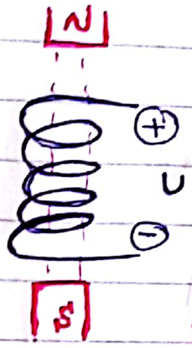
## * Poly phase system *

# Q ⇒ how do we generate electricity?

Induced voltage ← $\boxed{V = -N * \frac{d\phi}{dt}}$ → magnetic flux

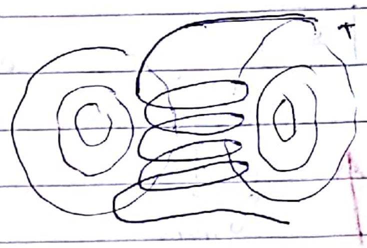
Coil #no. of turns. (N)

→ Faraday



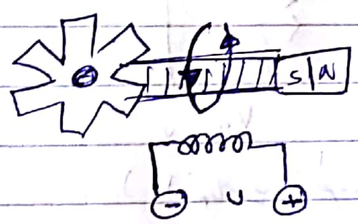

OR

Moving coil
Static field.



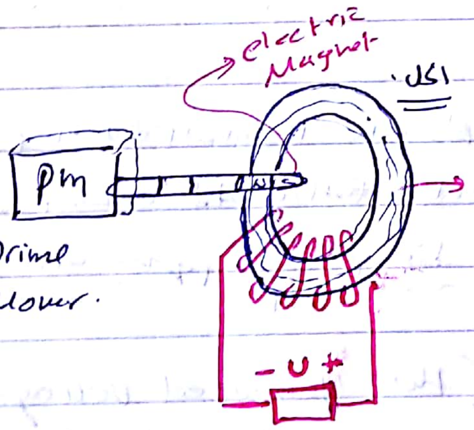

static coil moving field.

## * (synchronous generator) *




الحل للتخلص من عشوائية
حركة التربينة ؟؟ وشي
مضبوطة الحركة.

الحل ↓



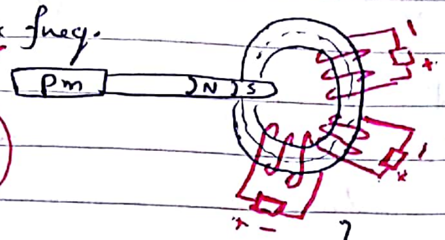

prime Mover.

the whole structure named as (generator)

* عشان نزيد الكفاءة . # اكل اف نزيد ملفات اخرى *

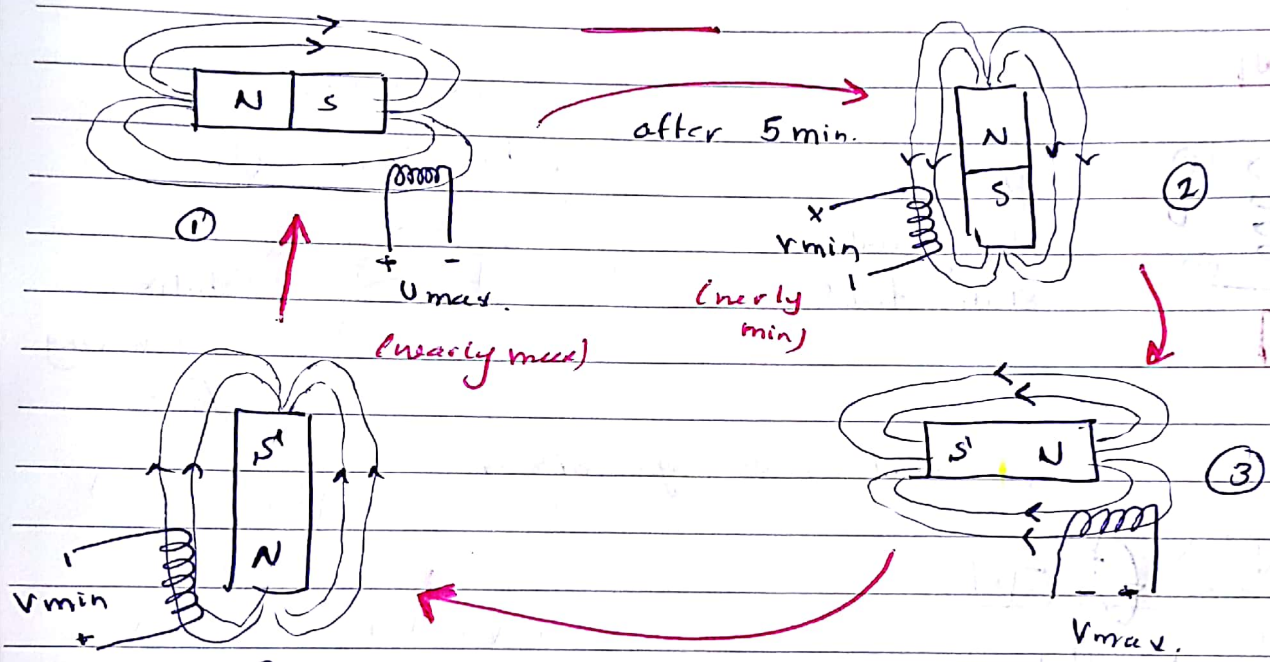
electric freq.

$$n = \frac{120 f}{P}$$



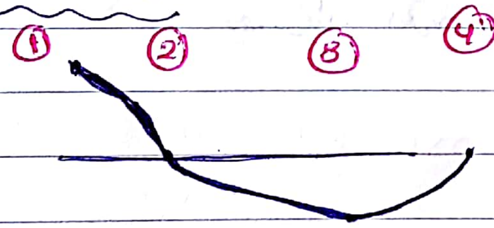

* افضل شيء تم اكتشافه
هو وجود
٣ ملفات .
(اقتصادياً وميكانيكياً)

* 3 - phase shift *




(اختلاف قطبية الجهد)

$$V = -N \frac{d\Phi}{dt}.$$

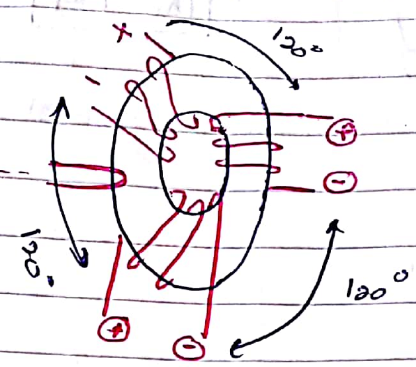



* الكلام السابق كان ملف واحد فقط.
* بالنسبة للملفات الباقية
يكون بينهم phase shift فقط.

+ (the generated voltages are AC voltages).

* To get less vibration *

we need a displacement between the inductors has (120°) value.



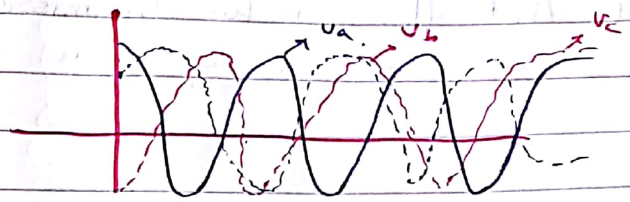

(Va) $v_1 = U_{max} \cos(\omega t)$

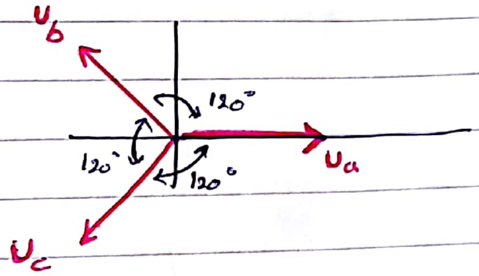
(Vb) $v_2 = U_{max} \cos(\omega t - 120°)$

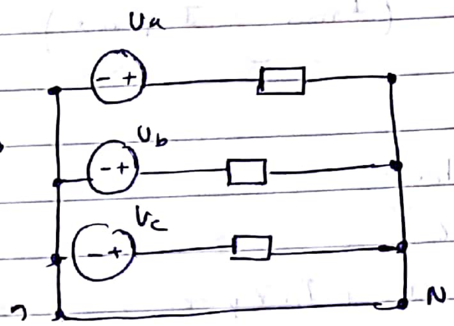
(Vc) $v_3 = U_{max} \cos(\omega t + 120°)$

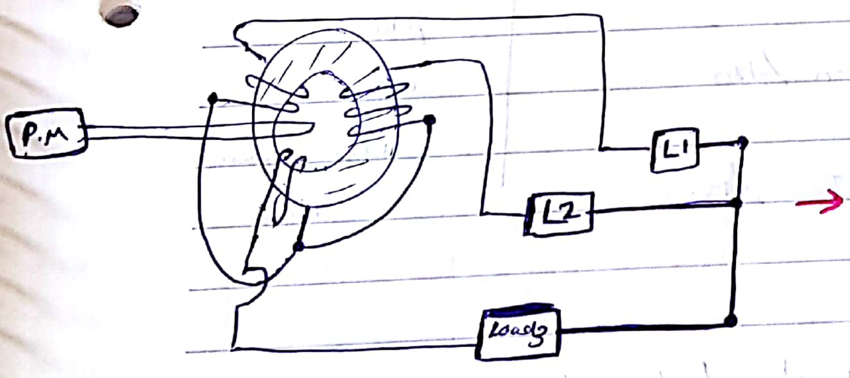
(All of them have the same max value).

