UNIT-VI

3-PHASE TRANSFORMERS

$\boxed{3\text{-}\phi \text{ transformers}}$

$v = V_m \sin\omega t \; ; \; i = I_m \sin(\omega t - \phi)$

$P = \frac{dw}{dt}$ $\quad w = qv$

$P_{(1-\phi)} = v.i$

$= V_m \sin\omega t \cdot I_m \sin(\omega t - \phi)$

$= v\frac{dq}{dt}$

$= \frac{V_m I_m}{2} \cdot 2\sin\omega t \cdot \sin(\omega t - \phi)$

$= vi$

$= \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \left[\cos(\cancel{\omega t} - \cancel{\omega t} + \phi) - \cos(\omega t + \omega t - \phi)\right]$

$= V \cdot I \left[\cos\phi - \cos(2\omega t - \phi)\right]$

$$\boxed{P_{(1-\phi)} = V \cdot I\cos\phi - VI\cos(2\omega t - \phi)}$$

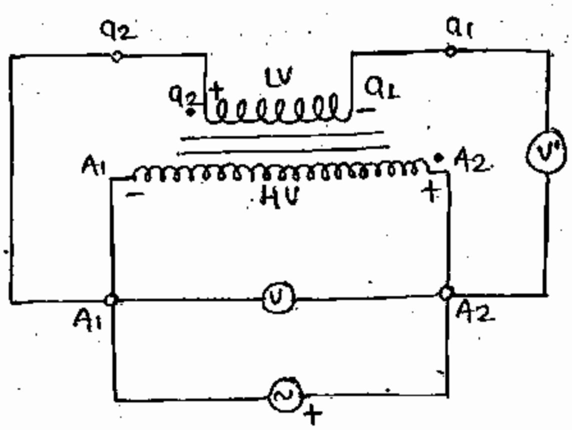
So; a 1-ϕ power suffers from double freq. componant.

<u>3000 kVA</u>

option 1: 1×3000 kVA, 3-ϕ unit

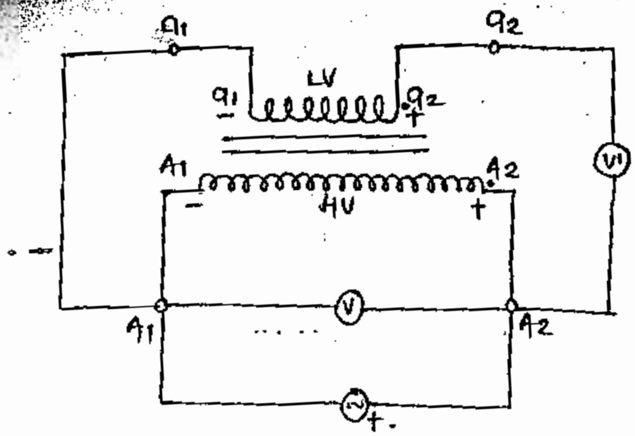
option 2: 3×1000 kVA, 1-ϕ TF connected in 3-ϕ bank

POLARITY TEST



$V' > V$

Fig:- additive polarity



$V' < V$

Fig :- Subtractive polarity.

* Phasor Groups →

Group (1) :- 0° → Yy0, Dd0, Dz0

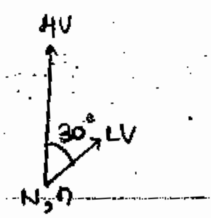
Group (2) :- 180° → Yy6, Dd6, Dz6

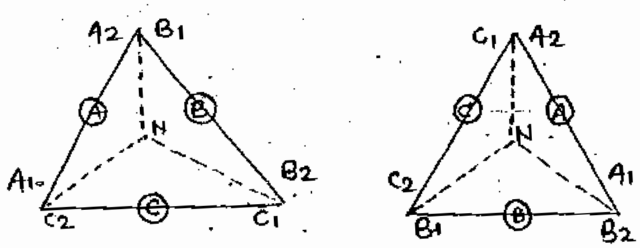
Group (3) :- 30° (lag) → Yd1, Dy1, Yz1

Group (4) :- 30° (lead) → Yd11, Dy11, Yz11

Y d 1

HV is star — LV is delta — Face of the clock





* British practise for phasor groups →

(1.) Phasor seq. in ABC.

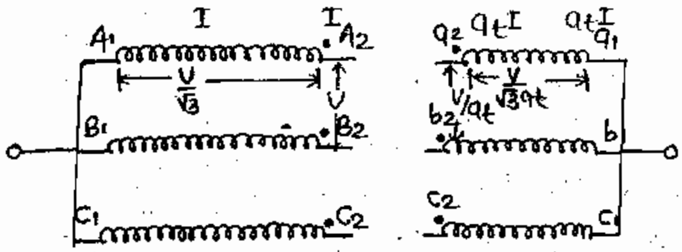
(2.) HV line (A-N) phasor always at 0 o'clock.

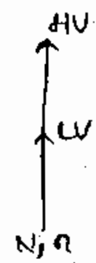
(3.) HV line 'A' terminal to be taken from A_2

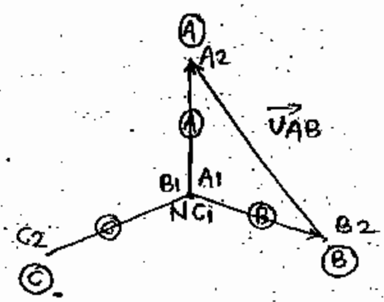
(4.) $\vec{V}_{a_2a_1}$ is in phase with $\vec{V}_{A_2A_1}$.

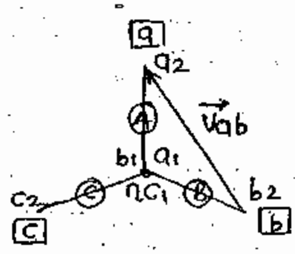
Yy0 →

$$a_t = \frac{N_{HV}}{N_{LV}}$$









$v_{AB} = v_{AN} - v_{BN}$

$v_{AN} = v_{AB} + v_{BN}$

Phase vol. transformation Ratio $= \frac{V}{\sqrt{3}} : \frac{V}{\sqrt{3}a_t} = a_t : 1$

line vol. transformation Ratio $= V : \frac{V}{a_t} = a_t : 1$

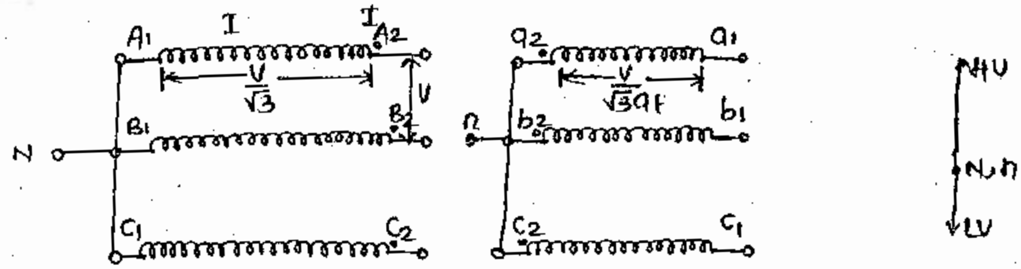
$S_{HV} = \sqrt{3}VI$ $\qquad$ $S_{LV} = \sqrt{3}\left(\frac{V}{a_t}\right)(a_t I)$

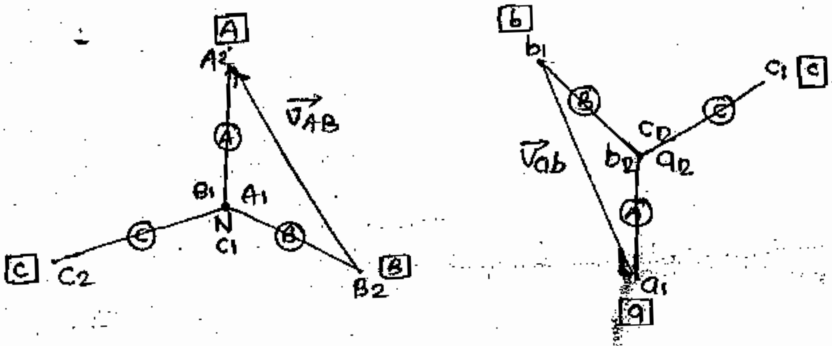
$= \sqrt{3}VI$

$= S_{HV}$

$$\boxed{S_{LV} = S_{HV}}$$

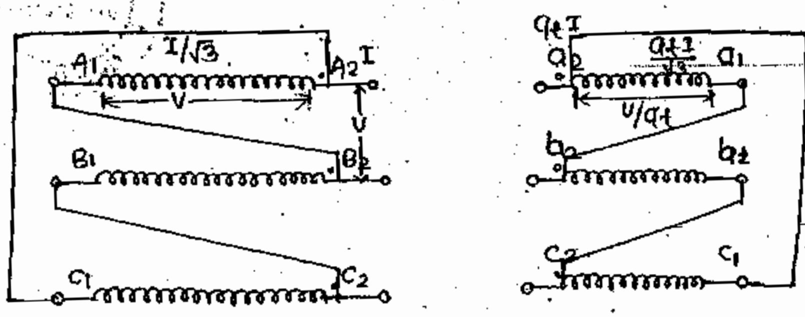
Yy6 →

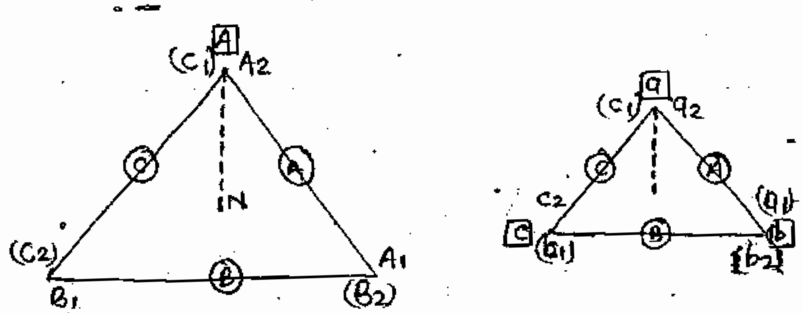




Dd0 →

* The British convection for Δ-Δ connection is that the HV side Δ & LV side Δ with the same combinations; this shows that a_1b_2, b_1c_2, c_1a_2





