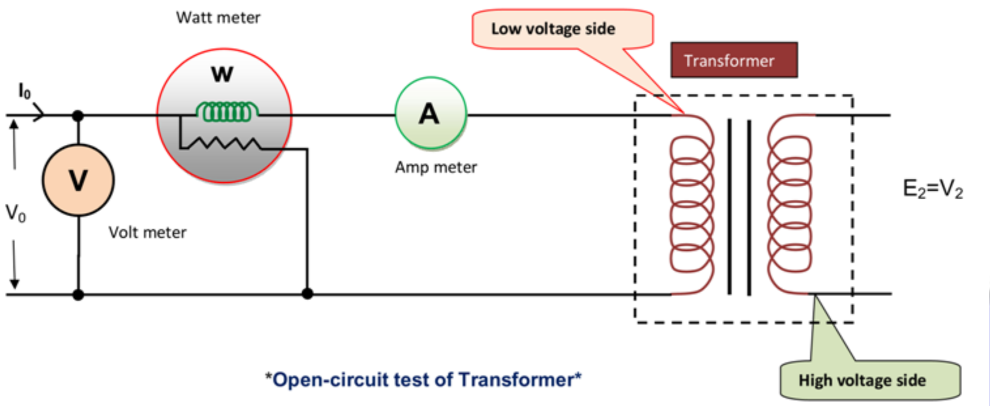
## 4-14 Open Circuit or No-Load Test:

The purpose of this test is to determine no-load loss or core loss and no-load current $I_o$ which is helpful in finding $X_o and\ R_o$.




*Open-circuit test of Transformer*

$P(w) = I_o V_1 \cos\emptyset_o$

$I_{mag} = I_o \sin\emptyset_o$

$\mathrm{I_c} = \mathrm{I_o}\cos\emptyset_o$

$\mathrm{X_o} = \frac{V_1}{\mathrm{I_{mag}}}$ , $\mathrm{R_o} = \frac{\mathrm{V_1}}{\mathrm{I_c}}$

Wher: $X_o = no\ load\ inductance$, $R_o = no\ load\ resistance$

$I_o = no\ load\ current$ , $V_1 = supply\ voltage$

$P = no\ load\ power$

If $W$ or $P_o$ is wattmeter reading, then:

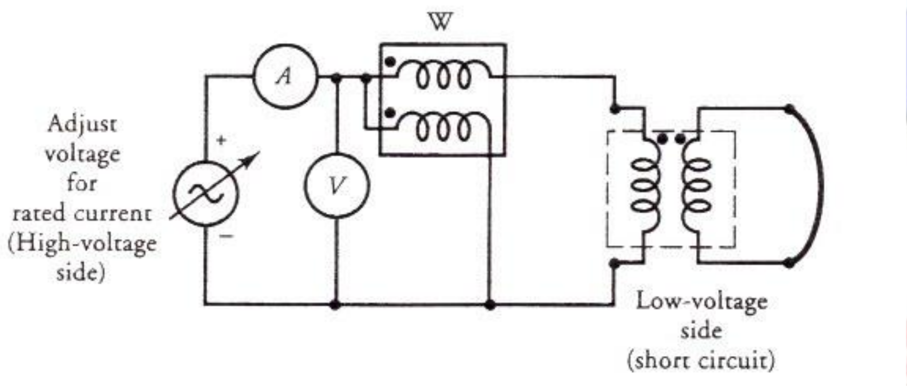
$P_o = V_1 I_o \cos\emptyset_o$ and $\cos\emptyset_o = \frac{\mathrm{P_o}}{\mathrm{V_1 I_o}}$

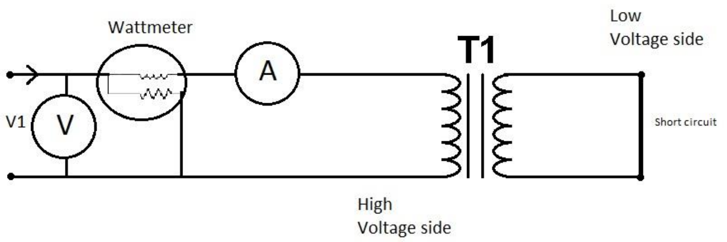
## 4-15 Short Circuit or Impedance Test:

