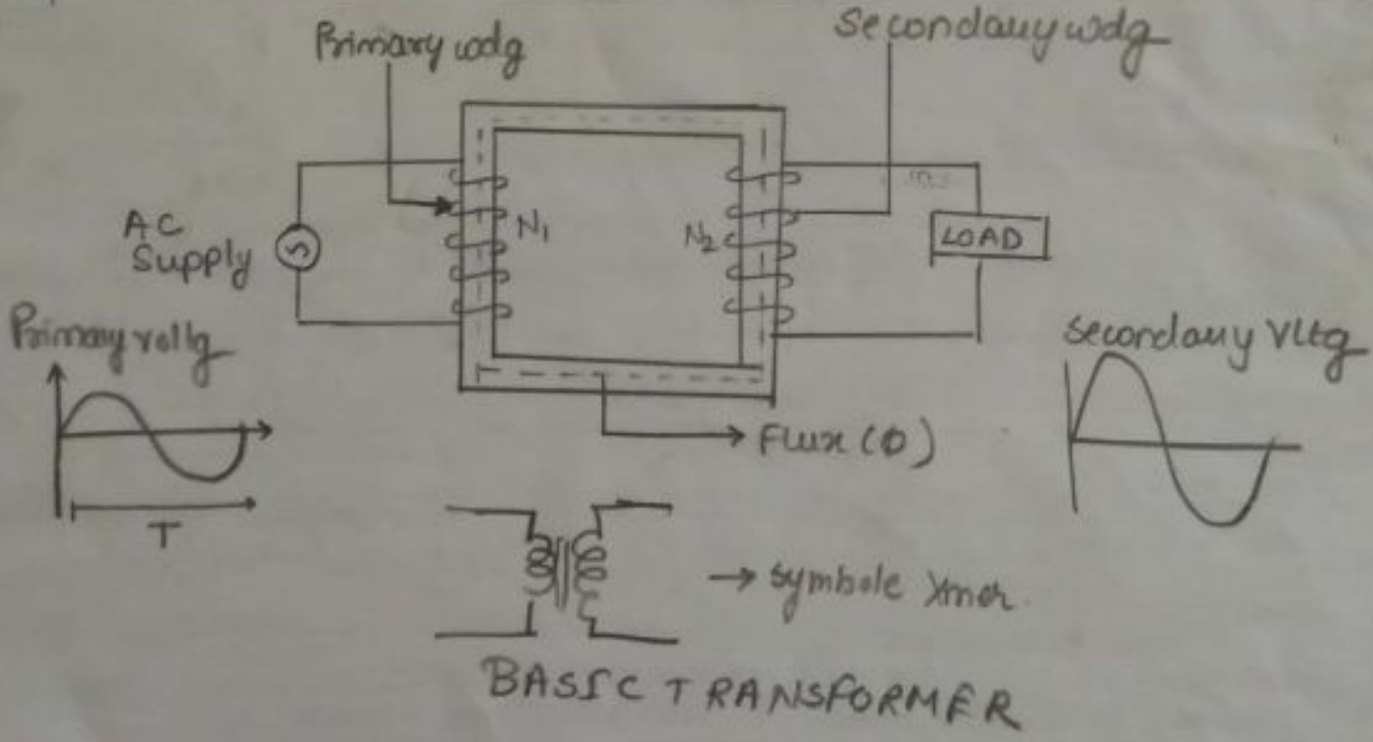
Single Phase Transformer

Working Principle :-

Transformer Works on Principle of mutual Induction which stats that when two coils are inductively coupled & If current in one coil is changed uniformly an emf is induced in the other coil.

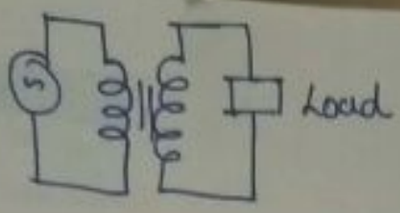
In its elementry form, it Consist of two inductive coil which are electrically seprated but linked through a common magnetic ckt The two coils have high mutual inductance.