phase vol. Xmation ratio $= V : \frac{V}{at} = at : 1$

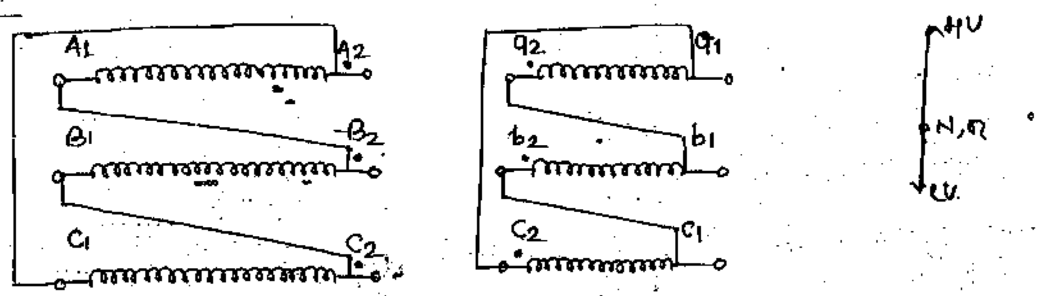
line vol. Xmation ratio $= V : \frac{V}{at} = at : 1$

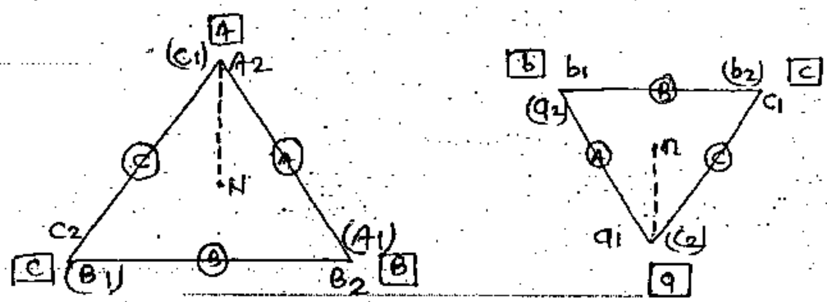
$S_{HV} = \sqrt{3} VI$ $\quad S_{LV} = \sqrt{3}\left(\frac{V}{at}\right)(at I)$

$= \sqrt{3} VI$

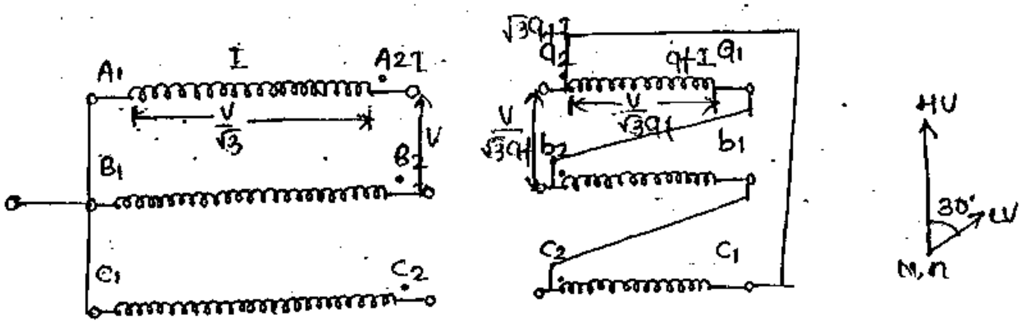
$\boxed{S_{LV} = S_{HV}}$

Dd6 →





Yd1 →



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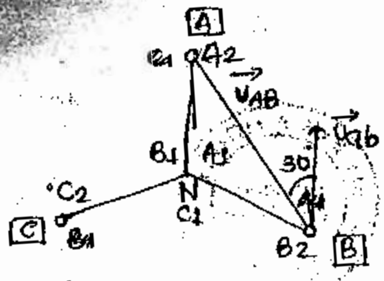
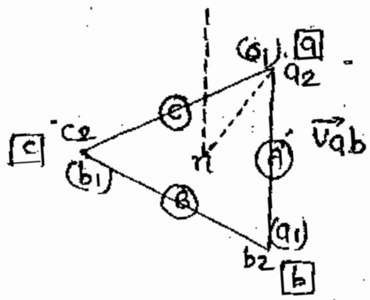




Phase vol. Xmation Ratio $= \frac{V}{\sqrt{3}} : \frac{V}{\sqrt{3}a_t} = a_t : 1$

line vol. Xmation Ratio $= V : \frac{V}{\sqrt{3}a_t} = \sqrt{3}a_t : 1$

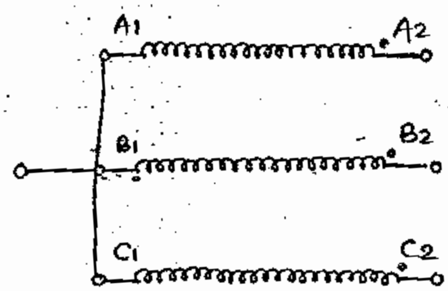
$S_{HV} = \sqrt{3}VI$

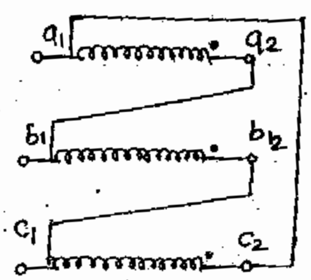
$$S_{LV} = \sqrt{3}\left(\frac{V}{\sqrt{3}a_t}\right)\cdot(\sqrt{3}a_t I)$$

