Unit-5 . Testing of Transformer

Testing of Transformers:

The structure of the circuit equivalent of a practical transformer is developed earlier. The performance parameters of interest can be obtained by solving that circuit for any load conditions. The equivalent circuit parameters are available to the designer of the transformer from the various expressions that he uses for design the transformers. But for a user these are not available most of the times. Also when a transformer is rewound with different primary & secondary windings the equivalent circuit also changes.

In order to gets the equivalent circuit parameter test methods are heavily depended upon. From the analysis of the equivalent circuit one can determine the electrical parameters. But if the temperature rise of the transformer is required, then test method is the most dependable one. There are several tests that can be done on the transformer, however a few common ones are discussed here.

These two tests on transformer, help to determine

1. The parameters of the equivalent circuit R_0, X_0, R_{01} (or) R_{02}, X_{01} (or) X_{02}

2. The voltage regulation

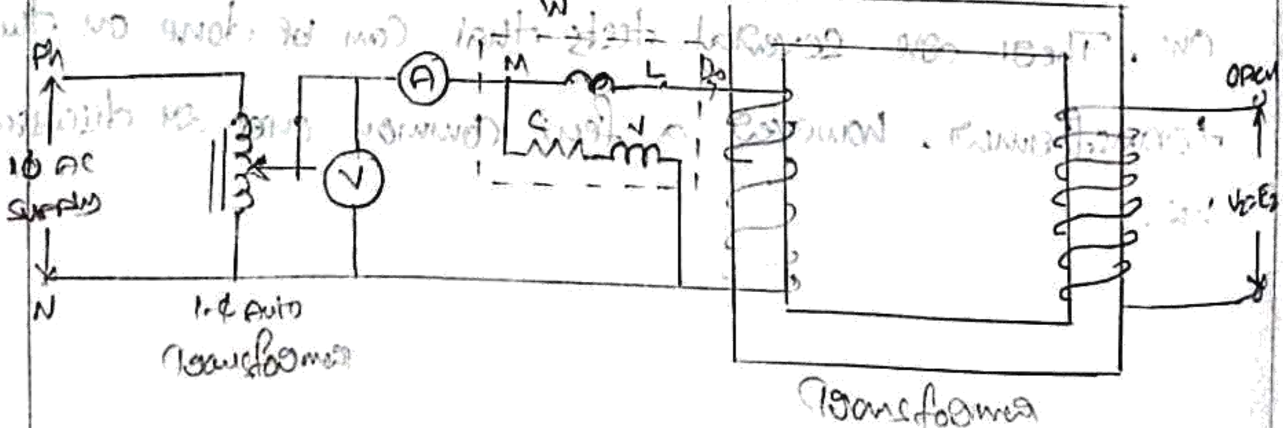
3. The iron & copper losses for calculating efficiency without actually loading the transformer

Moreover, the power required to carry out these tests is very small compared to load test on the transformer

Open - Circuit (or) No-load Test :-

The purpose of this test is to determine the iron loss and no load current I_0 and then by R_0 & X_0 of the equivalent circuit

The transformer is connected is such a way that one of the windings (usually HV winding) is kept open while the other (LV) is connected to the supply of rated voltage and frequency as shown in circuit diagram



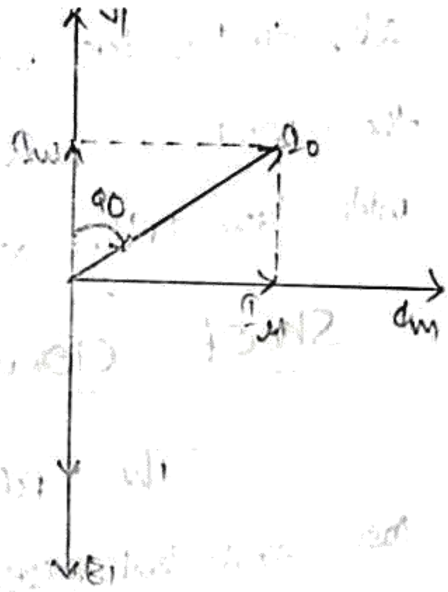
The ammeter (A) gives the no-load current I_0. As the no-load current is about 3-5% the F.L. current, the copper loss will be negligible. Therefore the reading of the wattmeter (W) will indicate the iron loss of the transformer.

With normal voltage applied to the primary, normal flux is set up in the core and therefore the reading of the normal iron loss will occur.

<u>Equivalent circuit parameters:</u>

The parameters R_0, X_0 of the equivalent circuit the transformer can be calculated as follows

Input power on no-load



$$W_0 = V_1 I_0 \cos\phi_0 = \text{Iron loss}, W_i$$

where V_1 = Primary voltage

I_0 = No-load current

$\cos\phi_0$ = No-load P.f

Power factor $\cos\phi = \frac{W_0}{V_1 I_0}$

From the value of P.f

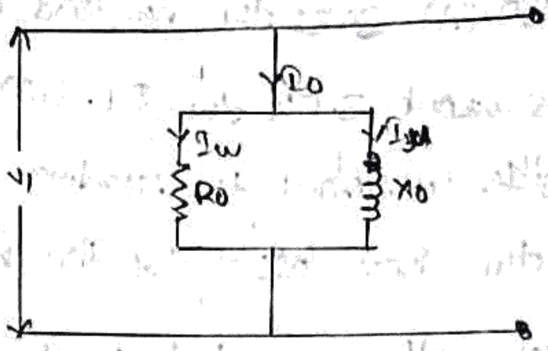
The active (or) working component of No-load current

$$I_w = I_0 \cos\phi_0$$

Magnetising (or) reactive component of No-load current

$$I_\mu = I_0 \sin\phi_0 \quad \text{(or)}$$

$$I_\mu = \sqrt{I_0^2 - I_w^2}$$



Equivalent circuit parameters

$$R_0 = \frac{V_1}{I_w} \quad \& \quad X_0 = \frac{V_1}{I_\mu}$$

Why O.C. Test conducted always on L.V. side a T/F :-

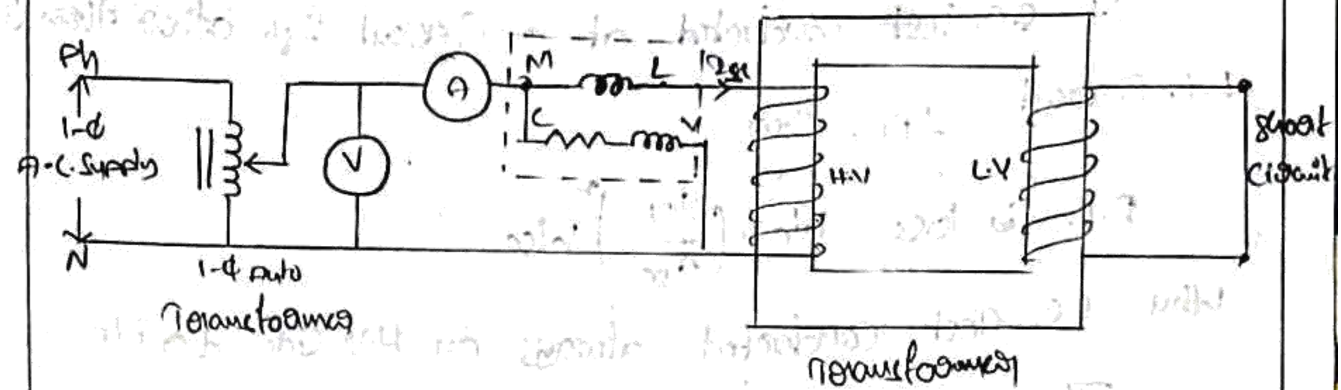
The O.C test is conducted always on L.V. side of a transformer. If the measurements where made on the H.V. side, the voltage required to be applied would be large and the current Io would be inconveniently small, cannot be measured with high better accuracy. (Measurement of Is difficult)

Short - circuit Test :-

The purpose of this is to determine the copper loss, equivalent resistance & reactance of the transformer.

