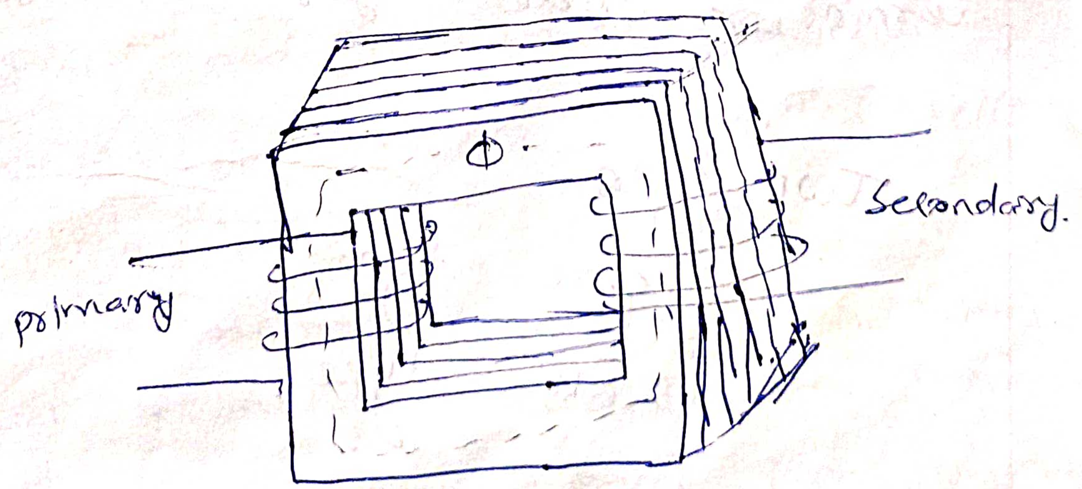
Ch-3

Single phase Transformer:-

Transformer is a static device which transforms electric power from one circuit to another circuit at same frequency.

principle:-

Basic principle involved in transformer is mutual induction: one coil is connected to a source of alternating voltage, an alternating flux is set up in the core, most of which is linked with the other coil in which it produces mutually induced e.m.f.. If the second coil is closed, a current flows in it and so electric energy is transferred from the first coil to the second.



Construction

-> It consists of two coils and laminated steel core.

-> Other necessary parts are some suitable container for assembled core and windings;

-> A suitable medium for insulating the core and its winding from its container.

-> Suitable bushings for insulating and bringing out the terminals of windings from the tank.

-> Core is of steel with high content of silicon, which is laminated inorder to minimize eddy current loss.

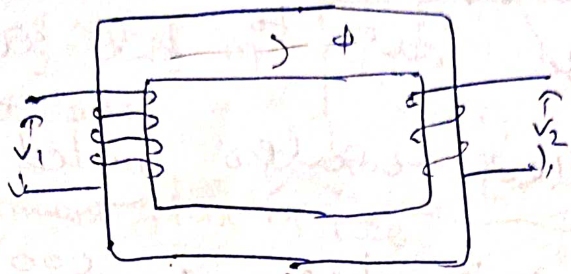
-> The laminations insulated from each other by a light coat of core plate varnish or oxide layers on the surface.

Two type

- core type
- Shell type.

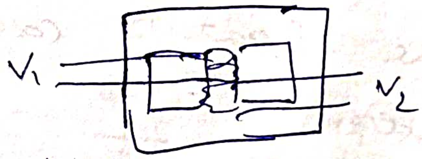
core type

In core-type transformers the windings surround a considerable part of the core.



Shell type

In shell-type transformer the core surrounds a considerable part of the winding.



cooling employed in t/f

- oil filled self cooled
- oil filled water cooled
- Air blast type.

Oil filled self cooled:

. Small and medium size distribution transformers are of oil filled self cooled type.

The assembled windings and cores of such transformers are mounted in a welded, oil tight steel tank provided with steel cover.

After putting the core at its proper place the tank is filled with purified high quality insulating oil.

