A single phase transformer operates on single phase power. ← (Single phase transformer.)

TRANSFORMERS

[A static electric device (no rotating parts) that transformers electrical energy from one circuit to another circuit without any direct electric connection. but w changed voltage.

Power is transferred from Primary → Secondary

Tasks of Transformer

a) Voltage up down

b) same voltage transfer

c) current up/ down

d) same power transfer

Principle of operation

when alternative V is applied to primary winding of a transformer, a current I flows through it.

The current produces an alt flux (ϕ).

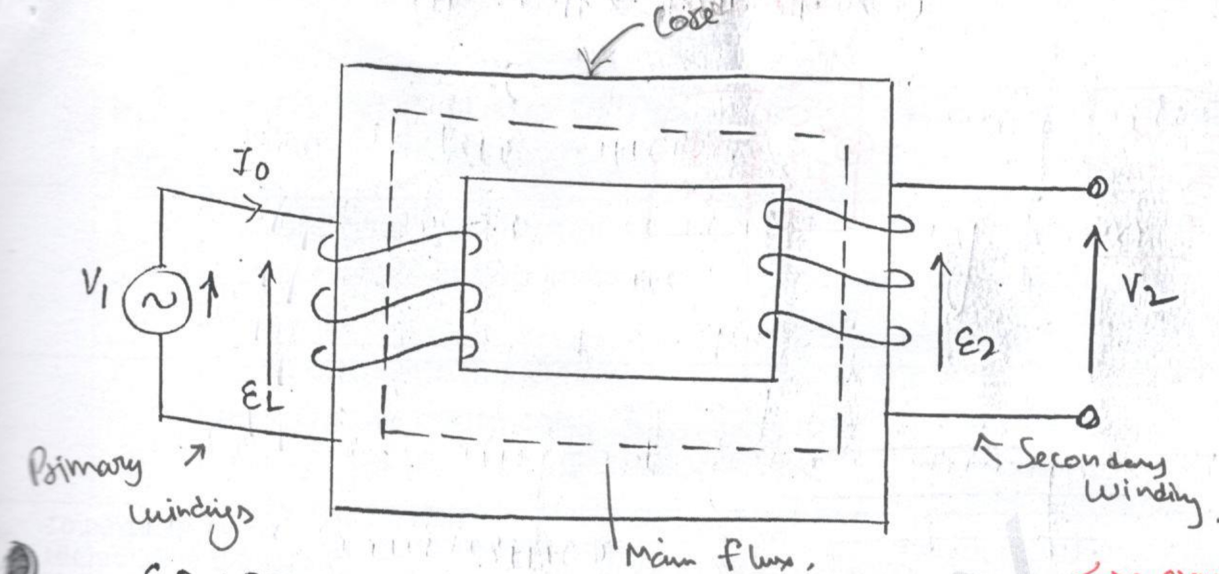
⇒ Acc. to Faraday's Law of EMI -

the flux will cause sey induced Emf E_1 in primary winding

and mutually induced emf E_2 in secondary winding.

But because of Lenz law,

emf in primary winding → is equal & opposite → applied voltage.



CONSTRUCTION of TRANSFORMATION

Core provides a magnetic path to channel flux.

Core - Magnetic Material ⇒ flux transfer
(soft iron) / CRGO silicon steel.
(cooled rolled grained oriented)

prevents
- hysteresis loss
- leakage flux

winding - Cu ⇒ current transfer

Tank

Coolant/ Insulating Coil

Bushings

TYPES

CORE transformer

- winding surround considerable parts of steel core
- 2 verticle legs (limbs)
- horizontal portion (yokes)
- Reduces leakage flux