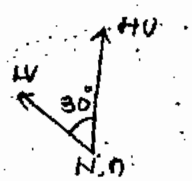
$$= \sqrt{3}VI$$

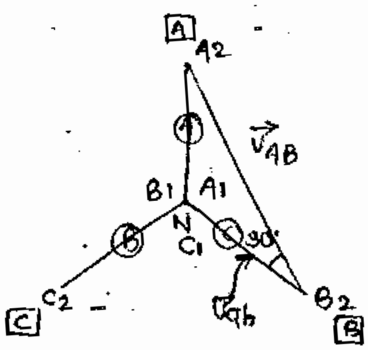
$$S_{LV} = S_{HV}$$

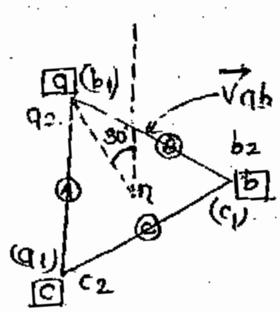
Yd11 →



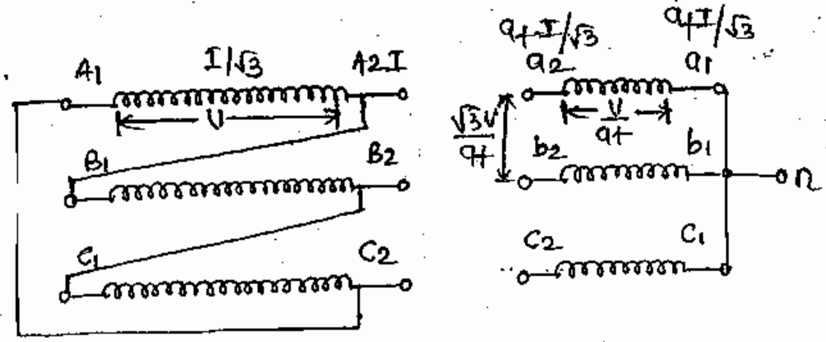


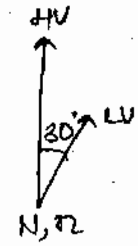


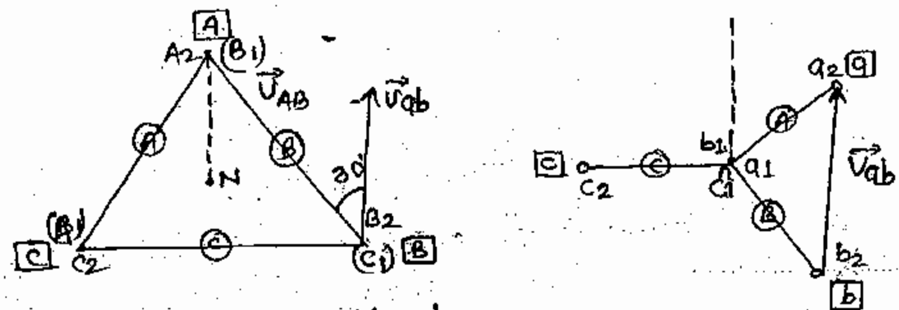




Dy1 →







Hint → Δ limb is decided by ⅄

$$\text{Phase vol. Xmation Ration} = V : \frac{V}{a_t} = a_t : 1$$

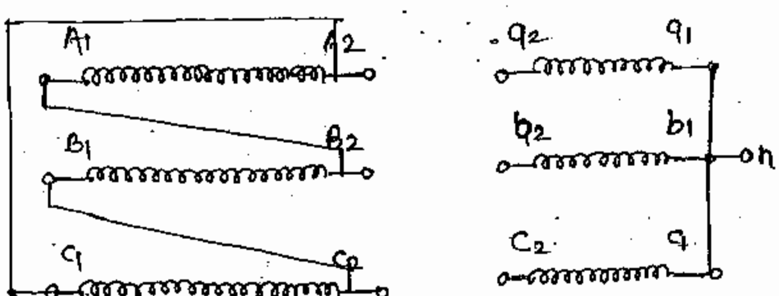
$$\text{line vol. Xmation Ratio} = V : \frac{\sqrt{3}V}{a_t} = \frac{a_t}{\sqrt{3}} : 1$$

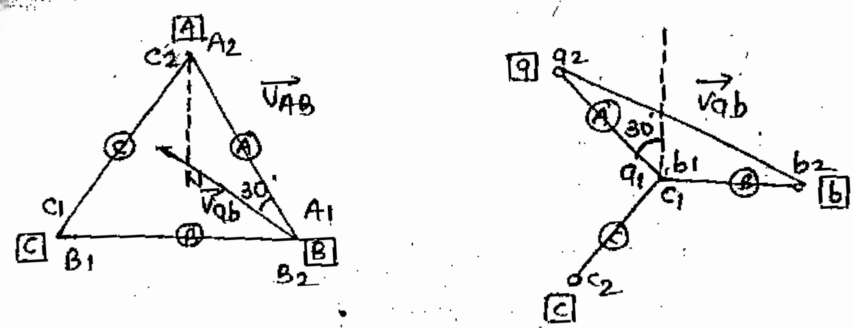
$S_{HV} = \sqrt{3}VI$ $\qquad$ $S_{LV} = \sqrt{3}\left(\frac{\sqrt{3}V}{a_t}\right)\left(\frac{a_t I}{\sqrt{3}}\right)$

$$= \sqrt{3}VI$$

$$S_{LV} = S_{HV}$$

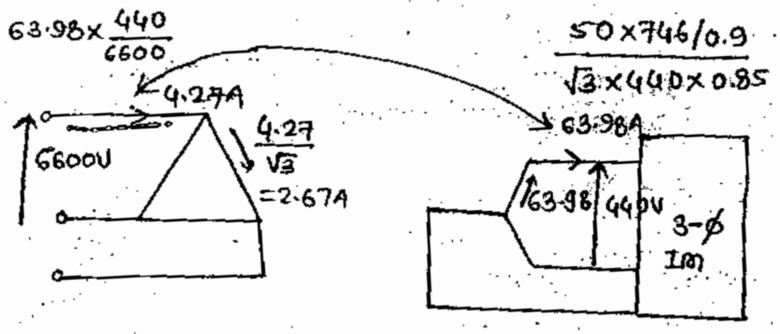
Dy11 →





Que.→ A 50HP 440V 3ϕ-Ind^n motor with an η of 0.9 at a PF of 0.85 on FL is supplied from a 6600/440V Δ-Y connected Xmer. Ignoring the magnetising current cal. the currents in the HV & LV windings of TF when the motor is running at FL.

Sol^n→



Que.→ A λ-λ-Δ Xmer with 1°, 2° & 3° voltages of 11kV, 1kV & 0.4kV has a magnetising current of 3A. There is a balance load of 600kVA at 0.8 PF lagging on the 2° wdg & a balance load of 150kW on the 3° wdg. Neglecting losses, find the 1° & 3° phase current if the 1° PF is 0.82 lag.

Sol^n→

$$I_1N_1 = I_2N_2 - I_3N_3 - I_0N_1$$

$$I_1 = I_2\frac{N_2}{N_1} - I_3\frac{N_3}{N_1} - I_0$$

$$\vec{S_1} = \sqrt{3}\times 11\times I_1 \angle \cos^{-1}(0.82)\ \text{kVA}$$

$$\vec{S_2} = 600\angle\cos^{-1}(0.8)\ \text{kVA} = 600\angle 36.87\ \text{kVA}$$

$$S_3 = \frac{150}{\cos\phi_3}\angle\phi_3\ \text{kVA}\ \text{(assuming lag. PF 3° load)}$$

$$S_0 = \sqrt{3}\times 11\times 3\angle 90°\ \text{kVA}$$
$$= 57.158\angle 90°\ \text{kVA}$$

$$S_3 = \frac{150}{\cos\phi_3} \angle \phi_3$$

$$= \frac{150(\cos\phi_3 + j\sin\phi_3)}{\cos\phi_3}$$

$$S_3 = 150(1 + j\tan\phi_3)$$

$$S_1 = S_2 + S_2 + S_0$$

$$\sqrt{3}\, 11 \times I_1 \angle \cos^{-1}(0.82) = 600 \angle \cos^{-1}(0.8) + (150 + j150\tan\phi_3) + \sqrt{3} \times 11 \times 3 \angle 90^\circ$$

$$15.623 I_1 + j10.905 I_1 = 630 + j\left[360 + 150\tan\phi_3 + 33\sqrt{3}\right]$$

equating real parts;

$$I_1 = \frac{630}{15.623} = 40.325A$$

equating imaginary parts;

$$10.905 = 360 + 150\tan\phi_3 + 33\sqrt{3}$$

$$\phi_3 = 8.56^\circ$$

$$150 \times 10^3 = \sqrt{3} \times (0.4 \times 10^3) \times I_3(\text{line}) \times \cos(8.56^\circ)$$

$$I_3(\text{line}) = 218.945A$$

$$I_3(\text{ph.}) = \frac{218.945}{\sqrt{3}} = 126.41A$$

$$\boxed{I_1 = 40.32A,\ I_3 = 126.41A}$$

* star is used for HV, low capacity.
* Δ is used for LV, high capacity.

Applications of diff. 3-ϕ TF connections→

* According to the general recommondation a λ connection is used for High vol., low capacity (kVA) appliⁿ where as a Δ connection is favoured for Low vol. High capacity appliⁿ.

* Since the kVA capacity of a TF is same on both sides, the natural choice would be a λ connection for HV side Δ connection for LV side.

* Accordingaly a λ-Δ connection is used for a step down appliⁿ where-as a Δ-λ connection is used for step up appliⁿ

* However there is an exception. In 2° distribution sys. a neutral connection is req. to feed 1-ϕ loads as there are mixed (3ϕ & 1ϕ) loads connected to the system.

Therefore a Δ-λ connection is used in the step down mode in 2° distribution TF.

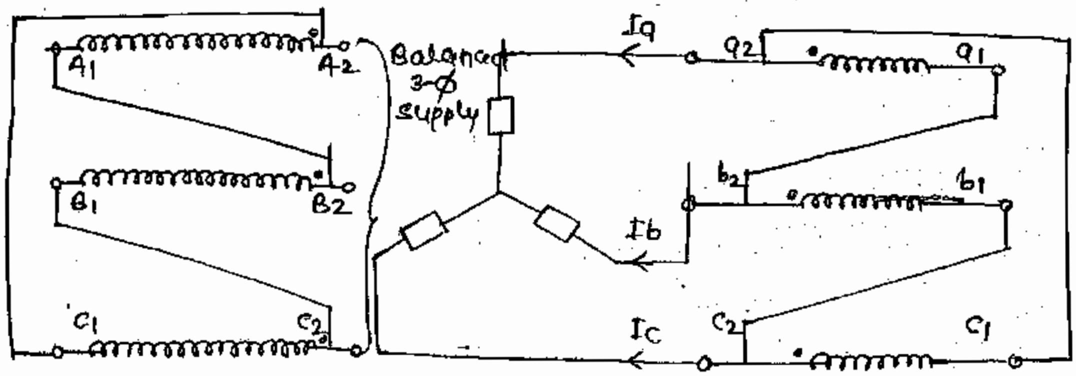
* A Δ-Δ connection is quite suitable to feed 3-ϕ loads of high capacity at LV levels.

If a 3-ϕ bank of 1-ϕ TF is used in Δ-Δ & a if one TF has to be removed then the remaining 2 TF may still be used in open Δ (or V) connection to continue to supply 3-ϕ loads although at a reduced capacity of 57.7%.