The oil serves to convey the heat from core and windings to the case from where it is radiated out to the surroundings.

Oil filled water cooled:

In this type a cooling coil is mounted near the surface oil through which water is kept circulating. The heat is carried away by the water.

Large transformers are constructed with this type.

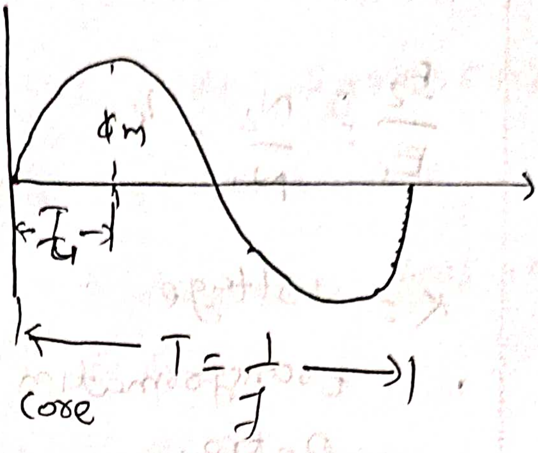
Air blast type:

For voltages below 25,000 V T/f can be built for cooling by means of air blast. The T/f is not immersed in oil, but is housed in a thin sheet metal box open at both ends through which air is blown from the bottom to the top by means of fan or blowers.

E.m.f. equation of a T/f :

N_1 = no. of turns in primary.

N_2 = No. of turns in secondary.



ϕ_m = maximum flux in core

$= B_m \times A$

f = frequency.

Average e.m.f. / turn $= \frac{d\phi}{dt}$

$= \frac{\phi_m}{\frac{1}{4f}} = 4f\phi_m$

r.m.s value of e.m.f. / turn $= 1.11 \times 4f\phi_m$

$= 4.44\, \phi_m f.$

E.m.f. in primary winding

= E.m.f. / turn × No. turns of primary

$$\text{E.m.f} = 4.44\, \phi_m f \times N_1$$

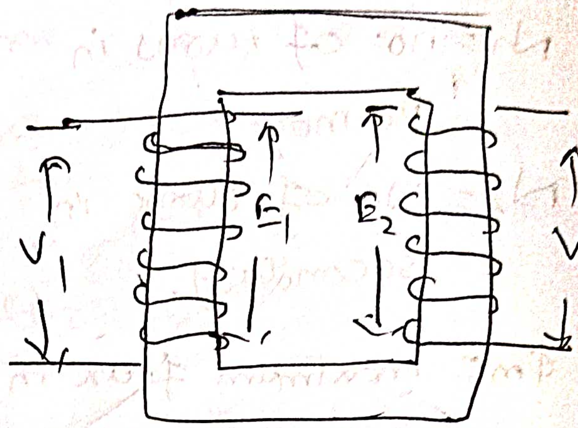
$$\text{E.m.f} = 4.44\, f\, N_1 \times B_m \times A \text{ volts}$$

$= 4.44 \times N_1 \times f \times B_m \times A$

Voltage Transformation Ratio (K)

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

K = Voltage transformation Ratio.