low winding → steel core
High V winding → outside

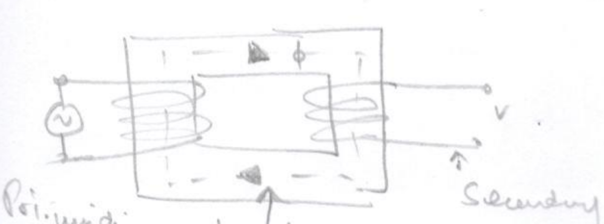
- Core is surrounded by

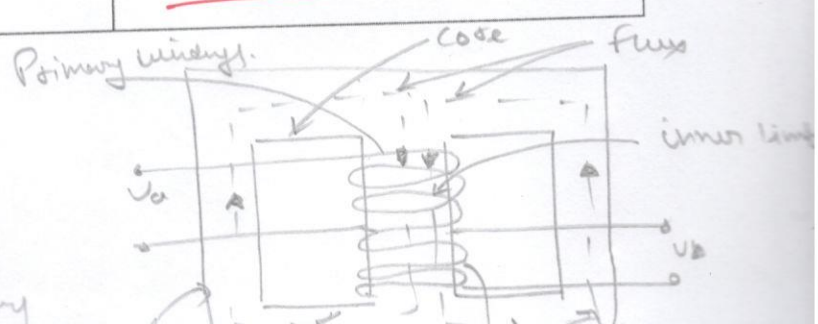
Shell Transformer

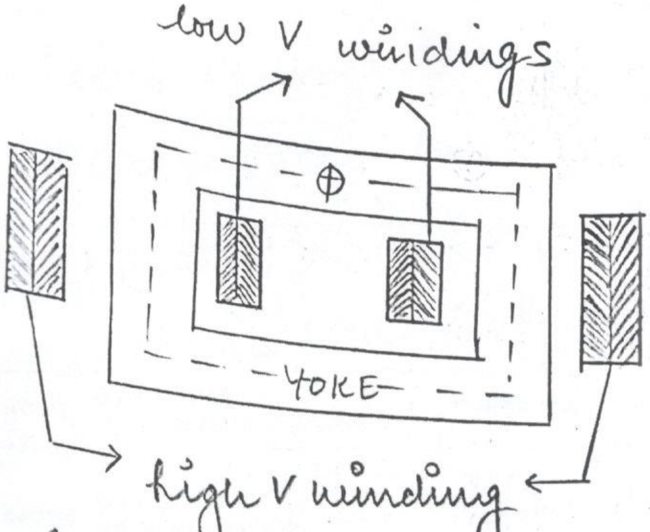
- windings are surrounded by major part of the core
- requires more conductor material
- low V winding & High V are wound over central limbs and are interleaved.
- Winding are surrounded by core.

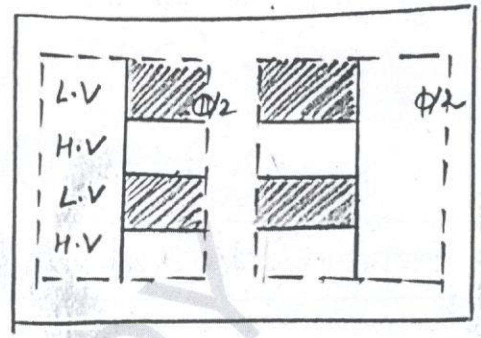
• Require less Insulation. • Require more Insulation.

S. No.	Core Type Transformer	Shell Type Transformer
1	In Core type transformer, the core consists of two limbs are two yoke.	In Shell type transformer, the core have three limbs and two yokes.
2	Total magnetic flux Ø flows through the entire core. This means that there exists a single magnetic circuit.	Half of the total flux Ø flows through the yoke and outer limbs i.e. there are two magnetic circuits. Total flux Ø only flows in the central limb.
3	The HV and LV winding in Core type transformer are concentric. LV winding is placed on the core. This LV winding is then surrounded by HV winding.	HV and LV winding in shell type transformer is interleaved or sandwiched on the central limb.
4	This type of transformer is used for high voltage and high power applications	It is suitable for low voltage and low power applications.
5	The conductor material requirement for winding is more as compared to shell type transformer.	The conductor material requirement is less.
6	Iron requirement for core construction is less.	The iron requirement for core construction is more as compared to core type transformer.
7	Core loss is more due to flow of total flux through the entire core.	Core loss is less as compared to ~~shell~~ Core type transformer. This is due to the fact that only half of the total flux flows in the core.
8	More copper conductor requirement leads to more ohmic loss.	Ohmic loss is less as conductor requirement is less.