This is an economical method for determining the follow:

$Z_{e1}, Z_{e2}, X_{e1}, X_{e2}, P_{cu}$. Equivalent impedance ($Z_{e1} or\ Z_{e2}$), leakage reactance ($X_{e1}\ or\ X_{e2}$) and total resistance ($R_{e1}\ or\ R_{e2}$) of the transformer as referred to the winding.

$P_{cu}$ losses at full load and at any load and then used to calculate the efficiency of transformer. Knowing $Z_{e1}\ and\ Z_{e2}$ , the total voltage drops in the transformer as referred to primary or secondary can be calculate and hence regulation of the transformer determined.




If Vsc is the voltage required to circulate rated load current , then:

$$Z_{e1} = \frac{V_{sc}}{I_1} \quad , \quad X_{eq} = \frac{V_1}{I_1}$$

ALSO

$P_{sc} = \mathrm{I}_1^2\ \mathrm{R}_{e1}$

$\mathrm{R}_{e1} = \frac{P_{sc}}{\mathrm{I}_1^2}$ and $\mathrm{X}_{e1} = \sqrt{\mathrm{Z}_{e1}^2 - \mathrm{R}_{e1}^2}$

Note:

$P_o$ =imput power in watts on the open cct test

= Iron loss =$P_c$

$P_{sc}$ = imput power in watts on the short cct test with full load current.

$P_{sc}$ = total copper loss on full load,

$\sum loss\ in\ full\ load = P_o + P_{sc}$

$\frac{full\ load\ VA \times P.f}{full\ load\ VA \times P.f + P_o + P_{sc}} \times 100$ŋ=

## 4-16 Voltage Drop in A Transformer:

Total transformer drops as referred to secondary

$= I_2\ R_{e1}\ \cos\varphi \mp \mathrm{I}_2\ \mathrm{X}_{e2}\ \sin\varphi$

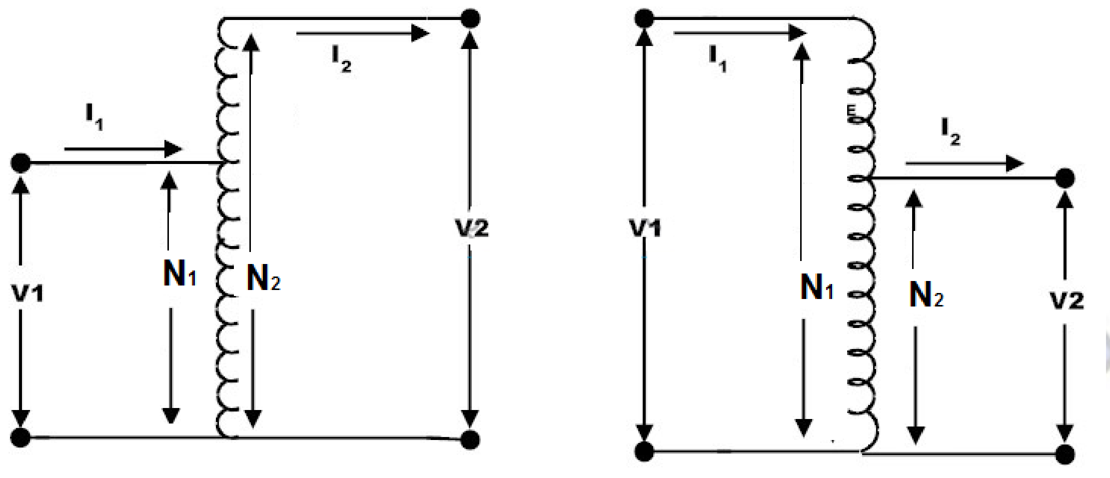
Total transformer drops as referred to primary

$= I_1\ R_{e1}\ \cos\varphi \mp I_1\ X_{e1}\ \sin\varphi$

Note: the upper sings are to be used +Ve for lagging power factor and – Ve for leading power factor.