In this test secondary winding short circuited by a thick wire (or) strip and variable low voltage is applied to the primary winding is applied to the primary with the half of a auto - transformer. An ammeter A, wattmeter W & voltmeter V are connected in the high-voltside, to measure short circuit current Isc, input power Wsc and applied primary

Voltage V_{sc}



The applied voltage is slowly increased until full load voltage is very small (5-7% of the rated voltage). So flux produced in the core is very small and therefore, iron losses are so small and negligible. Thus, the reading of the wattmeter is gives the F.L. copper losses of the transformer

Equivalent circuit parameters :-

The equivalent resistance & reactance of the transformer can be calculated as follows

Let W_{sc}, I_{sc} & V_{sc} be the readings of wattmeter, ammeter, voltmeter respectively. Thus,

F.L. copper loss $W_c = W_{sc} = (I_{sc})^2 R_{01}$

Equivalent resistance, impedance & reactance referred primary

$$R_{01} = \frac{W_{sc}}{(I_{sc})^2}$$

$$Z_{01} = \frac{V_{sc}}{I_{sc}}$$

$$X_{01} = \sqrt{(Z_{01})^2 - (R_{01})^2}$$

$$\cos\phi_{sc} = \frac{W_{sc}}{V_{sc} I_{sc}}$$

Note :-

If S.C. test conducted at a current I_{sh} other than the F.L. current I_{FL} then

$$\text{F.L. Cu loss } W_C = \left(\frac{I_{FL}}{I_{sc}}\right)^2 W_{sc}$$

Why S.C. test conducted always on H.V. side of a T/F :-

The S.C. test is conducted always on H.V. side of a transformer. If the measurements were made on the L.V. side the voltage needed would be inconveniently low and the current would be inconveniently high.

Voltage regulation from the short circuit test :-

Knowing the equivalent resistance & reactance referred to primary or secondary, voltage regulation of the transformer at any power factor can be determined by

$$\%\text{ voltage regulation} = \frac{I_1 R_{01}\cos\phi \pm I_1 X_{01}\sin\phi}{V_1}\times 100 \quad \text{(primary)}$$

$$= \frac{I_2 R_{02}\cos\phi_2 \pm I_2 X_{02}\sin\phi}{V_2}\times 100 \quad \text{(secondary)}$$

'+' sign for lagging power factor

'−' sign for leading power factor

Calculation of Efficiency from the O.C. & S.C Tests :-

W_0 = Input power in watts on the O.C. Test

= Iron loss, W_i

W_{sc} = Input power in watts on the S.C. Test with F.L. currents

= F.L. Cu. loss. W_c.

Total losses on full load = $W_i + W_c$

$$\text{F.L. Efficiency} = \frac{\text{F.L. KVA} \times \cos\phi}{(\text{F.L. KVA} \times \cos\phi) + W_i + W_c}$$

Efficiency at any load is given by

$$\eta = \frac{xS\cos\phi}{xS\cos\phi + W_i + x^2 W_c}$$

Where

S = FL KVA of the T/F. &

x = Fraction of the FL at which the T/F is working

Problems on Tests :-

① A 5 KVA, 220/110V transformer has the efficiency of 96.97% at 0.8 P.f lag. Its iron loss is 50 W & full-load regulation at 0.8 P.f is 5%.. Find the efficiency & regulation at 3/4 full load 0.9 P.f lag

Sol Given data :-

S = 5 KVA

W_i = 50 W

At FL i.e. x = 1 & at $\cos\phi = 0.8$

F.L efficiency $\eta = 96.97\% = 0.9697$

Output = $xS\cos\phi$ = $1 \times 5 \times 1000 \times 0.8$ = 4000 W

$$\text{Input} = \frac{\text{output}}{\text{F.L.}\,\eta} = \frac{4000}{0.9677} = 4127.99\ W$$

$$\text{Total loss} = \text{Input} - \text{output} = 4124.99 - 4000 = 124.99\ W$$

$$W_i + W_c = 124.99$$

$$W_c = 124.99 - 50$$

F.L Cu. losses $W_c = 74.99$

$$\%\ \text{resistance drop } V_R = \frac{\text{F.L. Copper loss}}{\text{VA rating of the T/F}} \times 100$$

$$= \frac{74.99}{5 \times 1000} \times 100$$

$$V_R = 1.5$$

$\cos\phi = 0.8$
$\sin\phi = 0.6$

$$\%\ \text{regulation} = x\,V_R\cos\phi + x\,V_X\sin\phi$$

$$5 = 1.5 \times 0.8 + V_X \times 0.6$$

$$\%\ \text{reactance drop } V_X = \frac{5 - 1.2}{0.6} = \frac{3.8}{0.6} = 6.33$$

At $\frac{3}{4}$ F.L. $x = \frac{3}{4}$ & At $\cos\phi = 0.9$

$$\text{output} = xS\cos\phi = \frac{3}{4} \times 5 \times 1000 \times 0.9 = 3375\ W$$

$$\text{Total losses} = W_i + x^2 W_c$$

$$= 50 + \left[\frac{3}{4}\right]^2 \times 74.99$$

$$= 92.18\ W$$

efficiency at $\frac{3}{4}$ F.L

$$\eta = \frac{\text{Output}}{\text{Output} + \text{losses}} = \frac{3375}{3375 + 92.18} \times 100$$

$$\eta = 97.34\ \%$$

% regulation at $\frac{3}{4}$ f.l. at 0.9 p.f lagging

$x = \frac{3}{4}$ $\cos\phi = 0.9$ $\sin\phi = 0.436$

% voltage regulation $= x V_R \cos\phi + x V_x \sin\phi$

$= \frac{3}{4} \times 1.5 \times 0.9 + \frac{3}{4} \times 6.33 \times 0.436$

$= 3.0822\%$

(2) A 100 kVA, 1100/440V 1-ϕ T/F has following test data:

O.C. test on L.V. side: 440V, 10A, 433 W

SC test on H.V side: 570V, 9.09A, 1660 W

Calculate the equivalent circuit parameters referred to L.V side & H.V side. Draw equivalent circuit diagram.