Core type transformer	Shell type transformer
• flux have single path around the legs	• flux in central limb divides equally and returns through the outer 2 legs
• concentric coil are used.	• interleaved coils are used.
• single mag. circuit	• double mag. circuit
• windings are uniform ↳ cooling is effect	• cooling is non effective.
• Low voltage sources	• High Voltage sources.
• Has two limbs	• Has three limbs

Transformation ratio

$$E_1 = 4.44 f N_1 \phi_m$$
$$E_2 = 4.44 f N_2 \phi_m$$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{1}{K}$$

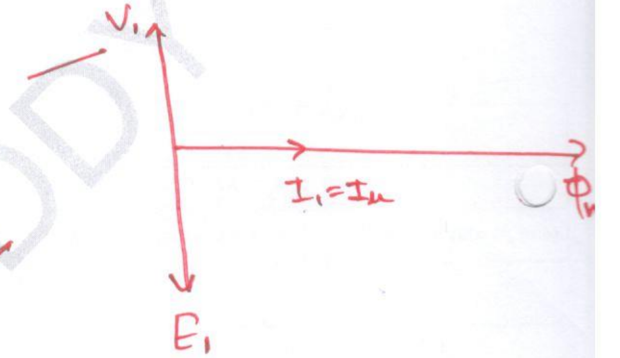
$\phi_m \Rightarrow$ Maximum flux in core in web
$N \rightarrow$ No. of turns in Primary and Secondary
$f \rightarrow$ Frequency of applied voltage.

EQUIVALENT CIRCUIT or Fuel load Trnsfr

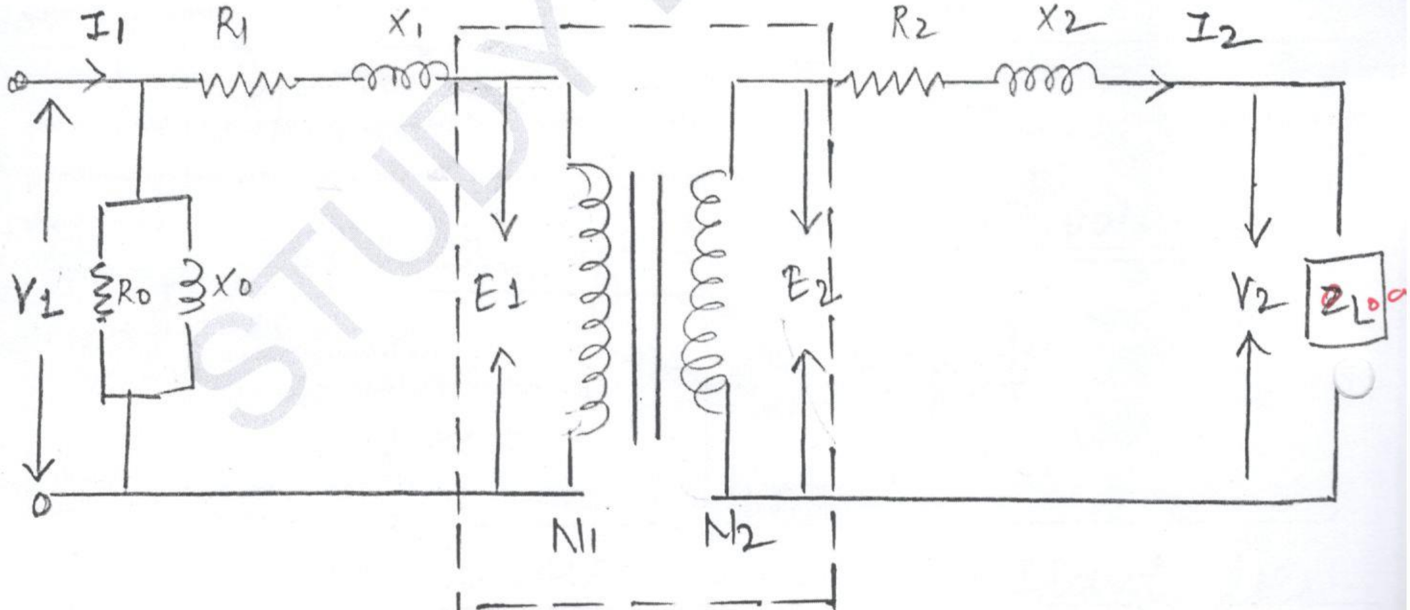
Ideal Transformers - Ideal Transformers is a imajary transfer it dosent Exist practically.