## 4-17 Auto – transformer:

It is transformer with one winding only. Because of on winding it use less cupper and hence is cheaper. Figure below shows both step down and step up auto-transformer.




(a)Step up Autotransformer (b)Step down Autotransformer

As compared to an ordinary 2-winding transformer of same output, an auto-transformer has higher efficiency but ,smaller size.

**Uses of auto-transformer:**

1-To give small boost to a distribution cable to current the voltages drop.

2-To give up to 50 to 60 at full voltage to an induction motor during starting.

3- As furnace transformers for getting a convenient supply to suit the furnace winding from 230 v supply.

4- As interconnecting transformer in 132kv/330kv system.

5- In control equipment for 1-phase and 3-phase electrical locomotives.

## 5 Parallel operation of single-phase transformer:

For supply a load excess of the rating of an existing transformer, a second transformer may the connected in parallel. There are certain definite conditions which must be satisfied in order to avoid any local circulating currents and to ensure that the transformers share the common load in proportion to their KVA ratings. The conditions are:

1-Primary windings of the transformer should be suitable for the supply system voltage and frequency.

2-The transformers should be properly connected with regard to polarity.

3- The voltage ratings of both primaries and secondaries should be identical.

4-The percentage impedance should be equal in magnitude and have the same X/R ratio in order to avoid circulating currents and operation at different power factor.

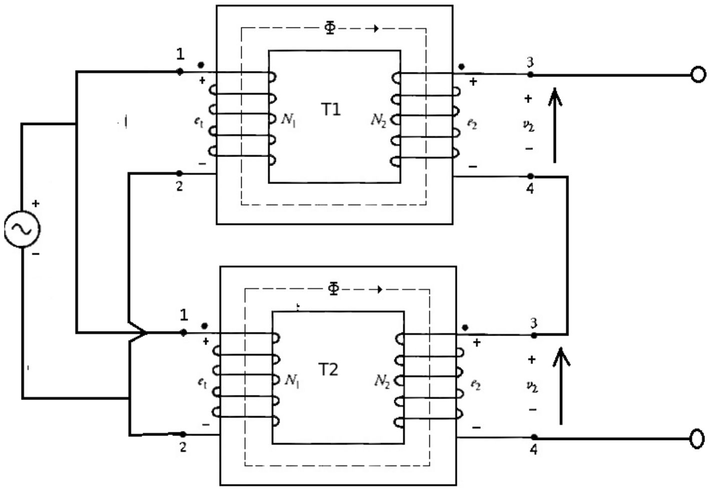
5- With transformers having different KVA ratings. The equivalent impedances should be inversely proportional to the individual KVA rating if circulating currents are to be avoided.

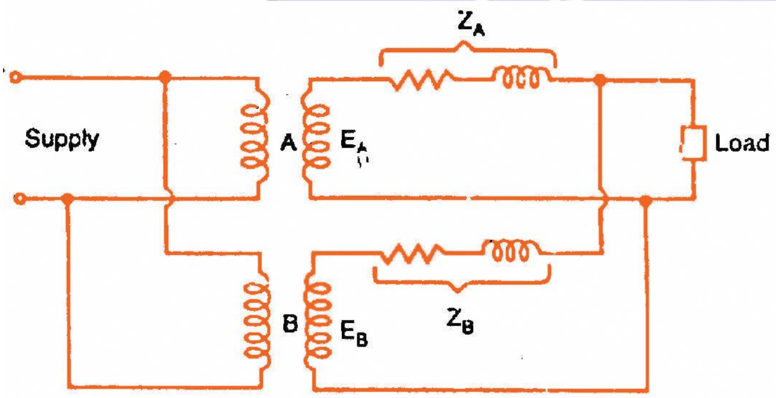
There are two cases for represent of parallel connections of single-phase transformers:

## 5-1 Ideal case:

## Equal voltage ratios:

At no-load of both secondaries is the same $E_A=E_B=E$ , and that the two voltage are coincident . There is no phase different between $E_A$ and $E_B$ which would be turn if the magnetizing different from each other.