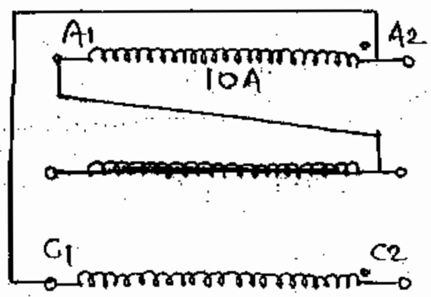
* Although a λ-λ connection appears to be quite attractive for HV appliⁿ it is seldom used without a 3° Δ wdg because of prob. related to magnetising current harmonics, unbalanced loads & unbalanced faults.

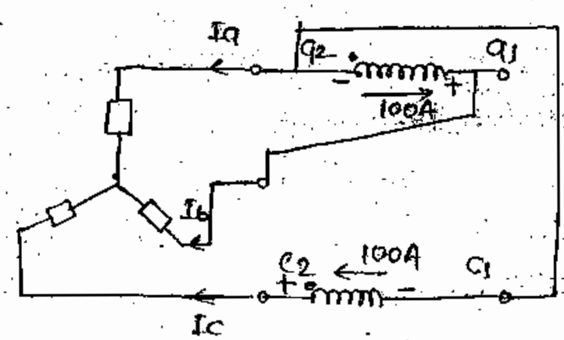
Vee (or) Open Δ-connection

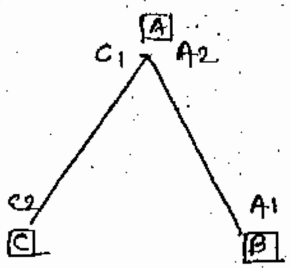
$I = \sqrt{3} \times 100A$

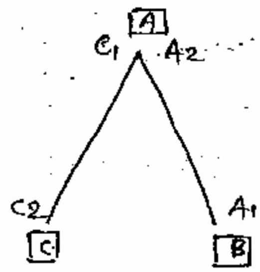


$I = 100A$









$$S_{\Delta-\Delta} = \sqrt{3} V \cdot I$$

$$S_L = \sqrt{3} V I \angle \phi$$

$$S_{Vee} = \sqrt{3} \cdot V \left(\frac{I}{\sqrt{3}}\right)$$

$$= VI$$

$$\frac{S_{Vee}}{S_{\Delta\Delta}} = \frac{VI}{\sqrt{3} VI}$$

$$= \frac{1}{\sqrt{3}} = 0.577$$

$$\boxed{\frac{S_{Vee}}{S_{\Delta\Delta}} = 57.7\%}$$

$\vec{S_C} = VI\angle\phi+30^\circ = \frac{S_L}{\sqrt{3}}\angle\phi+30^\circ$

$\vec{S_A} = VI\angle-(30-\phi)$

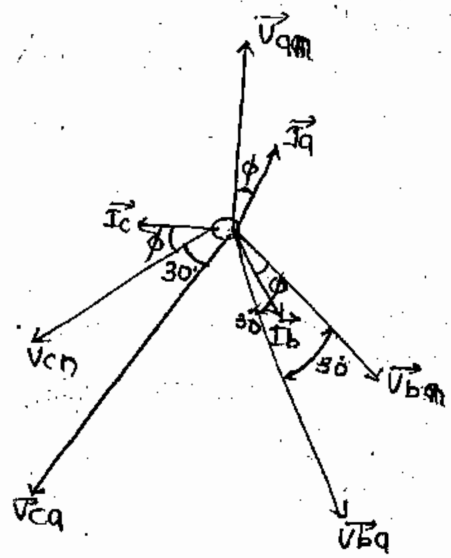
$\vec{S_A} = VI\angle\phi-30^\circ = \frac{S_L}{\sqrt{3}}\angle\phi-30^\circ$

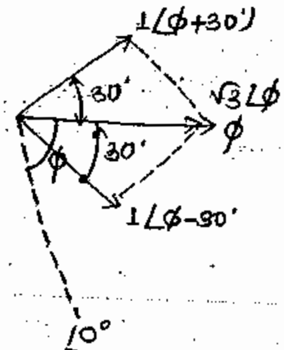
$\vec{S_C}+\vec{S_A} = VI[1\angle\phi+30^\circ + 1\angle\phi-30^\circ]$

$= VI[\sqrt{3}\angle\phi]$

$= \sqrt{3}VI\angle\phi$

$\boxed{S_C+S_A = \vec{S}_{load}}$





Que.→ A 3ϕ 1000 kVA 0.866 lag PF load is supplied by V connection at 400V. Determine the kVA o/p & operating PF of each TF. Neglect exciting current & all losses.

Sol^n→

$\phi = \cos^{-1}(0.866)$

$= 30^\circ$ lag

$\vec{S_C} = \frac{1000}{\sqrt{3}}\angle 30+30^\circ$

$= 0.577\angle 60^\circ$ kVA

at PF 0.5 lag.

$\vec{S_A} = \frac{1000}{\sqrt{3}}\angle 30^\circ-30$

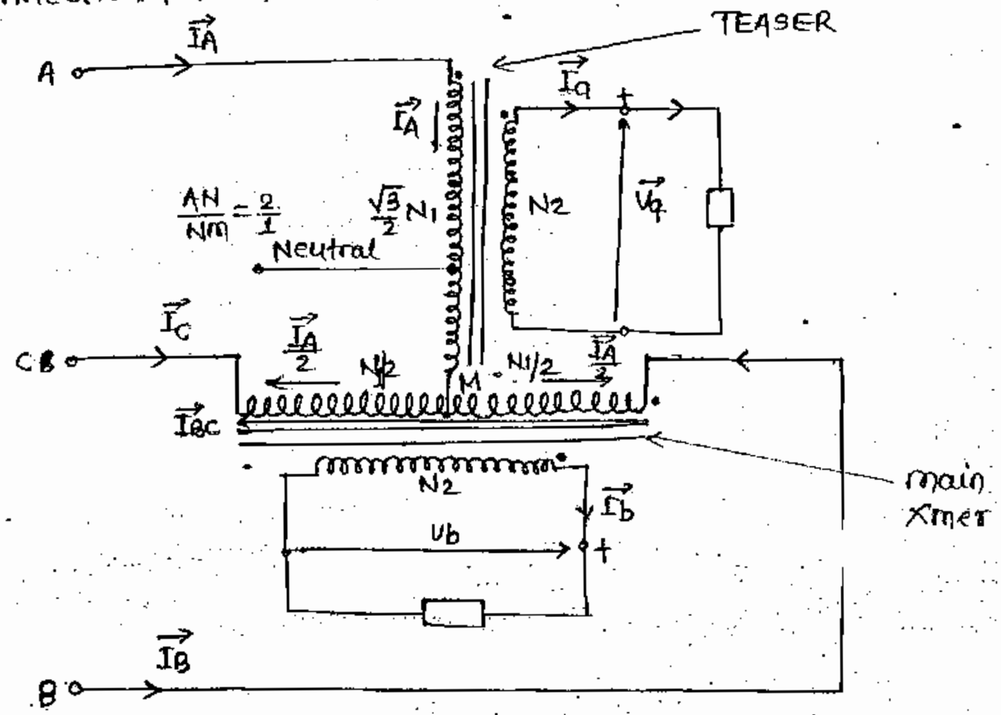
$= 0.577\angle 0^\circ$

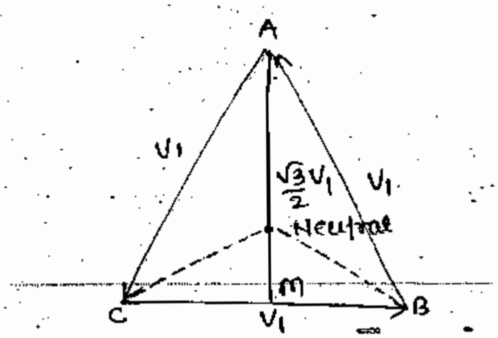
at PF $= 0^\circ$

DATE 29/11/14

SCOTT CONNECTION

* Scott connection for 3-ϕ to 2-ϕ conversion.