Sol

Given data:

100 kVA, 1100/440V 1-ϕ T/F

Transformation ratio $k = \frac{V_2}{V_1} = \frac{440}{1100} = 0.4$

O.C. test on L.V. side:

$V_1 = 440V$ $I_0 = 10A$ $W_0 = 433W$

$\cos\phi_0 = \frac{W_0}{V_1 I_0} = \frac{433}{440 \times 10} = 0.098$

$\sin\phi_0 = 0.995$

$R_0 = \frac{V_1}{I_w} = \frac{V_1}{I_0 \cos\phi_0} = \frac{440}{10 \times 0.098} = 448.98\,\Omega$

$X_0 = \frac{V_1}{I_\mu} = \frac{V_1}{I_0 \sin\phi_0} = \frac{440}{10 \times 0.995} = 44.22\,\Omega$

S.C. Test on H.V Side:

$V_{sc} = 570V$ $I_{sc} = 9.09A$ $W_{sc} = 1660W$

Equivalent resistance, impedance & reactance referred to HV side

$$R_{01} = \frac{W_{sc}}{(I_{sc})^2} = \frac{1660}{(9.09)^2} = 20.09\,\Omega$$

$$Z_{01} = \frac{V_{sc}}{I_{sc}} = \frac{570}{9.109} = 62.71\,\Omega$$

$$X_{01} = \sqrt{(Z_{01})^2-(R_{01})^2} = \sqrt{(62.71)^2-(20.09)^2} = 59.4\,\Omega$$

∴ Total resistance & reactance referred to L.V side

$$R_{02} = k^2 R_{01} = (0.4)^2 \times 20.09 = 3.214\,\Omega$$

$$X_{02} = k^2 X_{01} = (0.4)^2 \times 59.4 = 9.504\,\Omega$$

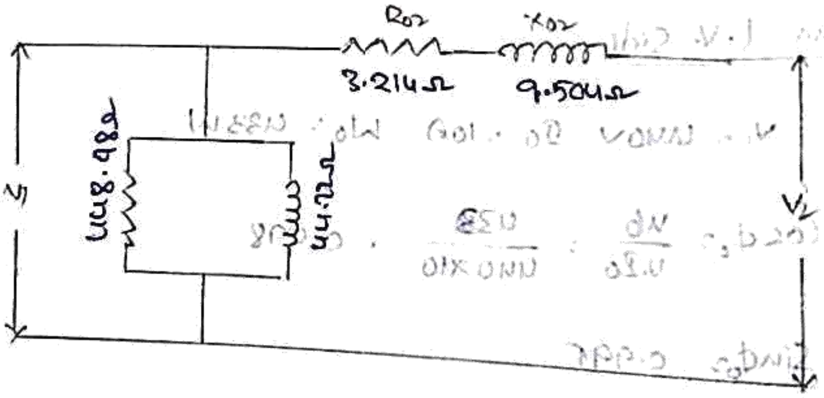
Equivalent circuit parameters referred to L.V. side

$R_0 = 448.98\,\Omega$

$X_0 = 44.22\,\Omega$

$R_{02} = 3.214\,\Omega$

$X_{02} = 9.504\,\Omega$



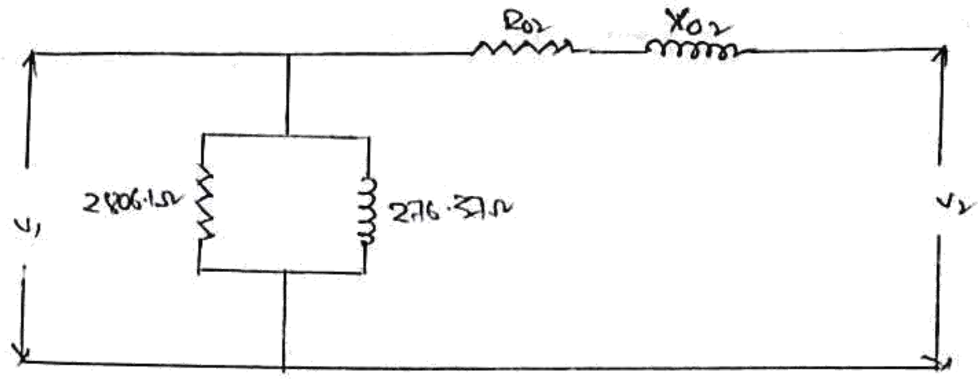
Equivalent circuit parameters referred to HV side