BASIC TRANSFORMER

One of two supplies are connected to source of alternating voltage is called Primary winding (P)

The other wdg is connected to load, This wdg is Connected to load is called secondary Winding (S)



When primary wdg is excited by an alternating voltage it circulates an alternating current. This current produces an alternating flux (ϕ) which complete its path through common magnetic core. As thus an alternating flux is developed links with secondary wdg

As flux is alternating, Accordding to Faradays law of an electromagnetic induction. Mutually induced emf get developed.

$V \rightarrow I \rightarrow \phi \rightarrow \phi_M \rightarrow$ emf induced in other coil.

* Can DC supply be used for Transformer.

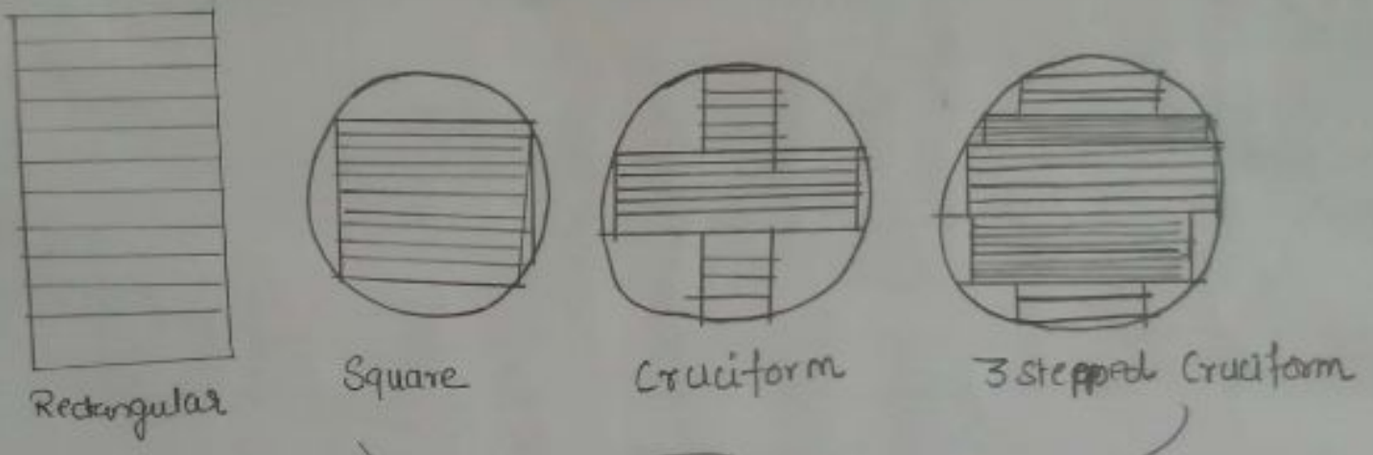
No, DC supply cannot be used for Xmer

* Transformer works on principle of mutual Inductions, for which current in one coil must change uniformly. If DC supply is given current will not change due to constant supply

* Practically wdg resistance is very small, For DC, $X_L = 0$ as it has no frequency, So total impedance of wdg is low & thus will draw very high current & may cause burning of wdg due to extra heat generated & may cause permanent damage

The cross section of limb depends on type of coil to be used either circular or rectangular.

For Small Xmer



Different Crossection

Types of Single phase transformer :-

1) Core type 2) Shell type 3) Berry type.

Core Type Transformer :- It has a single magnetic circuit. The core is rectangular having two limbs.

The coil used low cylindrical type wound in helical layers with different layers insulated from eachother by paper or mica.

Both the coils are placed on both the limbs. The low voltage coil is placed inside the core while high voltage coil surrounds low voltage coil.

Parts of Transformer:-

1] Core:- It is made up of high grade Silicon steel laminations. As its function is to carry the flux produced by wdg

Limb:- It is vertical portion of core & its function is to carry wdg

Yoke:- The top & bottom horizontal portion of core is called Yoke Its function is to carry flux produced by one wdg to reach other wdg & provide low reluctance path.