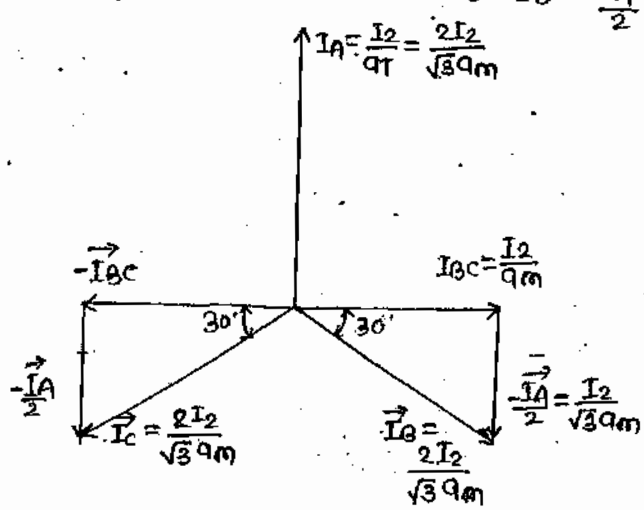
$$a_m = \frac{N_1}{N_2}$$

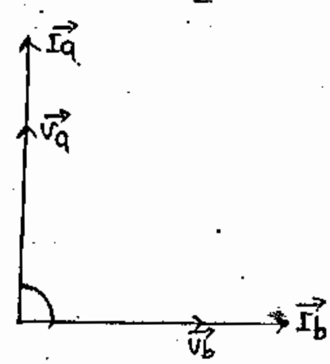
$$a_T = \frac{\sqrt{3}N_1/2}{N_2} = \frac{\sqrt{3}}{2}a_m$$

$$V_b = \frac{V_1}{a_m} \; ; \; V_q = \frac{\sqrt{3}V_1/2}{a_T} = \frac{\sqrt{3}V_1/2}{\sqrt{3}a_m/2}$$

$$V_q = \frac{V_1}{a_m} = V_b$$

$$\vec{I_B} = \vec{I_{BC}} - \frac{\vec{I_A}}{2} \; ; \; I_C = -I_{BC} - \frac{\vec{I_A}}{2}$$





unity pF load. ($I_q = I_b = I_2$)

$S_{main} = V_1 I_1$ $\quad S_{teaser} = \frac{\sqrt{3}}{2} V_1 \times I_1$

$$\frac{S_{main}}{S_{teaser}} = \frac{2}{\sqrt{3}} = 1.15$$

$$\boxed{\frac{S_m}{S_T} = 1.15}$$

Que.→ 2-1ϕ Furnaces A & B are supplied at 80V by means of Scott connected Xmer combination for a 3-ϕ 6600V system. The vol. of Furnace A is leading. Cal. the line currents on the 3-ϕ side when

(a) The furnaces take 800kW each at 0.8 PF lag.

(b) Furnace A takes 500kW at UPF & B take 800kW at 0.707 PF lag.

Soln→ Let; $V_B = 80\angle 0^\circ$, $V_A = 80\angle 90^\circ$

(a) $a_m = \frac{N_1}{N_2} = \frac{6600}{80}$

$a_m = 82.5$ $\quad a_T = \frac{\sqrt{3}}{2} a_m = \frac{\sqrt{3}}{2} \times 82.5 = 71.45$

$a_m = 82.5, \; a_T = 71.45$

$$I_b = \frac{800 \times 10^3}{80 \times 0.8} \angle -\cos^{-1}(0.8) = 12500 \angle -36.87^\circ A.$$

$$I_a = \frac{800 \times 10^3}{80 \times 0.8} \angle 90 - \cos^{-1}(0.8)$$

$$I_a = 12500 \angle 53.13^\circ A$$

$$\vec{I}_{BC} = \frac{\vec{I}_b}{a_m} = 151 \angle -36.87\, A, \quad \vec{I}_A = \frac{I_a}{a_T} = 174.95 \angle 53.13^\circ A$$

$$\vec{I}_B = \vec{I}_{BC} - \frac{\vec{I}_A}{2} \qquad I_C = -I_{BC} - \frac{I_A}{2}$$

$$= 174.96 \angle -66.87^\circ A \qquad = 174.96 \angle 173.13^\circ A$$

$$\boxed{I_A = 174.95 \angle 53.13^\circ A, \; I_B = 174.96 \angle -66.87^\circ A \\ I_C = 174.96 \angle 173.13^\circ A}$$

(b)

$$\vec{I_b} = \frac{800\times10^3}{80\times0.707}\angle -\cos^{-1}(0.707) \qquad \vec{I_q} = \frac{500\times10^3}{80\times1.0}\angle 90^\circ$$

$$= 14144.27\angle -45^\circ A \qquad = 6250\angle 90^\circ A$$

$$\vec{I_{BC}} = \frac{\vec{I_b}}{a_m} = 171.45\angle -45^\circ A$$

$$\vec{I_A} = \frac{\vec{I_q}}{a_T} = 87.47\angle 90^\circ A$$

$$\vec{I_B} = \vec{I_{BC}} - \frac{\vec{I_A}}{2} = 204.72\angle -53.69^\circ A$$

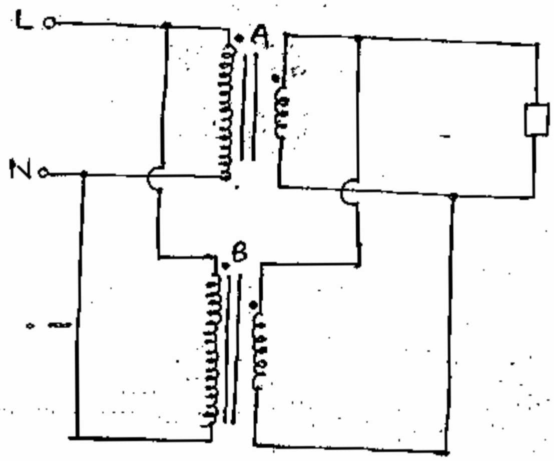
$$\vec{I_C} = -\vec{I_{BC}} - \frac{\vec{I_A}}{2} = 143.89\angle 147.47^\circ A$$

Parallel Operation Of Transformer

Cond^n to be satiesfied for parallel operation of Xmer →

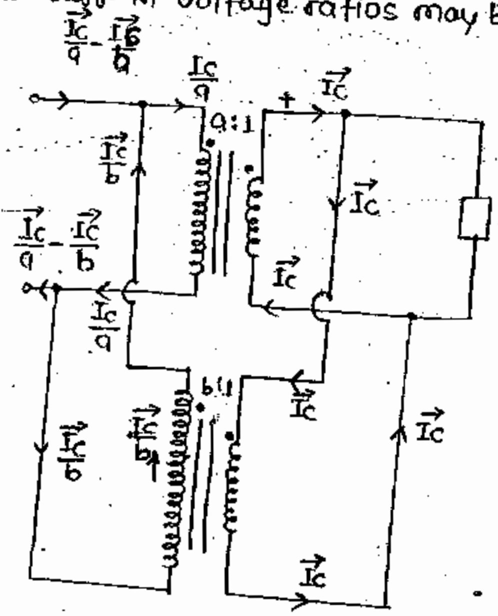
(A.) For 1-ϕ TF & 3-ϕ TF →

(a.) Same polarity. i.e. the dots must be connected to dots. (MUST)



(b.) Equal vol. Ratios (same vol. Rating) (MUST)

Note → A small diff. in voltage ratios may be permitted if unavoidable.



$E_A > E_B$

$\frac{V_1}{a} > \frac{V_1}{b}$

$b > a$

$I_c b > I_c a$

$\frac{I_c}{a} > \frac{I_c}{b}$

(c.) Same pu impedance for proportional load sharing. (desirable)

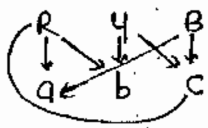
↓

Name plate Zpu

(d.) Same $\frac{X}{R}$ ratios. (i.e. same impedance angle) For same PF operation, as that of the load PF (desirable).

(B.) For 3-ϕ TF only →

(e.) Same phase sequence (MUST)



(F.) Zero phase diff between the corresponding line voltage.

This means that TF belonging to same phasor group may alone be parallel. (MUST)

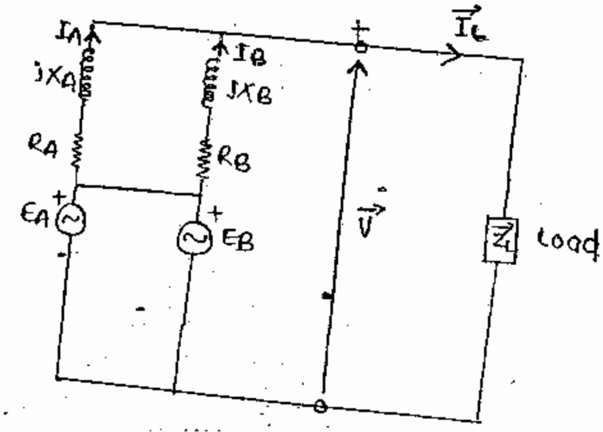
Dy11 (a) Yy0 (b) Dd0 (c) Yy6 ~~(d)~~ Yd1

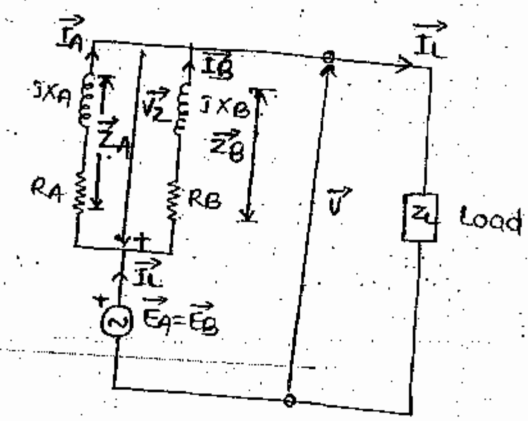
Because if we change the seq. of 1° then get 30° lead/lag.

