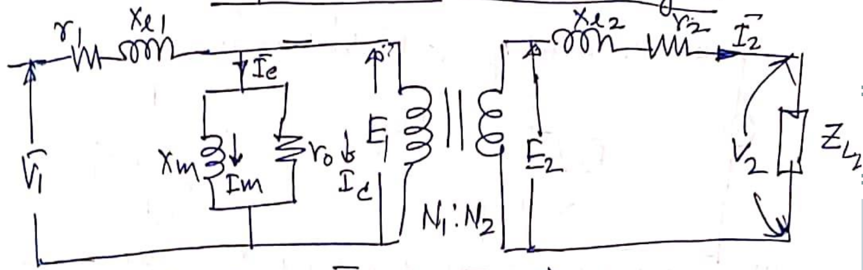
$$\bar{I}_2' = \frac{N_2}{N_1} I_2$$

Relaxing Assumptions of Ideal Transformer

And Introducing

- Coil Resistances
- Leakage Reactance
- Magnetizing Reactance
- Core Loss Resistance
- Magnetizing Current
- Core loss Current
- Primary Current
- Secondary Current
- Secondary Reflection current
- Transformer Equations
- Exact Equivalent Circuit

Equivalent Circuit Diagram



Equation 1 : $\bar{V}_1 = r_1\bar{I}_1 + j X_{e_1}\bar{I}_1 + \vec{E}_1$

Equation 2 : $\bar{E}_2 = r_2\bar{I}_2 + jX_{e_2}\bar{I}_2 + \bar{V}_2$

Equation 3 : $\bar{V}_2 = \bar{I}_2 Z_L$

$$\bar{E}_2 = (r_2 + jX_{e_2})\bar{I}_2 + \bar{V}_2 = (r_2 + jX_{e_2} + Z_{L_2})\bar{I}_2$$

$$\bar{I}_2' = \frac{N_2}{N_1}\bar{I}_2$$

$$\bar{I}_2' = \frac{N_2}{N_1}\frac{E_2}{(r_2 + jX_{e_2} + Z_{L_2})}$$

$$= \left(\frac{N_2}{N_1}\right)^2 \frac{\frac{N_1}{N_2}\bar{E}_2}{(r_2 + jX_{e_2} + Z_{L_2})} \quad \left(\frac{N_1}{N_2}\bar{E}_2 \rightarrow \bar{E}_1\right)$$

$$\bar{I}_2' = \frac{\bar{E}_1}{\left(\frac{N_1}{N_2}\right)^2 \left\{ r_2 + jX_{e_2} + Z_{L_2} \right\}}$$

if this ~~resist~~ impedance is multiplied by $\left(\frac{N_1}{N_2}\right)^2$ the combined impedance may be seen to be connected across $\bar{E}_1$, replacing ideal transformer and the secondary circuit.

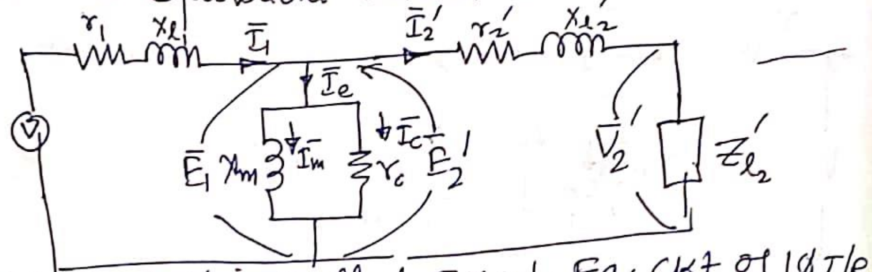
Introducing

The Following Quantities referred to primary
- Secondary Leakage Reactance
- Secondary Resistance
- Secondary Load Impedance
- Transformer Equations
- Exact Equivalent Circuit

@ipmishra

Referred Impedances.

So the equivalent circuit becomes:—



This circuit is called Exact Eq. ckt of 1φ T/R

where $r_2' = \left(\frac{N_1}{N_2}\right)^2 r_2$

$x_{l_2}' = \left(\frac{N_1}{N_2}\right)^2 x_{l_2}$

$Z_{l_2}' = \left(\frac{N_1}{N_2}\right)^2 Z_{L_2}$

These quantities are called secondary impedances referred to primary.

if we check power consumption in secondary resistance:

In actual circuit it is $= I_2^2 r_2$

In exact eq. ckt it is $= (I_2')^2 \cdot r_2'$

$$= \left(\frac{N_2}{N_1} I_2\right)^2 \left(\frac{N_1}{N_2}\right)^2 \cdot r_2$$

$$= \frac{N_2^2}{N_1^2} I_2^2 \cdot \frac{N_1^2}{N_2^2} \cdot r_2$$

$$= I_2^2 r_2$$

which is same as in actual ckt.

Referred voltages
&
Power in referred ckt (kVA this time)

$\bar{V}_2 = \bar{I}_2 Z_{l_2}$ actual ckt

$\bar{V}_2' = \bar{I}_2' \cdot Z_{l_2}'$ referred ckt

$$\bar{V}_2' = \left(\frac{N_2}{N_1} I_2\right)\left(\frac{N_1}{N_2}\right)^2 Z_{l_2}$$

$$= \left(\frac{N_1}{N_2}\right) I_2 Z_{l_2} = \frac{N_1}{N_2} \cdot \bar{V}_2$$

$$\boxed{\bar{V}_2' = \frac{N_1}{N_2} \bar{V}_2} \text{ and } \boxed{\bar{I}_2' = \frac{N_2}{N_1} \bar{I}_2}$$

Total Power in referred ckt:

$$P_2' = V_2' I_2' = \frac{N_1}{N_2} V_2 \cdot \frac{N_2}{N_1} I_2 \text{ (kVA)}$$

$$= V_2 I_2 = \text{Power in actual ckt (kVA)}$$