Winding:- The coils used are wound on limb & are insulated from each other. The function of wdg is to carry the current & produce the flux necessary for functioning of Xmer.

Conservator:- The oil in Xmer expands when temperature inside it increases due to heat while contract when temp decreases. Function of Conservator is to take up the expansion & contraction of oil without allowing it to come in contact with ambient air.

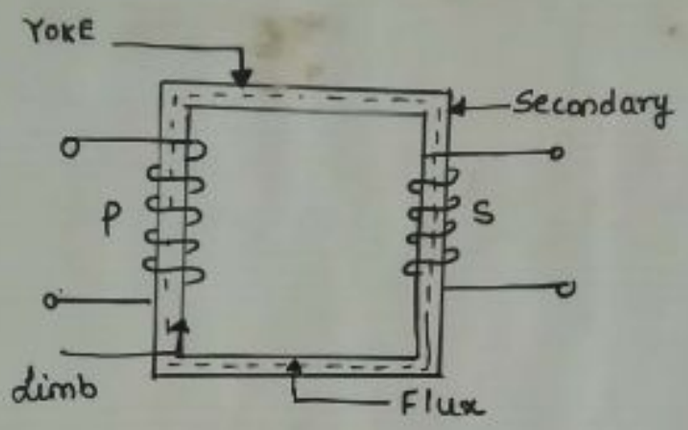
Breather:- This device extracts moisture from air & when air is taken in & does not allow oil to come in contact with moisture

Explosion vent:- It uses non metalic diaphragm which bursts when presure inside the Xmer becomes excessive which releases pressure.

Core:- The core of transformer is either square or rectangular Vertical portion of which coils are wound is called limb

Core is made up of no. of thin lamination

As coil core uniformly distributed over the two limbs, natural cooling is more effective



P → Primary
S → Secondary

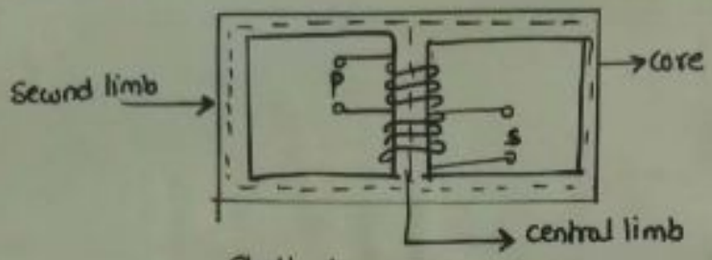
CORE TYPE TRANSFORMER

a double magnetic circuit

Shell type transformer:-

It has double magnetic ckt. The core has 3 limbs
Both the coil are placed on central limb
The core encircles most part of the coil.
The coils used are generally multilayer disc type or Sandwich coil.
The core are laminated. while arranging the lamination of the core, the care is taken that all the joints at alternate layers are staggered.

Generally for High voltage Xmer, the shell type of construction is preferred.



Shell type Transformer:

Berry Type Transformer:-

This has distributed magnetic ckt. The no. of independent magnetic circuits are more than 2. Its core construction is like spokes of wheels. Otherwise it is symetrical to that of shell type

EMF Equation of Transformer:

When the primary wdg is excited by an alternating voltage V_1, it circulates alternating current, producing an alternating flux ϕ.

Primary wdg has N_1 turns, The alternating flux (ϕ) linking with the primary wdg itself induces an emf it is denoted by E_1

The flux links with secondary wdg through common magnetic core it produces emf E_2 in the secondary wdg. This is mutually induced emf

The primary wdg is excited by purely sinusodial alternating voltage. Hence flux produced is also sinusodial in nature. as shown

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Que :- Derive Emf equations of Xmer - 6M Carry.