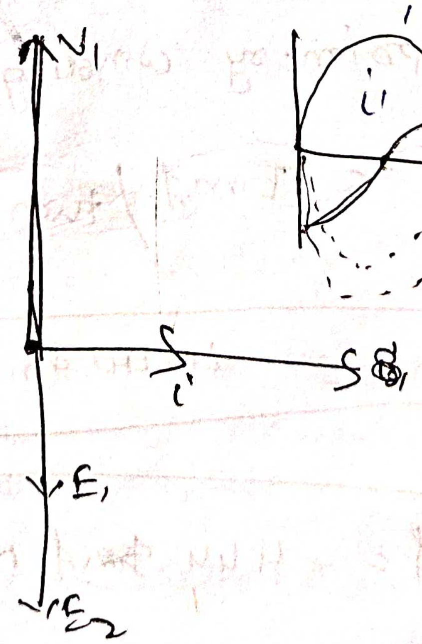


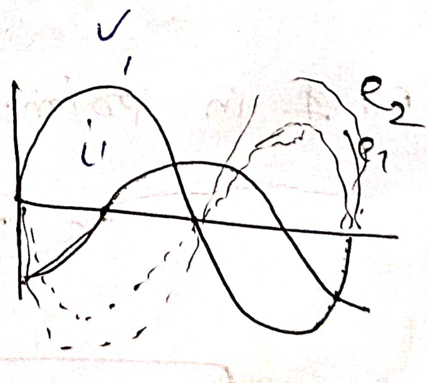
When $N_2 > N_1$ $K > 1$ Step-up T/f

$N_2 < N_1$ $K < 1$ Step-down T/f

Ideal T/f

- No ohmic losses or I^2R loss
- No saturation
- No magnetic leakage
- No core losses





Transformer with losses:

For actual t/f

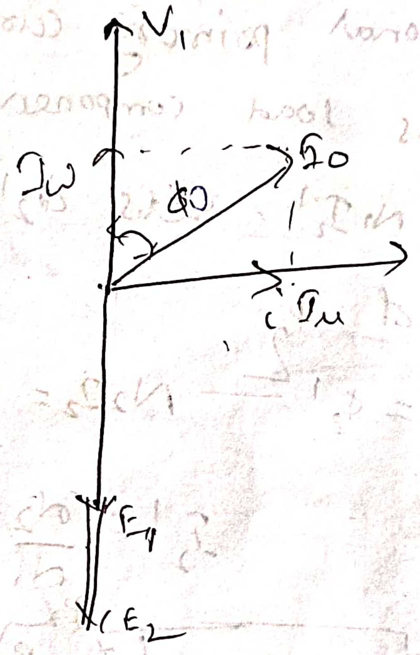
1) iron loss in the core i.e. hysteresis loss and eddy current loss.

2) & small amount of copper loss in the primary.

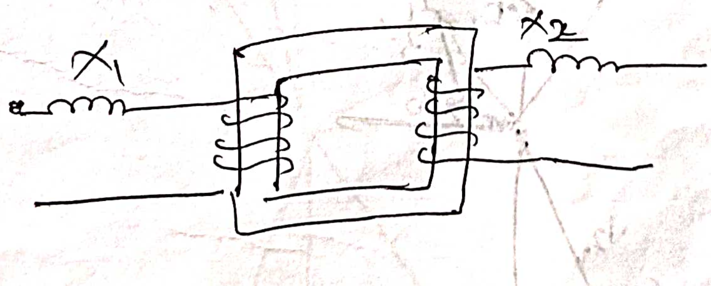
$I_w = I_0 \cos\phi_0$

$I_\mu = I_0 \sin\phi_0$

I_0 is 1% of F.L. primary current



Magnetic leakage



$X_1 = \frac{e_{L_1}}{I_1}$ $\quad X_2 = \frac{e_{L_2}}{I_2}$ =

Transformer on load :-

When secondary current I_2 is set up, then $N_2 I_2$ m.m.f. Hence flux ϕ_2.

ϕ_2 opposes main flux ϕ.

