Transformer and generator

Module - I

Single phase Transformer :- operation of practical transformer under no - load and on load with phasor dgm. Equivalent circuit, O.C & S.C test, all day efficiency, Voltage Regulation & Significance.

practical transformer on no load with phasor diagram

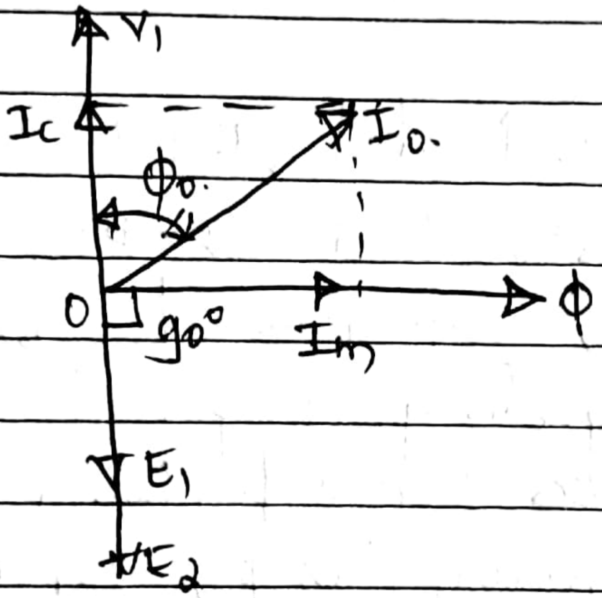
practical transformer has iron loss and small amount of primary Cu loss. The primary c/n under no load has to supply these losses denoted as Io

$\bar{I}_0 = \bar{I}_c + \bar{I}_m$

I_m → purely reactive component or magnetising component to produce flux.

I_c → Which supplies total losses called power component or wattful component or core loss component I_0.

Phasor diagram



$I_m = I_0 \sin\phi_0$ — ① $I_c = I_0 \cos\phi_0$ — ②

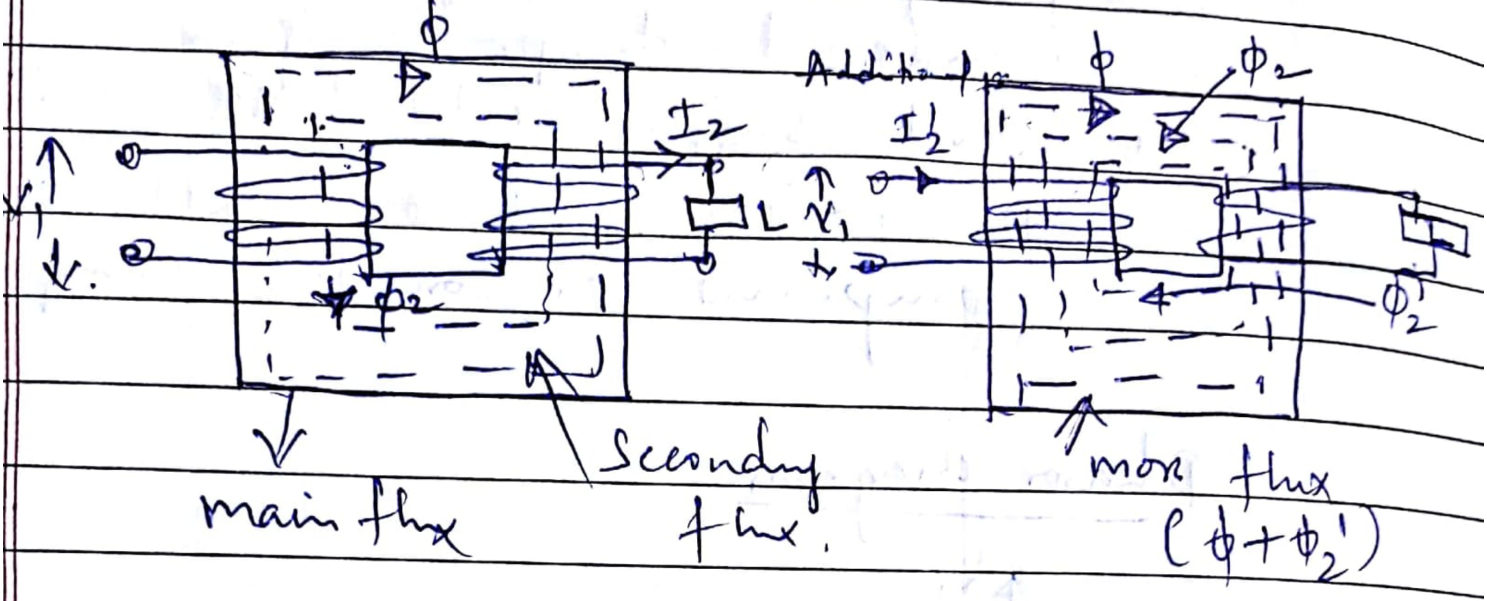
$$I_0 = \sqrt{I_m^2 + I_c^2}$$

$W_0 = V_1 I_0 \cos\phi_0 = V_1 I_c$.

$W_0 = V_1 I_0 \cos\phi_0 = P_i^o$ = Iron loss

Because Io is 3 to 5%. of F.L rated C/n

practical transformer on load (mmf Balancing on load



Transformer is loaded, $|I_2|$ & $\angle I_2$ is determined by load. Resistive load $\xrightarrow{I_2}V_2$, Inductive load $\rightarrow V_2$ $\downarrow I_2$, Capacitive $\uparrow I_2$ $\rightarrow V_2$

N_2I_2 – demagnetising ampere turns produce ϕ_2 which opposes main ϕ flux. (magnetising).

$\underline{\phi_2}$ Reduces main flux ϕ, E_1 ↓ (Reduces).

$\bar{V}_1 - \bar{E}_1$ increases due to which primary draws more current from supply.

I_2' Additional current or load component of primary ckt.

→ I_2' is antiphase with I_2 which sets up its flux ϕ_2' opposes ϕ_2 and helps main flux ϕ. ϕ_2' Neutralises ϕ_2.

→ $N_1 I_2'$ mmf balances $N_2 I_2$

→ flux in core is again maintained at constant level.

<u>Key point</u> :- Thus for any load cond^n, no load to full load flux in core is practically constant.

→ I_2' Neutralises changes in load, where flux & core losses are constant for all loads. Hence Transformer is <u>constant flux machine</u>

→ As balanced (mmf).

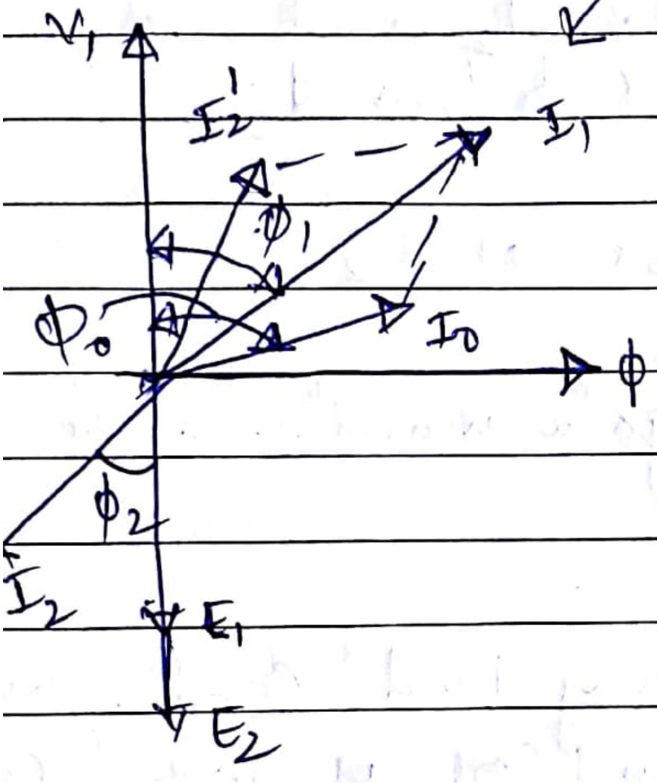
$$N_2 I_2 = N_1 I_2'$$

$$I_2' = \frac{N_2}{N_1} I_2 = K I_2 \quad \text{—} ①$$

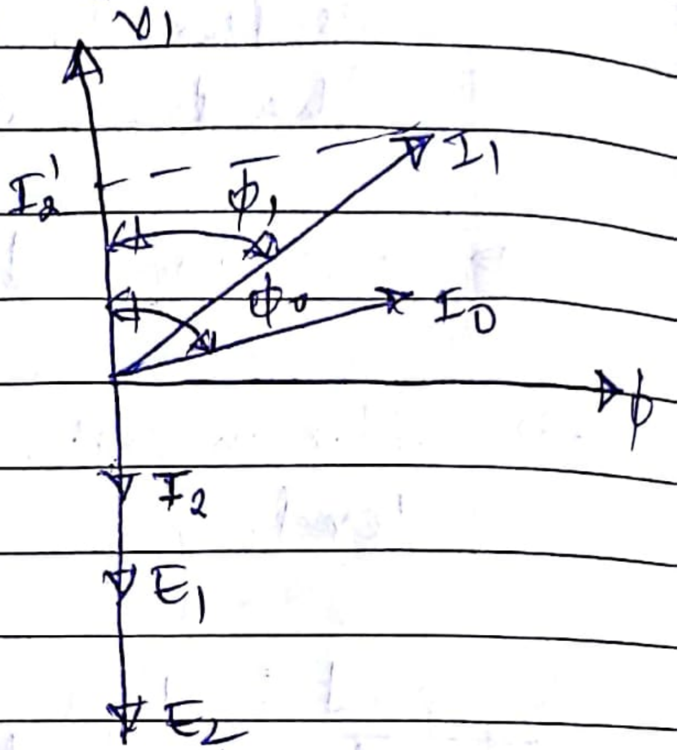
→ When ~~prima~~ tfr is loaded, primary c/n I_1

$$\bar{I}_1 = \bar{I}_0 + \bar{I}_2 \quad \text{—} ②$$

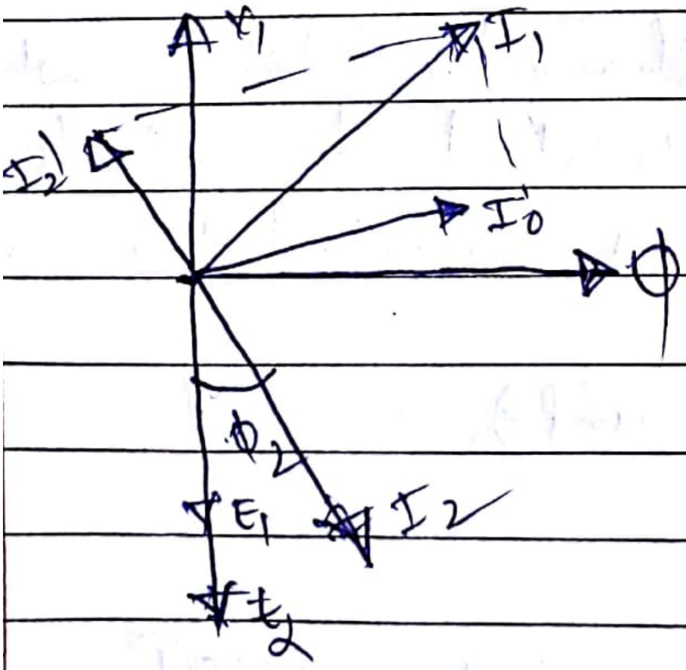
Resistive load



Inductive load



Capacitive load



No load

* The no-load c/n of transformer is 5A at 0.3 pf when supplied at 230V, 50 hz. The No of turns on primary winding is 200. Calculate:

i) max value of flux in core

ii) core loss iii) magnetising current

Sol^n^: $I_0 = 5A$, $\cos\phi_0 = 0.3$, $V_1 = 230V$, $N_1 = 200$.

i) $E_1 = 4.44 f \phi_m N_1$ --- $f = 50Hz$,

$E_1 = V_1 = 230V$

$230V = 4.44 \times \phi_m \times 50 \times 200$

$$\boxed{\phi_m = 5.18 \, mwb}$$

ii) Core loss = P_i = power i/p on no load

$= V_1 I_0 \cos\phi_0$

$= 230 \times 50 \times 0.3 = 345 W.$

iii) $I_m = I_0 \sin\phi_0$ --- $\phi_0 = \cos^{-1}(0.3)$

$= 72.54°$

$I_m = 5 \sin(72.54°) = 4.7696 A$ //

* A single phase transformer has turns ratio of 144/432 and operates at maximum flux of 7.5×10^{-3} Wb at 50 Hz. When on no load the transformer takes 0.24 KVA at p.f of 0.26 lag from the supply. If the transformer supplies a load of 1.2 KVA at a p.f of 0.8 lag, determine
i) magnetizing Cu ii) primary Cu iii) primary p.f.

Soln:- $N_1 = 144$, $N_2 = 432$, $\phi_m = 7.5 \times 10^{-3}$ Wb, $f = 50$ Hz

$V_1 = 4.44 N_1 \phi_m f = 4.44 \times 144 \times 7.5 \times 10^{-3} \times 50$

$V_1 = 239.76$ V

No load KVA $= V_1 \times I_0$

$\therefore 0.24 \times 10^3 = 239.76 \times I_0$

i.e $I_0 = 1$A & $\cos\phi_0 = 0.26$ lag (given).

i) $I_m = I_0 \sin\phi_0 = 1 \times 0.9656 = 0.9656$A.

ii) load KVA $= 1.2$ and $\cos\phi_2 = 0.8$

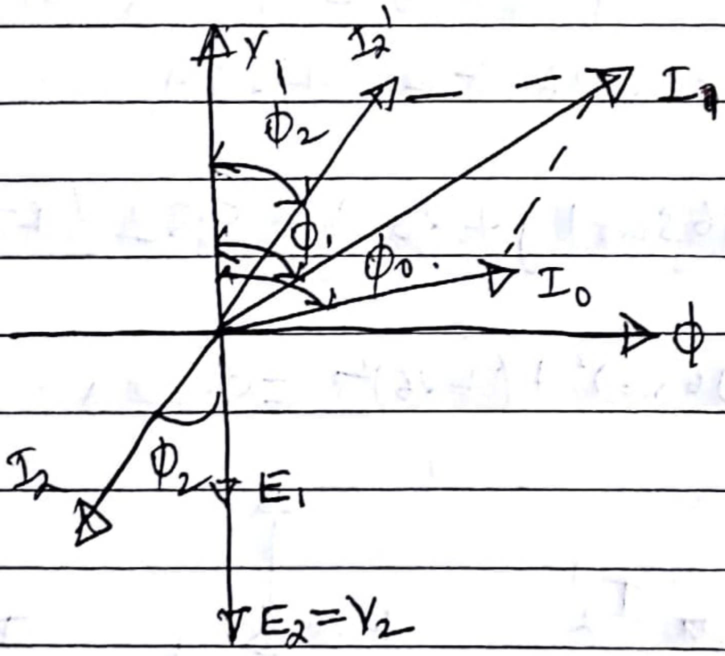
$$I_2 = \frac{\text{load kVA}}{V_2} = \frac{1.2 \times 10^3}{V_2}$$

$$V_2 = V_1 \times \frac{N_2}{N_1} = 719.28 \text{ V}.$$

$$I_2 = \frac{1.2 \times 10^3}{719.28} = 1.6683$$

$$K = \frac{N_2}{N_1} = \frac{432}{144} = 3.$$

$$I_2' = k I_2 = 2 \times 1.6683 = 5A$$



$\phi_0 = 74.93°$

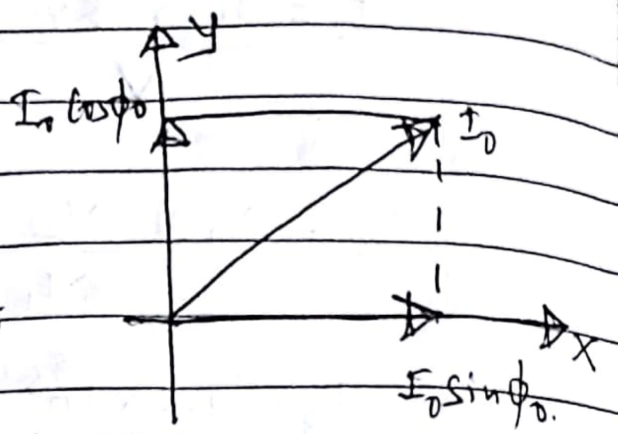
$\phi_2 = 36.869°$

$I_0 \cos\phi_0 = 0.26$ A

$I_0 \sin\phi_0 = 0.9656$ A.