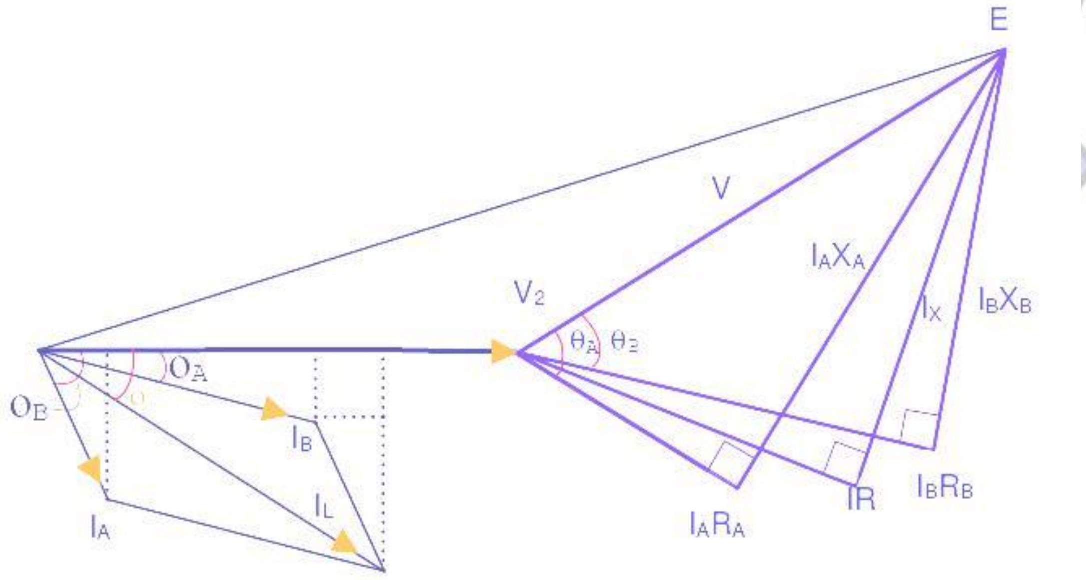




Figure 39: Phasor Diagram of Operation for two Transformers working in Parallel

Phasor diagram of 2 transformers in parallel:

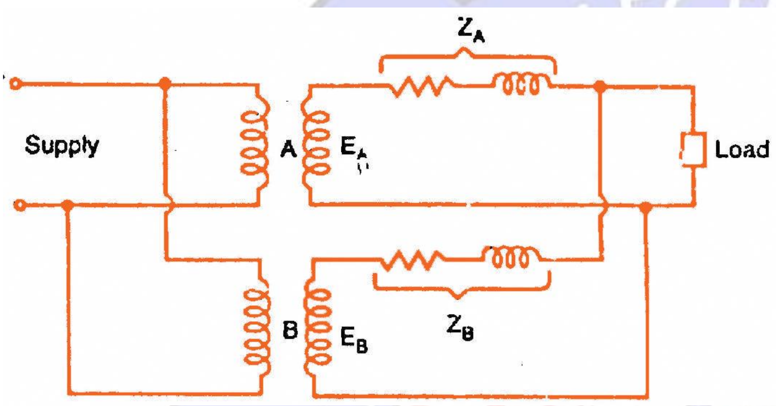
$I_A = \frac{I\, Z_B}{Z_A + Z_B}$ and $I_B = \frac{I\, Z_A}{Z_A + Z_B}$