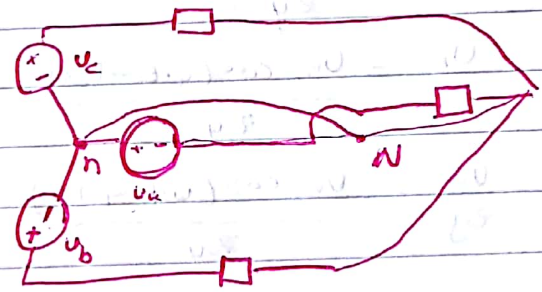
$$\boxed{v = -N \frac{d\phi}{dt}}$$




3- phase source.

3- phase generator.

Y- connected load generator

→ the neutral points of the 3 sources are connected together.

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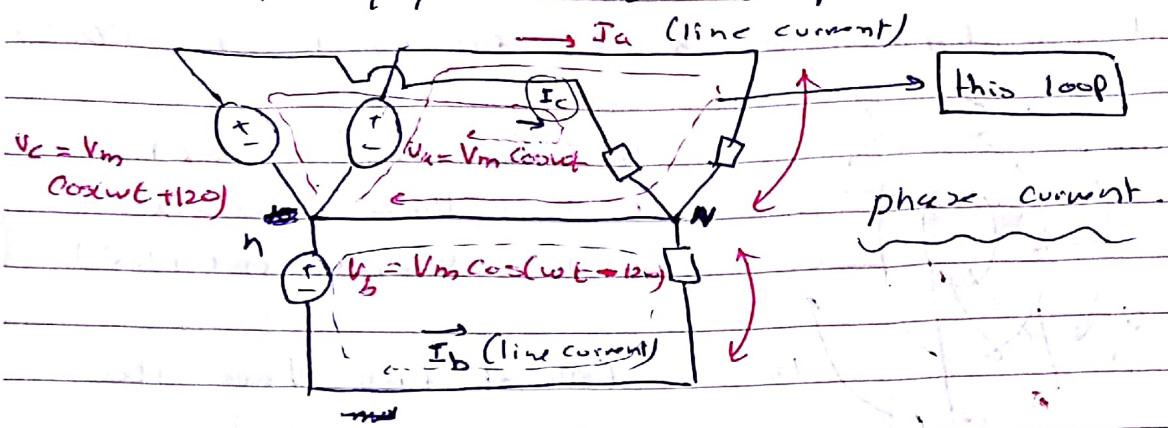
* Balanced Y-Y connected 3-phase system




* line current : the current that flows in the Trasmission line.
* phase current : " " " " " " " load.

In Y connected loads

($I_{min} = I_{phase}$)

@ this loop :-

KVL

$-V_m \cos\omega t + I_a Z_Y = 0$

$$I_a = \frac{V_a}{Z_Y} = \frac{V_m \cos(\omega t)}{Z_Y} = I_m \angle 0.$$

$$I_b = \frac{V_b}{Z_Y} = \frac{V_m \cos(\omega t - 120)}{Z_Y} = I_m \angle{-120}$$

$$I_c = \frac{V_c}{Z_Y} = \frac{V_m \cos(\omega t + 120)}{Z_Y} = I_m \angle 120$$

line & phase current the same Here.

# A Balance load will produced balanced current.

# The voltage across the loads is called phase voltage.

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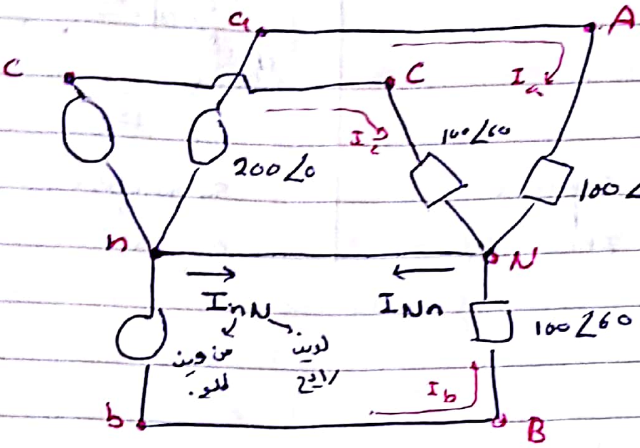
Ex.

find the phase & line current & the total power absorbed by the load for this balanced Y-Y connected 3-phase sys.




$Z_Y \rightarrow$ نفس (there is no shift)

$V_{an} = 200\angle 0.$

$V_{bn} = 200\angle -120.$

$V_{cn} = 200\angle 120.$

$I_a = I_{aA} = \dfrac{V_{an}}{Z_Y} = \dfrac{200\angle 0}{100\angle 60} = 2\angle -60 \text{ A}.$

$I_b = 2\angle -180^\circ = 2\angle \underbrace{-60-120}_{\text{(voltage shift)}}$ $\left(= V_{bn}/Z_Y = \dfrac{200\angle -120}{100\angle 60} = 2\angle -180 \text{ A}\right)$

$I_c = 2\angle -60+120^\circ = 2\angle 60^\circ$ or $\left(I_c = V_{cn}/Z_Y = \dfrac{200\angle 120}{100\angle 60} = 2\angle 60^\circ\right)$

* Real power in phase A.

$P_A = V_{rms} I_{rms} \cos(\theta - \phi) = V_{AN} I_a \cos(\theta_{V_{AN}} - \phi_{I_A})$

$= 200 * 2 * \cos(0+60) = 200 \text{ W}$

$P_B = V_{BN} I_B \cos(\theta_{V_{BN}} - \phi_{I_B}) = 200 * 2 * \cos(-120+180) = 400\cos 60 = 200 \text{ W}$

$P_C = V_{CN} I_C \cos(\theta_{V_{CN}} - \phi_{I_C}) = 200 * 2 * \cos(120-60) = 200 \text{ W}$

$P_{3\phi} = P_A + P_B + P_C = 600 \text{ W}$

$3\phi \rightarrow$ 3-phase

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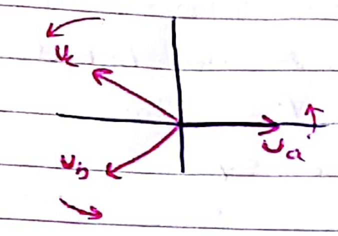
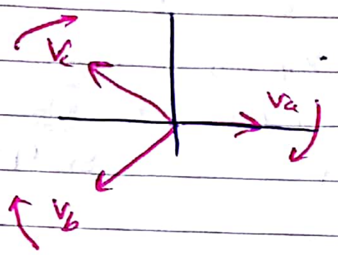
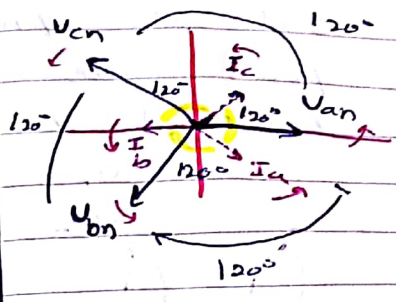



+ve sequence
3-phase system.




-ve sequence
3-phase system.




symmetric everywhere

$I_{Nn}$ (Nutral current)

$$I_{Nn} = I_a + I_b + I_c$$
$$= 2\angle{-60} + 2\angle{-120} + 2\angle{60}$$
$$= 2\cos -60 + 2j\sin -60 + 2\cos -120 + 2j\sin -120$$
$$+ 2\cos 60 + 2j\sin 60$$

$$= 1 - \sqrt{3} - 2 + 1 + \sqrt{3}$$
$$= 2 - 2 = \text{Zero.}$$

# Balanced 3-phase Y-Y connected system :-

$$I_a = I_m \angle 0, \quad I_b = I_m \angle \theta - 120, \quad I_c = I_m \angle \theta + 120.$$

$$I_{Nn} = I_m \angle \theta + I_m \angle \theta - 120 + I_m \angle \theta + 120°$$
$$= I_m \cos\theta + j I_m \sin\theta + I_m \cos(\theta - 120) + j I_m \sin(\theta - 120)$$
$$+ I_m \cos(\theta + 120) + I_m j \sin(\theta + 120°)$$

$$= \text{Zero.}$$

# The current flowing in a balanced $3\phi$ phase Y-Y connected is equal to zero.

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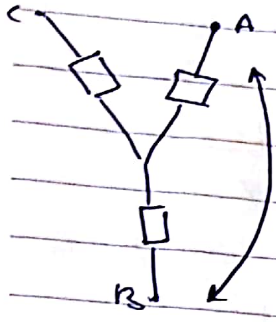
$V_{AB} \Rightarrow$ → line to line voltage.
(line voltage) └→ Phase to phase voltage.




phase voltages.