LOAD SHARING

Equal voltage Ratios

$E_A = E_B$





Two Xmer;

$$\vec{V_Z} = \vec{I_A}\vec{Z_A} = \vec{I_B}\vec{Z_B} = \vec{I_L} \times \vec{Z_{P}}$$

$$= I_L \times \frac{\vec{Z_A}\vec{Z_B}}{\vec{Z_A}+\vec{Z_B}}$$

where; Z_A & Z_B are in actual volts.

$$\vec{I_A} = \frac{Z_B}{Z_A+Z_B} \times \vec{I_L} \quad \& \quad \vec{I_B} = \frac{\vec{Z_A}}{Z_A+Z_B} \times \vec{I_L}$$

However if the impedance are expressed in pu then there pu values should be converted on a common base to insure that the ohmic ratio remain unchanged.

for 'n' Xmers →

$$\vec{V_z} = \vec{I_A}\vec{Z_A} \pm \vec{I_B}.\vec{Z_B} = \vec{I_C}\vec{Z_C} \text{ ------- } = \vec{I_n}\vec{Z_n} = \vec{I_L} \times \vec{Z_p}$$

$$\Rightarrow \vec{I_A}\vec{Z_A} = \vec{I_L} \times \vec{Z_p}.$$

$$\Rightarrow \vec{I_L} = \cancel{\vec{I_A}}\frac{\cancel{\vec{Z_B}}}{\cancel{Z_A}} = \frac{\vec{I_A}.\vec{Z_A}}{Z_p}$$

$$\Rightarrow \cancel{\frac{\vec{I_A} \times \vec{Z_A}}{\left(\frac{1}{Z_A}+\frac{1}{Z_B}+\frac{1}{Z_C}+\cdots\frac{1}{Z_n}\right)} = \vec{I_L}}$$

$$\vec{I_A}\vec{Z_A} = \frac{\vec{I_L}}{\left(\frac{1}{Z_A}+\frac{1}{Z_B}+\cdots\frac{1}{Z_n}\right)}$$

$$\vec{I_A} = \frac{\vec{I_L}}{Z_A\left(\frac{1}{Z_A}+\frac{1}{Z_B}+\cdots\frac{1}{Z_n}\right)}$$

$$\boxed{\vec{I_A} = \frac{\vec{I_L}}{\left(\frac{\vec{Z_A}}{Z_A}+\frac{\vec{Z_A}}{Z_B}+\cdots\frac{\vec{Z_A}}{Z_n}\right)}}$$

$$S_A = P_A + jQ_A = V_A I_A^*$$

$$S_A^* = P_A - jQ_A = V^* I_A$$

$$= V^* \frac{Z_B}{Z_A+Z_B} \times \vec{I_L}$$

$$\boxed{\vec{S_A^*} = \frac{\vec{Z_B}}{\vec{Z_A}+\vec{Z_B}} \times S_L^*}$$

Similarly;

$$\vec{S_B} = \vec{V}.I_B^*$$

$$S_B^* = V^* \vec{I_B}$$

$$\boxed{S_B^* = \frac{Z_A}{Z_A+Z_B} \times S_L^*}$$

Per unit loading →

$$\vec{I_j}\,\vec{z_{j(\Omega)}} = \text{constant}$$

$$\vec{I_j} \propto \frac{1}{\vec{z_{j(\Omega)}}}$$

$$V^*\cdot\vec{I_j} \propto \frac{1}{\vec{z_{j(\Omega)}}}$$

$$S_j^* \propto \frac{1}{\vec{z_{j(\Omega)}}}$$

$$S_j^* \propto \frac{1}{\vec{z_{j(pu)}} \times z_{j(Base)}}$$

$$S_j^* \propto \frac{1}{z_{j(pu)} \times \left[\frac{V^2_{rated}}{S_{j(rated)}}\right]}$$

$$S_j^* \propto \frac{S_{j(rated)}}{z_{j(pu)}}$$

$$\frac{S_j^*}{S_{j(rated)}} \propto \frac{1}{z_{j(pu)}}$$

$$S^*_{j(pu)} \propto \frac{1}{z_{j(pu)}}$$

* This means that the TF with lowest PU impedance on its own base (i.e. name plate z_{pu}) would have max^m PU loading & therefore would be the 1st to reach its FL.

For proportional load sharing

$$S_j \propto S_{j(rated)}$$

$$\frac{S_j}{S_{j(rated)}} = \text{constant}$$

$$S_{j(pu)} = \text{constant}$$

Since $S_{j(pu)} \propto \dfrac{1}{z_{j(pu)}}$

∴ For proportional load sharing

$$z_{j(pu)} = \text{constant}$$

Que.→ 2-1ϕ Xmers rated 1000 KVA & 500KVA respectively are connected in parallel on both HV & LV sides. They have equal voltage ratings of 11KV/400V & there pu impedances are $0.02+j0.07$ & $0.0455+j0.0788$ PU respectively.

(A) How will the following loads will share

360KVA at 0.9 PF lagging.

500kW at UPF.

(B) What is the largest value of 0.8PF lagging load that can be delivered by the parallel combination at the rated vol.

Determine the load shared & operating PF of the 2 TF under these condn.

Soln→ $Z_A = 0.0728\angle 74.05^\circ$ PU ; $Z_B = 0.091\angle 60^\circ$ PU

Because the value of the Z_A is less, then it will go for FL 1st.

Selecting 1000KUA as common Base ; Z_A will same

$$(Z_B)_{new} = 0.091\angle 60^\circ \times \frac{1000}{500}$$

$$(Z_B)_{new} = 0.182\angle 60^\circ \text{ PU}$$

$$S_L = 360 \text{ KVA}$$

part (A).

(i) $S_L = 360\angle 25.84^\circ$ KVA

$$\vec{S_A}^* = \frac{(Z_B)_{new}}{Z_A + (Z_B)_{new}} S_L^*$$

$$= \frac{0.182\angle 60^\circ}{0.0728\angle 74.05^\circ + 0.182\angle 60^\circ} \times 360\angle -25.84^\circ$$

$$= 258.78\angle -29.84^\circ \text{ KVA}$$

i.e. 224.42kW at 0.8674 PF lagging.

For 2 TF only, $S_B = \vec{S_L} - \vec{S_A}$

& For n TF $S_B^* = \frac{Z_A}{Z_A + Z_{B(new)}} \times S_L^*$

$$\vec{S_B} = 103.49\angle 15.8^\circ \text{ kVA}$$

i.e. 99.58 kW at 0.9622 PF lag.

(ii) $S_L = \frac{500}{10}\angle 0^\circ$ kVA

$$S_A^* = \frac{Z_{B(new)}}{\vec{Z_A} + Z_{B(new)}} \times 500\angle 0^\circ$$

$$= 359.34\angle -4^\circ \text{ kVA}$$

i.e. 358.47 kW at 0.9976 PF lag.

For 2 Xmer only; $\vec{S_B} = \vec{S_L} - \vec{S_A}$

n TF use common formula $S_B^* = \frac{\vec{Z_A}}{\vec{Z_A} + \vec{Z}_{B(new)}} \times S_L^*$

$$\vec{S_B} = 143.74\angle -10.04^\circ \text{ kVA}$$

i.e. 141.54 kW at 0.9847 PF lead.

(B.) Since $S_{pu} \propto \frac{1}{Z_{pu}}$; TF A would reach FL, 1st

$$S_{pu} \propto \frac{1}{Z_{pU}}$$

$$Z_A < Z_B$$

Then $\vec{S_A} = 1000\angle\phi_A$ kVA

Since $S_j^* \propto \frac{1}{Z_j(\Omega)}$

$$\frac{S_B^*}{S_A^*} = \frac{Z_A(\Omega)}{Z_B(\Omega)} \quad \text{OR} \quad \frac{S_B^*}{S_A^*} = \frac{\vec{Z_A}}{\vec{Z}_{B(new)}}$$

$$S_B^* = S_A^* \frac{Z_A}{Z_{A(new)}}$$

$$S_L^* = S_A^* + S_B^*$$

$$= S_A^* + S_A^* \times \frac{\vec{Z_A}}{\vec{Z}_{B(new)}}$$

$$= S_A^* \left[1 + \frac{\vec{Z_A}}{\vec{Z}_{B(new)}} \right]$$

$$S_L^* = S_A^* \left[1.3914 \angle 4^\circ\right]$$

$$= 1000 \angle -\phi_A * 1.3914 \angle 4^\circ$$

$$S_L \angle -36.87^\circ = 1391.4 \angle 4^\circ - \phi_A \text{ KVA}$$

$$\max^m S_L = 1391.4 \text{ KVA}$$

Equating angles $\Rightarrow -36.87^\circ = 4^\circ - \phi_A$

$$\phi_A = 40.87^\circ$$

i.e. $\vec{S_A} = 1000 \angle 40.87^\circ$ KVA

~~7/2~~ 756.2 KW at 0.7562 PF lag.