$I_2' \cos\phi_2 = 5\times0.8 = 4$A.

$I_2' \sin\phi_2 = 5\times0.6 = 3$A



$\bar{I}_1 = \bar{I}_0 + \bar{I}_2'$

∴ x component of $I_1 = I_0 \sin\phi_0 + I_2' \sin\phi_2$

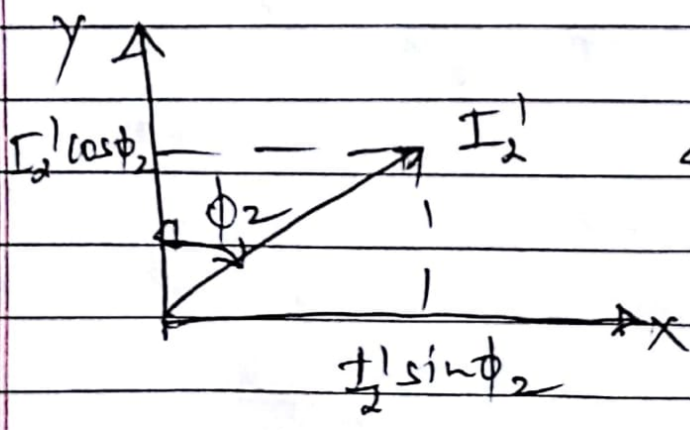
$= 0.9656 + 3 = 3.9656$ A.

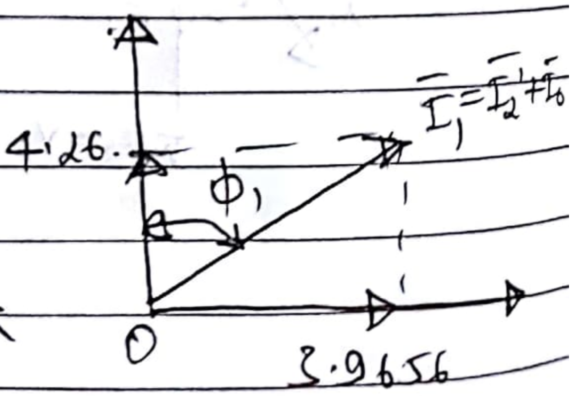
∴ y compont of $I_1 = I_0 \cos\phi_0 + I_2' \cos\phi_2$

$= 0.26 + 4 = 4.26$ A.

∴ $\bar{I}_1 = 3.9656 + j4.26$ A $= 5.82\angle 47.04$

$|I_1| = \sqrt{(3.9656)^2 + (4.26)^2} = 5.82$A.





iii) Note that ϕ is measured w.r.t V_1 axis i.e y- axis

$$\phi_1 = 90^\circ - 47.04^\circ = 42.96^\circ$$

Rectangular to polar given angle w.r.t x axis

$\cos\phi_1 = 0.7318$ lag — Primary p.f

Note:- Remember that ϕ_1 is angle betw V_1 and I_1 & as V_1 is vertical, ϕ_1 is measured with respect V_1. So do not convert Rectangular to polar as it gives angle w.r.t to axis & we want w.r.t y axis

Effect of winding Resistances

Resistance will not only cause power loss but also voltage drops.

$$\bar{E}_1 = \bar{V}_1 - \bar{I}_1 R_1 \quad \text{—} ①$$

$$\bar{E}_2 = \bar{V}_2 - \bar{I}_2 R_2 \quad \text{—} ②$$

→ I_1R_1 & I_2R_2 purely Resistive drops in phase (I_1 & I_2).

Equivalent Resistance

→ Transfer without affecting performance to make calculation easy.

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

$$= I_1^2 \left[R_1 + \frac{I_2^2}{I_1^2} R_2 \right]$$

$$= I_1^2 \left[R_1 + \frac{1}{K^2} R_2 \right]$$

$$= I_1^2 R_1 + I_1^2 \frac{1}{K^2} R_2$$

→ $\frac{R_2}{K^2}$ is Resistance Shifted to primary

Causes same Cu loss with R_1 as R_2 causes with I_2

→ equivalent resistance of secondary ref to primary

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

→ equivalent resistance of Transfer ref to prim

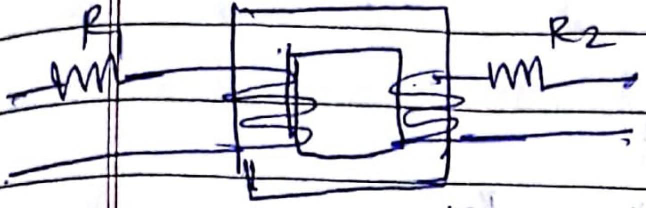
$$R_{1e} = R_1 + R_2' = R_1 + R_2/K^2$$

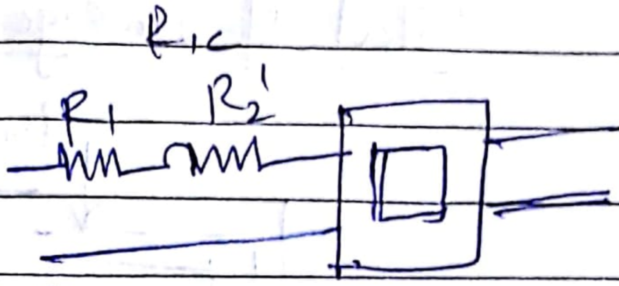
Total Cu loss $= I_1^2 R_{1e} = I_1^2 R_1 + I_2^2 R_2$

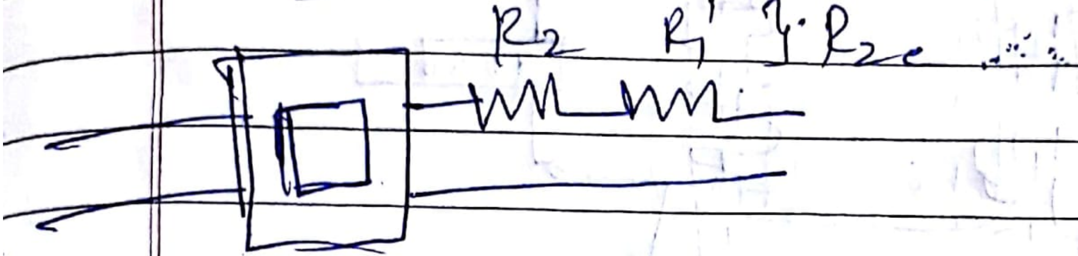
~~13500~~
~~20100~~

$R_{2e} = R_2 + R_1' = R_2 + K^2 R_1$

Total Cu loss $= I_2^2 R_{2e}$







Important Note :- $R_1 \to R_1'$ multiplied by K^2

$R_2 \to R_2'$ → divided by K^2

$K = N_2/N_1$

Gate

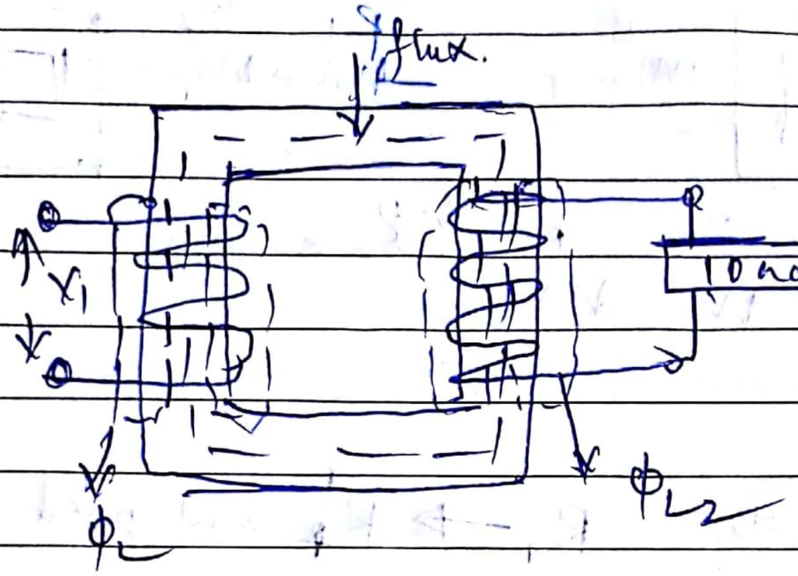
→ Hv winding is always low current winding. & Resistance of hv wdg is high (Hv wdg I ↓ R ↑

→ Lv side is High c/n side and Resistance low (Lv side. ↓ c/n ↑ R ↓).

→ Gate :- Lv → Hv side → R increses
Hv → Lv side → R decrese.

Key point : HV side → Low ch side → High resis side
LV side → High ch side → low resistance side

Effect of leakage Reactance



→ Assumption total ϕ links both P & second. but not true Some part of flux Of both take air path & link to same which is leakage flux. Thus two leakage fluxes.

→ ϕ_{L1} is primary leakage flux. ϕ_{L1} → I_1

→ ϕ_{L2} is Secondary " ϕ_{L2} → I_2

→ Due to ϕ_{L1} there is Self Induced emf e_{L1}

→ Due to ϕ_{L2} There is " e_{L2}

→ V_1 has to overcome voltage e_{L_1} to produce E_1 While induced emf E_2 has to overcome e_{L_2} to produce V_2

→ Thus. Self induced emf's are treated as. Voltage drops across fictitious reactances.

→ Reactances are X_1 & X_2 → leakage Reactance.

→ $e_{L_1} = I_1 X_1 =$ drop , $e_{L_2} = I_2 X_2 =$ drop

→ Note :- Avoid leakage flux both windings are placed on same limb.

Equivalent leakage Reactance

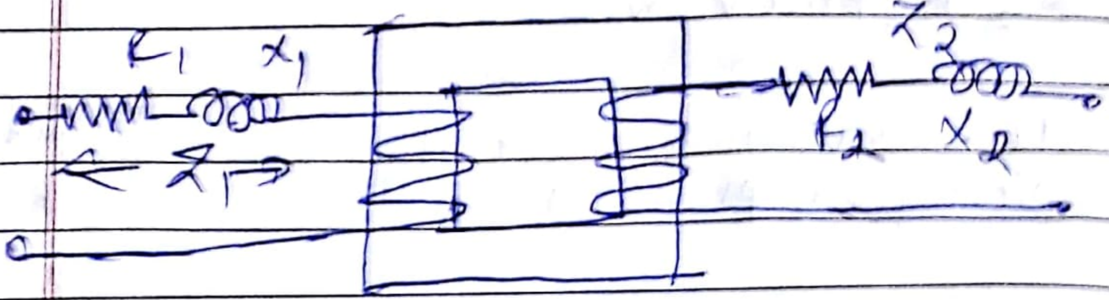
$X_{1e} = X_1 + X_2'$ where $X_2' = X_2 / K^2$

$X_{2e} = X_2 + X_1'$ $X_1' = K^2 X_1$.

$X_{2e} = X_2 + X_1'$, $X_1' = K^2 X_1$

$K = N_2 / N_1$.

Equivalent Impedance



$$Z_1 = R_1 + jx_1 \ \Omega$$
$$Z_2 = R_2 + jX_2 \ \Omega$$

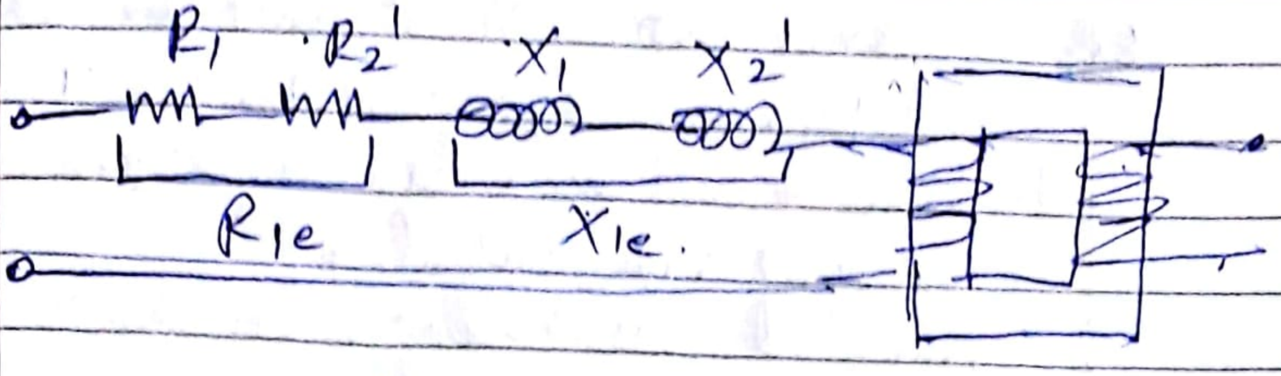
Magnitude $Z_1 = \sqrt{R_1^2 + x_1^2}$

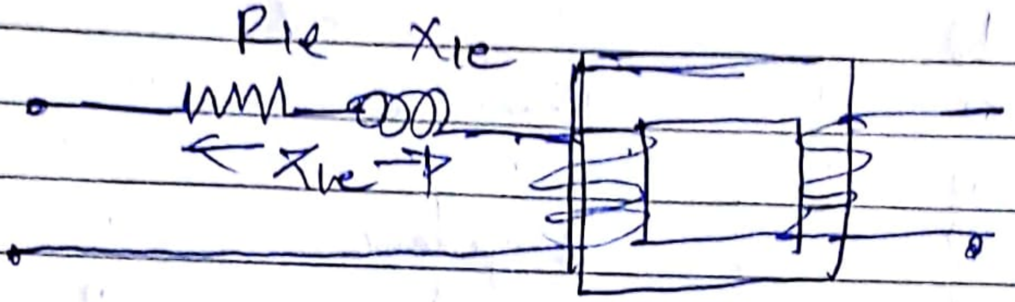
$$Z_2 = \sqrt{R_2^2 + X_2^2}$$

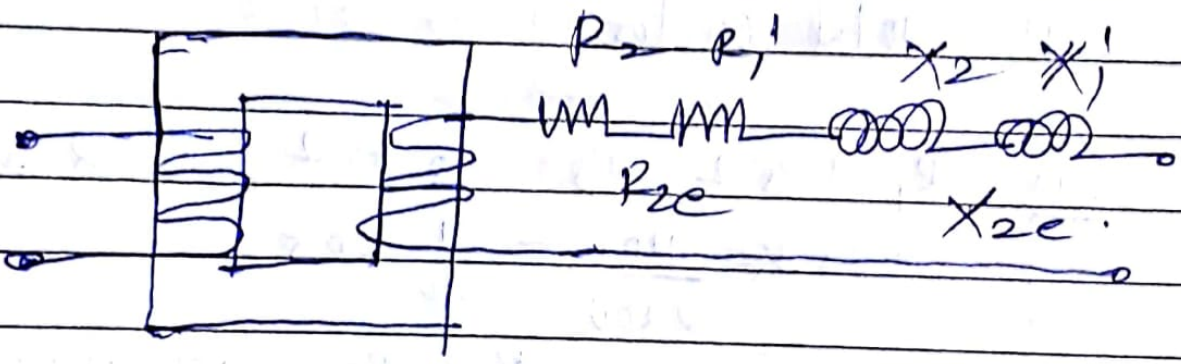
$$\left.\begin{aligned} Z_{1e} &= Z_1 + Z_2' = Z_1 + \frac{Z_2}{k^2} \\ Z_{2e} &= Z_2 + Z_1' = Z_2 + k^2 Z_1 \end{aligned}\right\}$$ equivalent impedance