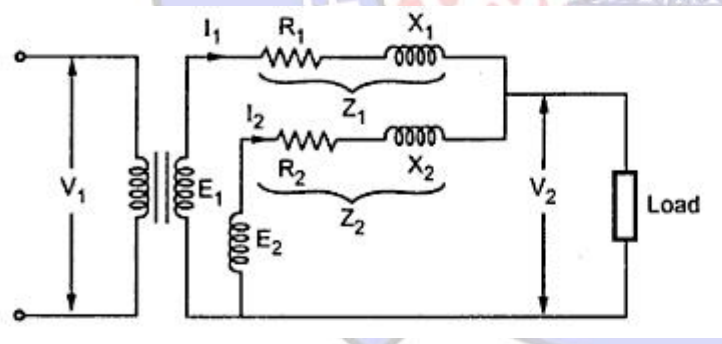
$V_2 I_A = \frac{V_2\, I\, Z_B}{Z_A + Z_B}$ and $V_2 I_B = \frac{V_2\, I\, Z_A}{Z_A + Z_B}$

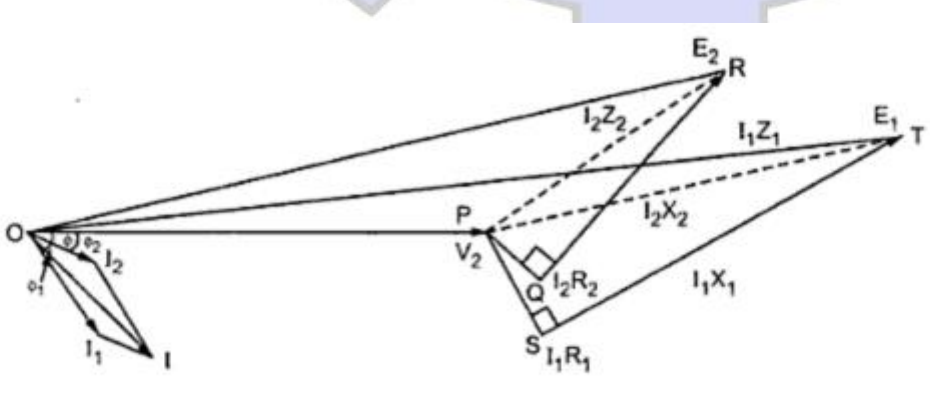
$S_A = S\, \frac{Z_B}{Z_A + Z_B}$ and $S_B = S\, \frac{Z_A}{Z_A + Z_B}$

## Unequal Voltage Ratios:

In this case the voltage ratios of the two transformers are different. It means that their no-load secondary voltages are unequal.




$E_A = I_A\, Z_A + V_2$

$$E_B = I_B\, Z_B + V_2$$

$$V_2 = I\, Z_L = (I_A + I_B)Z_L$$

$$E_A = I_A\, Z_A + (I_A + I_B)Z_L$$

$$E_B = I_B\, Z_B + (I_A + I_B)Z_L$$

$$E_A - E_B = I_A\, Z_A - I_B\, Z_B$$

$$\mathrm{I_A} = \frac{E_A - E_B) + I_B\, Z_B}{Z_A} \qquad Substituting\ I_A\ in$$

$$\mathrm{I_B} = \frac{E_B\, \mathrm{Z_A} - (\mathrm{E_A} - \mathrm{E_B})\mathrm{Z_L}}{\mathrm{Z_A\, Z_B} + \mathrm{Z_L}(\mathrm{Z_A} + \mathrm{Z_B})}$$

$$\mathrm{I}_A = \frac{E_A\, \mathrm{Z_B} - (\mathrm{E_A} - \mathrm{E_B})\mathrm{Z_L}}{\mathrm{Z_A\, Z_B} + \mathrm{Z_L}(\mathrm{Z_A} + \mathrm{Z_B})}$$

$$I = I_A + I_B = \frac{E_A\, Z_B + E_B\, Z_A}{Z_A\, Z_B + Z_L(Z_A + Z_B)} \quad \times \frac{{}^{1}/_{Z_A\, Z_B}}{{}^{1}/_{Z_A\, Z_B}} \quad \times Z_L$$