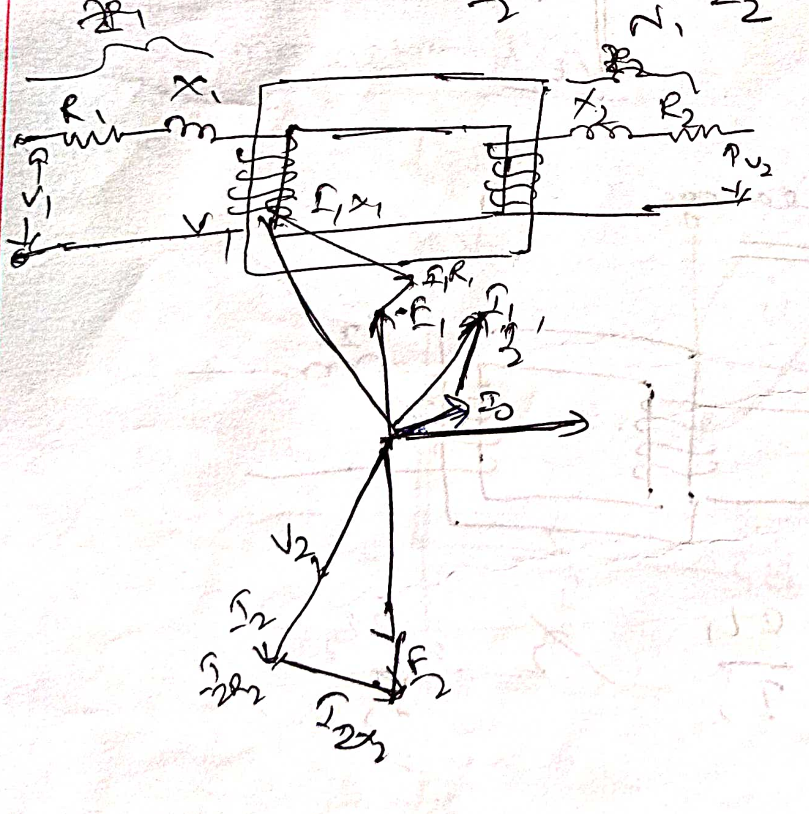
Hence E_1 is reduced.

So additional primary current be I_2'. It is known as load component of primary current.

This $N_1 I_2'$ sets ϕ_2' which neutralises effect of ϕ_2.