100 n% zero losses -

- ⓧ core losses (hysteresis & Eddy) • 100% Efficent.
- ⓧ ohmic losses (cu losses, I^2R losses)
- No leakage flux. -
- 100% permeability $\beta = \mu H$ —
  or Infinite Permibiality.



$$\boxed{I_m = I_0 \sin\phi_0}$$



Idea Transformer

Ye Banane ko Bol sktc hai!

Losses in a Transformer

1. Core loss – core gets subjected to alt. alternating flux
or Iron loss. (P_i)

2. Copper loss – windings carry currents when transformer is loaded. (I^2R)
(P_c)

CORE LOSS –

- Due to alt. flux set up in the mag. ~~force~~ core of the transformer, it undergoes a cycle of magnetisation & demagnetisation

– There is loss of energy – Hysteresis loss.

Hysteresis loss $\Rightarrow$ $\boxed{K_h \; B_m \; f \; V}$

K_h → Hysteresis constant
B_m → max flux density
f → frequency
V → volume of core

- Eddy current loss $\Rightarrow$ $\boxed{K_e \; B_m^2 \; f^2 \; t^2}$ watts/unit volume

K_e → eddy current const
t → thickness of the core

- Core loss is also called → constant loss

Iron losses are minimised by using $\boxed{\text{high grade core material}}$

↳ silicon steel – very low hysteresis loss
– manufacture core in form of laminations.

2. **Copper loss** (I^2R)

- due to power wasted in the form of I^2R due to resistance of primary & secondary windings.

$$\text{Cu loss } (P_{cu}) = I_1^2 R_1 + I_2^2 R_2$$

$$P_{cu} \propto I^2 \propto (KVA)^2$$

- Total losses = Iron/core loss + Copper loss

$$\Rightarrow P_I + P_{cu}$$

Voltage Regulation of Transformer

- change in the magnitude of the secondary terminal voltage, when full load

$$\%\text{ Voltage Regulation} = \frac{E_2 - V_2}{V_2} \times 100 \quad \text{or} \quad V_R = \frac{V_{in} - V_{Rated}}{V_{Rated}} \times 100$$

E_2 = secondary terminal voltage on NO load.

V_2 = secondary terminal voltage on GIVEN load.

$$\%R = \frac{I_2 R_{2e} \cos\phi + I_2 X_{2e} \sin\phi}{V_2} \times 100$$

I_2 - full load secondary current

V_2 - no load secondary V.

R_{2e} - Resistance in secondary

X_{2e} - Reactance in secondary

$\cos\phi$ = Load power factor.

Efficiency of a Transformer

Ratio of output power to input power is called

Power output = Power input − Total losses.

Power input = Power output + Total loss

= Power output + P_I + P_{cu}

Efficiency − $\eta = \dfrac{\text{Power output}}{\text{Power input}}$

$$\eta = \frac{\text{Power output}}{\text{Power output} + P_I + P_{cu}}$$

Power output = $V_2 I_2 \cos\phi$

$$\boxed{\eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_I + I_2^2 R_{2e}}}$$

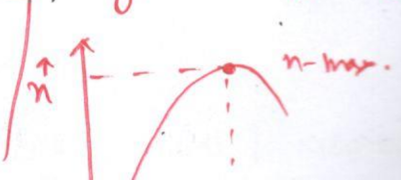
($V_2 I_2$ = VA rating)

$$\boxed{\eta = \frac{\text{VA rating} \times \cos\phi}{\text{VA rating} * \cos\phi + P_I + I_2^2 R_{2e}}}$$

$$\% \eta = \frac{\text{VA rating} \cos\phi}{\text{VA rating} \cos\phi + P_I + I_2^2 R_{2e}} \times 100$$

$$\boxed{n = \frac{\text{Actual load}}{\text{full load}}}$$

for max. Efficiency:-



Why Transformer is rated in kVA not in kW?