$V_{AB} = \underline{V_{AN}} - \underline{V_{BN}}$ (phase to Nutral voltage)

$= V_m \angle 0 - V_m \angle -120$

$= V_m - V_m \cos(-120) - jV_m \sin(-120)$

$= V_m + \frac{1}{2} V_m + \frac{\sqrt{3}}{2} V_m$

$= \sqrt{3} V_m \left( \frac{\sqrt{3}}{2} + \frac{1}{2} j \right)$ $\cos 30 + j\sin 30$

$= \sqrt{3} V_m \angle +30°$.

$V_{BC}$ → line to line voltage. (line voltage)

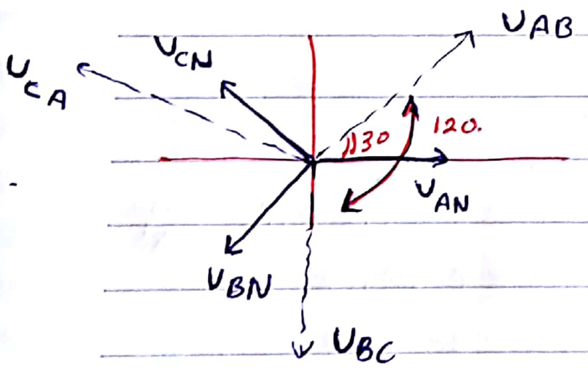
$V_{BC} = V_{BN} - V_{CN}$

$V_{AN} = V_m \angle 0$.
$V_{BN} = V_m \angle -120$
$V_{CN} = V_m \angle 120$

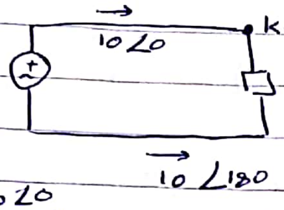
$= V_m \angle -120 - V_m \angle 120$

$= V_m \cos(-120) + V_m j \sin(-120) - V_m \cos 120$
$- jV_m \sin(120$

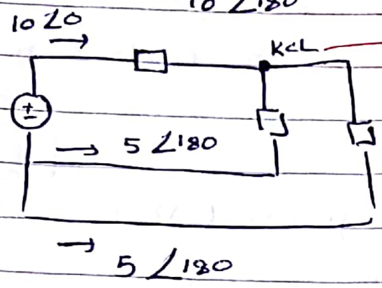
$= \sqrt{3} V_m \angle -90$ $(30 - 120)$



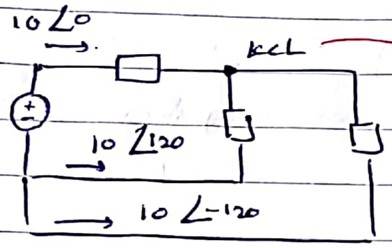
Y–Y Connected loads.



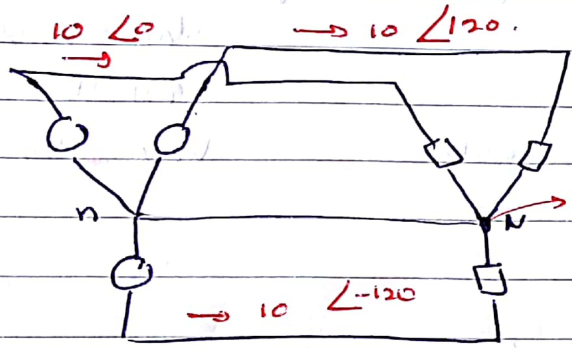

KCL → $10\angle 10 + 10\angle 180 = \text{zero}$




KCL → $10\angle 0 + 5\angle 180 + 5\angle 180 = \text{zero}$

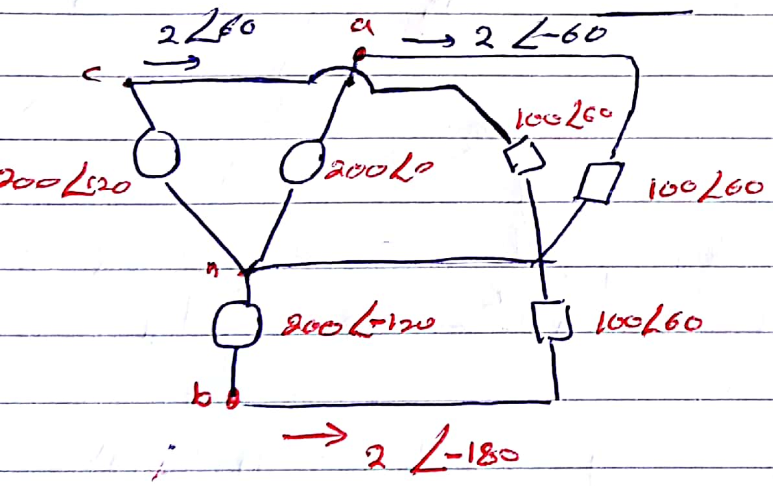



KCL → $10\angle 0 + 10\angle 120 + 10\angle -120 = 0$




KCL

$10\angle 0 + 10\angle 120 + 10\angle -120 = 0$



RMS value دي

$V_{AN}(t) = 200\sqrt{2}\cos\omega t$

$i_A(t) = 2\sqrt{2}\cos(\omega t - 60)$

$p(t) = 800[\cos\omega t * \cos \omega t - 60]$

$= 200 + 400\cos(2\omega t - 60)$ W

$V_{BN}(t) = 200\sqrt{2}\cos(\omega t - 120)$

$i_B(t) = 2\sqrt{2}\cos(\omega t - 180)$

$P_B(t) = V_{BN}(t) \cdot i_B(t)$

$= 200 + 400\cos(2\omega t + 60)$ W

→ for single phase load $(p \to fun(t))$

$p(t) = \frac{V_m I_m}{2}\cos(\theta - \phi) + \frac{V_m I_m}{2}\cos(2\omega t + \theta + \phi)$

$V_{CN}(t) = 200\sqrt{2}\cos(\omega t + 120)$

$i_C(t) = 2\sqrt{2}\cos(\omega t + 60)$

$P_C(t) = V_{CN}(t) * i_C(t)$

$= 200 + 400\cos(2\omega t + 180)$

$P_{3\phi} = P_C(t) + P_B(t) + P_A(t)$

$P_{3\phi} = 600 + \underbrace{400\cos(2\omega t - 60) + 400\cos(2\omega t + 60) + 400\cos(2\omega t + 180)}$

$P_{3\phi} = 200 + 400\angle -60 + 200 + 400\angle 60 + 200 + 400\angle 180$

$= 200 + 400\cos -60 + 400j\sin(-60) + 200 + 400\cos 60 + j400\sin 60$

$+ 200 + 400\cos 180 + j400\underbrace{\sin 180}_{=0}$

$= 600$ W

$P_{3\phi} = \underline{\underline{600}}$ W (not function of t)

* جمع ال phasor بينهم

ازاحة 120°

مجموع = $\underline{\underline{\text{Zero}}}$

## 3φ

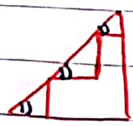
(600 W)

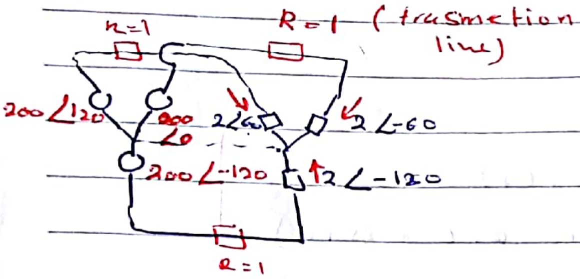
PF = 0.5

$PF_A = 0.5 = \cos(0+60)$

$PF_B = 0.5 = \cos(-120+180)$

$PF_C = 0.5 = \cos(120-60)$





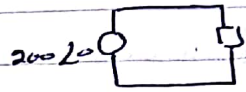

power losses by T.L, R=1Ω

$= I_a^2 R + I_b^2 R + I_c^2 R$

$= 4+4+4 = 12$ W

## 1φ

(600 W), PF=0.5




$P = V_{rms} I_{rms} \cos(\theta - \phi)$ → 0.5

600, 200∠0

$\boxed{I_{rms} = 6\,A}$

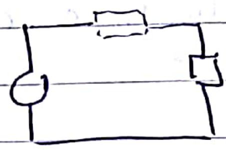
التيار الي مر هونه

أعلى

عشان انقل نفس الطاقة

لازم ازيد التيار بال 1φ).

R=1

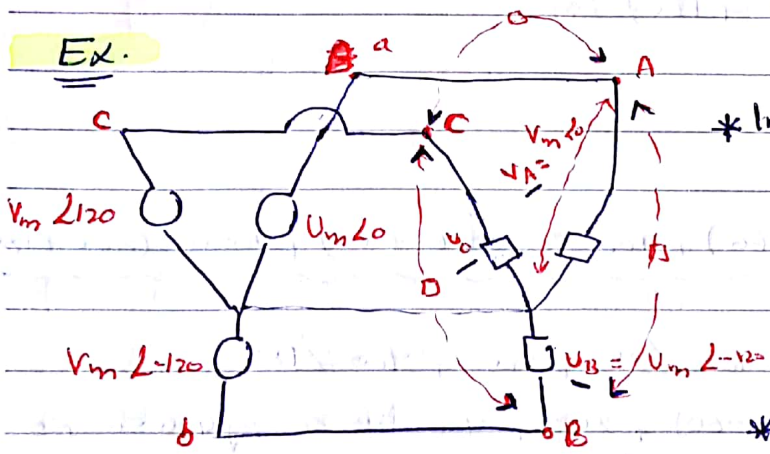


T.L losses.