$$\phi_2 = \phi_2' \qquad N_2 I_2 = N_1 I_2'$$

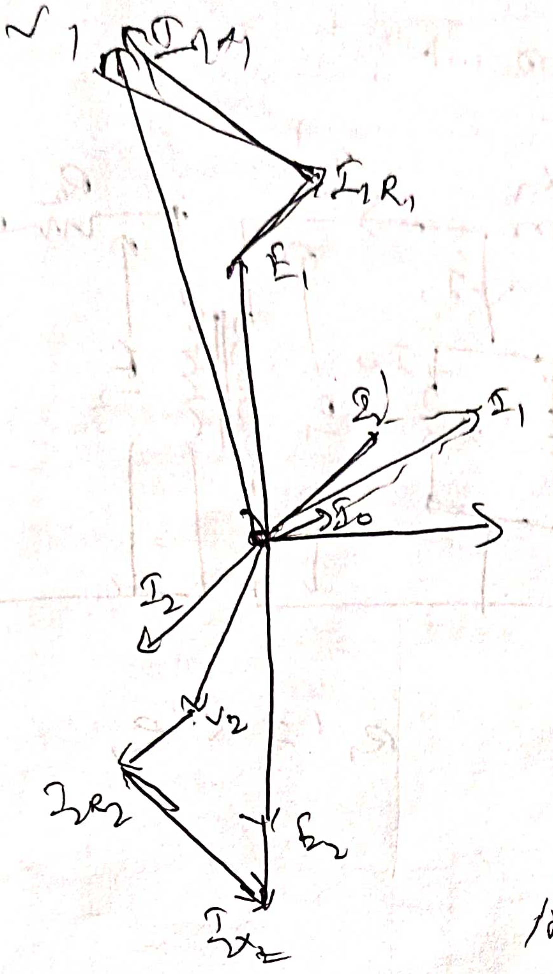
$$I_2' = \frac{N_2}{N_1} I_2 = K I_2.$$



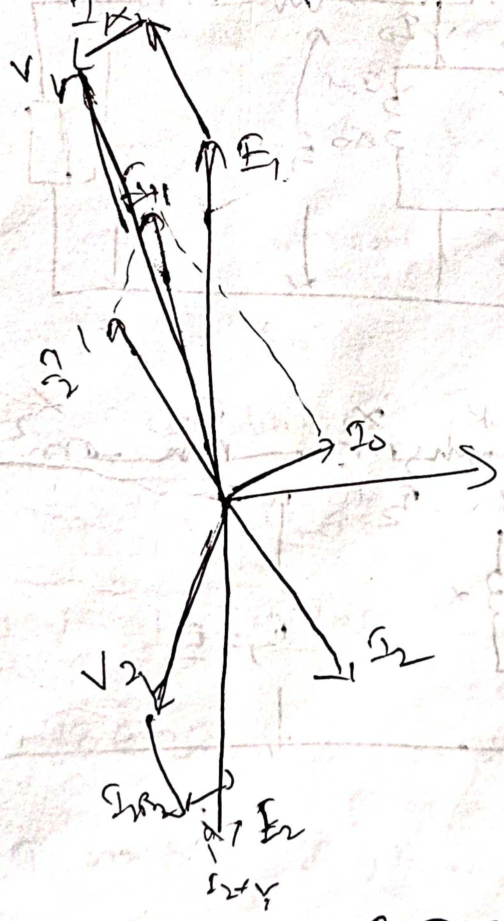
$V_1 = E_1 + I_1 Z_1$

$V_2 = E_2 + I_2 Z_2$

resistance

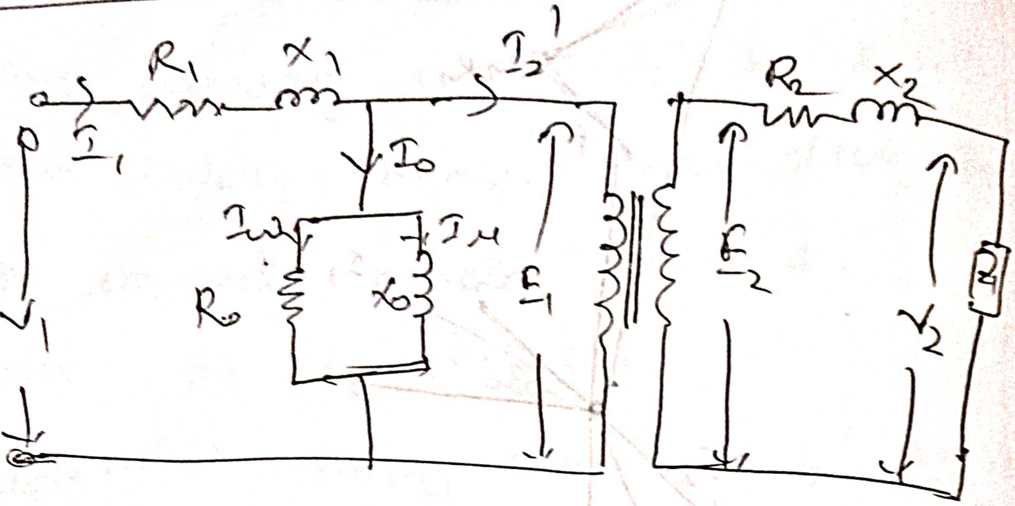


Inductance



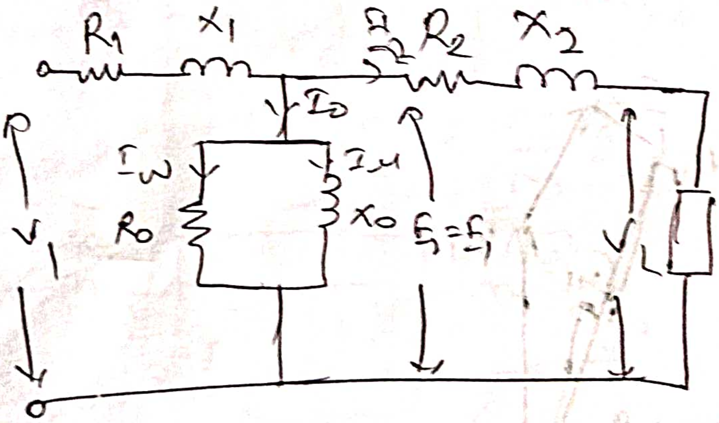
Capacitance

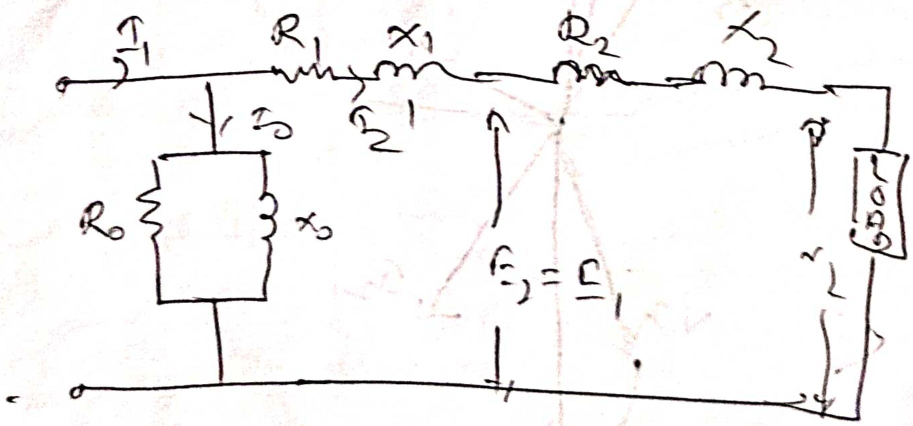
Equivalent circuit :-