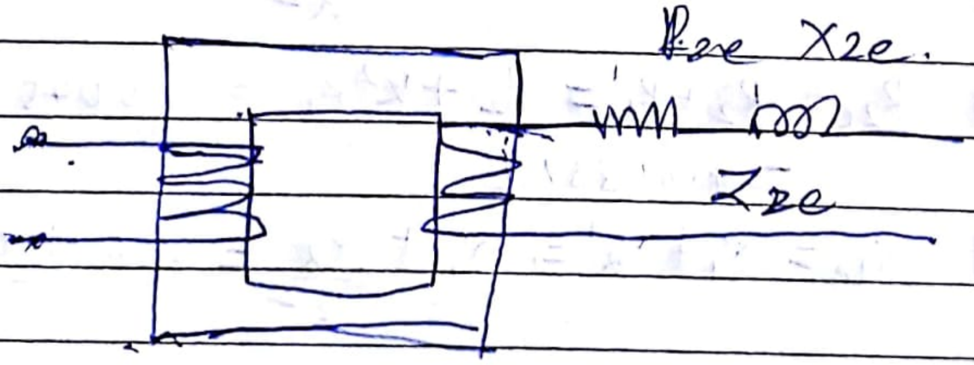
$Z_{1e} = \sqrt{R_{1e}^2 + X_{1e}^2}$ $Z_{2e} = \sqrt{R_{2e}^2 + X}$

$$\boxed{Z_{2e} = k^2 Z_{1e} \ , \quad Z_{1e} = \frac{Z_{2e}}{k^2}}$$


R_1
R_2'
X_1
X_2'
R_{1e}
X_{1e}


R_{1e}
X_{1e}
Z_{1e}


R_2
R_1'
X_2
X_1'
R_{2e}
X_{2e}


R_{2e}
X_{2e}
Z_{2e}

Ex: A 15KVA, 2200/110V transformer has $R_1 = 1.75\Omega$, $R_2 = 0.0045\Omega$. The leakage Reactances are $X_1 = 2.6\Omega$ and $X_2 = 0.0075\Omega$. Calculate

a) Equivalent resistance reffered to Primary.

b) " " Secondary

c) " Reactance " Primary

d) " " " Secondary

e) " Impedance " Primary

f) " Impedance " Secondary

g) Total Cu loss

Soln:- $R_1 = 1.75\Omega$, $R_2 = 0.0045\Omega$, $X_1 = 2.6\Omega$, $X_2 = 0.0075$

$$K = \frac{110}{2200} = \frac{1}{20} = 0.5$$

a) $R_{1e} = R_1 + R_2' = R_1 + \frac{R_2}{K^2} = 1.75 + \frac{0.0045}{(0.05)^2} = 3.55\Omega$

b) $R_{2e} = R_2 + R_1' = R_2 + K^2 R_1 = 0.0045 + (0.5)^2 \times 1.75$

$= 0.00887\Omega$

c) $X_{1e} = X_1 + X_2' = X_1 + \frac{X_2}{K^2} = 2.6 + \frac{0.0075}{(0.05)^2} = 5.6\Omega$

d) $X_{2e} = X_2 + X_1' = X_2 + K^2 X_1 =$

$= 0.0075 + (0.05)^2 \times (2.6)$

$= 0.014\Omega$

e) $Z_{1e} = R_{1e} + j X_{1e} = 3.55 + j5.6 \Omega$.

$\therefore |Z_{1e}| = \sqrt{3.55^2 + 5.6^2} = 6.6304 \Omega$

f) $Z_{2e} = R_{2e} + j X_{2e} = 0.00887 + j\,0.014 \Omega$

$|Z_{2e}| = \sqrt{(0.00887)^2 + (0.014)^2} = 0.01657 \Omega$

g) F.L Cu loss, Calculate F.L Cu.

$I_1 = (F.L) = \frac{25 \times 1000}{2200} = 11.36 A$.

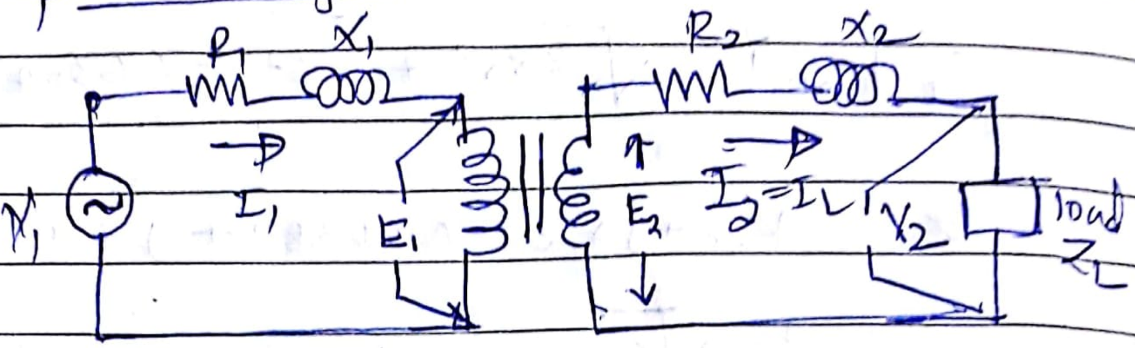
$\therefore$ Total Cu loss $= I_1^2 R_{1e} = (11.36)^2 \times 3.55$
$= 458.419 W$

Cross Checked.

$I_2 = \frac{25 \times 1000}{110} = 227.272 A$

Total Cu loss $= I_1^2 R_1 + I_2^2 R_2$
$= 458.419 W$.

phasor diagram



$$\therefore\ \overline{V_1} - \overline{I_1 R_1} - \overline{I_1 x_1} + \overline{E_1} = 0$$

$$\overline{V_1} = -\overline{E_1} + \overline{I_1 R_1} + \overline{I_1 x_1} \quad —— ⓧ$$

$$= -\overline{E_1} + \overline{I_1}(R_1 + jx_1)$$

$$= -\overline{E_1} + \overline{I_1 Z_1} \quad —— ①$$

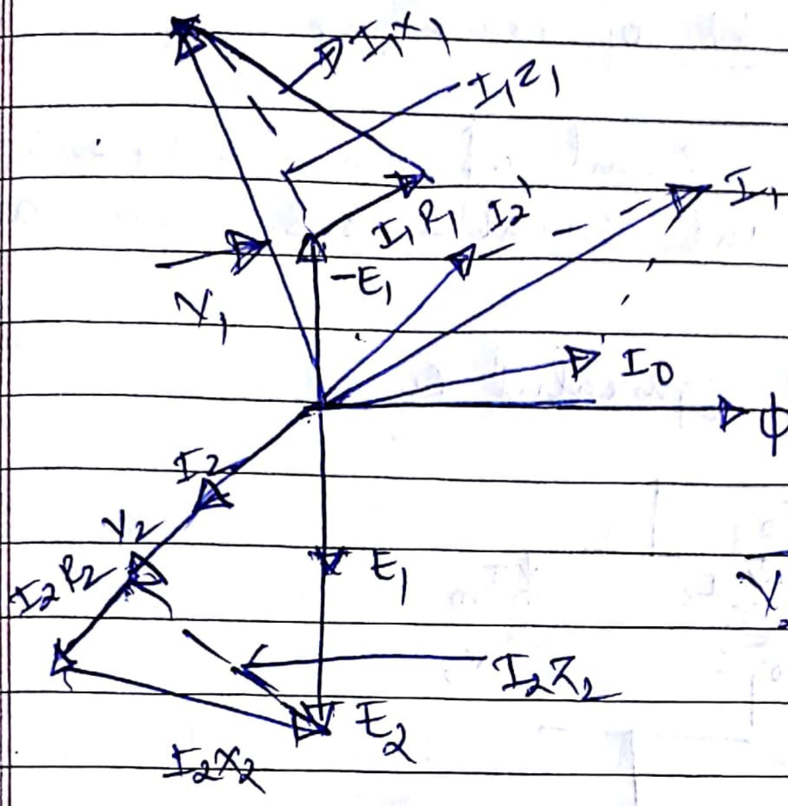
$$\therefore\ \overline{E_2} = \overline{V_2} + \overline{I_2 R_2} + I_2 \overline{X_2}$$

$$E_2 - \overline{I_2 R_2} - \overline{I_2 x_2} - V_2 = 0$$

$$\overline{V_2} = \overline{E_2} - \overline{I_2}(R_2 + jx_2)$$

$$= \overline{E_2} - \overline{I_2 Z_2} \quad —— ②$$

Unity pf load, $\cos\phi_2 = 1$



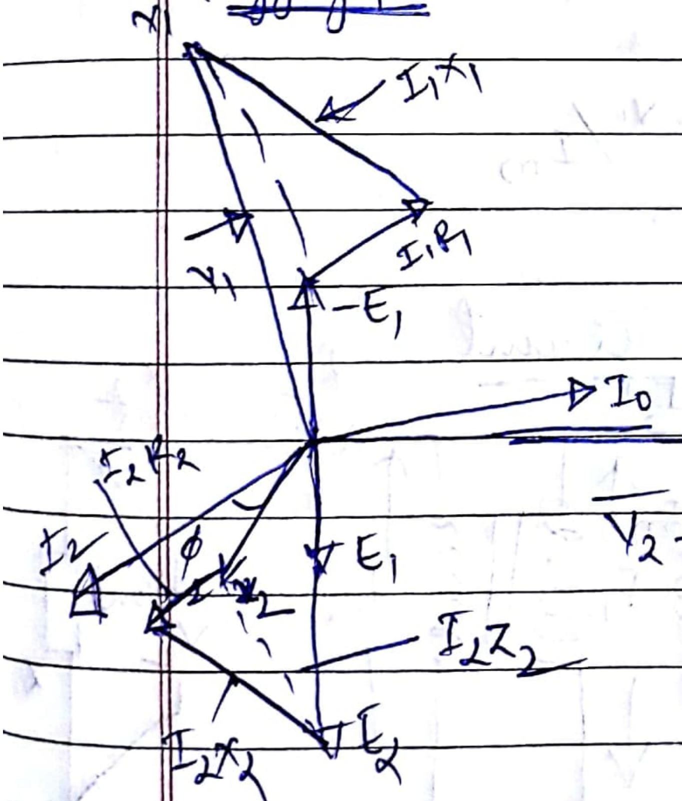
$-\overline{E}_1 + \overline{I_1Z_1} = \overline{V}_1$

$I_2' = -I_2.$

$\overline{V}_2 + \overline{I_2Z_2} = \overline{E}_2$

10/8/18

lagging p.f



$\overline{V}_2 + \overline{I_2Z_2} = \overline{E}_2$

* Capacitive home work.

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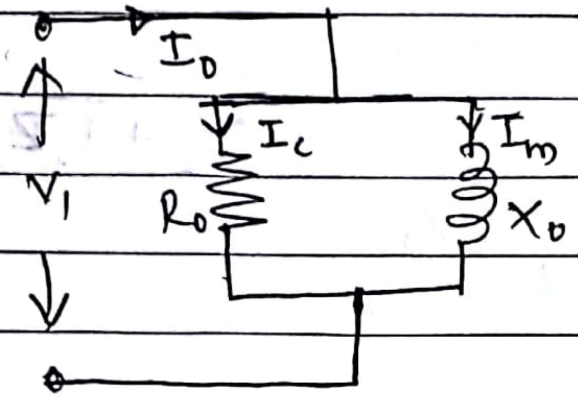
Equivalent ckt of Transformer

→ equivalent circuit of machine means Combination of fixed and variables, resistance and reactances