$P = I^2 R = 36$ W

اعلى من ال losses بال 3φ.

## Ex.




* In Y connected load

$$\boxed{I_{load} = I_{phase}}$$

* Voltage across load is phase to nutral voltage (phase voltage) → from phase to nutral.

* line to line voltage → from phase to phase

$V_{BC} = V_{BN} - V_{CN} = \sqrt{3}\, U_m \angle -90$

$U_{AB} = V_{AN} - V_{BN} = \sqrt{3}\, U_m \angle 30$

line to line voltages.

$V_A$ & $V_B$ & $V_C$ → phasor voltages.

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$$V_{CA} = V_{CN} - V_{AN} = V_m \angle 120 - V_m \angle 0$$

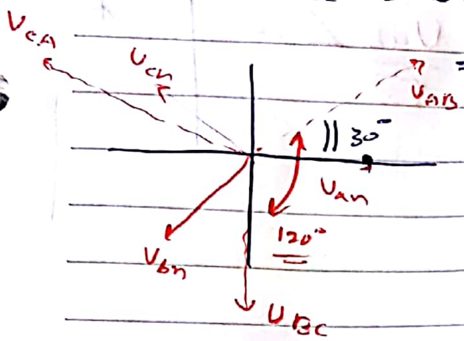
$$= V_m \cos 120 + j V_m \sin 120 - V_m$$

$$= -\frac{V_m}{2} + \frac{V_m \sqrt{3}}{2} j - V_m$$

$$= V_m \frac{\sqrt{3}}{2} j - \frac{3 V_m}{2}$$

$$= \sqrt{3} V_m \Big[ \underbrace{\tfrac{1}{2}}_{\sin 150} j - \underbrace{\tfrac{\sqrt{3}}{2}}_{\cos 150} \Big] = \sqrt{3} V_m \angle 150^\circ$$

$V_{CA}, V_{AB}, V_{BC} \rightarrow$ بينهم ازاحة $120^\circ$.




$V_{an} = V_{AB} \cos 30^\circ$.

$|V_{AB}| > |V_a|$

بمقدار $\sqrt{3}$

**Example :-**

Given that $V_{an} = 50 \angle 15^\circ$, $Z_Y = 5 \angle 60$

→ find phase voltages, line voltages, line currents, phase currents, given that its a balanced Y-Y connected load.

Solution

$V_{an} = 50 \angle 15^\circ \rightarrow V_{AB} = 86.6 \angle 45^\circ$ (30+15)

$V_{bn} = 50 \angle -105^\circ \rightarrow V_{BC} = 86.6 \angle -75$ (105+30)

$V_{cn} = 50 \angle 135^\circ \rightarrow V_{CA} = 86.6 \angle 165$ (135+30)

phase voltages. line voltages.

$$I_a = \frac{V_{an}}{Z_Y} = \frac{50 \angle 15}{5 \angle 60} = 10 \angle -45^\circ \text{ A}.$$

$$I_b = 10 \angle -45-120 = 10 \angle -165^\circ \text{ A}.$$

$$I_c = 10 \angle -45+120 = 10 \angle 75 \text{ A}.$$

line currents = phase currents. in Balanced Y connected load.

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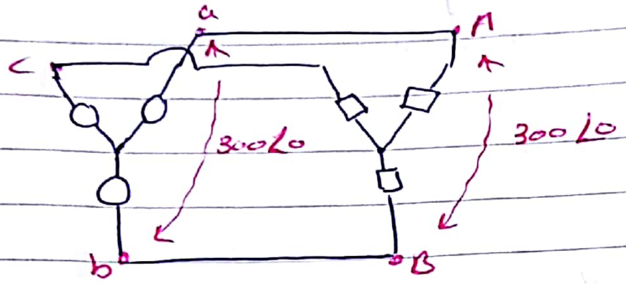
## Example.

A Balanced $3\phi$ Y-Y connected system with line voltage (line to line) $V_{ab} = 300\angle 0$ volt & suppling a load with 1200 w & a leading PF of .8, find the line current & per-phase load impedance.



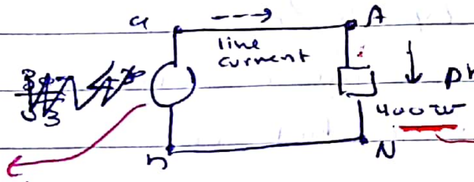

$$V_{ab} = \sqrt{3}\, V_{an} \angle 30$$

$$V_{an} = \frac{V_{ab}}{\sqrt{3}} \angle -30$$

$$V_{an} = \frac{V_{ab}}{\sqrt{3}} \angle -30 = \frac{300}{\sqrt{3}} \angle -30^\circ$$

# per-Phase equivalent ckt

$\Rightarrow$ Take phase A.




$\frac{300}{\sqrt{3}} \angle -30$

1200 w ($3\phi$)

$1\phi = \frac{1200}{3} = 400$ w

$\rightarrow$ usually power given in Question it is $3\phi$ power.

line current = phase current.

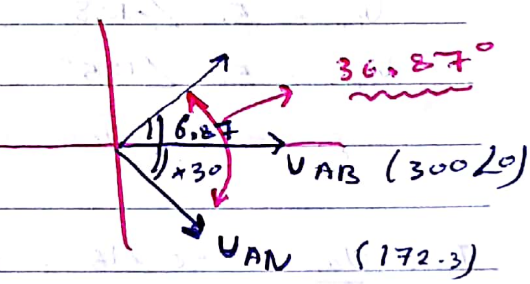
$P = V_{rms} I_{rms} \cos \theta - \phi \rightarrow$ PF

$P = V_{AN} I_a \cos \theta - \phi$

$P = V_{AN} I_a * PF$

$400 = \frac{200}{\sqrt{3}} * I_a * 0.8$

$$\boxed{I_A = 2.89 \text{ A}}$$



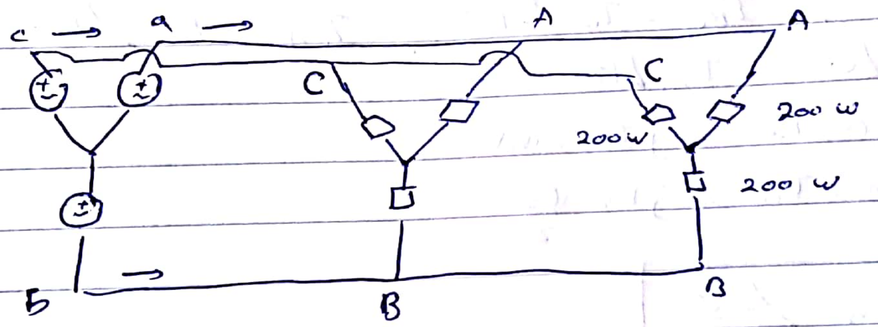

Current leading voltage by $\cos^{-1}(.8) = 36.87^\circ$, So

(PF= .8 leading).

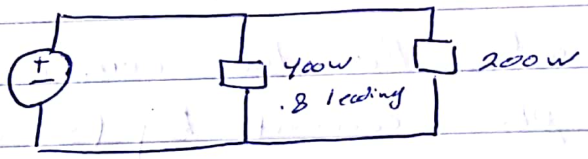
$I_a = 2.89 \angle 6.87$.

Ex.

if a Balanced 600 W load is added to the ~~previous~~ previous system (in parallel), Find the new line current.




اذا ما اعطاني PF ← بعتبره = 1




$P = |V||I| \cos(\theta - \phi) \Rightarrow 200 = 173.2 * |I|$

$|I| = 1.115$ , $I = 1.115 \angle -30^\circ$

* $I_{line} = 1.115 \angle -30^\circ + 2.89 \angle 6.87 = 3.87 \angle -3.4$ A.

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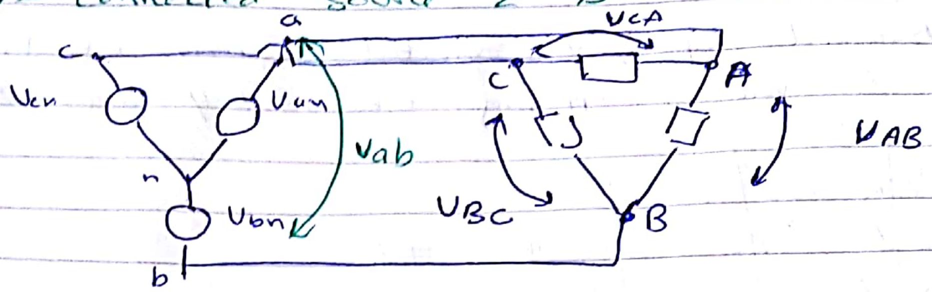
* Y- Connected source & Δ connected load.




→ The neutral point is not accesable.
→ increasing the load voltage.

* The voltage across the load is line to line voltage.
$V_{AB} = \sqrt{3}\, V_{an} \angle +30°$

* In Δ connection : $I_{line} \neq I_{phase}$.
at (A) : $I_a + I_{CA} = I_{AB}$
→ $I_a = I_{AB} - I_{CA}$.