$$R_2' = \frac{R_2}{K^2} \qquad R_1' = K^2 R_1$$

$$E_2' = \frac{E_2}{K} = E_1$$





$$Z_1 = Z_1 + Z_m \parallel (Z_2' + Z_L')$$

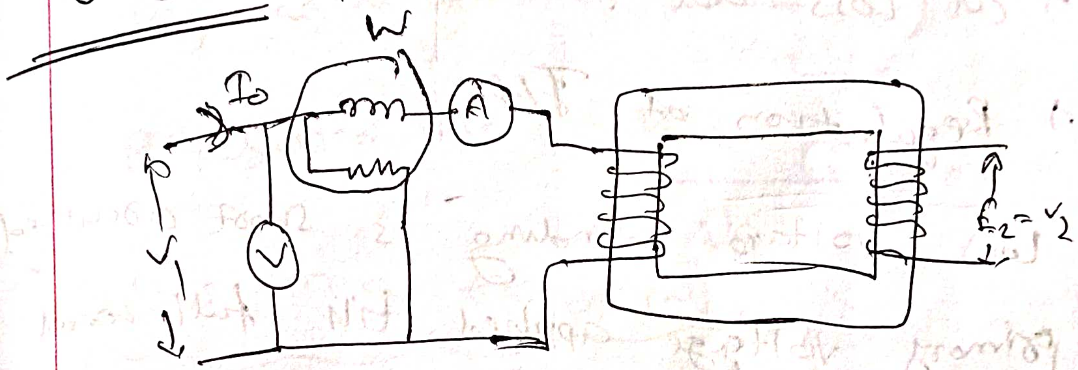
$$= Z_1 + \frac{Z_m (Z_2' + Z_L')}{Z_m + Z_L' + Z_2'}$$

Transformer tests :-

open circuit test

& short circuit test

O.C. test :-



first No load loss i.e. core loss.

no load current I_0

then X_0 & R_0

Low voltage winding is supplied and high voltage is left open.