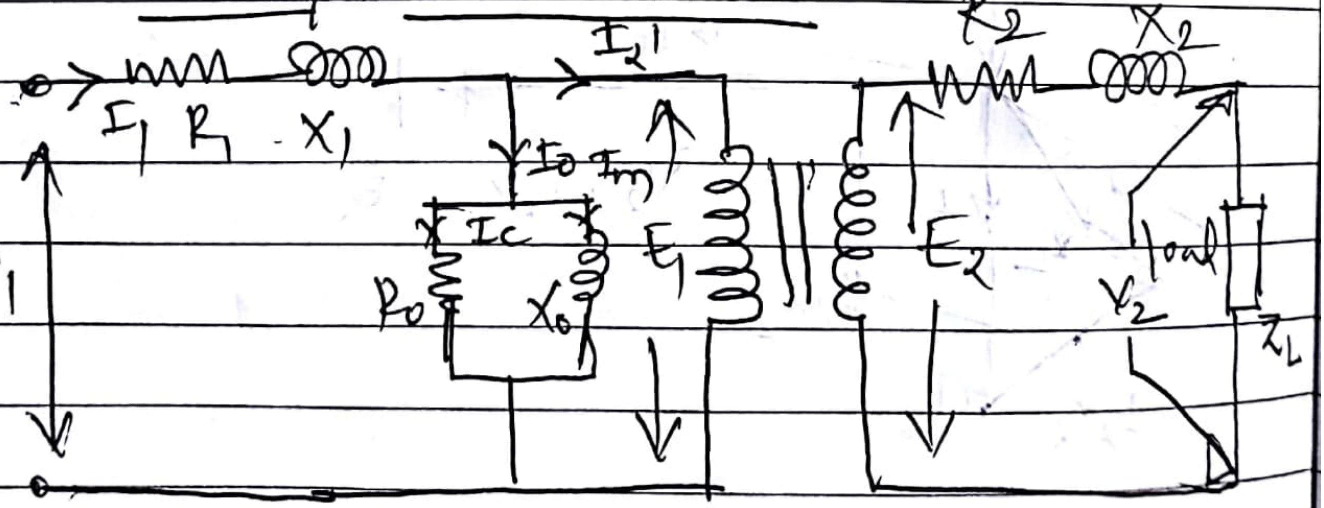
No load Equivalent circuit



exciting circuit, $R_0 \parallel X_0$, no load Reactance X_0, Resistance R_0

$$R_0 = \frac{V_1}{I_c} \;\&\; X_0 = V_1/I_m$$

load Equivalent Circuit

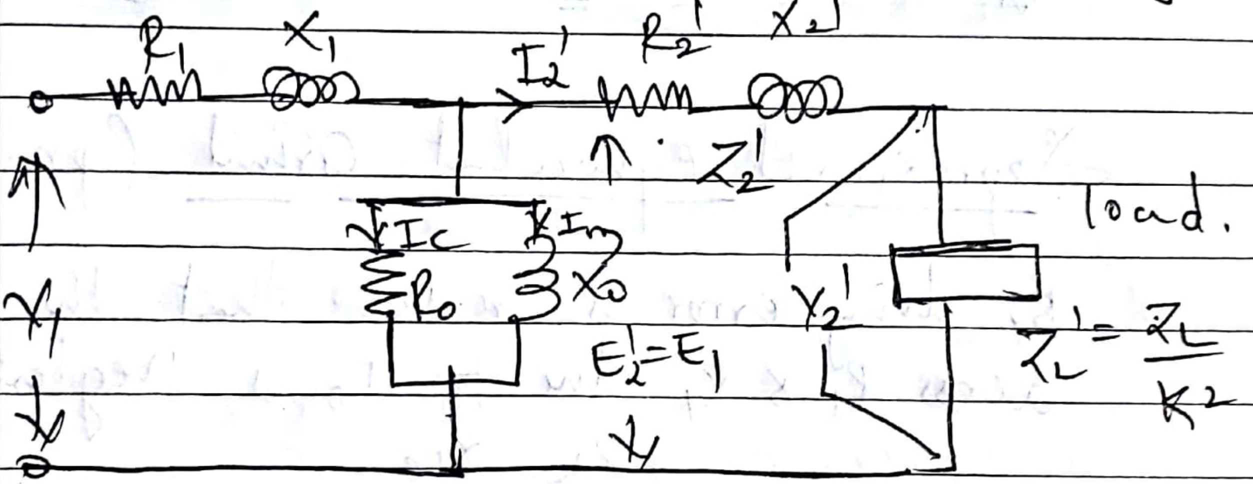


Secondary parameters to primary

$R_2' = \frac{R_2}{K^2}$, $X_2' = \frac{X_2}{K^2}$, $Z_2' = \frac{Z_2}{K^2}$

$E_2' = \frac{E_2}{K}$, $I_2' = K I_2$, $K = N_2/N_1$

Exact equivalent circuit reffered to primary

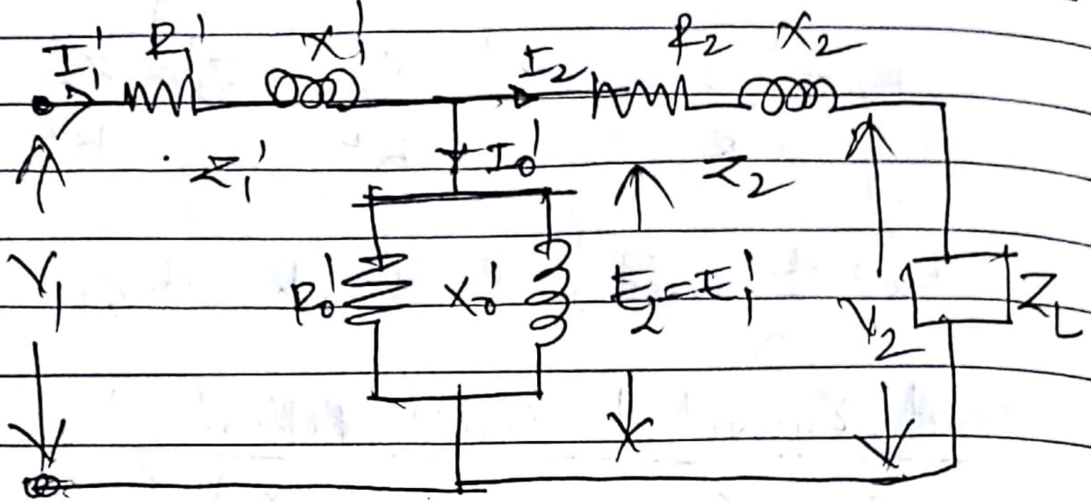


Primary parameter to secondary

$R_1' = K^2 R_1$, $X_1' = K^2 X_1$, $Z_1' = K^2 Z_1$

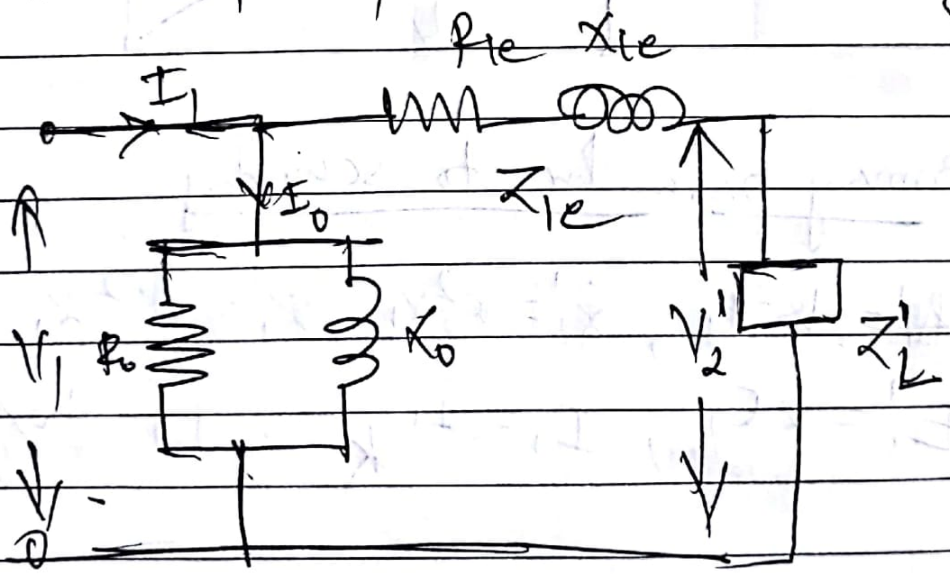
$E_1' = K E_1$, $I_1' = I_1/K$, $I_0' = I_0/K$.

exact equivalent circuit Reff to Secondary



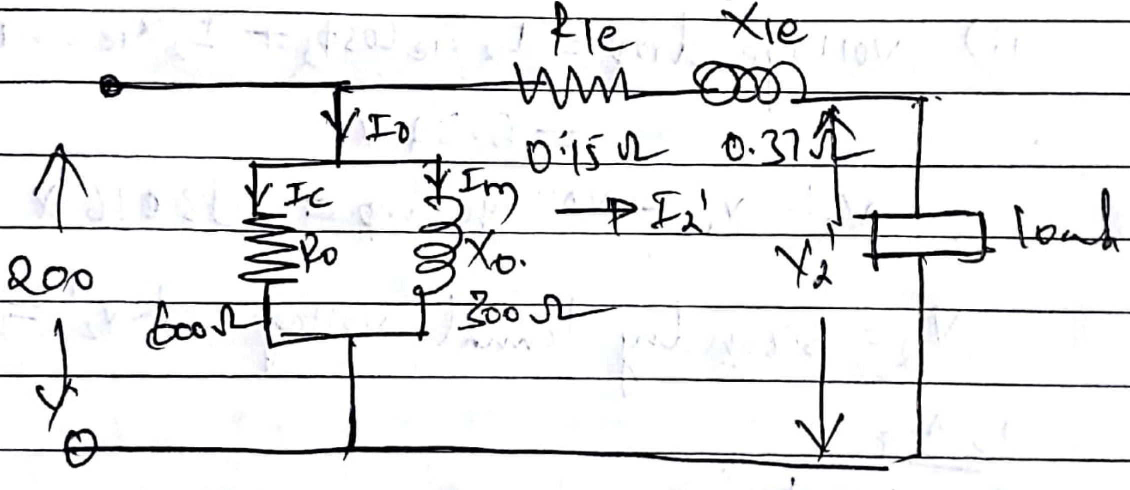
Approximent equivalent Circuit (primary).

By doing error is created that the drop across R_1 & X_1 due to I_0 is neglected.



* The equivalent circuit of 200/400V, step up transformer has following parameter Reffered to LV side:
Equivalent resistance = 0.15 Ω, Eqn Reactance = 0.37 Ω
core loss component of resistance = 600 Ω,
magnetising Reactance = 300 Ω
When transformer is supplying load of 10A at p.f of 0.8 lag, Calculate
i) primary Cur ii) secondary terminal voltage

→



$K = \frac{400}{200} = 2$, $I_2' = KI_2 = 2 \times 10 = 20A$.

$\cos\phi_2 = 0.8$, $\phi_2 = 36.86°$

$I_2' = 20 \angle -36.86° = 16 - j12A$.

$V_1 = 200 \angle 0° V$.

$I_C = \frac{V_1}{R_0 + j0} = \frac{200\angle 0°}{600 \angle 0°} = 0.333 \angle 0° = 0.333 + j0 A$.

$$I_m = \frac{V_1}{0 + jX_0} = \frac{200\angle 0^\circ}{300\angle 90^\circ} = 0.666\angle -90^\circ \text{ A.}$$

$$= 0 - j0.666 \text{ A.}$$

$\bar{I_0} = \bar{I_c} + \bar{I_m} = 0.333 - j0.666$ A.

$\bar{I_1} = \bar{I_0} + \bar{I_2'} = (16 + 0.333) - j(12 + 0.666)$ A

$= 16.333 - j12.666$ A $= 20.668\angle -37.793$ A.

i) $|I_1| = 20.668$

ii) Voltage drop $= I_2' R_{1e} \cos\phi_2 + I_2' X_{1e} \sin\phi_2$

$= 6.84$ V.

$V_2' = V_1 -$ Voltage drop $= 193.016$ V

V_2 = secondary terminal voltage $= KV_2' = 386.32$ V.

13 Aug

megha, Suhashini

All day Efficiency of Transformer

$$\eta = \frac{\text{o/p power}}{\text{i/p power}} = \text{power efficiency.}$$

It is not true measure of performance of some Special types of transformer as distribution transformer

Distribution transformer — residential & commercial loads.

· load varies on such during period of day.

→ Most period of day tfr are working at 30 to 40% of F·L or even less than that the primary of such transformer is energised. at its rated voltage for 24 hours, to provide continuous supply to consumer

→ Core loss which depends on voltage take place continuously for all loads. but Cu loss depends on load cond^n.

→ For no load Cu loss is negligible small while on F·L given at its Rated value hence power efficiency ~~ω~~ cannot give true measure of true efficiency of such transformer.

→ In such transformer energy o/p is calculated in (KWh). · energy spent in supplying various losses is also determined by KWh.

→ They ratio of total energy output to total energy i/p (o/p + losses) calculated.

Such ratio is Called Energy η or All day η of transformer.

→ Performance of various distribution transformer is compared.

$$\% \text{ All day } \eta = \frac{\text{O/p energy in kwh during}}{\text{I/p energy in kwh a day}}$$

$$= \frac{\text{O/p energy}}{\text{O/p energy} + \text{Energy spent T.L}}$$

* Find All day η of 1ϕ transformer having max η ~~of~~ for 98% at 15kVA at upf and loaded as follows.

12 hrs – 2 kW at 0.5 pf lag

6 hrs – 12 kW at 0.8 pf.

6 hrs – no load.

Solⁿ:- $\eta_{max} = 98\%$ at 15kVA, $\cos\phi = 1$

$$\% \eta_{max} = \frac{[\text{VA for } \eta_{max}] \times \cos\phi}{[\text{VA for } \eta_{max}] \times \cos\phi + 2P_i} \times 100.$$

$\therefore \; 0.98 = \dfrac{15\times10^3\times1}{15\times10^3\times1+2P_i}$ i.e $P_i = 153.061\,W.$

P_{cu} at 15 kVA $= P_i = 153.061\,W.$

Energy o/p $= [2\times12] + [12\times6] = 96$ kWh.

Energy spent due to iron loss.
$= P_i \times 24$ hrs $= 3.673$ kWh

To Calculate energy spent due to cu loss:

i) load 1, 2 kW, $\cos\phi = 0.5$

kVA supplied $= \dfrac{kW}{\cos\phi} = \dfrac{2}{0.5} = 4$ kVA

load 1 P_{cu} = P_{cu} at 15 kVA $\times \left(\dfrac{4}{15}\right)^2$

$= 153.061 \times 0.0711 = 10.8843\,W.$

$\therefore$ Energy spent = load 1 P_{cu} × hrs = 10.88×12
$= 136.6116$ Wh $= 0.1306$ kWh.

ii) Load 2, 12kw at $\cos\phi = 0.8$ for 6 hrs.

$$\therefore \text{KVA Supplied} = \frac{\text{KW}}{\cos\phi} = \frac{12}{0.8} = 15 \text{ KVA}.$$

load 2 P_{cu} = P_{cu} at 15 KVA = 153.061 W.

∴ Energy spent = 153.061 × 6 = 918.366 Wh

= 0.9183 kwh.

iii) No Copper loss for no load

Total energy spent = 3.6734 + 0.1306 + 0.91836 = 4.722kw

$$\text{All day } \eta = \frac{\text{Total energy o/p in 24 hrs}}{\text{T.E o/p in 24 hrs} + \text{Energy spent in 24 hrs}} \times 100$$

$$= \frac{96}{96 + 4.722} \times 100 = 95.311\%$$

14 Ans

① megha, Subhashini, Sushma, mahesh.

② ↓ ↓ ↓, mahesh, Suraj.

Date

Indirect loading Tests on Transformer

- η & R at any load & p.f predetermined. by Indirect.
- equivalent circuit parameter
  ① O.C ② S.C.

Advantages.

O.C. Test

Varia, Connection, Input meters:

Voltmeter Resistance is high,

V_0	I_0	W_0
Rated		

The o/p power is zero, cu losses are low, W_0 i/p power is used iron loss

R_0' & X_0' if meters are connected in secondary.

& we can find R_0 & X_0.

Short Circuit Test (Impedance test)

low voltage test or Reduced voltage test

V_{sc}	I_{sc}	W_{sc}
	Rated	

$W_0 = P_i = \text{Iron loss}$

$W_0 = V_0 I_0 \cos\phi_0$

$$\cos\phi_0 = \frac{W_0}{V_0 I_0}$$

$I_c = I_0 \cos\phi_0$ & $I_m = I_0 \sin\phi_0$

$R_0 = \frac{V_0}{I_c}\Omega$ $\quad X_0 = \frac{V_0}{I_m}\Omega$

$W_{sc} = (P_{cu})_{F.L} = \text{F.L cu loss}$

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

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

$W_{sc} = I_{sc}^2 R_{1e} = \text{cu loss}$

$$\boxed{R_{1e} = \frac{W_{sc}}{I_{sc}^2}} \qquad Z_{1e} = \frac{V_{sc}}{I_{sc}} = \sqrt{R_{1e}^2 + X_{1e}^2}$$

$$X_{1e} = \sqrt{Z_{1e}^2 - R_{1e}^2}$$

$$\eta = \frac{n \times (\text{VA Rating}) \cos\phi}{n(\text{VA Rating})\cos\phi + W_0 + n^2 W_{sc}} \times 100$$

Voltage Regulation and its Significance

Bcoz vtg drop at primary & secondary (Impedance) it is observed Secondary terminal voltage drops from its no load value (E_2) to load value V_2 as load & load Cu ↑.

This decrease in secondary terminal voltage Expressed as fraction of no load secondary terminal voltage is called Regulation of transformer $E_2 =$ (no load) $V_2 =$ (given load)

% voltage Regulation $= \frac{E_2 - V_2}{V_2} \times 100$.

$E_2 - V_2 / V_2$ (per unit Regulation).

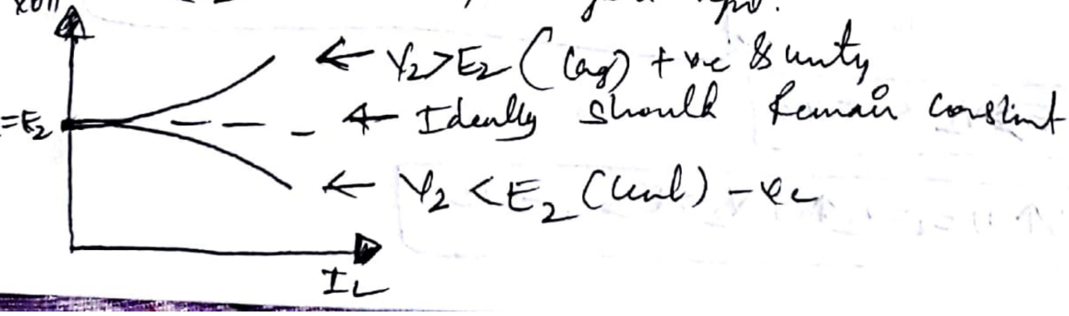
Secondary terminal voltage does not depend only on magnitude of load Cu but also nature of p-f of load.

if V_2 is determined for full load and specified pf cond^n the Reg^n is called F.L Regulation.

As load Cu I_L increases, voltage drop tend to increase and V_2 drops more & more

$V_2 < E_2$ (lagg pf) positive Reg^n.

$E_2 < V_2$ (lead) negative Regn.