* let's suppose that :

$I_{AB} = I_m \angle 0$ , $I_{BC} = I_m \angle -120°$ , $I_{CA} = I_m \angle 120°$
So, $I_a = I_m \angle 0 - I_m \angle 120$
$I_a = I_m - I_m \cos 120 - j I_m \sin 120$.
$I_a = I_m + 0.5 I_m - j I_m \frac{\sqrt{3}}{2}$.

$$\boxed{I_a = \sqrt{3}\, I_m \angle -30°}$$

* for a Δ connected load, the line current is ~~gra~~ greater than the phase current by $\sqrt{3}$ and lags it by (30°)

Ex. Find the line currents for 3 phase y- connected balanced system with a line voltage of $V_{ab} = 300\angle 0$ and supplies 1200 w to a D - connected load, PF = 0.8 lagging, then find the phase impedance.

* Since $V_{ab} = 300\angle 0^\circ$ so, $U_{AB} = 300\angle 0$.

to find the currents:-

$P_{AB} = |U_{AB}||I_{AB}|\cos(\theta - \phi)$

$|I_{AB}| = \dfrac{400}{300 * 0.8} = 1.667\ A$

$\phi = -\cos^{-1}(PF) = -36.87$

so, $I_{AB} = 1.667\angle -36.87$.

# phase Currents:

- $I_{AB} = 1.667\angle -36.87^\circ$, $I_{BC} = 1.667\angle -156.87$, $I_{CA} = 1.667\angle 83.13^\circ$

→ to find the line currents:

$I_{Line} = \sqrt{3}\ I_{phase}\ \angle -30^\circ$

$I_a = \sqrt{3} * 1.667\angle -36.87 * \angle -30^\circ = 2.89\angle -66.87^\circ$.

$\cancel{I_b = \sqrt{3} * 1.667\angle -187.87^\circ\ A}$

$I_b = 2.89\angle -187.87^\circ$

$I_c = 2.89\angle 53.13^\circ$

* لو اعطاني بالسؤال Van بدل ال Vab بطلع ال Vab

$V_{ab} = \sqrt{3}\ V_{an}\angle +30^\circ$.

→ To find Z.

$Z_A = \dfrac{U_{AB}}{I_{AB}} = 180\angle 36.87 = Z_B = Z_C$.

* we have 4 connections.

(1) Y-Y (2) Y-D (3) D-Y (4) D-D.

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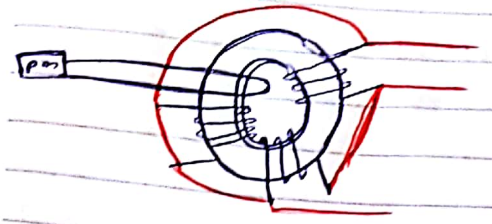
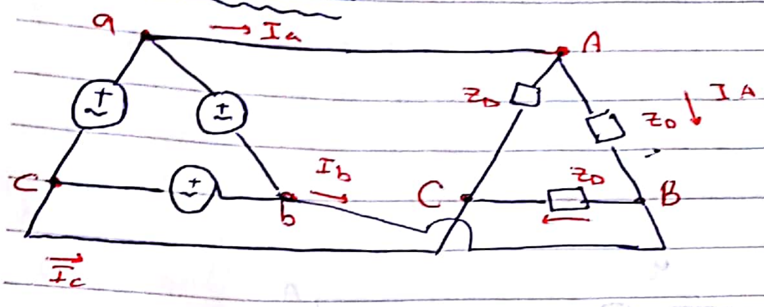
* Can we connect the source as a Δ?



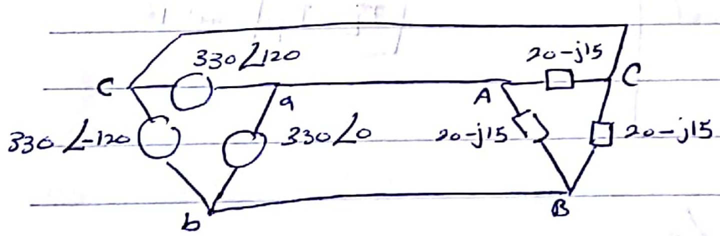

**Δ–Δ Connected**




* The voltage across the load is (line to line voltage)
* $I_{Line} \neq I_{phase}$.
* $I_{line} = \sqrt{3} * I_{phase} \angle -30°$

Ex.
a Balanced Δ connected load of $Z_D = 20 - j15\ \Omega$ is connected to Δ source with $V_{ab} = 330 \angle 0$, find phase & line current.

مع ملاحظة انا بجيب لاطلع ال $I_{phase}$ مشان اطلع $I_{Line}$.




$$I_{AB} = \frac{V_{AB}}{Z_D} = \frac{V_{ab}}{Z_D} = \frac{330 \angle 0}{20 - j15} = 13.2 \angle 36.87.$$

$$I_{BC} = 13.2 \angle 36.87 - 120.$$

$$I_{CA} = 13.2 \angle 36.87 + 120.$$

* $I_{Line} = \sqrt{3}\, I_{phase} \angle -30$

$I_a = \sqrt{3}\, I_{AB} \angle -30$

$I_b = \sqrt{3}\, I_{BC} \angle -30$

$I_c = \sqrt{3}\, I_{CA} \angle -30$

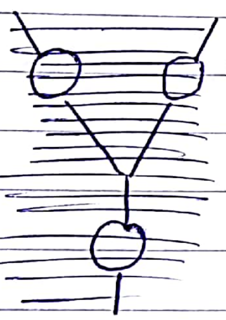
$I_a = \sqrt{3} * 13.2 \angle 36.87 - 30$

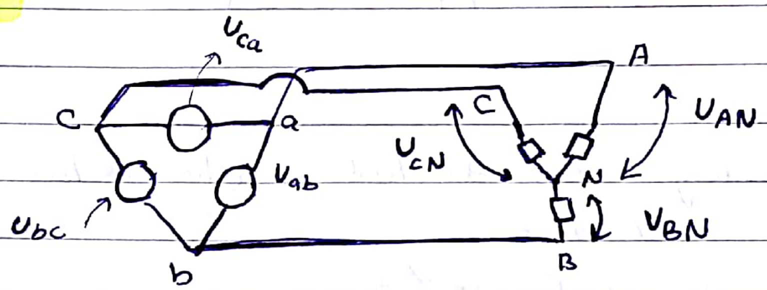
$= 22.86 \angle 6.87\ A$

$I_b = 22.86 \angle 6.87 - 120\ A$

$I_c = 22.86 \angle 6.87 + 120\ A$

## D-Y connected






* $\boxed{I_{Line} = I_{phase}}$

صار الحكي بدده مع جزئية توصيل ال load اذا كان التوصيل Y connected فأكيد $\boxed{I_L = I_p}$

* The voltage accross the load is line to nutral voltage

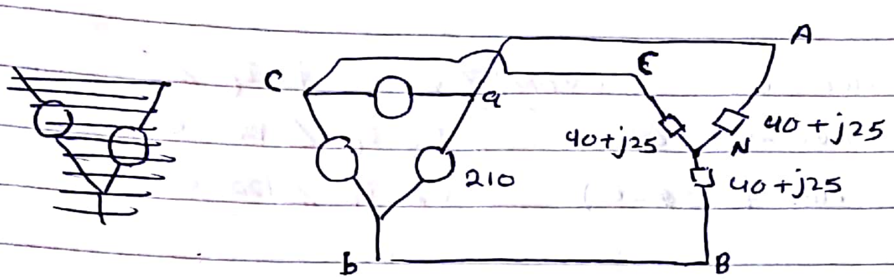
$$V_{LL} = \sqrt{3}\, V_{LN} \angle 30$$

(line to line) (line to nutral)

$$V_{LN} = \frac{V_{LL}}{\sqrt{3}} \angle -30^\circ$$

## Example.

A Balanced Y- connected load with $Z_y = 40 + j25$ is supplied by a D - connected source with a line voltage of 210 Volt.
Calculate the Phasor & line Currents, Take $V_{ab}$ as your reference.




$$I_a = \frac{V_{AN}}{Z_y}.$$

$$|V_{ab}| = 210$$

$$V_{ab} = 210 \angle 0$$

$$V_{AN} = \frac{210}{\sqrt{3}} \angle -30 = 121.2 \angle -30 \text{ volt.}$$

$$I_a = \frac{121.2 \angle -30}{40 + j25}$$

$$= 2.57 \angle -62 \text{ A}$$

$$I_b = 2.57 \angle -62-120 \text{ A}.$$

$$I_c = 2.57 \angle -62+120 \text{ A}.$$

phase currents. (= line cur

~~[illegible]~~

* لو كان ال $V_{bc}$
my reference.

$$V_{bc} = 210 \angle 0$$

$$V_{ab} = 210 \angle -120.$$

$$V_{ca} = 210 \angle 120 \text{ or } \angle -240.$$

$$V_{an} = \frac{210}{\sqrt{3}} \angle 90°$$

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## * power in $3\phi$ system.