Form Factor = $\frac{\text{RMS Value}}{\text{Average Value}}$ = 1.11

RMS Value = 1.11 × Average Value

= 1.11 × 4 f ϕ_m = 4.44 f ϕ_m

There are N_1 no. of primary turns hence the secondary turns the RMS value of induced emf of secondary is denoted by E_2

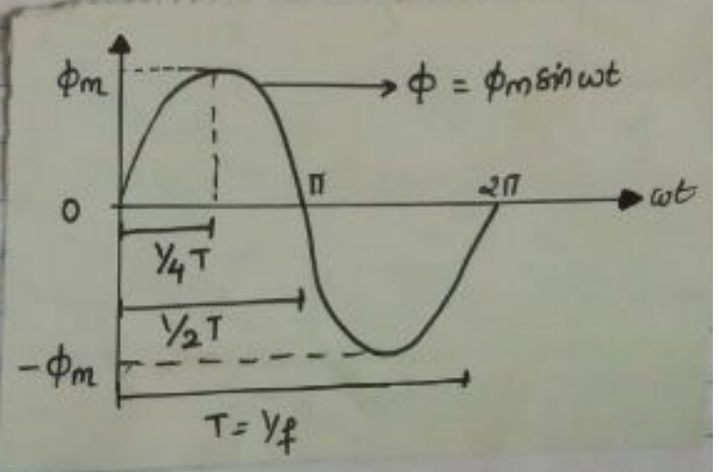
$E_1 = N_1 \times 4.44 f \phi_m$ Volts

$E_2 = N_2 \times 4.44 f \phi_m$ Volts.

E_1, E_2 → emf equations of Xmer

Ideal Transformer has following properties

1] It has no losses
2] Its coils have Zero Resistance
3] Leakage flux is Zero i.e. 100% flux produced by Primary with Secondary



Ratios of Transformer

Transformation ratio

$E_1 = 4.44 f \phi_m N_1$

$E_2 = 4.44 f \phi_m N_2$

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

ϕ = flux

ϕ_m = Maximum Value of flux

N_1 = No. of Primary Wdg

N_2 = No. of secondary Wdg

f = frequency of supply voltage

E_1 = RMS Value of primary induced emf

E_2 = " " " secondary " "

According to faraday's Law of Electromagnetic Induction Avg emf induced in each turn is proportional to avg rate of change of flux.

∴ Average e.m.f per turn = Average rate of change of flux = $\frac{d\phi}{dt}$

$$\frac{d\phi}{dt} = \frac{\text{change in flux}}{\text{Time required for change in flux}}$$

Consider $\frac{1}{4}^{th}$ cycle of flux as shown in fig. Complete cycle gets completed by $\frac{1}{f}$ seconds. In $\frac{1}{4}$th time period the change in flux from 0 to ϕ_m

$$\frac{d\phi}{dt} = \frac{\phi_m - 0}{\frac{1}{4f}} = 4f\phi_m \text{ wb/second}$$

As dt for $\frac{1}{4}$ T is $\frac{1}{4f}$ seconds

Average emf per turn = $4f\phi_m$ volts

As ϕ is sinusodial the induced emf in each turn of both Wdg is also sinusodial in nature

Voltage ratio

$\frac{E_2}{E_1} = \frac{V_2}{V_1} = K$ $\quad V_2 = E_2$, $V_1 = E_1$ $\rightarrow$ no load.

current ratio

$V_1 I_1 = I/P$

$V_2 I_2 = O/P$

$\frac{V_2}{V_1} = \frac{I_1}{I_2} = k$

An 80 KVA, 3200/400 V, 50Hz single phase transformer has turns on secondary Calculate 1) No. of turns on primary 2) No. of turns secondary full load current 3) C/s area of the if flux density is 1.2T

$E_1 = 3200$ $\quad E_2 = 400$ V $\quad N_2 = 111$, 80 KVA, $f = 50$ Hz

$\frac{N_1}{N_2} = \frac{E_1}{E_2}$, $\quad N_1 = 888$

$I_2(FL) = \frac{VA}{V_2} = \frac{80 \times 10^3}{400} = 200$ A

3) $E_2 = 4.44 f \phi N_2$

$400 = 4.44 \phi \times \phi_m \times 50 \times 111$

$\phi_m = 0.016231$ Wb & $B_m = 1.2$ T

$B_m = \phi_m / A_c$ $\quad A_c = 0.013525\ m^2$

Voltage Regulation :- The voltage drop should be as small as possible hence less the regulation better is performance of Xmer.