New $\vec{S_B} = S_L - S_A$ for 2 TF

Also in general $S_B^* = S_A^* \times \dfrac{\vec{Z_A}}{Z_{B(new)}}$

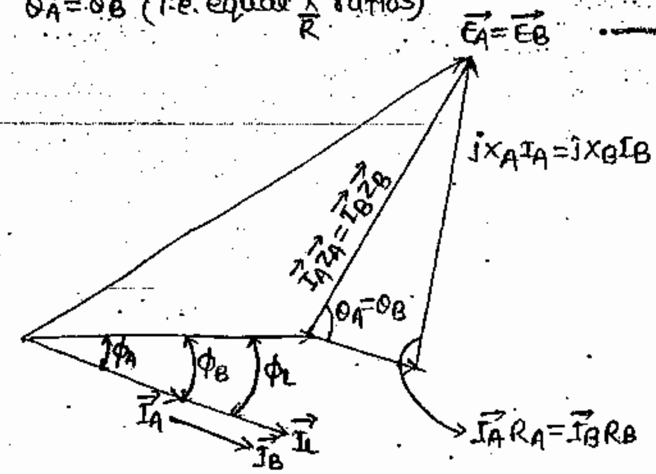
$$\vec{S_B} = 399.97 \angle 26.83^\circ \text{ KVA}$$

i.e. 356.92 KW at 0.8923 PF lag.

Phasor diagram $\rightarrow$

$E_A = E_B$

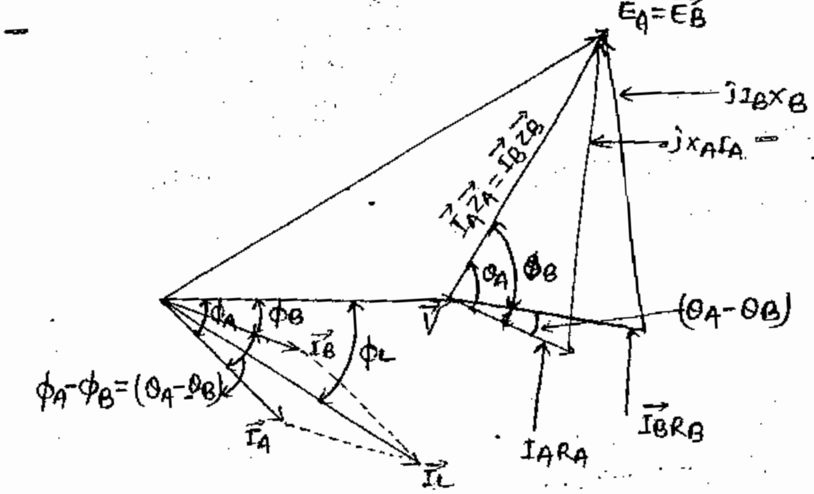
$\theta_A = \theta_B$ (i.e. equal $\frac{X}{R}$ ratios)



$E_A = E_B$

$\theta_A > \theta_B$ (a unequal $\frac{X}{R}$ ratio)

lagging PF load.



Unequal voltage Ratios →

$E_A > E_B$

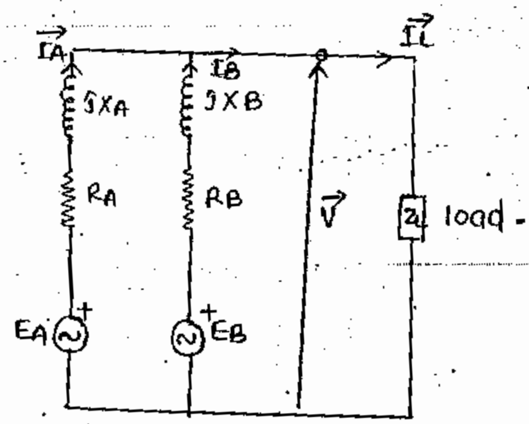
$E_A = \vec{V} + \vec{I_A}\vec{Z_A}$

$= (\vec{I_L} \cdot \vec{Z_L}) + \vec{I_A}\vec{Z_A}$

$\vec{E_A} = (\vec{I_A} + \vec{I_B})\vec{Z_L} + \vec{I_A} \cdot \vec{Z_A}$

$(\vec{Z_A} + \vec{Z_B}) \cdot \vec{I_A} + \vec{I_B}\vec{Z_L} = \vec{E_A}$ ——— (i)

$Z_L \vec{I_A} + (Z_B + Z_L) I_B = E_B$ ——— (ii)



steps→

(i) calculate $\vec{I_A}$ & $\vec{I_B}$

(ii) $\vec{I_L} = \vec{I_A} + \vec{I_B}$

(iii) $\vec{V} = \vec{I_L}\vec{Z_L}$

(iv) $\vec{S_A} = \vec{V} \cdot I_A^*$; $\vec{S_B} = \vec{V} \cdot I_B^*$

Use of millman's theorem (OR) parallel generator theorem →

steps→

(i) $\vec{V} = \vec{I_{sc}}\vec{Z_p}$

where $\vec{I_{sc}} = \sum_{j=1}^{n} \frac{E_j}{Z_j}$

& $\frac{1}{\vec{Z_p}} = \frac{1}{\vec{Z_L}} + \sum_{h=1}^{n} \frac{1}{Z_j}$

(2.) $\vec{I_j} = \dfrac{\vec{E_j} - \vec{V}}{\vec{Z_j}}$ where; $j = 1, 2, \ldots, n$.

(3.) $\vec{S_j} = \vec{V} \cdot \vec{I_j}^*$ where; $j = 1, 2 \ldots n$

$\vec{S_L} = \sum_{j=1}^{n} \vec{S_j}$

Calculation check $S_L = V \cdot I_L^*$

Also; $\vec{S_L} = \dfrac{(V)^2}{Z_L^*}$

$= V \cdot \left(\dfrac{V}{Z_L}\right)^*$

$= \dfrac{V \cdot V^*}{Z_L^*}$

$= \dfrac{V^2}{Z_L^*}$

Que.→ 2, TF A & B are connected in parallel to a common load $2 + j1.5\,\Omega$. There impedances in 2° terms are $Z_A = (0.15 + 0.5j)\,\Omega$ & $Z_B = (0.1 + 0.6j)\,\Omega$. There NL terminal voltages are $E_A = 207\angle 0°$ & $E_B = 205\angle 0°$. Find the power o/p & PF of each TF.

Soln→

$\vec{I_{SC}} = \dfrac{\vec{E_A}}{Z_A} + \dfrac{\vec{E_B}}{Z_B}$

$= \dfrac{209\angle 0°}{(0.15 + 0.5j)} + \dfrac{205\angle 0°}{0.1 + 0.6j}$

$= 782.105\angle -76.625°$

$\dfrac{1}{Z_P} = \dfrac{1}{Z_L} + \dfrac{1}{Z_A} + \dfrac{1}{Z_B}$

$(Z_P)^{-1} = (Z_L)^{-1} + (Z_A)^{-1} + (Z_B)^{-1}$

$Z_P = 0.258\angle 72.85°$

$\vec{V} = \vec{I_{SC}} \cdot \vec{Z_P}$

$= 189.25\angle -3.78°\,V$.

$S_A = V \cdot I_A^*$

$= 7.988\angle 35.03°\,kVA$

i.e. 6.541 kW at cos 35.03° lag

i.e. 0.8189 PF lag

$S_B = V \cdot I_B^*$

$= 6.353\angle 39.09°\,kVA$

i.e. 4.931 kW at cos 39.09 PF lag

i.e. 0.7762 PF lag

$S_L = S_A + S_B$

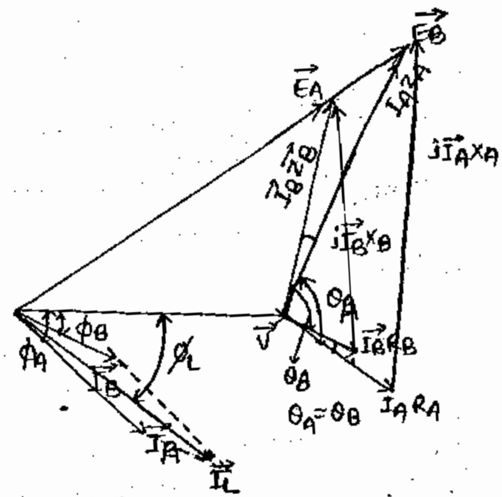
$= 14.332\angle 36.828°$

$I_A = \dfrac{E_A - \vec{V}}{Z_A} + \cancel{\dfrac{E_B - \vec{V}}{Z_B}} = 42.21\angle -38.81\,A$

$I_B = \dfrac{E_B - \vec{V}}{Z_B} = 33.57\angle -42.87°\,A$

Phasor diagram →

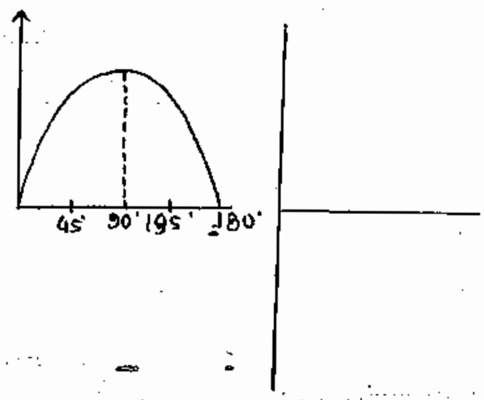
$E_A > E_B$, $\theta_A = \theta_B$, lagging PF load.