Approximate voltage drop $= E_2 - V_2 = I_2 R_{2e} \cos\phi_2 + I_2 X_{2e} \sin\phi$

Constants of transfm

$$\% R = \left\{ \left(\frac{I_2 R_{2e}}{E_2} \right) \cos\phi \pm \left(\frac{I_2 X_{2e}}{E_2} \right) \sin\phi \right\} \times 100$$

$\boxed{\frac{I_2 R_{2e}}{E_2} \text{ or } \frac{I_1 R_{1e}}{\cancel{E_1}} \text{ is per unit resistive drop } (V_R)}$

V_1

$\boxed{V_X = \frac{I_2 X_{2e}}{E_2} = \frac{I_1 X_{1e}}{E_1} = \text{per unit Reactance drop}}$

$V_R \times 100$ (percentage)

$$\% R = [V_R \cos\phi \pm V_X \sin\phi] \times 100$$

$\boxed{V_R = \frac{I_{2e} R_{2e}}{V_2} = \frac{I_{1e} R_{1e}}{V_1}}$ $\boxed{V_X = \frac{I_{2e} X_{2e}}{V_2} = \frac{I_{1e} X_{1e}}{V_1}}$

Zero voltage Regulation

At a certain leading pf $E_2 = V_2$ $(R = 0)$ $\left(\begin{smallmatrix} E_2 \uparrow \\ -ve \end{smallmatrix} \right)$

For zero Rg

$E_2 = V_2 \Rightarrow E_2 - V_2 = 0$

$V_R \cos\phi - V_X \sin\phi = 0 \Rightarrow V_R \cos\phi = V_X \sin\phi$
(leading)

$\tan\phi = \frac{V_R}{V_X} \Rightarrow$ $\boxed{\cos\phi = \cos\left\{ \tan^{-1}\left(\frac{V_R}{V_X} \right) \right\}}$.

$\boxed{\text{lag \& upf } E_2 > V_2 \text{ \& } +ve}$

$\boxed{\text{lead }, V_2 \uparrow \; 1)\; E_2 = V_2 \uparrow \; 2)\; V_2 > E_2 \;, -ve}$

Cond^n max vtg Regn

$$\% R = [V_R \cos\phi + V_X \sin\phi] \times 100$$

Diff w.r.t ϕ

$$\frac{d(R)}{d\phi} = -V_R \sin\phi + V_X \cos\phi = 0$$

$$\boxed{\tan\phi = \frac{V_X}{V_R} = \frac{X_{1e}}{R_{1e}} = \frac{X_{2e}}{R_{2e}}}.$$

$$\boxed{\cos\phi = \frac{R_{2e}}{Z_e} = \frac{R_{1e}}{Z_{1e}}} \qquad \boxed{\sin\phi = \frac{X_{2e}}{Z_{02e}} = \frac{X_{1e}}{Z_{1e}}}$$

As $\tan\phi$ is +ve

max vtg Regn occurs at lagg pf.

mag of max vtg Regn is

$$R_{max} = \left[V_R \frac{R_{1e}}{Z_{1e}} + V_X \times \frac{X_{1e}}{Z_{1e}} \right] -$$

$$= \left[\frac{I_1 R_{1e}}{V_1} \times \frac{R_{1e}}{Z_{1e}} + \frac{I_1 X_{1e}}{V_1} \times \frac{X_{1e}}{Z_{1e}} \right]$$

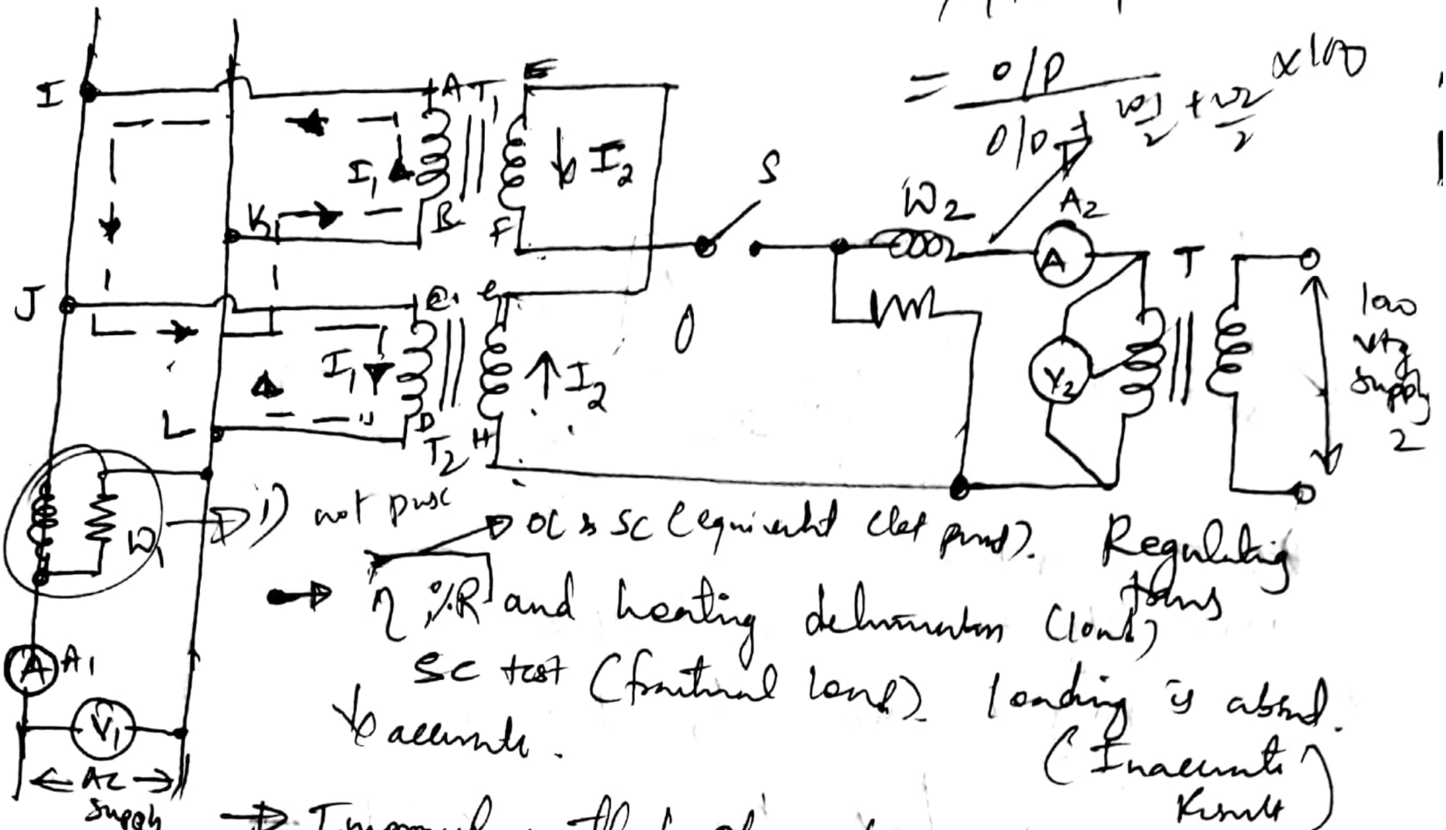
$$\boxed{R_{max} = \frac{I_1}{V_1 Z_{1e}} \left[R_{1e}^2 + X_2^2 \right] = \frac{I_1 Z_{1e}}{V_1} = Z_{pu}}.$$

Sumpners test (Back to Back test)

— Regulation also Determined

$\% \eta_{F.L}$ of each tfr

$$= \frac{O/P}{O/P + \frac{W_1}{2} + \frac{W_2}{2}} \times 100$$



1) not pure → OC & SC (equivalent ckt para). Regulating terms

→ η %R and heating determination (load)

SC test (fractional load) loading is absent. (Inaccurate Result)

Not accurate.

→ Improved method of predicting %R & η than OC & SC

2) Two Identical transformer, one tfr is loading on another, power taken from supply is that much used for losses

3) a) primaries are connected in parallel across V_1

b) Secondary series opposition

c) Secondaries are supplied from another low vtg supply

P_i per tfr $= \frac{W_1}{2}$ (T_1 & T_2).

Advantages & disadvantage

$(P_{cu})_{F.L}$ per tf $= \frac{W_2}{2}$

! A 5kVA, 220/110 volts 1 φ tf has max η of 96.97% at 0.8 pf lag. It has core loss of 50W & Full load Regulation at 0.8 p.f lag is 5%. Find η & Re at F.L 0.9 pf lag. 93.23, 3.96%.

Soln:- 5kVA, 220/110V, η_{max} 96.97%, $\cos\phi = 0.8$, $P_i = 50$ W

AT η_{max}, $P_{cu} = P_i = 50$W.

$$\%\eta_{max} = 0.9697 = \frac{n \times 5 \times 10^3 \times 0.8}{n \times 5 \times 10^3 \times 0.8 + 2 \times 50}$$

$$4000n + 100 = 4124.9871\, n$$

$n = 0.8$ i,e η_{max} occurs at 80% of F.L

$$P_{cu(\eta_{max})} = 50 = 0.8^2 (P_{cu})_{F.L}$$

$$P_{cu(FL)} = 78.125 \text{ W}$$

$$I_{1(F)} = \frac{5 \times 10^3}{220} = 22.7272 \text{ A}$$

$$P_{cu(F.L)} = I_{1(FL)}^2 R_{1e} \Rightarrow R_{1e} = 0.1512\,\Omega$$

Reg at 0.8 (F.L) is 5%

$$5 = \frac{22.7272[0.1512 \times 0.8 + X_{1e}\, 0.6]}{220} \times 100$$

$$X_{1e} = 0.605\,\Omega$$

Regn and η on F.L for $\cos\phi = 0.9$ lag is

$$\%\eta = \frac{5 \times 10^3 \times 0.9}{5 \times 10^3 \times 0.9 + 50 + 78.125} \times 100 = 93.231\%$$

$$\%R = \frac{22.72[0.1512 \times 0.8 + 0.605 \times 0.435]}{220} \times 100 = 3.968\%$$

* The η at upf of 6600/384 V, 200 kVA, 1ϕ Tr is 98% at both F.L & H.L. The p.f on N.L is 0.2 & F.L Regulation at lpf of 0.8 is 4%. Draw equivalent ckt. Ref to LV side

Soln $\% \eta_{F.L} = 0.98 = \dfrac{200 \times 10^3 \times 1}{200 \times 10^3 \times 1 + P_i + P_{cu(F.L)}}$

$\therefore P_i + P_{cu F.L} = 4081.6326.$ — ①

$\% \eta(H.L) = \dfrac{1/2 \times 200 \times 10^3 \times 1}{1/2 \times 200 \times 10^3 \times 1 + P_i + P_{cu(F.L)} \times 1/4} \times 100$

$\therefore P_i + \frac{1}{4} P_{cu(F.L)} = 2040.8163.$ — ②

Solve ① & ②.

$P_{cu F.L} = 2721.088\,W$ & $P_i = 1360.544\,W.$

$I_{1(F.L)} = \dfrac{200 \times 10^3}{6600} = 30.303\,A.$

$P_{cu(F.L)} = 2721.088 = (I_1)^2 \times R_{1e} = 30.303^2 \times R_{1e}$

$R_{1e} = 2.9632\,\Omega$

$\% R = \cancel{3}. 4 = \dfrac{30.303\,[2.9632 \times 0.8 + X_{1e} \times 0.6]}{\cancel{2}6600} \times 100$

$X_{1e} = 10.569\,\Omega$

$K = \frac{384}{6600} = 0.05818.$ equival ckt Reff

$R_{2e} = K^2 R_{1e} = 0.01\ \Omega$. $X_{2e} = K^2 X_{1e} = 0.0357\Omega$

$\cos\phi_0 = 0.2$ & $P_i = 1360.544\ W$

$W_0 = P_i = V_1 I_0 \cos\phi_0 \Rightarrow 1360.544 = 6600 \times I_0 \times 0.2$

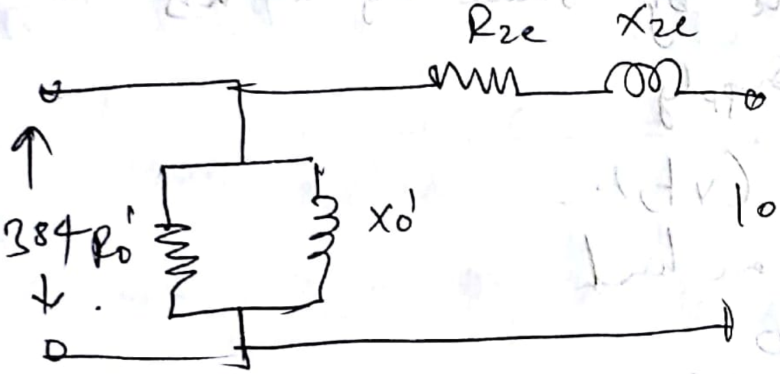
$I_0 = 1.0307\ A$

$I_c = I_0 \cos\phi_0 \Rightarrow 0.2061 A$, $I_m = I_0 \sin\phi_0 = 6.d\ A$

$R_0 = \frac{V_1}{I_c} = \frac{6600}{0.2061} = 32023.29\Omega$, $X_0 = \frac{V_1}{I_m} = \frac{6600}{1.01} = 6534.69\Omega$

Reff to LV

$R_0' = K^2 R_0 = 108.4$ $X_0' = K^2 X_0 = 22.12\Omega$



HV, LV (S.C)

LV, HV (O.C).

→ A 5kVA, 500/250 V, 50 Hz, 1φ Transf gave following reading

O.C Test : 500 V, 1A, 50W (LV side open) HV . LV

S.C Test : 25 V, 10A, 60W (LV side short) HV. LV.

Determine i) η on F.L, 0.8 lag p.f η = 97.32%

ii) Vtg Reg on F.L, 0.8 leading p.f R = -1.95%

iii) η on 60% of F.L / 0.8 lead p.f. η = 97.103.

iv) Draw equivaln ckt Reff to primary.

iii) Nil Cu loss for no load

∴ Total energy spent = $3.6734 + 0.1306 + 0.91836$

$= 4.72236$ kWh.

$$\therefore \text{All day } \eta = \frac{\text{Total energy o/p in 24 hrs}}{\text{Total energy o/p in 24 hrs + Energy spent in 24 hrs}}$$

$$= \frac{96}{96 + 4.72236} \times 100 = 95.311\%$$

\# There are two 100 kW transformers. Each has a max η of 98%. but in one transformer max η occurs at F.L while, in the other it occurs at H.L. Each transformer is on F.L for 4 hrs, on H.L for 6 hrs & one tenth load for 14 hrs per day. Determine all day η of each transformer.

→ **Trans 1**, % η_{max} at F.L.

$$0.98 = \frac{100 \times 10^3}{100 \times 10^3 + 2P_i} \quad \text{i.e } P_i = 1020.4081 \text{ W} = (P_{cu})_{FL}$$

Energy spent for iron loss = $1020.4081 \times 24 = 24.489$ kWh

Energy o/p for 24 hrs = $100 \times 4 + \frac{1}{2} \times 100 \times 6 + \frac{1}{10} \times 100 \times 14$

$= 840$ kWh.

Energy spent in Cu loss

28, 30, 32, 34, 35, 36, 39, 41,
42, 43, 46, 47, 52

Load 1 ; 4 hrs, F.L.

$E_1 = (P_{cu})_{FL} \times 4 = 1020.4081 \times 4 = 4.081$ kWh

Load 2 : 6 hrs, $\eta = 0.5$

$P_{cu} = \eta^2 \times P_{cu\,F.L} = 255.102$ W

$E_2 = 255.102 \times 6 = 1.5306$ kWh

load 3 : 14 hrs, one tenth load ie $n = 0.1$

$P_{cu} = n^2 \times P_{cu\,F.L} = 10.204\,W$

$E_3 = P_{cu} \times 14 = 0.1428$ kWh

Total Energy spent $= P_i + E_1 + E_2 + E_3$

$= 30.2434$ kWh

All day $\eta = \frac{o/p}{o/p + \text{Eng spent}} \times 100 = \frac{840}{840 + 30.2434}$

$= 96.524\%$

Transformer 2 %. η_m occurs at $n = 0.5$

$\%0.98 = \frac{0.5 \times o/p}{0.5 \times o/p + 2P_i} \times 100$

$P_i = 510.204$ W, $P_{cu} = 510.204$ W at $n = 0.5$

$P_{cu}(H.L) = n^2 \times P_{cu}(F.L)$

$P_{cu\,FL} = 2040.8163$ W $= 2.0408$ kW

P_i = Energy Spent for iron loss $= 510.204 \times 24$

$= 12.2448$ kWh

o/p = 840 kWh.