$V_{AN} = \sqrt{2}\, V_p \cos(\omega t) \rightarrow \sqrt{2}\, V_p \angle 0$

$V_{BN} = \sqrt{2}\, V_p \cos(\omega t - 120) \rightarrow \sqrt{2}\, V_p \angle -120$.

$V_{CN} = \sqrt{2}\, V_p \cos(\omega t + 120)$. $\rightarrow \sqrt{2}\, V_p \angle 120$.

$\rightarrow$ Take $Z_Y = Z \angle \theta$

$i_a = \sqrt{2}\, I_p \cos(\omega t - \theta) \equiv (V_{AN}/Z_Y) \rightarrow \sqrt{2} I_p \angle \theta$

$i_b = \sqrt{2}\, I_p \cos(\omega t - 120 - \theta) \rightarrow \sqrt{2}\, I_p \angle -120 - \theta$

$i_c = \sqrt{2}\, I_p \cos(\omega t + 120 - \theta) \rightarrow \sqrt{2}\, I_p \angle 120 - \theta$.

$P_A = |I_p||V_p| \cos\theta \rightarrow (\theta - \phi)$

$P_B = |I_p||V_p| \cos\theta$.

$P_C = |I_p||V_p| \cos\theta$

$P_{total} = P_{3\phi} = 3 |V_p||I_p| \cos\theta$

phase current. (RMs value)

phase nutral voltage. (RMs)

angle between phase to nutral voltage & phase current.

$P_{3\phi} = 3 * P_{1\phi}$.

$Q_{total} = Q_{3\phi} = 3|V_p||I_p| \sin\theta$.

$= 3 * Q_{1\phi}$

$S_{(total)} = S_{3\phi} = 3\, V_p I_p^* = 3 * S_{1\phi}$

$S_{3\phi} = P_{3\phi} + j\, Q_{3\phi}$.

$|S_{(total)}| = 3|V_p||I_p| = 3 * |S_{1\phi}|$

$\hookrightarrow$ Apparent power.

* How to represent power quantities using line voltage & line current.

$P_{3\phi} = 3|V_p||I_p| \cos\theta$

**Y-connected loads**

$\boxed{I_p = I_L}$

$\boxed{|V_p| = \frac{|V_L|}{\sqrt{3}}}$

$P_{3\phi} = 3 * \frac{|V_L|}{\sqrt{3}} * |I_L| \cos\theta$

line to line.

angle between phase & neutral voltage

↳ line current & phase current.

**Δ-connected**

$\boxed{V_p = V_L}$

$\boxed{|I_L| = \sqrt{3}|I_p|}$

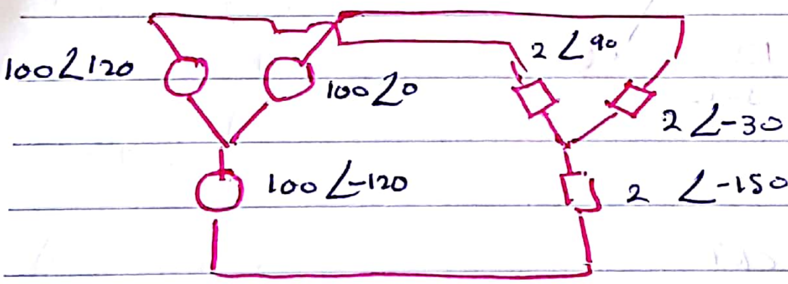
$P_{3\phi}$

$P_{3\phi} = 3|V_L|\frac{|I_L|}{\sqrt{3}} \cos\theta$.

$P_{3\phi} = \sqrt{3}|V_L||I_L| \cos\theta$

* $P_{3\phi} = 3|V_p||I_p| \cos\theta$.
* $P_{3\phi} = \sqrt{3}|V_L||I_L| \cos\theta$.

$\angle V_p$ & $I_p$




$P_{3\phi} = 3 * 100 * 2 * \cos(0 - -30)$

$= \sqrt{3} * 300$ w

Using line values :-

$P_{3\phi} = \sqrt{3} * \sqrt{3} * 100 * 2 \cos(30)$

$= 300\sqrt{3}$ w.

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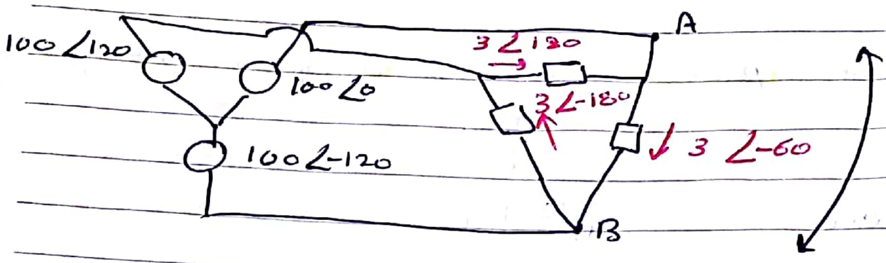


$V_{AB} = \sqrt{3}\, V_{AN} \angle 30$

$V_{AB} = 100\sqrt{3} \angle 30$

$P_{3\phi} = 3|V_p||I_p| \cos\theta$

$= 3 * [100 * \sqrt{3}] * 3 * \cos(30 - -60) = \text{Zero}.$

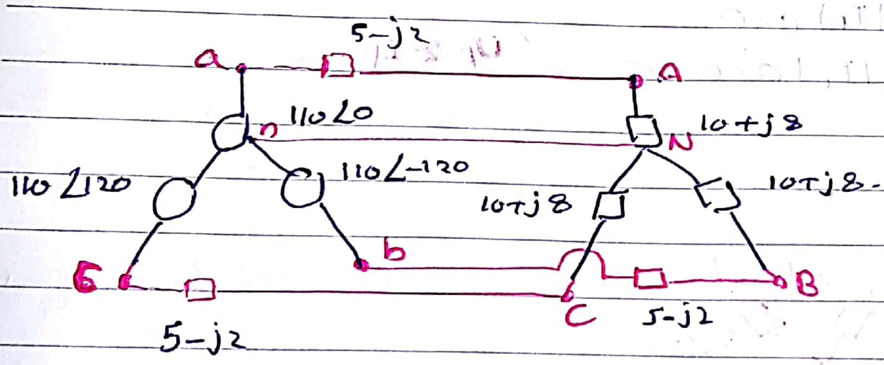
using line :-

$P_{3\phi} = \sqrt{3}\,|V_L||I_L| \cos\theta.$

$= \sqrt{3} * \underbrace{100 * \sqrt{3}}_{V_L} * \underbrace{\sqrt{3} * 3}_{I_L} * \cos(30 + 60) = \text{Zero}$

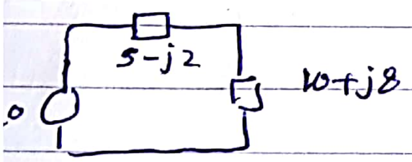
Ex.

given the CKT shown find the source complex power & the load complex power & the T.L losses.



* Single phase equivalent ckT

→ Take phase A.



$I_a = \frac{110 \angle 0}{15 + j6} = 6.8 \angle -21.8°$

$S_{(source)\,3\phi} = 3 * V_p * I_p^*$

$= 3 * 110 \angle 0 * 6.8 \angle 21.8$

$= 2247 \angle 21.8$

$= \underbrace{2087}_{P_{3\phi}} + j\,\underbrace{834.6}_{Q_{3\phi}}$

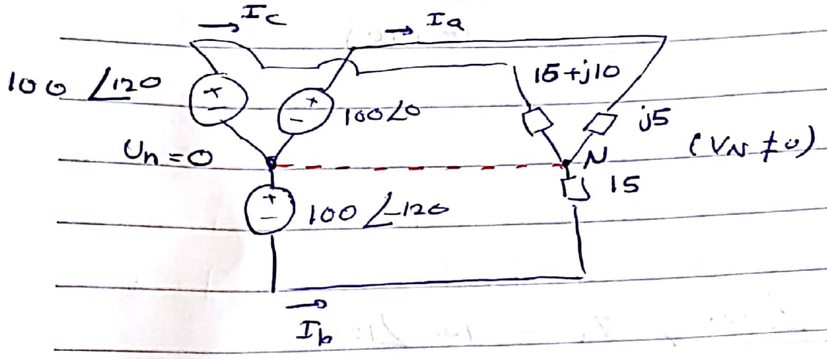
$S$ (load)

$$V_{AN} = \text{(voltage division)} = \frac{110\angle 0 * (10+j8)}{15+6j}$$

$$S_{load} = 3\, V_p\, I_p^*$$
$$= 3\, Z_p * I_p * I_p^*$$
$$= 3\, Z_p\, |I_p|^2$$

$$= 3 * (10+j8) * (6.8)^2$$
$$= 1392 + j1113 = 1782 \angle 38.66^\circ$$

* unbalanced system:-




KVL. (first way).

1. $-100\angle 0 + j5 - 15 I_b + 100\angle 120 = 0$
2. $-100\angle 120 + I_c(10+j10) + 15 I_b + 100\angle -120 = 0$
3. ----

* ~~better way~~. second way:

KCL.