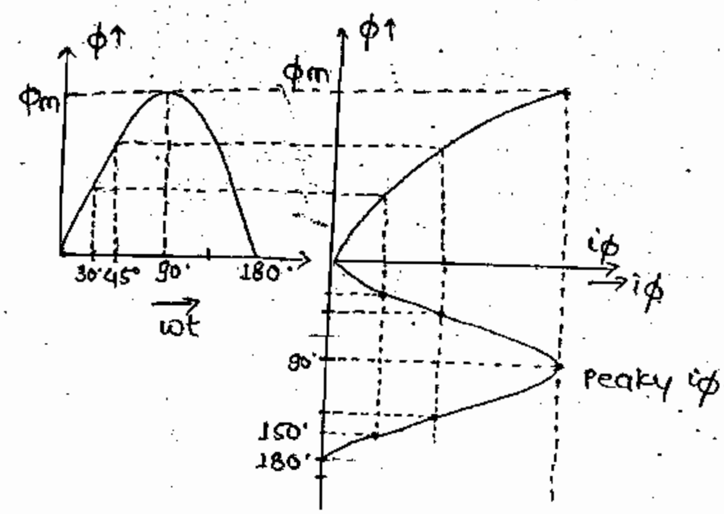
* Magnetisation Current phenomenon in the TF →

* If the applied vol. to the TF is sinusoidal then the core flux should also be sinusoidal.

* If the magnetisation curve of core material would have been linear then the magnetising current would also have been sinusoidal.



* Model TF are operated with high flux density in the core due to economic reason & this drives the core into deep saturation. Obviously the magnetisation curve becomes highly non-linear.

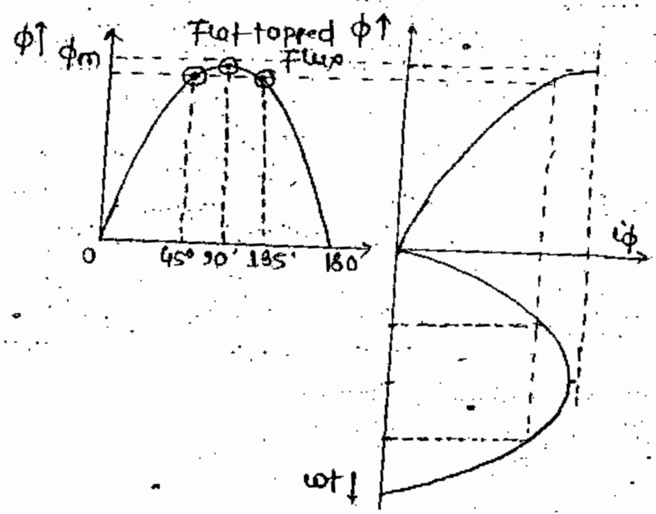


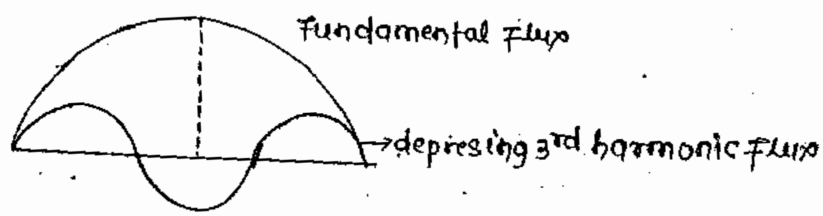
* With such a non-linear magnetisation c/s a sinusoidal flux may only be obtained with a peaky magnetising current containing dominant a 3rd harmonic component.

5. The 3rd harmonic componant of the magnetising current may flow only if the electric circuit permits.
Thus it can easily flow in 1-ϕ TF of 1-ϕ circuit. However in 3-ϕ TF the 3rd harmonic current of 3 phasors are all in phase; thereby constituting 0 seq. current.
Hence they can flow only in the 1° star neutral of the TF is connected to the source neutral (or) it can flow in closed Δ.

* In a λ-λ TF there is no path for flow of 3rd harmonic componants of magnetising current & therefore the magnetising current remains sinusoidal if higher non-triplant odd harmonics are neglected.

* with a sinusoidal magnetising current the core flux becomes flat toped containing dominant depresing 3rd harmonic flux componant.





* The 3rd harmonic componant of flux may get easily establish only is magnetic ckt permits.
Hence the 3rd harmonic flux componants may get estabished easily in those TF that have indepandant magnetic ckts such as in 3-ϕ bank of 1-ϕ TF, 3ϕ shell type TF & 5 limbed (OR 4 limbed) core type TF.

* Concequently in magneticaly independant TF the 3rd harmonics flux gets strongly established resulting into a peaky ~~induced~~ emf in both wdgs; that in creates high insulation stress in both wdgs in addition to producing a highly objecnable phenomenon called oscillating neutral.

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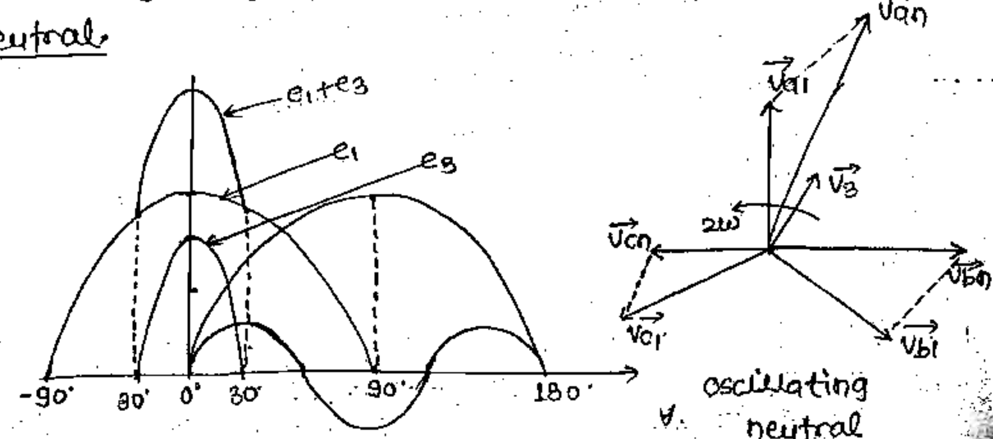
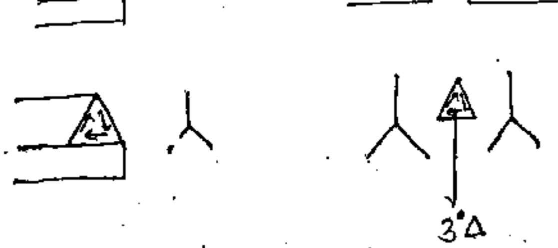
$\vec{V}_{a3} = \vec{V}_{b3} = \vec{V}_{c3} = \vec{V}_3$



* The soln to the above prob. is to provide a 3°Δ wdg in a λ-λ TF so that the electric ckts permits flow of 3rd harmonic components in the closed 3°Δ, that eventualy would restore harmonic variation to the core flux.

* The presence of a Δ-wdg provides a low reluctance path for 0-seq. currents & therefore restores harmonic variation (sinusoidal) to the core flux & also facilitatedes 1-ϕ loads besides reducing the effect of floating (or) shifting neutral.

It also prevents current choking in λ-λ TF. The presence of Δ also helps in detection of unsymmetrical faults; perticularly those involving ~~drum~~ ground.



* The problems discussed above relate to those TF that have magnetically independant ckts.
However a 3-limb core type TF has magnetically interlinked ckt & therefore the 3rd harmonic flux forming 0 seq. finds a very high reluctance path through air & tank valves.
Concequently the magnitude of 3rd harmonic flux remains extreamly low although it altimately results in tank valve heating.
Therefore large 3 limb core TF are provided with a cu ring that surrounds the core there by providind a cu screen for the 3rd harmonic flux & minimizes tank valve heating.
Hence a 3-limbed core type TF may be connected in λ-λ without a 3°Δ.
However if the unbalance is expected to exceed then it is recommended to use a 3°Δ wdg.

* A 3 limbed core type TF does not permit easy excess to 3rd harmonic flux & this results into increased 5th & 7th harmonic componants in the magnetising current.
These componant can't be suppressed by any electric connection. Hence if these harmonics are objectionable then a 4-limbed (or) 5 limbed st. should be provided.

Note:- The 1° λ neutral in a λ-λ connection is not connected to the genr neutral to provide a path for 3rd harmonic componant of magnetising current.
This is because the genr ϕ vol. itself contain 3rd harmonic vol. & this would appear across the 1° ϕ of TF.
Obeously then the 2° λ ϕ would now contain 3rd harmonic vol. componant in all its 3-ϕ.
Since the 2° λ neutral would be grounded, 3rd harmonics currents would flow in the xn line resulting into objecnable communication interferance. Thus the other alternative of providing a 3°Δ wdg is adopted to allow flow of 3rd harmonics of magnetising current.