Transformers are basically used to change the voltage level from primary side to secondary side. They do not consume any Power. Basically we can say that, transformers are used to transfer Electrical energy.

When a manufacturer designs a Transformer, He knows about the voltage rating of both Primary and secondary side and he also knows the Current through its windings. But he doesn't have any knowledge about power factor of the Load.

This is because, we do not know that which load is going to connect with the transformer and what will be its power factor.

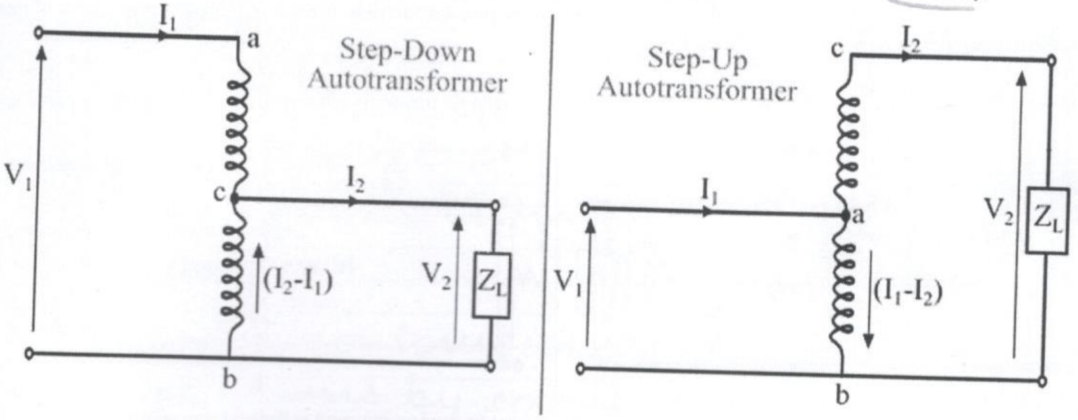
For example, a transformer can use to supply an Inductive load like fan. And it can also be use to supply a resistive load like Iron or heater.

We know that, both types of load have different power factor and we can not determine that which particular load is going to connect with the transformer.

So, manufacturer can not predict the type of load and hence he doesn't know anything about power factor of the load. So, he can not give the rating in kW (as power factor $\cos\phi$ is needed to find power rating in Watts).

(as power factor cosφ is needed to find power rating in Watts).

An autotransformer is a type of electrical transformer in which a part of the winding is common to both primary and secondary circuit. Unlike a two winding transformer where power transfer is only inductive, the power transformer in an autotransformer is both inductive and conductivity.



ai
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For max. Efficiency when iron loss = copper loss.
$I_2^2 R_2 = P_i$ → its max condition

Auto Transformer [SINGLE PHASE]

· single winding transformer

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = K$$

$\therefore$ $\dfrac{\text{Output VA of auto transformer}}{\text{Output VA of two winding transformer}}$

$$= \frac{V_2 I_2}{V_2(I_2 - I_1)} = \frac{a}{a-1}$$ [step-down transformer]

$$= \frac{V_1 I_1}{V_1(I_1 - I_2)} = \frac{a}{a-1}$$ [step-up transformer]

Advantages –

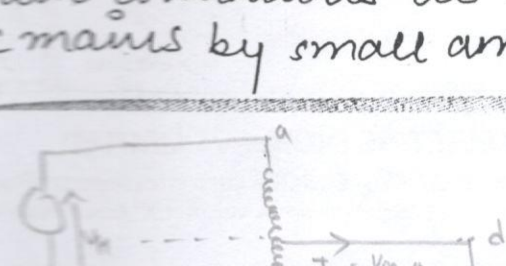
- required less winding material than 2 winding.
- Saves copper.
- smallest in size and BHOT CHEAP.
- Higher ~~losses~~ efficiency – lesser losses.
- Reduced voltage Drops.