$$R_0 = \frac{(R_0)_{LV}}{k^2} = \frac{448.98}{(0.4)^2} = 2806.12\,\Omega$$

$$X_0 = \frac{(X_0)_{LV}}{k^2} = \frac{44.22}{(0.4)^2} = 276.37\,\Omega$$

$R_{01} = 20.09\,\Omega$

$X_{01} = 59.4\,\Omega$



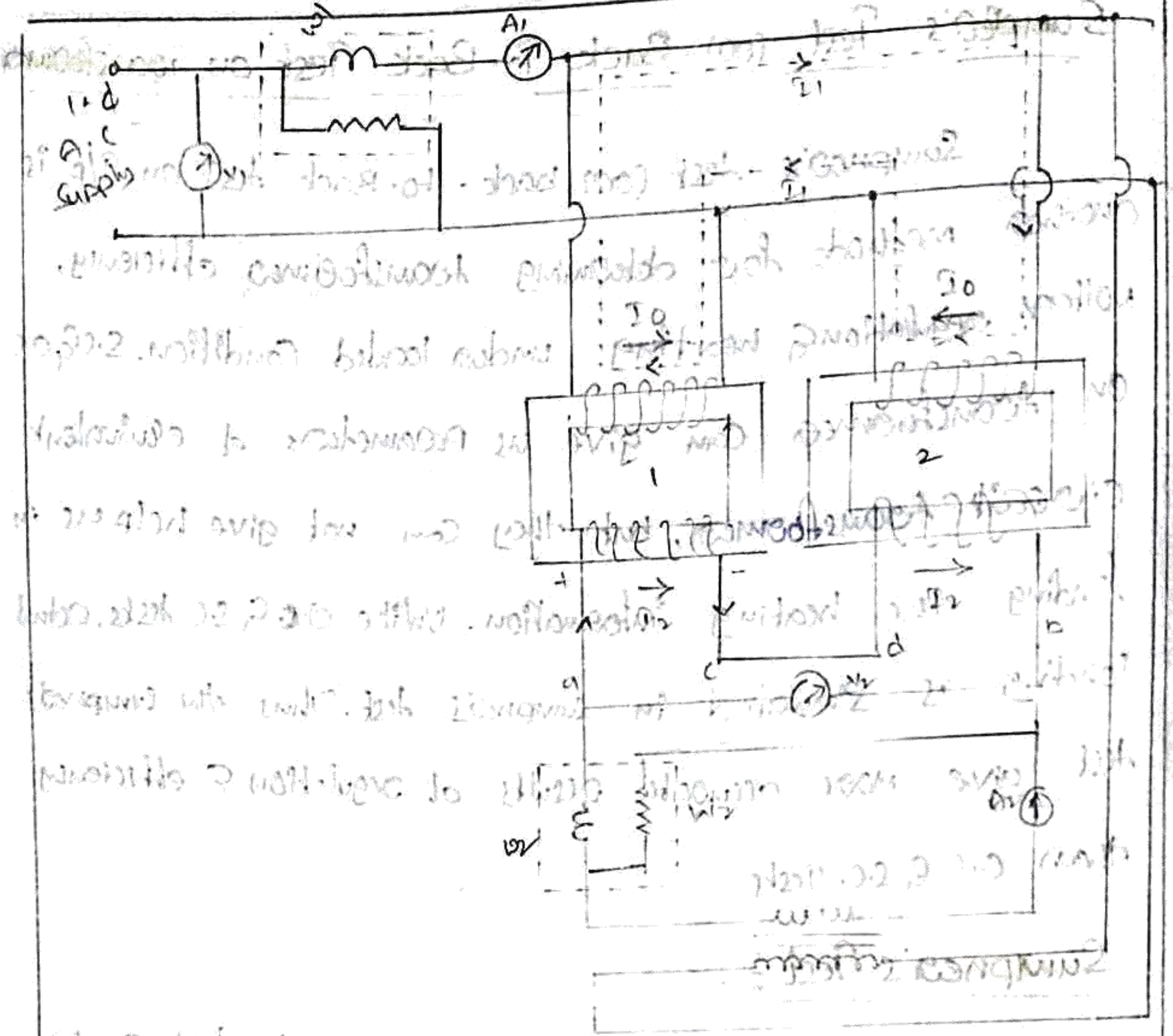
R02
X02
2806.1Ω
276.37Ω
V1
V2

Sumpner's Test (or) Back-To-Back Test on Transformer

Sumpner's test (or) back-to-Back test on T/F is another method for determining transformer efficiency, voltage regulation & heating under loaded condition. S.C & O.C on transformer can give us parameters of equivalent circuit transformer, but they can not give help us in finding the heating information. Unlike O.C & S.C. tests, actual loading is simulated in sumpner's test. Thus the sumpner's test give more accurate results of regulation & efficiency than O.C & S.C. Tests

Sumpner's Test :-

Sumpner's test (or) back-to-back test can be employed only when two identically transformers are available. Both transformers are connected to supply such that one transformer is loaded on another primaries of the two identical transformers are connected in parallel across a supply. secondaries are connected in series such that emf's of them are opposite to each other. Another low voltage supply is connected in series with secondaries to get the reading as shown in the circuit diagram as shown in figure



In above diagram, T_1 & T_2 are identical transformers; secondaries of them are connected in voltage opposition. i.e. E_{EF} & E_{GH}. Both the emf's cancel each other as transformers are identical. In this case, as per superposition theorem, no current flows through secondary. And thus the noload test is simulated. The current drawn from V_1 is $2I_0$, where I_0 is equal to no load current of each transformer. Thus input power measured by wattmeter "W_1" is equal to iron loss of both transformer i.e, iron loss per transformer $P_i = \frac{W_1}{2}$

Now, a small voltage V_2 is injected into secondary with the help of a low voltage V_2 is injected into T/F. The voltage V_2 is adjusted so that, the rated current I_2 flows through the secondary. In this case, both primaries & secondaries carry rated current. Thus short circuit test is simulated and wattmeter W_2 shows total full load copper losses of both transformers.

Copper loss per transformer $P_{cu} = \frac{W_2}{2}$

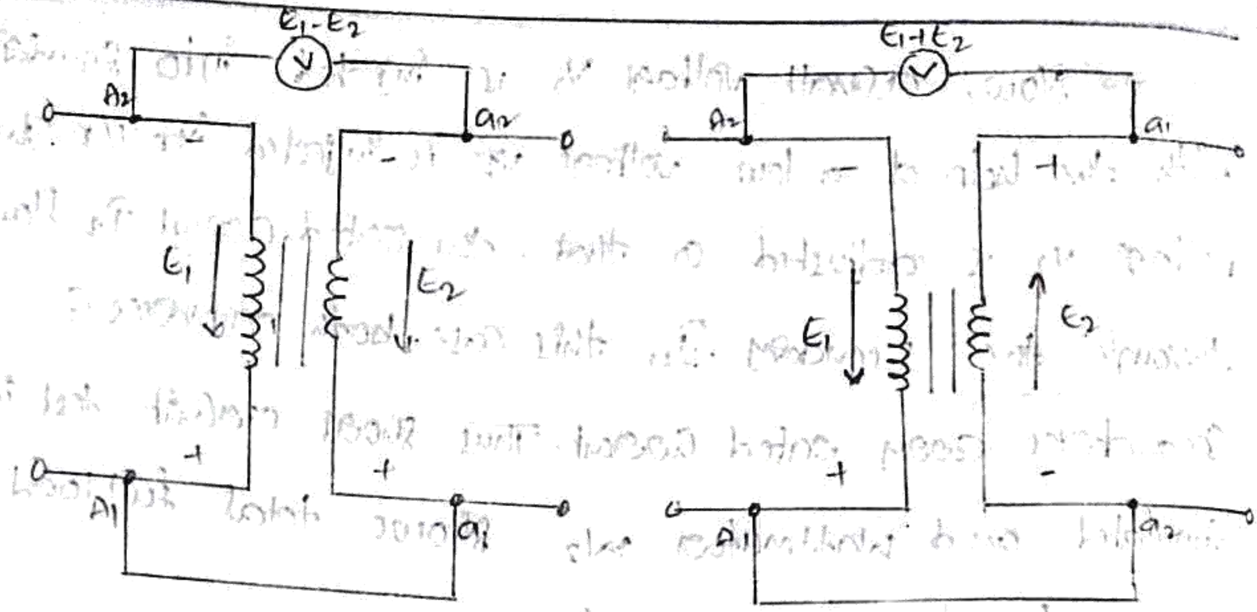
From above test results, the full load efficiency of each transformer can be given as

$$\% \text{ F.L. efficiency of each T/F} = \frac{\text{output}}{\text{output} + \frac{W_1}{2} + \frac{W_2}{2}} \times 100.$$

Polarity Test on a Transformer :-

The purpose of this test is to find out the terminals having the same instantaneous polarity. The relative polarities of the primary & secondary terminals must be known if the transformers are to be operated in parallel

On the primary side of a two-winding T/F, one terminal is positive with the other terminal at any instant. One terminal of the secondary winding is positive with the other terminal. H.V (or) H.T terminals are marked A_1 & A_2 & L.V. (or) L.T terminals are a_1 & a_2



Substractive Polarity — Additive Polarity

Now the two windings are connected in series across a voltmeter. A voltage of suitable value is applied to the H.V winding as shown in fig A. If the polarities of the windings are marked on the diagram i.e "When the O/p has a Subtractive polarity (emf's as marked on E1 & E2 will be in same direction) the voltmeter will reads $E_1 - E_2$."

If the windings are wound in the opposite direction on the magnetic core, emf's E_1 & E_1 will be in the opposite direction and the voltmeter will reads $E_1 + E_2$, the transformer has additive polarity as shown fig B.

In additive polarity, the windings are subjects are to high voltage stresses, therefore generally the polarity used is substractive.