$I_a + I_b + I_c = 0$ , $V_N \neq 0$

* قبل ما أوصل سلك nN

$I_a + I_b + I_c = I_{Nn}$.

$V_N =$ zero.

* بعد ما شلته :-

$I_a + I_b + I_c = 0$.

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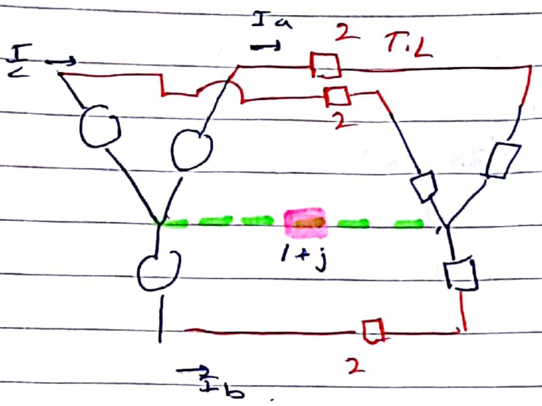
$$* I_a = \frac{100\angle 0 - U_N}{j5}$$

$$* I_b = \frac{100\angle -120 - U_N}{15}$$

$$* I_c = \frac{100\angle 120 - U_N}{10 - j10}$$

$$\frac{100\angle 0 - U_N}{j5} + \frac{100\angle -120 - U_N}{15} + \frac{100\angle 120 - U_N}{10+10j} = 0$$

* find $U_N$ then $I_a, I_b, I_c$




$$I_a = \frac{100\angle 0 - U_N}{2+j5}$$

$$I_b = \frac{100\angle -120 - U_N}{12}$$

$$I_c = \frac{100\angle 120 - U_N}{17+10j}$$

(لو وصلنا السلك).

$$I_a = \frac{100\angle 0}{2+j5}, \quad I_b = \frac{100\angle -120}{12}, \quad I_c = \frac{100\angle 120}{17+10j}$$

(لو وصلنا مقاومة على السلك)

$U_N \neq 0$

$$I_{Nn} = \frac{U_N}{1+j} = I_a + I_b + I_c$$

$$I_a = \frac{100\angle 0 - U_N}{2+j5}$$

$$I_b = \frac{100\angle -120 - U_N}{12}$$

$$I_c = \frac{100\angle 120 - U_N}{17 - j10}$$

$$\frac{100 - U_N}{2+j5} + \frac{100\angle -120 - U_N}{12} + \frac{100\angle 120 - U_N}{17+j10} = \frac{U_N}{1+j}$$

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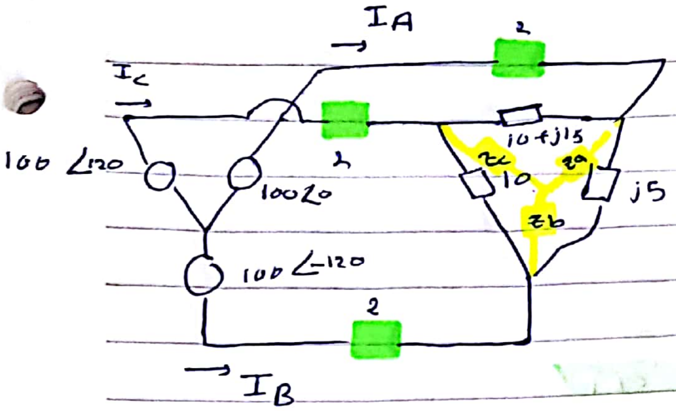


* without T.L impedence:-

$$\cancel{I_{AB} = \frac{U_{AB}}{j5}\angle 30 . \quad I_{BC} = \frac{U_{BC}}{10}}$$

$$\cancel{I_{AB} = \frac{\sqrt{3}\,100\angle 30}{j5}, \quad I_{BC} = \frac{\sqrt{3}*100\angle -90}{10}.}$$

$$I_{AB} = \frac{U_{AB}}{j5} = \frac{\sqrt{3}*100\angle 30}{j5}.$$

$$I_{BC} = \frac{U_{BC}}{10} = \frac{\sqrt{3}*100\angle -90}{10}.$$

$$I_{CA} = \frac{U_{CA}}{10+j15} = \frac{\sqrt{3}*100\angle 150}{j15+10}.$$

* with T.L.

$U_{ab} \neq U_{AB}$.

$\Delta - Y$ transphormation.

$$Z_a = \frac{j5\,(10+j5)}{j5+10+j5+10} \quad \ldots\ldots$$

$$I_a = \frac{100\angle 0 - U_N}{2+Z_a}.$$

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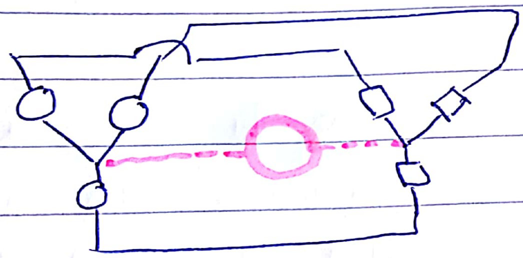

short circuit

(there is Nn line)

open ckT

(there is no Nn line)

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## * power measurement.

→ power is measured in the lab using adevice called wattmeter.

# How does wattmeter work:

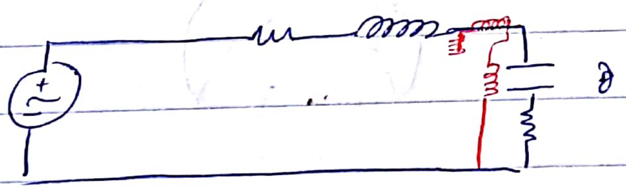
(displacement of pointer)
Deflection.

$P_{measured} \propto V, I, \cos\theta.$

$P = V_{rms}\ I_{rms} \cos(\theta - \phi)$

Ex.

find the wattmeter reading (find the real power absorbed by the load)



2 coils → parallel (voltage coil)
└→ Series. (current coil)

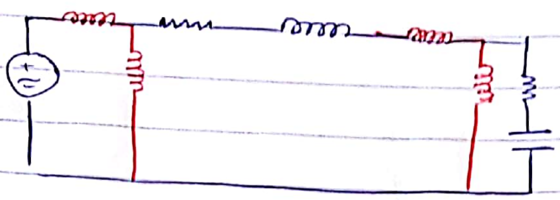
current coil → load current.

voltage coil → load voltage.

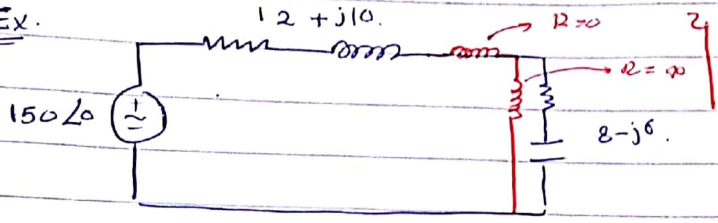
ال wattmeter بيحسب ال power لل load

لو بدي احسب ال power لل source كما

ال coils عنده.



Ex.




$P = V_{rms} I_{rms} \cos(\theta - \phi)$

$V_{load} \rightarrow$ voltage division $= \dfrac{150\angle 0 * (8-j6)}{(20+j4)} = 73.5 \angle -84°$

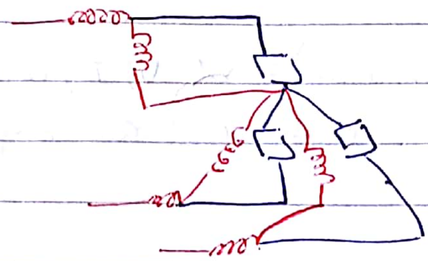
$I_{load} \rightarrow \dfrac{150 \angle 0}{20+j4} = 7.35 \angle -11.3°.$

$W_{reading} = P(load) = V_{rms} I_{rms} \cos(\theta - \phi)$

$= 73.5 * 7.32 * \cos(-84 + 11.3)$

$= 432.1 \; W$

* Power measurement in 3 phase system

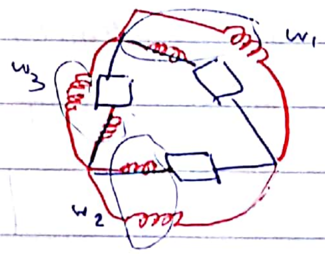


$P_{3\phi} = W_1 + W_2 + W_3$

if the load is Balanced

$P_{3\phi} = 3W_1$

* for a D connected load.