Disadvantages

- ✓ Direct connection b/w high V to low V causing serious damage to equipments.
- ✓ the short circuit current is larger.

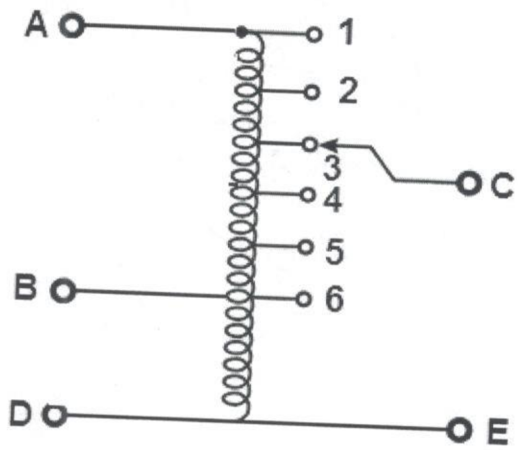
Applications

- ✓ used to obtain continuous ac V.
- ✓ Boosting AC mains by small amt.
- ✓ To start the induction motor.



Autotransformer

The working principle of autotransformer and construction is similar to that of conventional two winding transformers. However, it differs in the way in which the primary and the secondary are inter-related.



In a two-winding transformer, primary and secondary are only magnetically linked by a common core but are completely insulated from each other. But in the case of an auto transformer windings are connected electrically as well as magnetically.

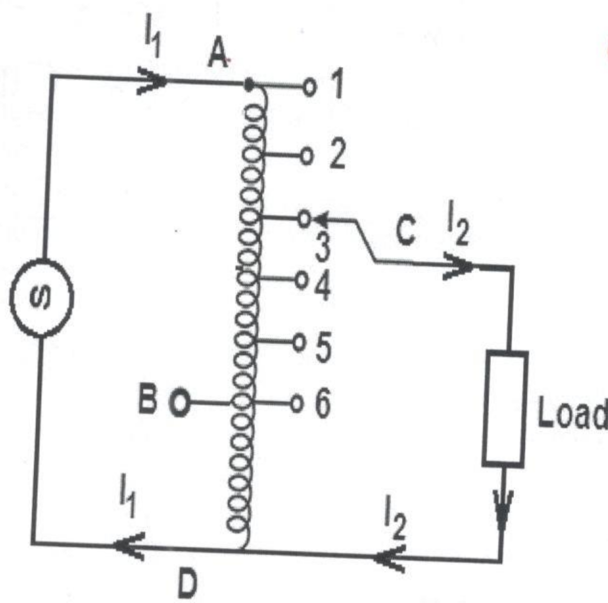
It consists of only one winding wound on a laminated magnetic core, with a rotary movable contact. The same auto transformer can be used as a step-down or a step-up transformer.

Working Principle of Autotransformer

The circuit diagram of an auto transformer is shown in Figure. When the single phase AC supply is connected between A and D terminals and output is taken from C and E terminals, this auto transformer will operate as a step-down transformer.

Because the number of turns in winding between A and D terminal (i.e. primary winding) is more than the number of turns in winding between C and E terminal (i.e. secondary winding).

On the other hand, when the single phase AC supply is connected between B and D terminals and output is taken from C and E terminals, the same auto transformer will operate as a step-up transformer.

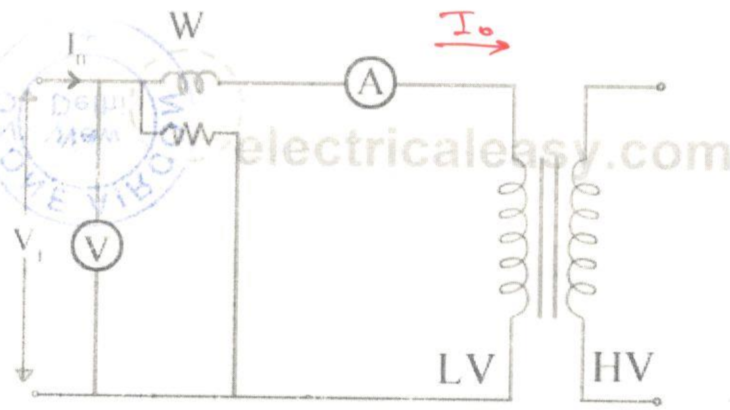


Because the number of turns in winding between B and D terminal (i.e. primary winding) is less than the number of turns in winding between C and E terminal (i.e. secondary winding). We can make small variations in output voltage by taking the output from different tapings of the auto transformer.