Expression for Voltage Regulation

$$\%R = \frac{E_2 - V_2}{V_2} \times 100$$

Losses in Transformer :-

Transformer exist two type of losses

1) The core gets subjected to an alternating flux, Causes core loss
2) Coil Carry current when Xmer is loaded Causes copper loss

Core or Iron losses :-
Due to alternating flux is set up in magnetic core of Xmer, it undergoes a cycle of magnetisation & demagnetisation due to hysteresis effect there is loss of energy in this process

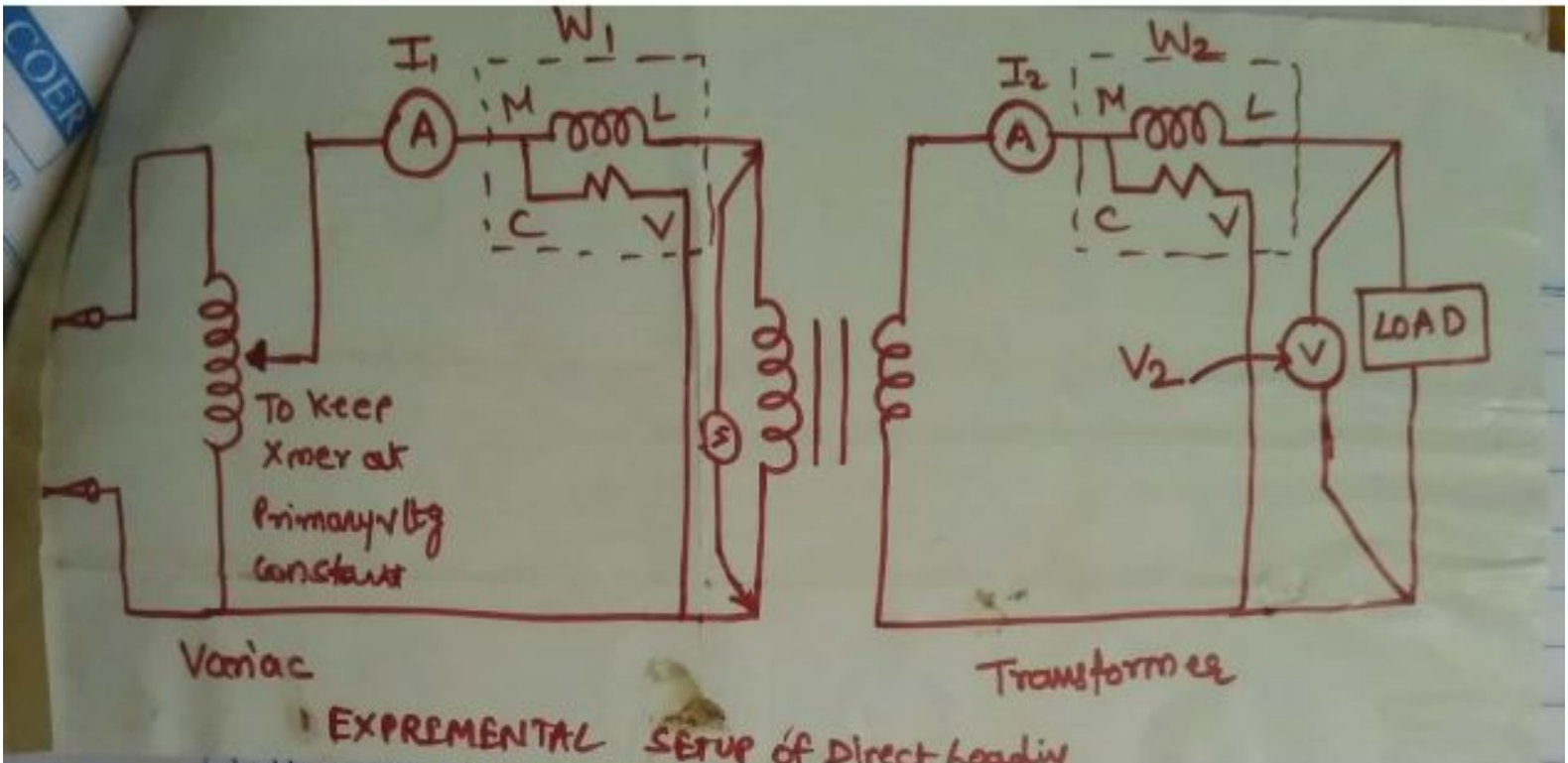
Hysteresis loss = $K_h B_m^{1.67} f v$ Watts