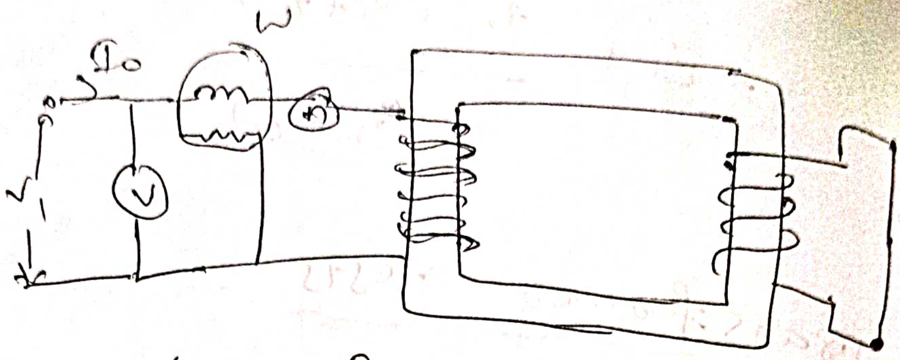
as I_0 is small cu-loss is negligible.

$W = V_1 I_0 \cos\phi_0$. $\cos\phi_0 = \frac{W}{V_1 I_0}$.

$I_\mu = I_0 \sin\phi_0$, $I_w = I_0 \cos\phi_0$.

$X_0 = \frac{V_1}{I_\mu}$, $R_0 = \frac{V_1}{I_w}$.

Short circuit test:



- We can find Z_{01} or Z_{02}, X_{01} or X_{02} & R_{01} or R_{02}.
- Cu loss at full load.
- Regulation of T/F.

Low voltage winding is short circuited. Primary voltage applied till full load current flows through secondary.

Since less voltage is applied flux will be less and core loss is very small. So watt meter reading is FL Cu loss.

$$Z_{01} = \frac{V_{sc}}{I_1} \quad \& \quad W = I_1^2 R_{01}$$

$$R_{01} = \frac{W}{I_1}$$

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

*** Why transformer rated in KVA ?

Cu loss depends on current & core loss depends on voltage i.e. total loss independent of power factor. So transformers in KVA not in KW.

Regulation of T/F

Regulation down = $\frac{V_{NL} - V_{FL}}{V_{NL}} \times 100$

Regulation up = $\frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$

Losses in a transformer:-

No mechanical losses

Core loss

Hysteresis & Eddy current loss.

$W_h = \eta B_{max}^{1.6} f V$ watt

$W_e = P B_{max}^2 f^2 t^2$ watt

Copper loss

Total Cu. loss = $I_1^2 R_1 + I_2^2 R_2$

$= I_1^2 R_{01}$ or $I_2^2 R_{02}$.

Condn for max. efficiency

$$\eta = \frac{o/p - loss}{o/p} \times 100$$

$$\therefore \eta = \frac{V_1 I_1 \cos\phi_1 - I_1^2 R_{01} - W_i}{V_1 I_1 \cos\phi_1}$$

$$\eta = 1 - \frac{I_1 R_{01}}{V_1 \cos\phi_1} - \frac{W_i}{V_1 I_1 \cos\phi_1}$$

$$\frac{d\eta}{dI_1} = 0 - \frac{R_{01}}{V_1 \cos\phi_1} + \frac{W_i}{V_1 I_1^2 \cos\phi_1}$$

$$\frac{d\eta}{dI_1} = 0$$

$$\frac{R_{01}}{V_1 \cos\phi_1} = \frac{W_i}{V_1 I_1^2 \cos\phi_1}$$

$$W_i = I_1^2 R_{01} \text{ or } I_2^2 R_{02}$$

Cu loss = Iron loss

All day efficiency:

$$\eta_{all-day} = \frac{\text{output in kwh}}{\text{Input in kwh}} \text{ (for 24 hours)}$$

Less than commercial efficiency

Parallel operation of single phase T/f

Cond^{ns} for parallel operation

1. primary windings of the T/f should be suitable for the supply system voltage & frequency.
2. Transformers should be properly connected with regard to polarity.
3. voltage rating of both primary and secondary should be ~~equal~~ identical i.e. K should be equal.
4. percentage impedance should be equal in magnitude and $\frac{X}{R}$ ratio should be equal
5. with different KVA equivalent impedance should be inversly proportional to the individual KVA rating.