· Core losses depends on voltage
· Copper losses depends on Current.

Open Circuit And Short Circuit Test On Transformer

Open circuit test or no load test on a transformer is performed to determine 'no load loss (core loss)' and 'no load current I_0'. The **circuit diagram for open circuit test** is shown in the figure below.



Usually high voltage (HV) winding is kept open and the low voltage (LV) winding is connected to its normal supply. A wattmeter (W), ammeter (A) and voltmeter (V) are connected to the LV winding as shown in the figure. Now, applied voltage is slowly increased from zero to normal rated value of the LV side with the help of a variac. When the applied voltage reaches to the rated value of the LV winding, readings from all the three instruments are taken.

The ammeter reading gives the no load current I_0. As I_0 itself is very small, the voltage drops due to this current can be neglected.

The input power is indicated by the wattmeter (W). And as the other side of transformer is open circuited, there is no output power. Hence, this input power only consists of core losses and copper losses. As described above, no-load current is so small that these copper losses can be neglected. Hence, now the input power is almost equal to the core losses. Thus, the wattmeter reading gives the core losses of the transformer.

Sometimes, a high resistance voltmeter is connected across the HV winding. Though, a voltmeter is connected, HV winding can be treated as open circuit as the current through the voltmeter is negligibly small. This helps in to find voltage transformation ratio (K).

· Ammeter will measure the Io current in primary side produced due to no Load Current on High Voltage or Secondary Side.

· It have only core losses.

· I^2R losses is very small (Negligible).

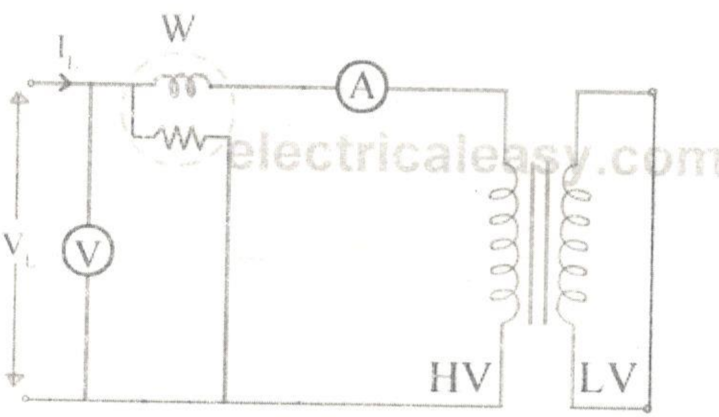
- If rated voltage is 400V. we will use 2 to 5% of voltage.
- Core loss is very small.
- It has only I^2R losses (copper losses).

Short Circuit Or Impedance Test On Transformer

The **connection diagram for short circuit test** or impedance test on transformer is as shown in the figure below. The LV side of transformer is short circuited and wattmeter (W), voltmere (V) and ammeter (A) are connected on the HV side of the transformer. Voltage is applied to the HV side and increased from the zero until the ammeter reading equals the rated current. All the readings are taken at this rated current.

The ammeter reading gives primary equivalent of full load current (I_{sc}).

The voltage applied for full load current is very small as compared to rated voltage. Hence, core loss due to small applied voltage can be neglected. Thus, the wattmeter reading can be taken as copper loss in the transformer



Why Transformers Are Rated In KVA?

From the above transformer tests, it can be seen that Cu loss of a transformer depends on current, and iron loss depends on voltage. Thus, total transformer loss depends on volt-ampere (VA). It does not depend on the phase angle between voltage and current, i.e. transformer loss is independent of load power factor. This is the **reason that transformers are rated in kVA**.