Energy spent in cu loss

load 1 $E_1 = 2040 \times 4 = 8.1632$ kWh

2 $E_2 = 0.5^2 \times 2040.81 \times 6 = 3.061$ kWh

3 $E_3 = (0.1)^2 \times 2040.81 \times 14 = 0.285$ kWh

Total energy spent $= 23.75$ kWh

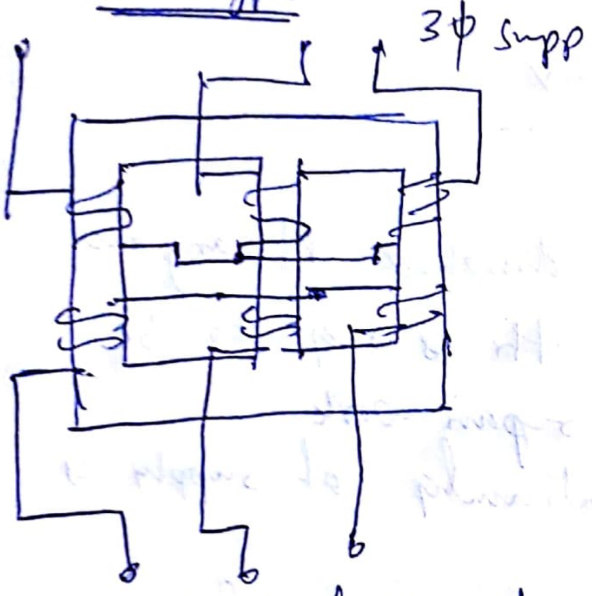
All day $\eta = \frac{840}{840 + 23.75} = 97.24\%$

Introduction Three phase transformer

- generation voltage (3φ) — 13.2kV, 22kV or higher
- Transmission power — 110kV, 132kV, or 400kV.
- So gen to Transmission 3φ tfr reqres. (step up) (Transmission)
- Distribution — 6600V, 440V, 230V etc (step down) (utilization)
- interconnected 3 single phase transform or single 3φ tfr

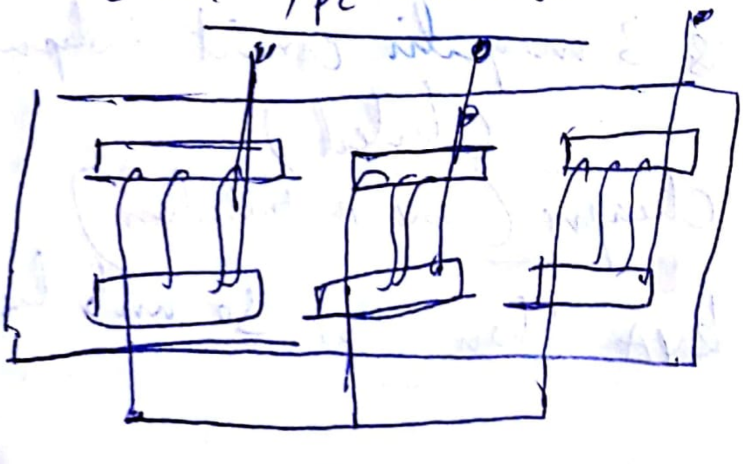
Construction of 3φ

Core type



each limb has
3 legs, 2 yoke, primary & secondary, one phase,
Two windows, flux in one leg down in other two legs.

Shell type Constructi



33,

Advantages of single 3ϕ transformer over bank

1) occupies less space for same rating
2) weights less 3) cost is less
4) easy for operator (one unit) 5) Transported easily
6) core size & material less
7) more efficient 8) 3 terminal are brought out & 6 terminals
9) overall bus bar structure, switch gear & installation is simpler.

9 -
8 -

Bank of single phase transformer

→ 3 transformers are identical.

→ Saving in Iron. Advantage drawback if any one phase becomes faulty whole . Tfr is reqd to be removed from service, for repair work.

→ reliability is improved & continuity of supply is maintain

Bring word out

→ possible to replace the single phase from spares

→ 3ϕ electrically connected & 3 magnetic circuit independ. (Linked)

→ preferred in mines, Cheaper (one installation)

→ one tfr with higher kVA than other so unbalanced load supplied

* A 2300/230 V, 500kVA, 50Hz Distribution
Core loss of 1600W at rated vtg & cu loss 7.05kW F.L.
During day loaded as

% load	0%	20%	50%	80%	100%	125%
P.f	—	0.7	0.8	0.9	1	0.85
Hrs	2	4	4	5	7	2

Determine all day η. = 98.04%.

Date (29/8/18)

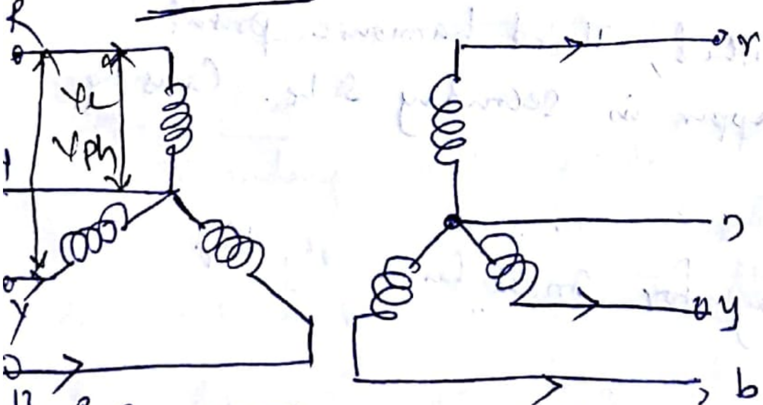
3,4,10 | 11,12,16, | 26,28,30 | 31,32,34,35,36, || 41,43,46,48,
49, 51.

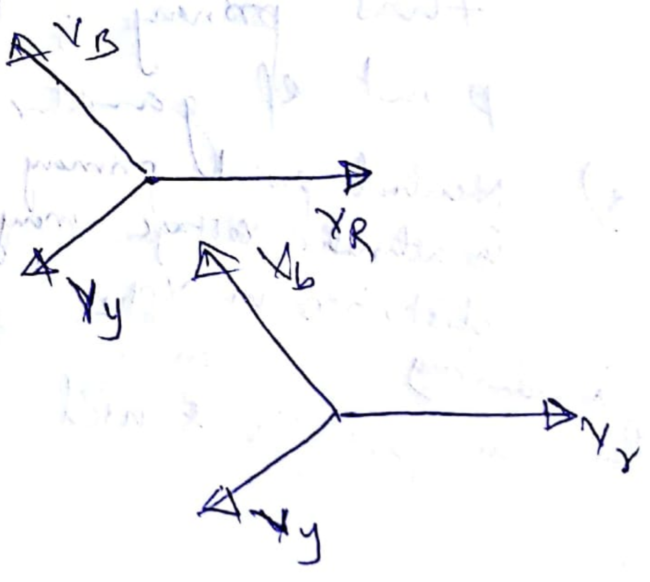
Three phase Tfr Connection

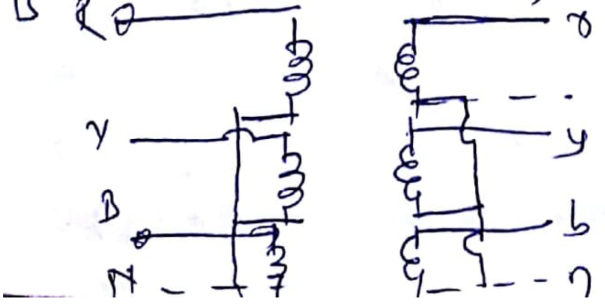
→ Voltages can be raised or lower

i) Y-Y ii) Δ-Δ iii) Y-Δ iv) Δ-Y v) open Delta or V connection vi) Scott Connection or T-T conn.

Y-Y







$V_{ph_1} = \frac{V_{L1}}{\sqrt{3}}$, $V_{ph_2} = k\left(\frac{V_{L1}}{\sqrt{3}}\right)$ as $\frac{V_{ph_2}}{V_{ph_1}} = k$

$V_{L_1} = \sqrt{3}\, V_{ph_1}$ ~~$V_{L_2} = \sqrt{3}$~~ V_{ph_2}

$V_{L_2} = \sqrt{3}\, V_{ph_2}$
$= \sqrt{3}\, k\left(\frac{V_{L1}}{\sqrt{3}}\right) = kV_{L_1}$

Advantages $V_{ph} = 1/\sqrt{3}\, V_L$

1) less no turns reqr, Stress on insulation is less, Construction economical

2) $I_L = I_{ph}$, wdg carry high c/n, a ↑, mechanically strong, heavy loads & Short ckt Bear

3) no phase shift betw primary & secondary vtg

4) neutral, suitable for 3ϕ, four wire system

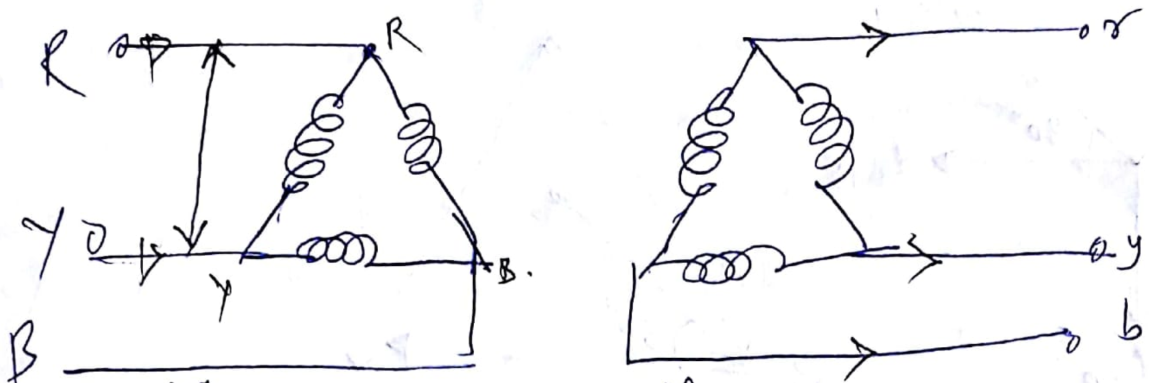
Disadvantages (Small high vtg tfr)

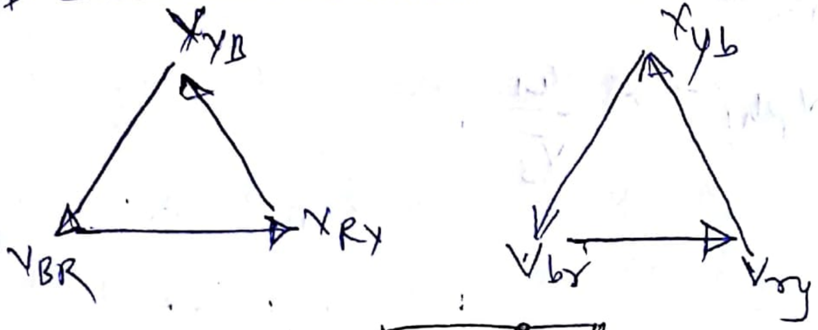
1) if load is unbalanced secondary (performance not satisfactory) shifting of neutral point is possible. So to prevent this primary is to be connected to star point of generator.

2) Neutral point primary earthed, Third harmonic present in alternator voltage may appear in secondary side. Causing distortion in V_{ph_2}

disadvantage
Rare in practice & used only for small high vtg tfr

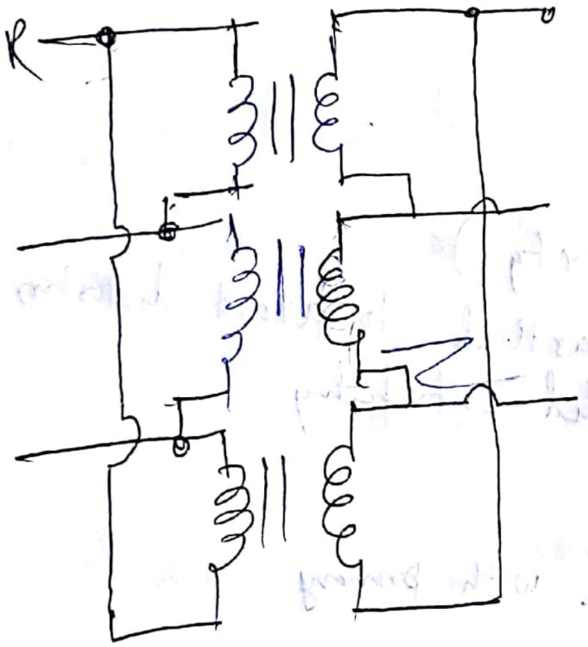
Delta - Delta Connection





30

4|12,16|30|34|~~44~~,46|



large low vtg Tfr
no phase shift

$V_{L1} = V_{ph1}$

$k = \frac{V_{ph2}}{V_{ph1}} \Rightarrow V_{ph2} = kV_{ph1}$

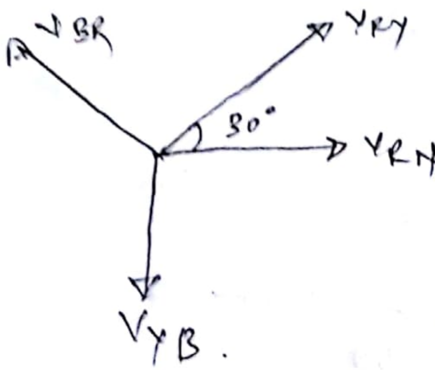
$V_{L2} = V_{ph2} = KV_{L1}$

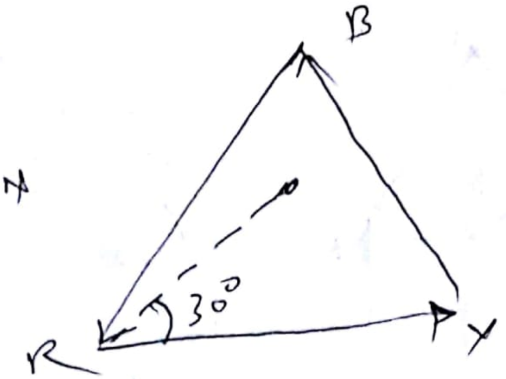
Advantages

1) secondary vtg sinusoidal, Im contain 3rd harmonic component, where Delta provides closed path for circulation.
2) Allows unbalanced loading (phase vtg remains constant)
3) Bank of 3 Tfr, operated on 2 if 1 is disable Reduced ?
4). no distortion in secondary vtg
5) $V_{ph} = V_L$ (more turns), But $I_{ph} = I_L/\sqrt{3}$ (a ↓), economical

Dis adv :- absence of neutral point (no 3 phase four wire system

Star - Delta





$V_{ph_1} = V_{L1}/\sqrt{3}$, $V_{ph_2} = K V_{ph_1} = K \frac{V_{L1}}{\sqrt{3}}$.

∴ $V_{ph_2} = V_{L2}$

$V_{L2} = K \frac{V_{L1}}{\sqrt{3}}$

Adv

1) As primary star (Small Large high vtg)
2) neutral available primary earthed to avoid distortion
3) large unbalanced loads handled satisfactory

Disadv

Secondary vtg is not in phase with primary.