Eddy current loss = $K_e B_m^2 f^2 t^2$ Watts / unit volume

$K_e \rightarrow$ Eddy current Constant

$t \rightarrow$ Thickness of core.

They are denoted by P_i



EXPREMENTAL SETUP of Direct Loading

following observation table is prepared

V_1	I_1	W_1	V_2	I_2	W_2	
Rated	--	--	E_2 V	0 A	0 W	→ No load
Rated	—	—	—	—	—	
Rated	--	--	--	—	—	

Calculation W_1 = I/P Power

W_2 = o/P Power

$$\% \eta = \frac{W_2}{W_1} \times 100$$

$$\% R = \frac{E_2 - V_2}{E_2} \times 100 \qquad E_2 \text{ is Constant}$$

$E_2 = V_2$ on no load cond^n the regulation is Zero.

Direct loading Method of finding Efficiency & Regulation

Efficiency & Regulation of xmer operating on any load & load power factor can be determined by using direct loading method.

In this method transformer secondary is connected to load directly for which η & regulation is required.

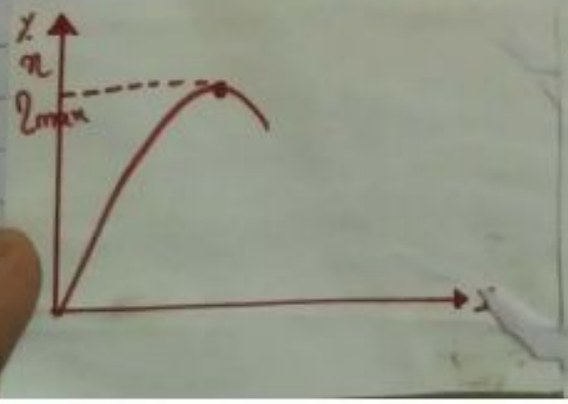
Primary is connected to variac to adjust primary voltage to its rated value

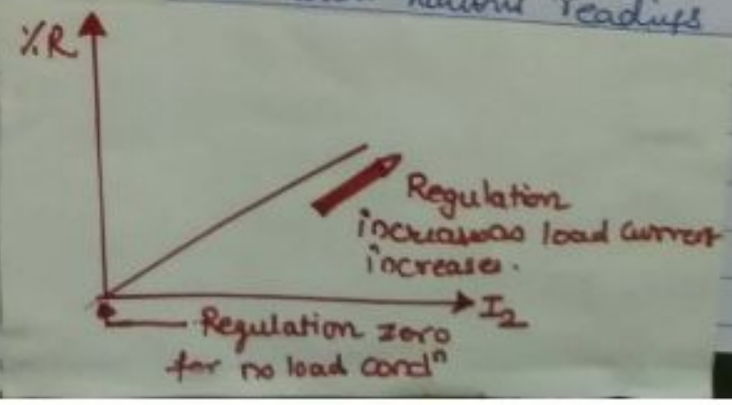
On Primary & secondary ammeter, Voltmeter & Wattmeter are connected to measure currents, voltages & Wattages on b.s. of xmer

Procedure:

1) Make sure that load is off
2) Switch on the supply & adjust variac to get rated primary voltage to be observed on V_1 → Voltmeter
3) observe the readg on no load first & note down V_1, I_1, W_1, V_2, I_2 & W_2. It can be observed that on no load $I_2 = 0$ & $W_2 = 0$ while $E_2 = V_2$

Switch on load step by step. And note down various readings





Auto transformer.