Advantages of Sumpner's test :-

1. Two large transformers can be tested

2. Transformers temperature rise can be measured

3. Accurate efficiency can be calculated

4. Transformers are tested under F.L. Condition with a small expenditure of energy

Disadvantages of Sumpner's test :-

1. It needs two identical transformers

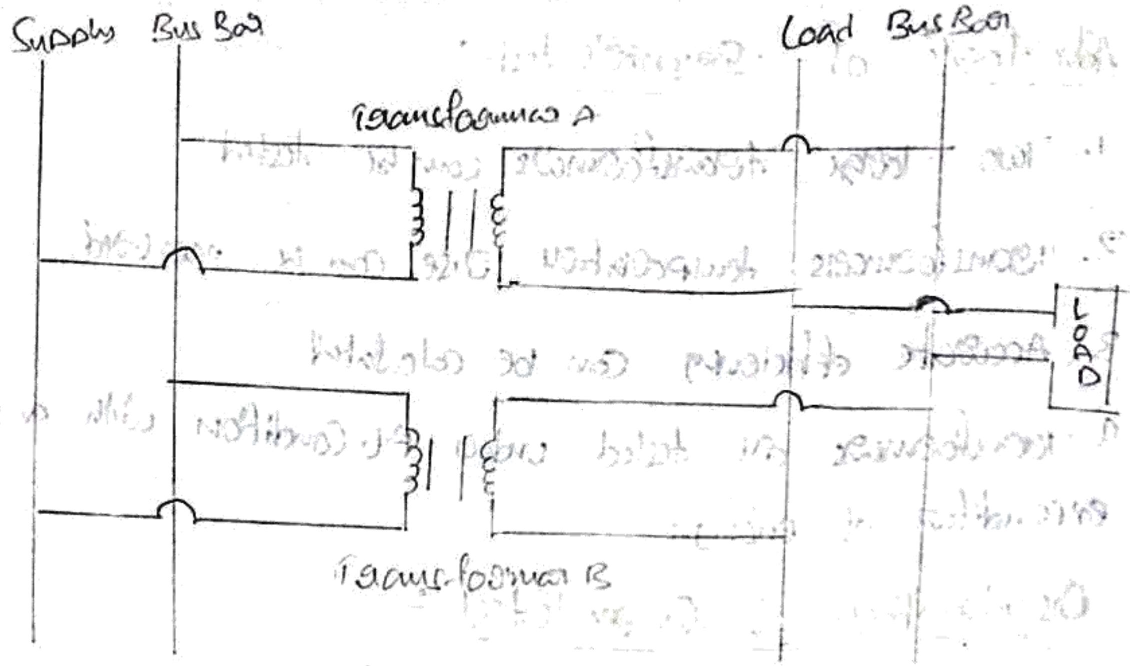
Parallel operation of Transformers :-

Generally the transformers are installed to distribute the power to the consumers

Defination :-

Two transformers are said to be connected in parallel when the primary windings are connected to supply bus-bars and the secondary windings are connected to the load bus-bars.

As shown in figure Two 1-ϕ Transformer A & B in parallel. while connecting two or more transformers in parallel. It is essential that their terminals 1 similar polarity are joined to the same bus-bar. The wrong connections may result in a dead S.C. hence the T/Fs may be damaged. If they are not provided with fuses, circuit breakers



Necessity :-

Many times two or more transformers are installed in parallel instead of one large transformer. The parallel operation of T/F is necessary due to the following reasons

1. Greater flexibility :-

To supply a increased load more than the rating of an existing transformer, it becomes necessary either

(a) To replace the existing transformer by another of a higher rating.

(b) To connect another transformer in parallel with the existing only one.

2. Reliability of Supply :-

It may be preferable to operate two transformers in parallel, instead of one large unit from the point of view of reliability or maintaining uninterrupted supply

3. Efficient Operation:-

Transformers can be switched off or on, depending upon the power demand. Due to this, losses decrease and the system becomes more economical and efficient in operation.

4. More life:-

Any transformer can be taken out of the circuit for repair, regular maintenance (or) periodic overhauling thus the life of the transformer increases.

Conditions for satisfactory parallel operation of T/F:-

The following are the conditions for successful operation of transformers in parallel.

1. "Polarities of the two transformers must be the same." i.e. the windings have the same polarity must be joined together otherwise, there will be a dead short circuit.

2. "The voltage ratios of the two transformers must be same". If voltage ratios are not equal, the no-load secondary voltages are not equal and this will cause a flow of circulating current b/w the secondaries. Even a small voltage difference can cause a large circulating current since the impedances of transformers are small. This will result is unequal load sharing.

3. "The percentage impedance (or) per unit impedance of the two transformers must be the same:

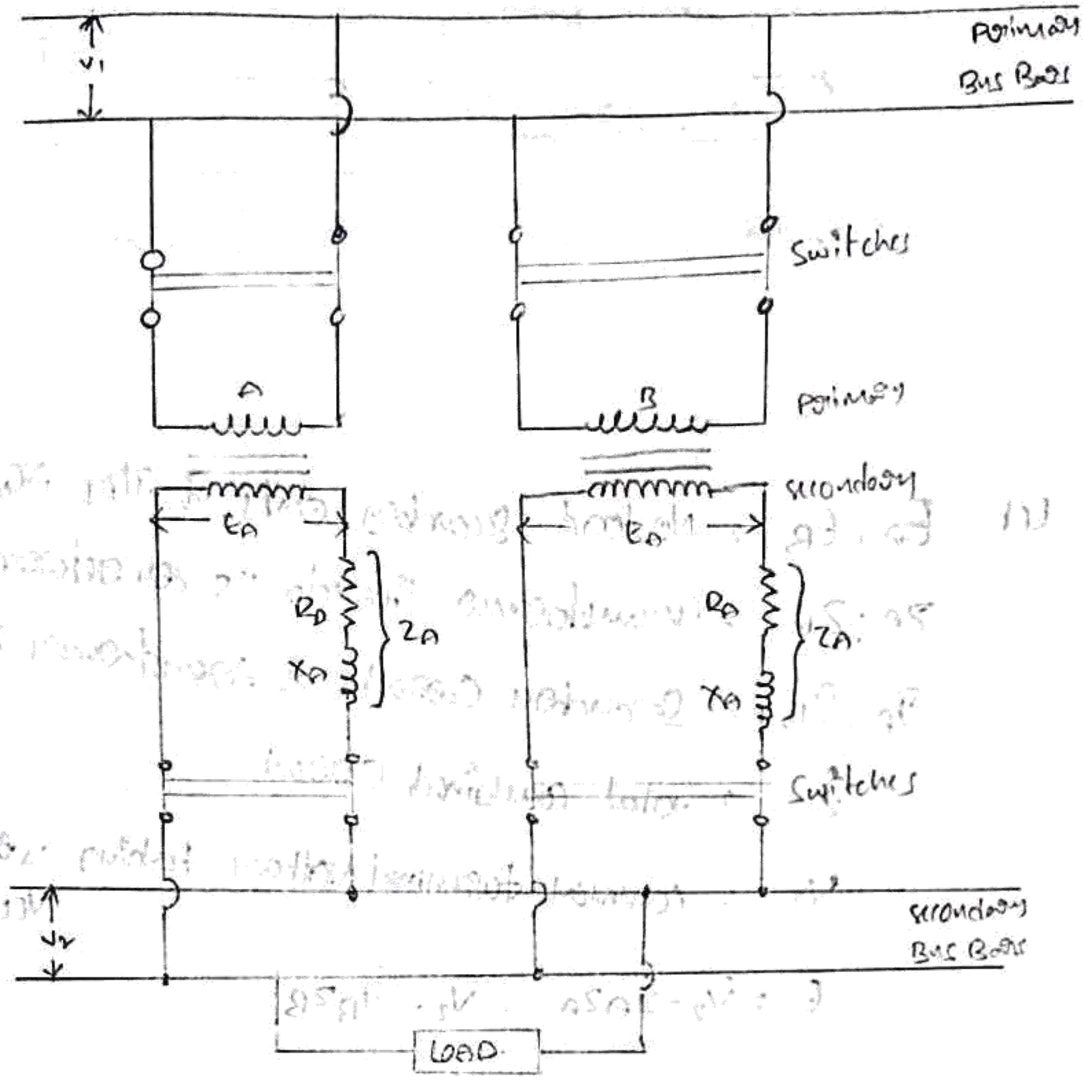
In order that, to share the total connected load between the two transformers is proportional to their kVA rating. The ohmic impedances should be inversely proportional to their ratings (or) the per unit impedances are equal