D-d

primary $V_{L1} = V_{ph_1}$ $k = V_{ph_2}/V_{ph_1}$

$V_{ph_2} = kV_{ph_1}$

Star, $V_{L2} = \sqrt{3} V_{ph_2} \Rightarrow (\sqrt{3} k) V_{ph_1}$

$= (\sqrt{3} k V_{L1})$

Adv

1) primary Δ wdg cross section is less.
2) neutral available (3 ϕ, four wire sys)
3) no distortion due to 3rd harmonic component.
4) Star connection (saving in insulation)
5) large unbalanced load handled

Disadv

phase betw second & primary

- A 3 ϕ step down tfr is connected to 6600 V mains & it takes 10A. Calculate secondary line vtg, line c/n, o/p for a) $\Delta - \Delta$ b) $\lambda - \lambda$ c) $\lambda - \Delta$ d) $\Delta - \lambda$. $K = 1/12$
Turns Ratio/phase is 12. Draw connection dgm

Soln :- $V_{L1} = 6600$ vtg $I_{L1} = 10$ A.

a) $V_{L2} = 550V$, $I_{L2} = 120 A$, $o/p = \sqrt{3} V_{L2} I_{L2}$
$= 114.315$ kw.

b) $\lambda - \lambda$, $V_{L2} = 550V$, $I_{L2} = 120 A$, $o/p = 114.315$ kw

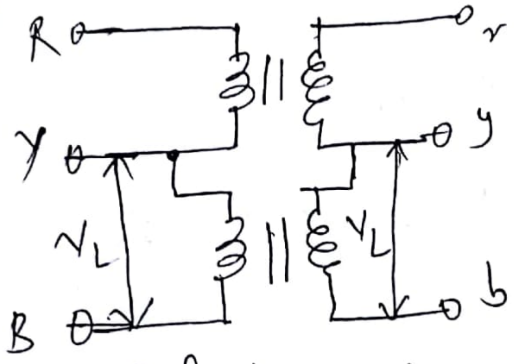
c) $\lambda - \Delta$

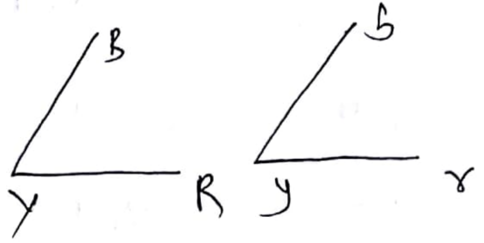
$V_{L2} = 317.543 V$, $I_{L2} = 207.846$, $o/p = \sqrt{3} V_{L2} I_{L2}$
$= 114.315$ kw.

c) $\Delta - \lambda$

$V_{L2} = 952.62$, $I_{L2} = 69.282$, $o/p = 114.315$ kw.

Open delta or V-V Connection





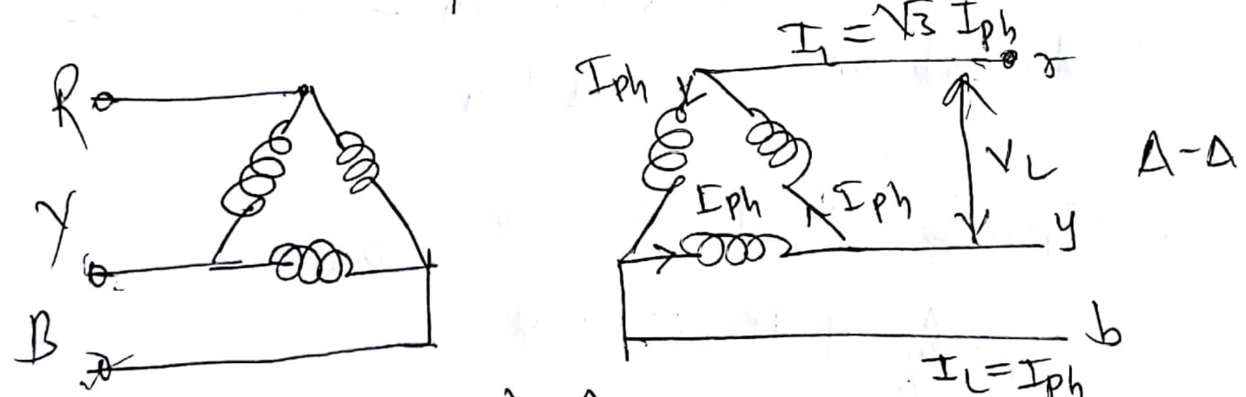
Head pain

Reduced Capacity, future load will increase

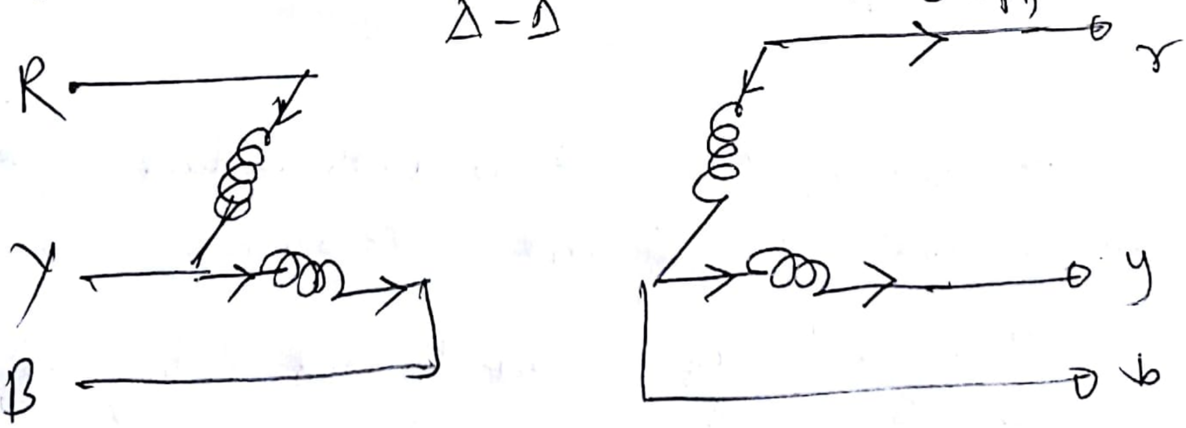
V-V bank load carried = 2/3 of capacity of Δ-Δ bank

but load carried by V-V bank is only 57.7%

It can be proved



Δ-Δ



V-V

Δ-Δ Capacity $= \sqrt{3} V_L I_L, = \sqrt{3} V_L (\sqrt{3} I_{ph})$

Δ-Δ Capacity $= 3 V_L I_{ph}$.

V-V Capacity $= \sqrt{3} V_L I_L = \sqrt{3} V_L I_{ph}$

$$\frac{\text{V-V Capacity}}{\Delta\text{-}\Delta \text{ Capacity}} = \frac{\sqrt{3} V_L I_{ph}}{\cancel{3} V_L I_{ph}} = \frac{1}{\sqrt{3}} = 0.557 = 58\%$$

Its not 66.7%

$$\text{Reduction in Rating} = \frac{66.67 - 57.735}{57.735} \times 100 = 15.476$$

The overload each transformer given as (3 operating one removed)

$$\frac{\text{Total load in V-V}}{\text{VA / transformer}} = \frac{\sqrt{3} V_L I_{ph}}{V_L I_{ph}} = \sqrt{3} = 1.732$$

$$\frac{\text{Operating Capacity of Tfr in V-V}}{\text{Available Capacity of Tfr in V-V}} = 0.866$$

Slow

Advantages

1.) if one is not operate, Can Continue with Reduced Capacity
2) 3ϕ load is Small, V-V Connection economical.
3) If there is possibility of increase in load future, add one transformer, Capacity can be increased
4) Connection acts as automatic Standby

Disadvantage

1) Avg pf at which V-V bank is operating is less than that with load. This power p.f is 86.6% of balanced load p.f

2) V-V bank operate at diff. p.f except for balanced upf.

3) The terminal vtgs available on Secondary Side become unbalanced. This may happen eventhough load is perfectly balanced.

$P_1 = KVA \cos(30-\phi)$, $P_2 = KVA \cos(30+\phi)$.

→ Δ-Δ bank. Consisting of 3 40kVA, 2300/230V tfr Supplies a load of 80kVA. If one is Removed, find for Resulting V-V connection

i) KVA load Carried by each tfr

ii) percent of rated load Carried by each tfr.

iii) Total KVA rating of V-V bank

iv) Ratio of V-V bank to Δ-Δ bank tfr rating

v) percent increase in load on each tfr when bank is converted into V-V bank.

12, 49,

(more, Explanation, more problem, proper notes, loudly, clarity, doubts

* A balanced 3φ load of 30 kVA, at a power factor of 0.866 lagging, is Connected to two tfr Connected in open delta, to a 230V 3φ system. Find the power delivered by each transfr

Sol: 30kVA is total load, Cosφ = 0.866 i.e φ = 30°

∴ operating Capacity of each tfr = 30/2 = 15 kVA

$\frac{\text{operating capacity}}{\text{Available } ''} = 0.866 \Rightarrow$ Available kVA of each tfr $= \frac{15}{0.866} = 17.32$ kVA

∴ $P_1 = \text{kVA} \cos(30-\phi) = 17.32 \times \cos(0) = 17.32$ kW

$P_2 = \text{kVA} \cos(30+\phi) = 17.32 \times \cos(60) = 8.66$ kW

Check 30kVA × 0.866 = 25.98 kW = $P_1 + P_2$

* Two tfr Connected in open delta supply a 400kVA balanced load operating at 0.866 pf lagging. The load vtg is 440V. Find i) kVA supplied by each tfr ii) kW supplied by tfr

Sol: Total load to be Supplied = 400 kVA

operating Capacity each tfr $= \frac{400}{2} = 200$ kVA.

i) $\frac{\text{Operating Capacity}}{\text{Available } ''} = 0.866 \Rightarrow$ Available $= \frac{200}{0.860} = 230.946$ kVA

ii) kw supplied by each tfr is

$P_1 = kVA \times \cos(30-\phi)$ & $P_2 = kVA \cos(30+\phi)$

$\phi = 30^\circ$

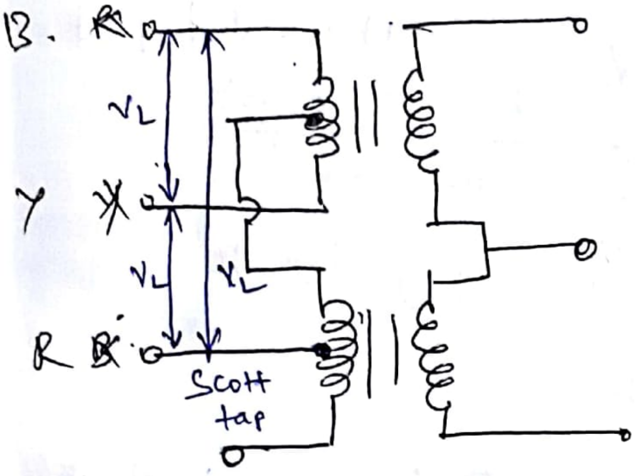
$P_1 = 230.946 \cos(0^\circ) = 230.946$ kw

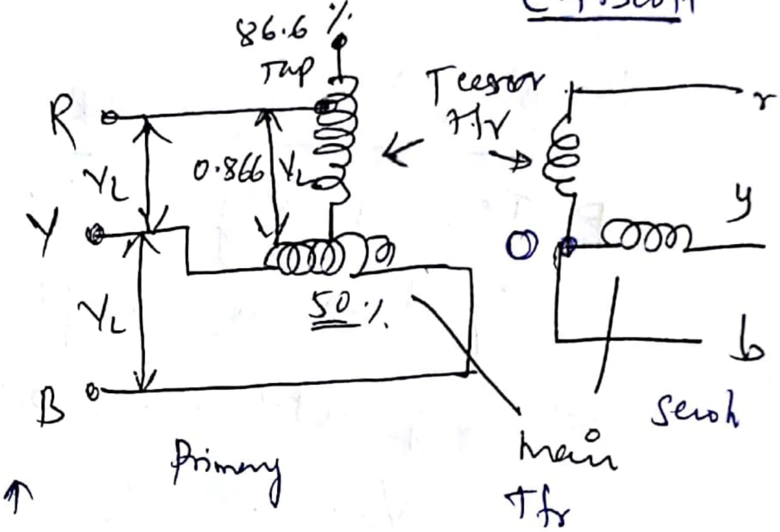
$P_2 = 230.946 \cos(60^\circ) = 115.474$ kw

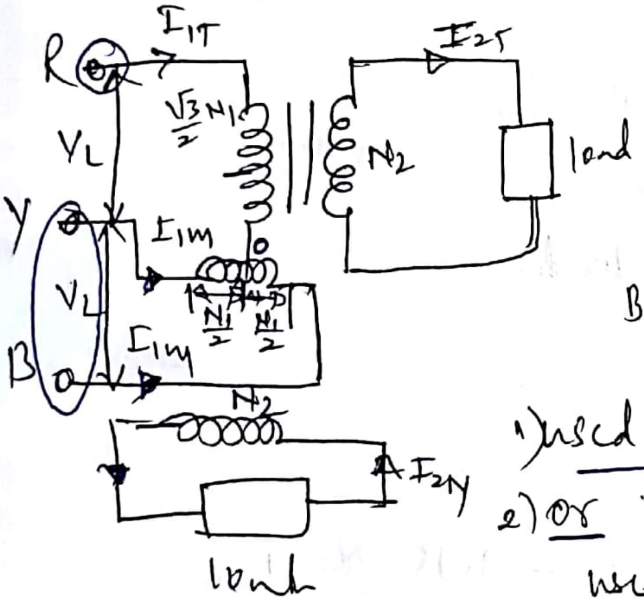
$P_1 + P_2 = 346.419$ kw $= 400$ kVA $\times 0.866$ kw.