An autotransformer is a spl. type of xmer such that a part of wdg is common to both primary as well as secondary. It has only wdg wound on magnetic core.

→ With help of xmer voltages can be stepped up & stepped down.

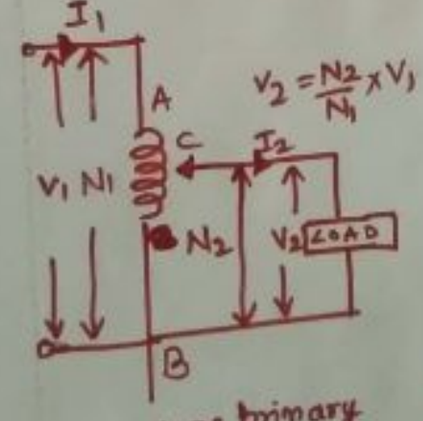
Fig 1 shows the step down xmer, AB acts as primary wdg while part of primary wdg BC act as secondary. The position C called as % tapping point, can be selected as per requirement.

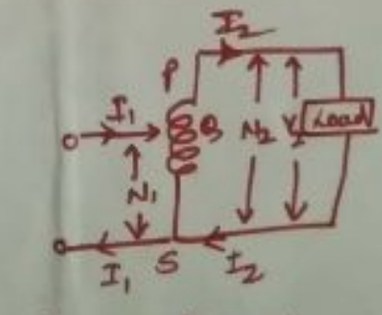
Fig 2:- Shows step up xmer where QS act as a primary wdg while PS acts as secondary wdg

Neglecting the losses

$$K = \frac{V_2}{V_1} = \frac{I_2}{I} = N_2$$

Ac





AC - Act as primary
CB - Act as secondary

QS → Primary
PS → secondary

AUTO TRANSFORMER.

Applications:-

1] For interconnecting systems which are operating roughly at same voltage

2] For starting rotating M/c like induction, Synchronous Motor.

3] To give a small boost to distribution cable to correct for voltage drop

4] As a furnace xmer for getting required supply voltage

5) As a variac, to vary the voltage to the load, smoothly from zero to rated value, such variac are commonly used for dimming the lights in cinema halls.

Advantages:-

1] Copper required is very less

2] % η is higher Compared to two wdg Xmer

3] Size & cost is less compared to 2 wdg Xmer

4] The resistance & leakage reactance is less Compared to 2 wdg Xmer

5] Copper loss $I^2R \rightarrow$ is less.

6] ~~Due to less Resistance~~

Limitation:-

1) Low Impedance hence high short ckt currents for short ckt on secondary side.

2) If a section of wdg common to primary & secondary is opened, full primary voltage appears across secondary resulting in higher voltage on secondary & danger of accidents

3] No seprabon bet^n primary & secondary which is risky in case of high voltage levels.

A 1ϕ xmer when connected to lamp load gave following results

S.No	V_1	I_1	W_1	V_2	I_2	W_2
	200	1.5	60	100	0	0
	200	12.9	2510	97	25	2425

Calculation %. η and %. Regulation of xmer at $I_2 = 25A$

At $I_2 = 25\ A$

$W_1 = 2510\ W$ $\quad$ $W_2 = 2425\ W$

$$\%.\eta = \frac{2425}{2510} \times 100 = 96.6135\ \%.$$

Ans $E_2 = V_2$ on no load $= 100\ V$

$V_2 = 97$ $\quad$ $I_2 = 25\ A$

$$\%.R = \frac{100 - 97}{100} \times 100 = 3\ \%.$$