4. "The quality of the impedances (i.e., ratio of winding resistance to reactance) of the two transformers must be equal." If ratios R/X are not equal, the two T/Fs will operate at different power factors for supplying a common load

The condition 1. is absolutely essential and must be full filled. Where as condition 2 must be satisfied to a very close degree and conditions 3 & 4 should also be satisfied as per as possible for better load sharing

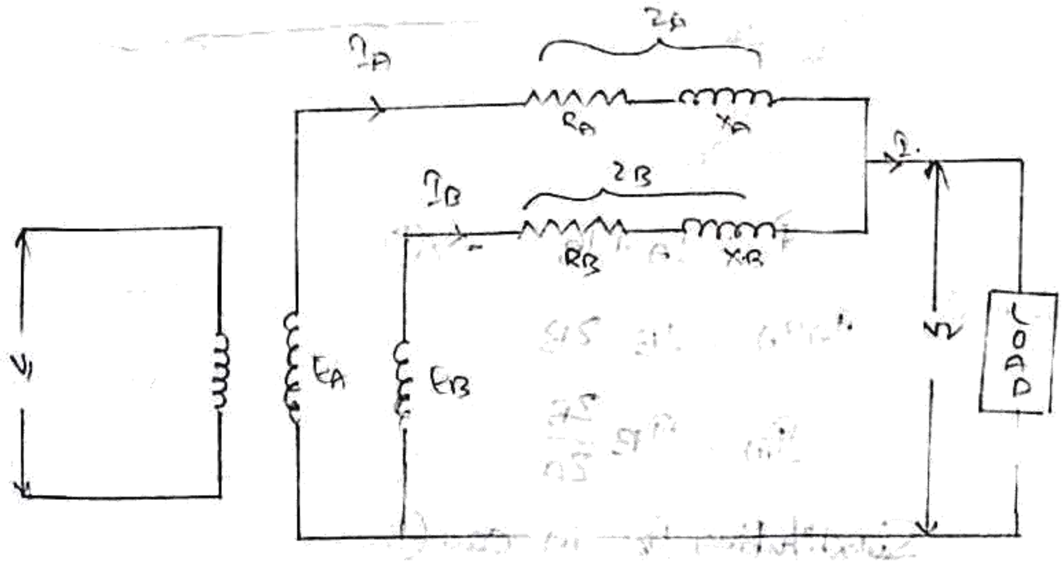
Load sharing between Two transformers:

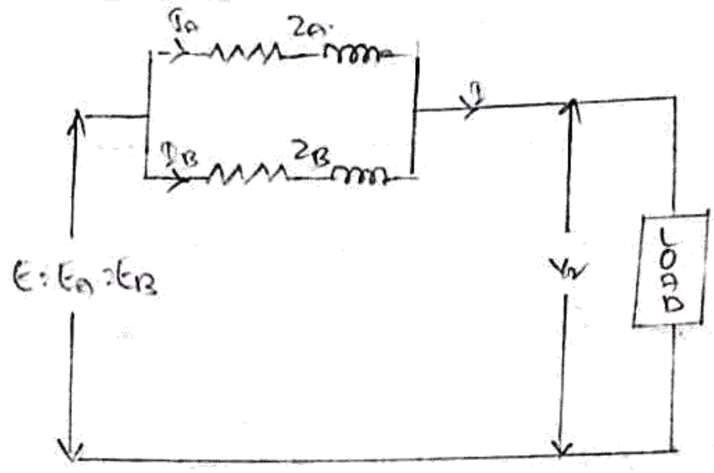
The figure shows two single-phase transformers connected in parallel and supplying current to the common load



Equal voltage ratios :-

When the transformers have equal voltage ratio $E_A = E_B = E$ the equivalent circuit of two transformers referred to the secondaries would then be as shown below





Let E_A, E_B = No load secondary emfs of T/Fs A & B

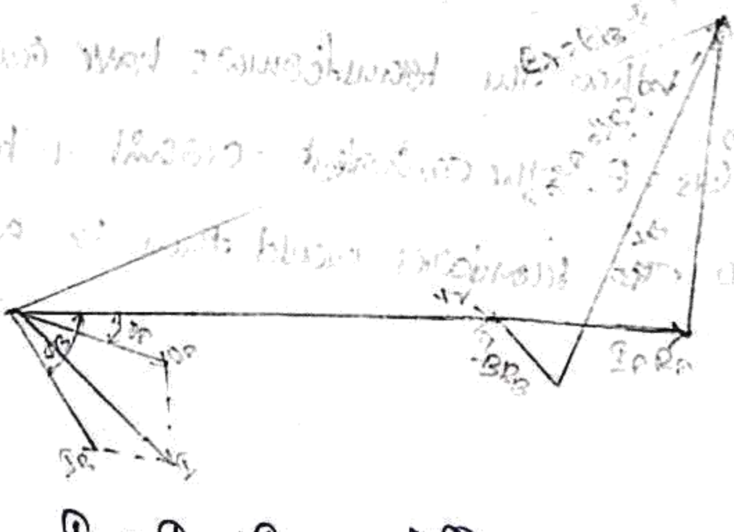
Z_A, Z_B = Transformer impedances referred to secondary

I_A, I_B = Secondary currents of transformers A & B

I = Total combined current

V_2 = common terminal voltage taking as reference vector

$$\bar{E} = \bar{V_2} - \bar{I_A} Z_A = \bar{V_2} - \bar{I_B} Z_B$$



$$I = I_A + I_B \rightarrow (1)$$

$$I_A Z_A = I_B Z_B$$

$$I_A = I_B \frac{Z_B}{Z_A}$$

Substituting I_A in eqn (1)

$$I = I_B \frac{Z_B}{Z_A} + I_B = I_B\left[\frac{Z_B}{Z_A}+1\right]$$

$$I = I_B\left[\frac{Z_A+Z_B}{Z_A}\right]$$

Load current shared by transformer B.

$$I_B = I \frac{Z_A}{Z_A+Z_B}$$

load current shared by transformer A

$$I_A = I \frac{Z_B}{Z_A+Z_B}$$

Multiplying both sides by voltage V_2. we get

$$V_2 I_B = V_2 I \frac{Z_A}{Z_A+Z_B}$$

$$V_2 I_A = V_2 I \frac{Z_A}{Z_A+Z_B}$$

$V_2 I \times 10^{-3}$ = kVA of the combined load = S

Thus kVA supplied by transformer A

$$S_A = S \frac{Z_B}{Z_A+Z_B}$$

kVA supplied by transformer B

$$S_B = S \frac{Z_A}{Z_A+Z_B}$$

$$\frac{S_A}{S_B} = \frac{Z_B}{Z_A}$$

The loads shared in kVA are inversely proportional to their impedances.