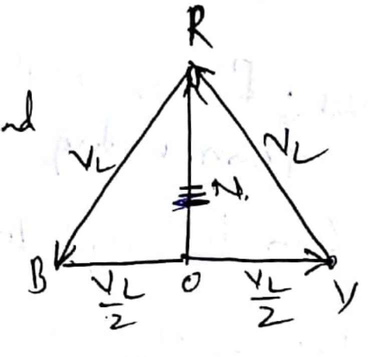
Conversion of three phase to two phase (Scott Connection)

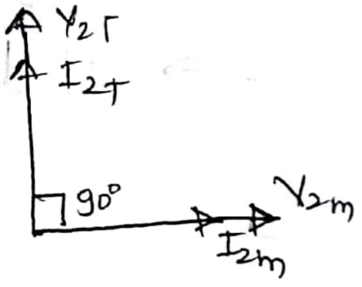
C.F. Scott











1) used for furnaces (~~2 phase electric~~)

2) or Three phase load can be used from available 2φ supply

- 50% tapping main tfr (Two tfr with diff rating) or (Identical tfr with tapping for interchangeability & provision of spares).
- 86.6% tapping teaser tfr.
- one end of Teaser tfr pw. is connected to centre tapping on primary wdg main tfr. [Two phase 3 wire systems obtain]
- Two ends of main tfr & 86.6% tapping point on T.T connected to supply (Balanced)

[E_t is same in primary & equal no turns on secondary]

if $\sqrt{3}/2 N_1$

- N_1 turns connected betw (Y & B)
- $V_{RY} = V_{YB} = V_{BR} = V_L$ (Line vtges)
- $\boxed{V_{RO} = \sqrt{3}/2\, V_L \ \& \ V_{RN} = V_L/\sqrt{3}}$

N is neutral point

O is not

- Terminal vtg on secondary having same turns equal in magn & phase shift of 90° betw them
- vtg betw N & O will be

$$\frac{\sqrt{3}}{2}V_L - \frac{1}{\sqrt{3}}V_L = 0.288 V_L \simeq 0.29 V_L \ (1/3 \text{ of } 0.866$$

- N divides RO in 2:1 Ratio of Teaser winding
- let us consider upf load.
- $$K = \frac{I_{1T}}{I_{2T}} = \frac{N_2}{N_1}$$

$$I_{1T} = I_{2T} \times \frac{N_2}{\left(\frac{\sqrt{3}}{2}N_1\right)} = 1.15 \frac{N_2}{N_1} I_{2T}$$

$$\boxed{I_{1T} = 1.15\, k\, I_{2T}}$$

Each half of p.w main tfr carries cln of I_{1m}.
Consisting two parts

i) $I_{1m} = \frac{N_2}{N_1} I_{2m} = k I_{2m}$

ii) equal to one half of teaser cln $\frac{1}{2} I_{1T}$

$$= \frac{I_{1T}}{2} = \frac{1.15 k I_{2T}}{2} = 0.58 k I_{2T}$$

The line cln on primary side vectorially given by

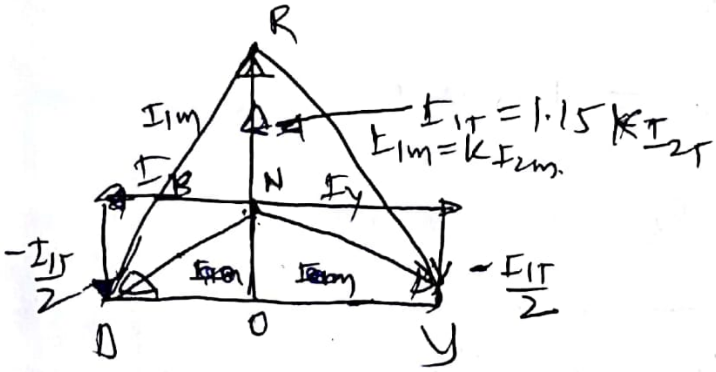
$$\bar{I}_R = \bar{I}_{1T}$$

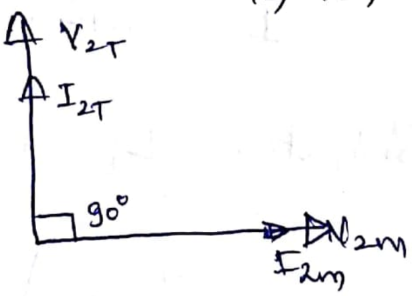
$$\bar{I}_Y = \bar{I}_{1m} - \frac{\bar{I}_{1T}}{2} \qquad \bar{I}_B = -\bar{I}_{1m} - \frac{\bar{I}_{1T}}{2}$$

magnitude

$$I_R = I_{1T}, \quad I_Y = I_B = \sqrt{(I_{1m})^2 + \left(\frac{1}{2} I_{1T}\right)^2}$$

11, 12, 18, 19, 25, 41, 43,
48, 49, 52,





→ $-\frac{I_{1T}}{2}$ no effect on core & does not take part in balancing Secondary Amp turns of main tfr.

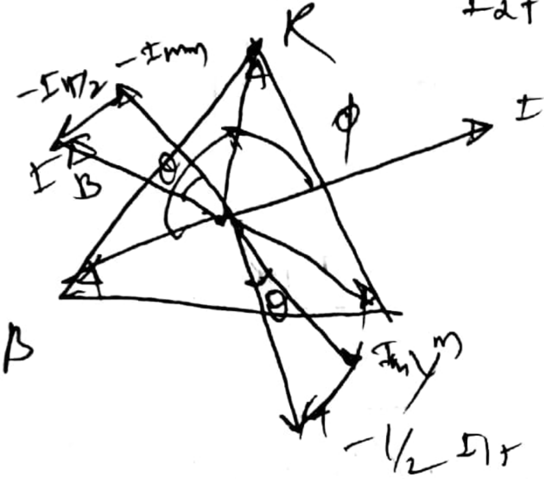
→ When two phase load of upf is balanced the 3φ side also balanced.

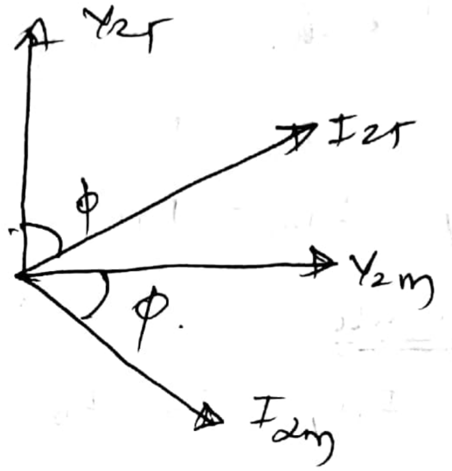
→ consider two phase load at 1pf

→ The 3φ side is again balanced as Clu drawn from 3φ Sysytem are equal balanced & lag by angle φ.

→ let us consider equal clu at a pf of cosφ lagging

$I_{2T} = I_{2m} = I_2$





Now

$I_M = k I_{2m} = k I_2$

$I_{1T} = 1.15\, k\, I_{2T} = 1.15\, k\, I_2$

Subjection $I_R = 1.15\, k\, I_2$

$$I_Y = I_B = \sqrt{(k I_2)^2 + \left(\frac{1}{2} \cdot 1.16\, k\, I_2\right)^2}$$

$$= 1.16\, k\, I_2$$

Thus all clu in primary std equal in magnit

$$\tan\theta = \frac{1/2\, I_{1T}}{I_{1m}} = \frac{1/2\,(1.16\, k\, I_2)}{k\, I_2} = 0.58 \quad \theta = 30$$

* Two electric furnaces are supplied with 1 φ ~~cty~~ ckt circuit at 80V from a, 3 φ, 11000V. system by means of two single phase scott connected thr with similar secondary wdg, when the load on ~~one~~ one furnace is 500kw & on the other 800kw, what cur will flow in each of 3 lines

i) At up.f ii) 0.8 pf lag

6, 12, 18, 24, 30, 32, 33, 35, 37, 38, 43, 44, 51, 54, (55).

let them (It's not in your control). let them see.

Don't care let them.

3 |
01, 11, 12, (30), 33, 42, 48, 50,

Sol^n :-

Furnace 1 (500kW) − 80 V

furnace 2 (800 kw) − 80 V.

$$I_{2T} = \frac{P}{V\cos\phi} = \frac{500 \times 10^3}{80 \times 1} = 6250A.$$

main thr $K = \frac{V_2}{V_1} = \frac{80}{11000} = 7.27 \times 10^{-3} = 0.00727$

(Teaser thr) $K = 1.1547 \times K(\text{main thr})$

$= 8.394 \times 10^{-3} = 0.0084.$

$I_R = I_{1T} = K(\text{teaser Thr}) \times I_{2T}$

$= 0.0084 \times 6250 = 52.46\ A$

(main thr) $I_{2m} = \frac{P}{V\cos\phi} = \frac{800 \times 10^3}{80 \times 1} = 10,000\ A.$

$I_{1m} = K(\text{main thr}) \times 10,000$

$= 0.00727 \times 10,000 = 72.7A.$

Total cur Current $= \sqrt{(72.7)^2 + (26.23)^2}$

$I_Y = I_B = 77.28$

5 (Tue). 5|09|17

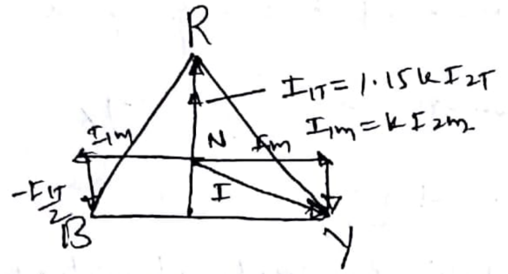
4, 11, 12, 43, 48,

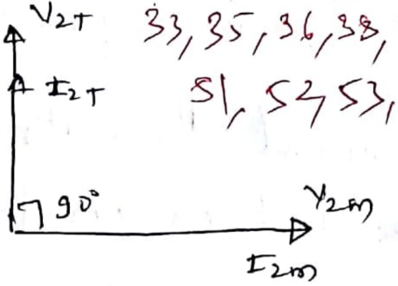
Tue (Afternoon)

04, 12, 53,

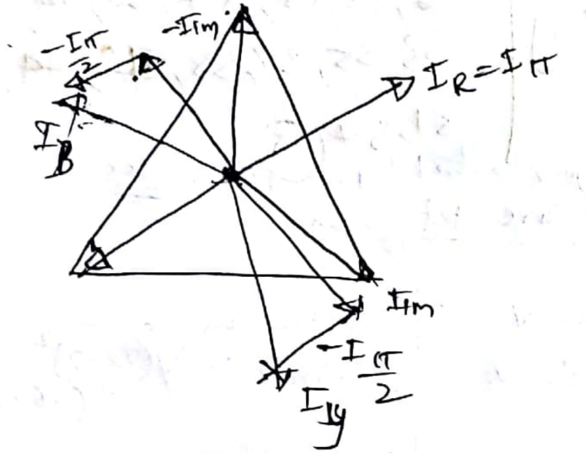
At upf

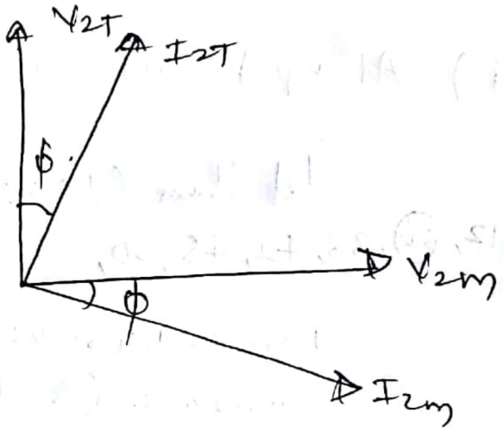
1, 2, 3, 4, 6, 8, 10, 11, 12, 13, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, ㉗ 28, 30, 31, 32, 33, 35, 36, 38, 43, 48, 49, 50, 51, 52, 53, 54,





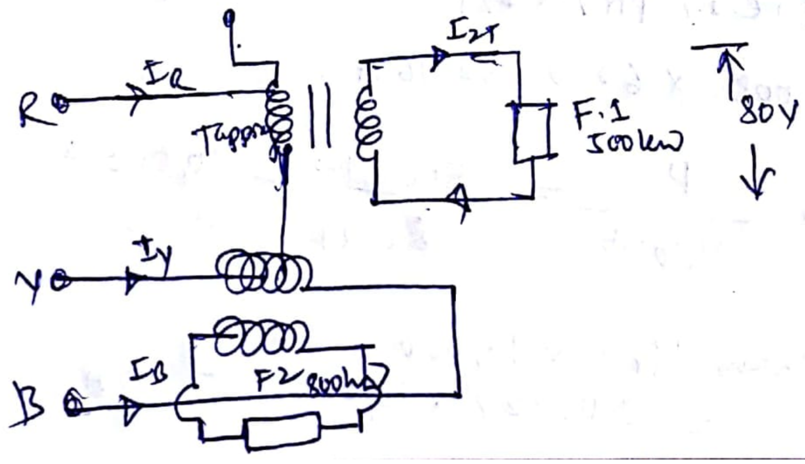
At lagg





* Two 110 volts single phase electric furnace take load of 500 kw and 800kw respectively at pf of 0.71 lag & are Supplied from 6600V, 3ϕ, 50hz mains through scott connected tfr. combination. Calculate the Ch in 3ϕ lines neglecting transformer losses. Draw phasor Diagram

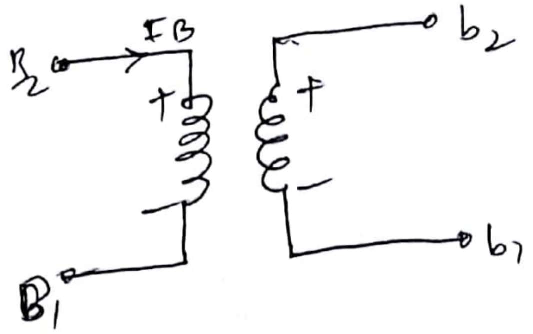
$I_R = 197.13\,A \quad I_Y = I_B = 144.94\,A.$



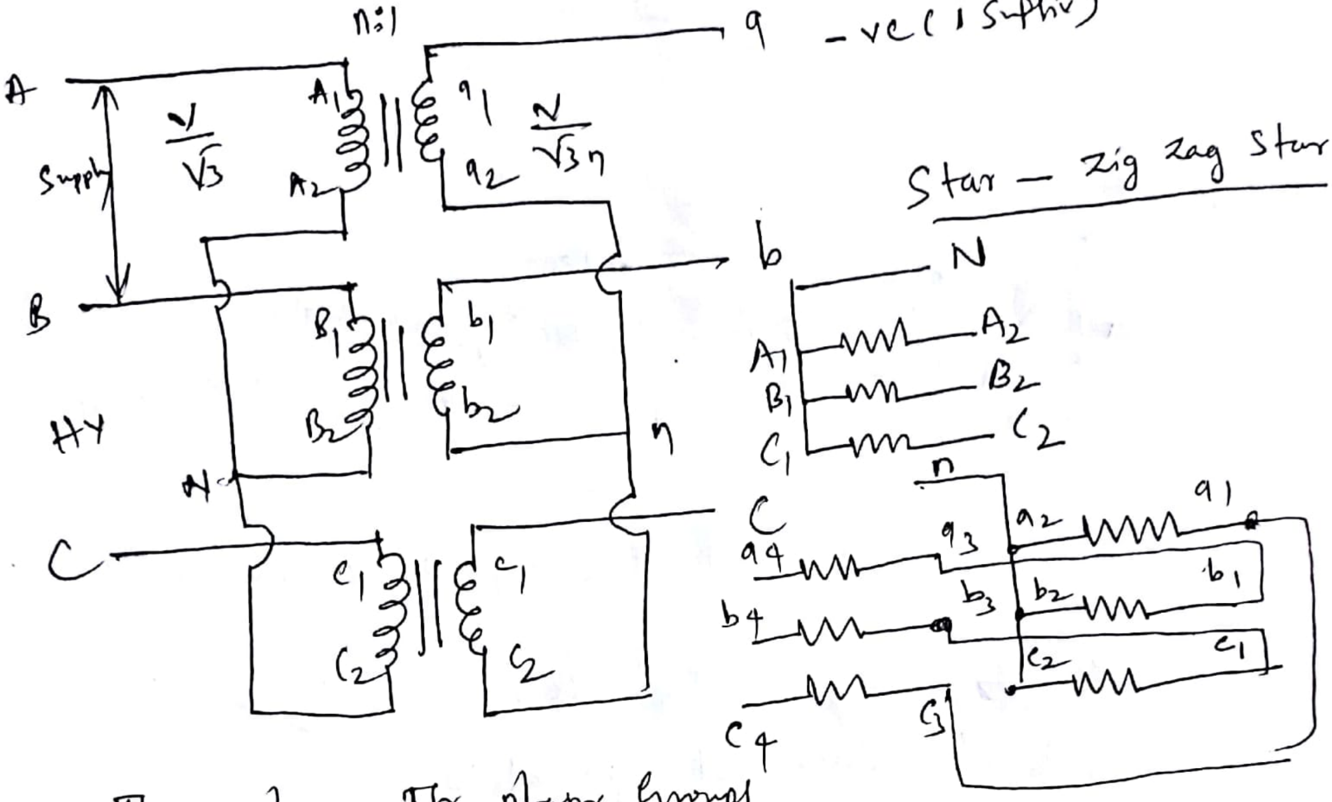
labelling of Transformer terminals

Thur (9/11/
19, 21, 28, 30, 32,
43, 48, 59 85

Page



HV (Capital letters)
LV (Small letters).
+ve (2)
-ve (1 Suffix)



Star — Zig zag Star

Three phase Tfr phasor Groups

- → Vector dgm of primary & secondary emf are useful to describe Characteristics, advantages & disadvantage
- → Construction of vector Dgm principle

1)

6, 11, 12, 13, ⑱, 22,
30, 33, 8