<u>Note</u>:- If the kVA ratings of the two transformers are different, then impedances of both should be adjusted to common base kVA

Problems on Parallel operation of 1-ϕ Transformers:

(1) Two 1-ϕ transformers with equal turns have impedance of (0.5+j3) and (0.6+j10) with respected to the secondary if they operating parallel determine How they will share of total load of 100 kW at power factor is 0.8 lagging.

Sol Given data:

Impedance of Transformer A $(Z_A) = (0.5+j3)\ \Omega = 3.04\angle 80.53\ \Omega$

Impedance of transformer B $(Z_B) = (0.6+j10)\ \Omega = 10.01\angle 86.5$

Total Impedance $(Z_A+Z_B) = 13.04\angle 85.16$

Total load = 100 kW

Power factor $\cos\phi = 0.8$ lagging

$\phi = \cos^{-1}(0.8) = -36.86$

$$S_A = S \cdot \frac{Z_B}{Z_A+Z_B}$$

$S = \frac{100}{0.8} = 125\angle -36.86$

$S_A = 125\angle -36.86 \cdot \frac{10.01\angle 86.56}{13.04\angle 85.16}$

$= 95.95\angle 86.56$

$= 96$

$S_B = 125\angle -36.86 \cdot \frac{3.04\angle 80.53}{13.04\angle 85.16}$

$= 29.14\angle 80.53$

$S_B = 30$

2. Two 1-φ transformers A & B rated at ~~250~~ ~~kVA~~ each are operated in parallel and supply a load of 1000A & 0.8 p.f lag. The total impedances of the two transformers in terms of secondary are $2+j3\ \Omega$ & $2.5+j5\ \Omega$ respectively. Calculate the current supplied by each transformer.

Sol

Given data:

Impedance of transformer A referred to secondary

$$Z_A = 2+j3 = 3.605\angle 56.31^\circ$$

Impedance of transformer B referred to secondary

$$Z_B = 2.5+j5 = 5.59\angle 63.43^\circ$$

$$Z_A+Z_B = (2+j3)+(2.5+j5) = (4.5+j9) = 9.178\angle 60.64^\circ$$

Load power factor $\cos\phi = 0.8$

$$\phi = \cos^{-1}(0.8)$$

$$\phi = -36.87^\circ$$

Total load current to be shared

$$I = 1000\angle -36.87$$

load current shared by transformer A

$$I_A = I\frac{Z_B}{Z_A+Z_B} = 1000\angle -36.87 \times \frac{5.59\angle 63.43}{9.178\angle 60.64}$$

$$I_A = 609.06\angle -34.08^\circ$$

load current shared by transformer B

$$I_B = I\frac{Z_A}{Z_A+Z_B} = 1000\angle -36.87 \times \frac{3.605\angle 56.31}{9.178\angle 60.64}$$

$$I_B = 392.79\angle -41.2^\circ$$

Auto Transformers :-

An auto transformer is a transformer having a single winding, part of this winding is common to both the primary & secondary. The input & output circuits are electrically connected.

Auto transformers work on the same principle as an ordinary two-winding transformer. It is used when transformation ratio differs little from unity.

Types :- An auto transformer may step-down (or) step up the voltage

(1) **Step-down Auto transformer :-**

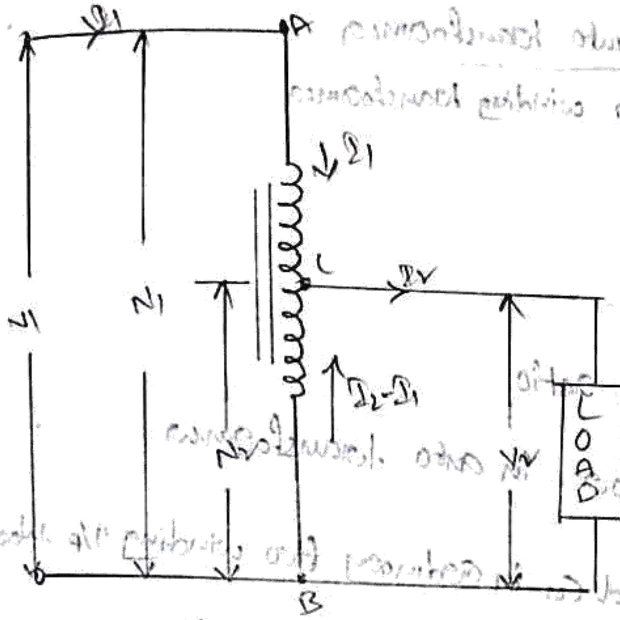
In this case the complete winding acts as primary winding while the tapped section of this winding works as secondary winding as shown in fig (A). The current I_2 is larger than the current I_1

ii) **Step-up Auto Transformer :-**

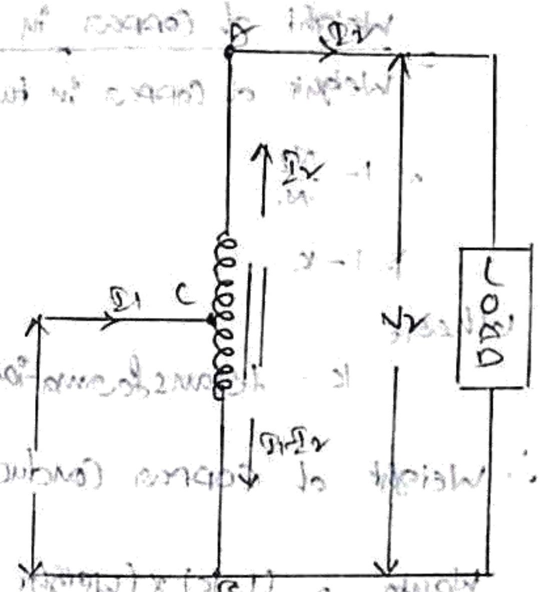
In this case, the whole winding works as a secondary winding and its portion performs the function of primary winding as shown in figure(B). The current I_2 is less than the current I_1.

As shown in fig (A). AB is the primary winding has a tapping at C and the supply voltage applied across it

The portion BC forms the secondary and as such load is connected across BC.



Step-down



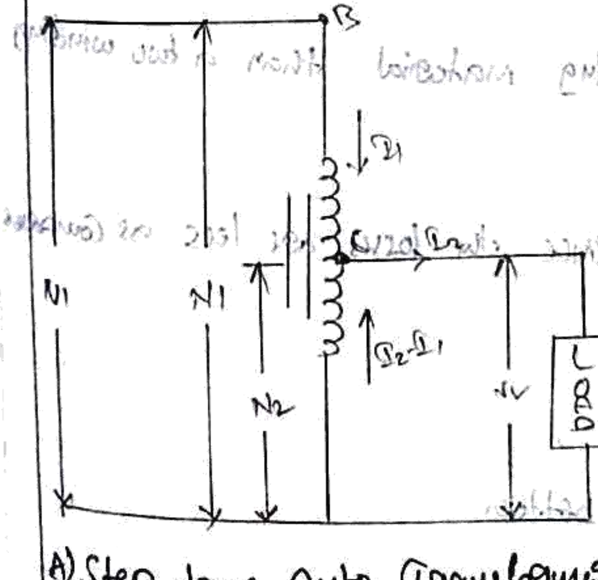
Step-up

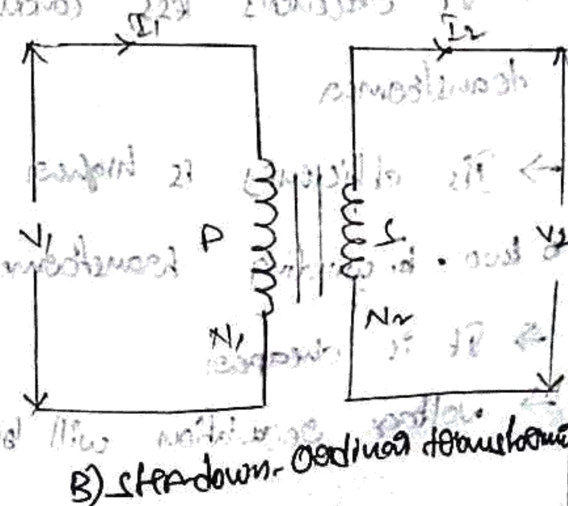
The transformation ratio k can be represented in the same way as in two-winding transformers

$$k = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2}.$$

<u>Saving of copper in auto transformer</u>:-

For the same capacity & voltage ratio, an auto transformer requires less winding material than a two-winding transformer.





A) Step-down Auto Transformer

B) Step-down ordinary transformer

The primary winding has N_1 turns & secondary winding has N_2 turns

$$= \frac{\text{Weight of copper in auto transformer}}{\text{Weight of copper in two winding transformer}}$$

$$= 1 - \frac{N_2}{N_1}$$

$$= 1 - K$$

where

K = transformation ratio

∴ Weight of copper conductor in auto transformer

$W_{auto} = (1-K) \times$ (weight of Cu. in ordinary two winding T/F W_{ord})

Saving of conductor material $= W_{ord} - W_{auto}$

$$= W_{ord} - (1-K) W_{ord}$$

$$= [1-(1-K)] W_{ord}$$

$$= K W_{ord}$$

Thus the use of an auto transformer there is saving in the weight of copper equal to K times of weight of copper in the two winding transformer

Advantages :-

→ It requires less conducting material than a two winding transformer

→ Its efficiency is higher since the losses are less as compared to two winding transformer

→ It is cheaper

→ voltage regulation will be better

→ Continuously varying voltage can be obtained

Disadvantages:

→ The two windings are not electrically separated & in case of failure of insulation b/w the two, either a severe shock may be felt on the low-voltage side

→ The use of auto transformer is more economical only when transformation ratio is nearer to unity

→ It is smaller in size

Applications:

→ Generally used for starting of induction motors

→ Used as a variac, to give a variable output voltage

→ Used as a line booster, to increase the voltage by a small amount

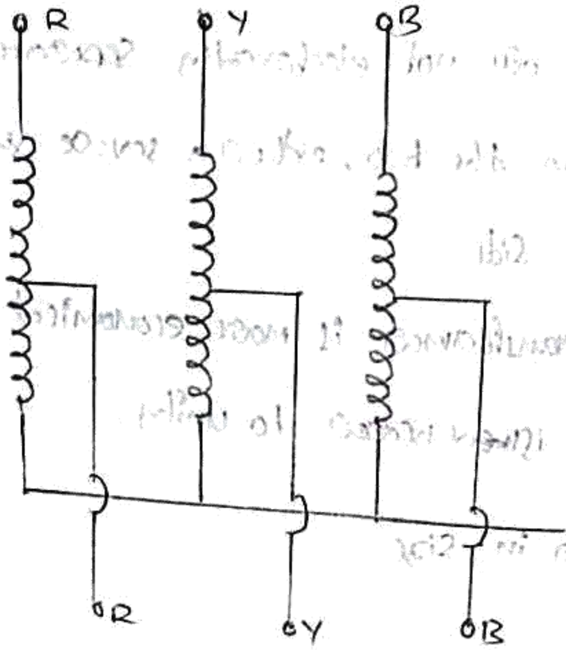
→ Used in the laboratories to conduct various tests at low voltages

→ Used as regulation transformers, where only a small variation of voltage is required

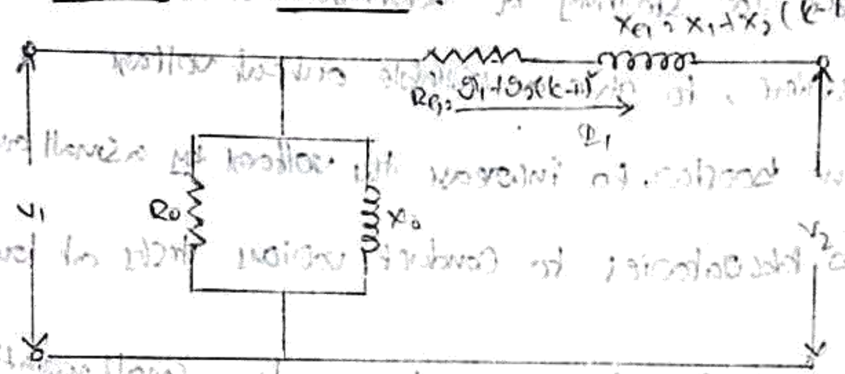
→ Used as furnace transformers, for getting a convenient supply to suit the furnace winding from normal 230V AC supply

3-ϕ Auto Transformer:

In case of 3-ϕ auto transformer, three sets of windings are placed over each limb. The tappings are taken from the suitable points as shown in below figure. The windings are connected with a common star & finally the voltages is obtained. These are generally used to start 3-ϕ induction motor the tappings are so adjusted that, the suitable voltage for starting of the motor is obtained



Equivalent circuit:



The auto transformer may be considered as two winding transformer with the part AC as primary winding and the part CB of the winding as secondary. The turn ratio can be take as

$$\frac{\text{Primary winding turns}}{\text{Secondary winding turns}} = \frac{N_1 - N_2}{N_2}$$