$P_{3\phi} = W_1 + W_2 + W_3$

If the load is Balanced

$P_{3\phi} = 3W$

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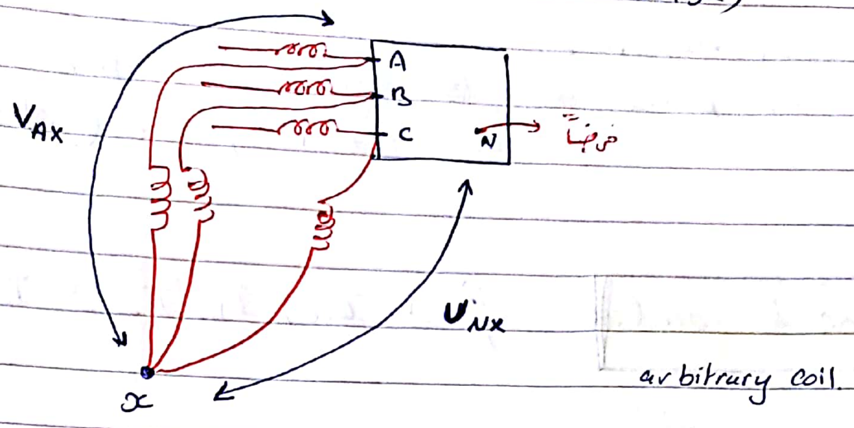
(the nutral point is not accessible)



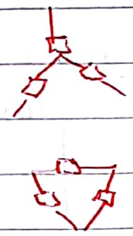

$$P_{3\phi} \overset{??}{=} w_1 + w_2 + w_3$$

$$w_1 = \frac{1}{T}\int_0^T v_{AN}(t) \cdot i_a(t) \cdot dt$$

$$w_2 = \frac{1}{T}\int_0^T v_{BN}(t) \cdot i_b(t) \cdot dt$$

$$w_3 = \frac{1}{T}\int_0^T v_{CN}(t) \cdot i_c(t) \cdot dt$$

for



$$w_1 = \frac{1}{T}\int_0^T v_{Ax}(t) \cdot i_a(t) \cdot dt$$

$$w_2 = \frac{1}{T}\int_0^T v_{Bx}(t) \cdot i_b(t) \cdot dt$$

$$w_3 = \frac{1}{T}\int_0^T v_{Cx}(t) \cdot i_c(t) \cdot dt$$

$$\boxed{\begin{aligned} v_{Ax} &= v_{AN} + v_{Nx} \\ v_{Bx} &= v_{BN} + v_{Nx} \\ v_{Cx} &= v_{CN} + v_{Nx} \end{aligned}}$$

$$P_{3\phi} = \frac{1}{T}\int_0^T (v_{AN} + v_{Nx})\, i_a(t) \cdot dt + \frac{1}{T}\int_0^T (v_{BN} + v_{Nx}) \cdot i_b(t) \cdot dt + \frac{1}{T}\int_0^T (v_{CN} + v_{Nx}) \cdot i_c(t) \cdot dt$$

$$= \frac{1}{T}\left[v_{AN}(t) \cdot i_a(t) + v_{bn}(t) \cdot i_b(t) + v_{CN}\, i_c(t) + v_{Nx}\underbrace{(i_a + i_b + i_c)}_{= zero}\right]$$

(in Δ & Y without nutral)

$$= \frac{1}{T}\int_0^T v_{AN}(t) \cdot i_a(t) \cdot dt + \frac{1}{T}\int_0^T v_{bn}(t) \cdot i_b(t) \cdot dt + \frac{1}{T}\int_0^T v_{CN}(t) \cdot i_c(t) \cdot dt$$

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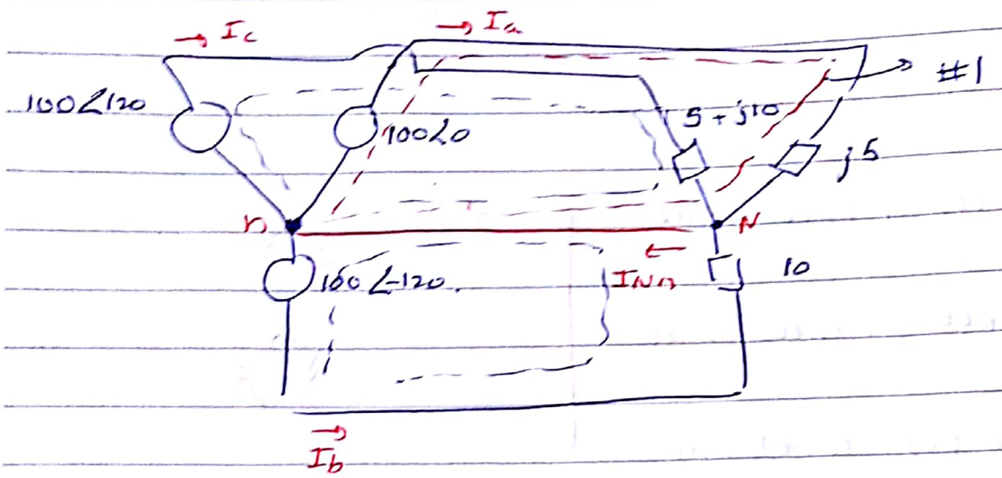
$P_{3\phi} = W_1 + W_2 + W_3$.

the ~~care~~ choice of point α β will not affect the total power ($3\phi$ power).

**Unbalanced load**

find $I_a$, $I_b$, $I_c$ & $I_{Nn}$.




KVL at #1.

$-100\angle 0 + j5 I_a = 0$

$I_a = \dfrac{100\angle 0}{j5} = 20\angle -90°$ A.

KVL

$I_b = \dfrac{100\angle -120}{10} = 10\angle -120$ A.

KVL

$I_c = \dfrac{100\angle +120}{5+10j}$ #

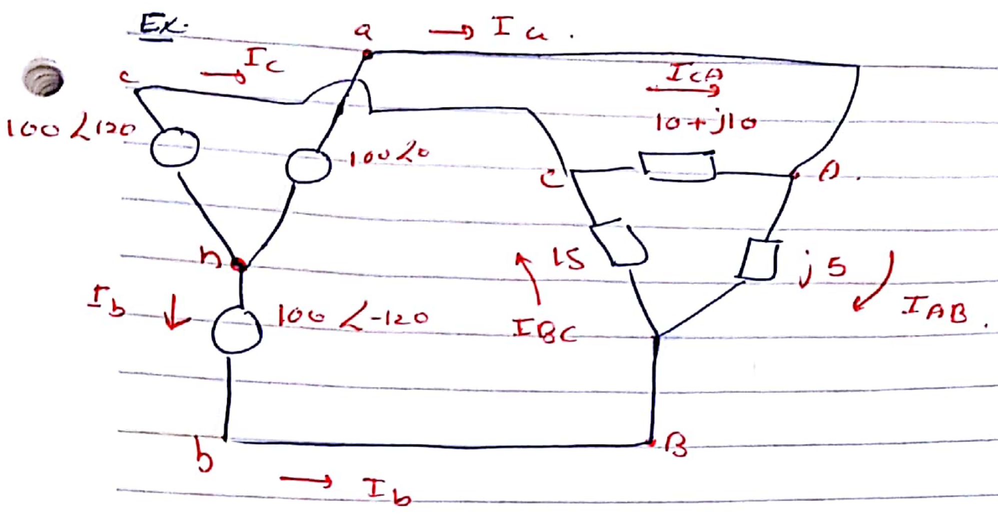
$I_{Nn} = I_a + I_b + I_c = 20\angle -90° + 10\angle -120° + \dfrac{100\angle 120}{5+10j} \neq$ Zero.

$V_N = V_n = 0$.

alway = zero

عالم يفكر بغير ذلك.

Ex:




find phase & line currents.

$$I_{AB} = \frac{U_{AB}}{j5} = \frac{U_{ab}}{j5} = \frac{100\sqrt{3}\ \angle 30}{j5} = 20\sqrt{3}\ \angle -60\ A.$$

$$I_{BC} = \frac{U_{BC}}{15} = \frac{U_{bc}}{15} = \frac{100\sqrt{3}\ \angle -90}{15} = 6.66\sqrt{3}\ \angle -90\ A.$$

$$I_{CA} = \frac{U_{CA}}{j10} = \frac{U_{ca}}{10+j10} = \frac{\sqrt{3} * 100\ \angle 150}{10+j10}$$ #.

بفرق 120°.

→ for Balanced load

$I_{line} = \sqrt{3}\ I_{phase}\ \angle -30.$

→ ~~for~~ here ~~we~~ (non balanced load) we applied KCL

$I_a + I_{CA} = I_{AB}$

$I_a = I_{AB} - I_{CA}.$

$I_b + I_{AB} = I_{BC}$

$I_b = I_{BC} - I_{AB}.$

$I_c + I_{BC} = I_{CA}.$

$I_c = I_{CA} - I_{BC}.$

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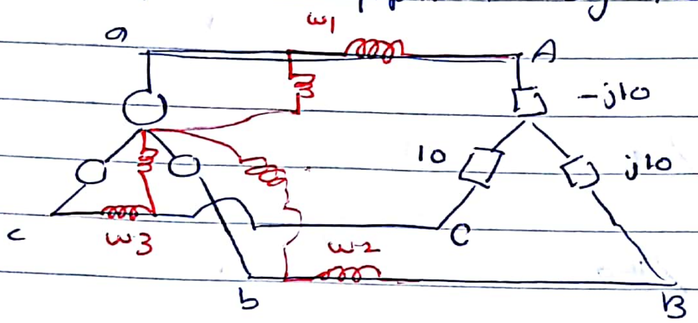
Find the reading of the 3 wattmeters & find the total power supplied by the source.

$V_{ab} = 100\angle 0$.




$w_1 \Rightarrow V_{an}$ & $I_a$. , $V_{an} = (100/\sqrt{3})\angle -30$.

$w_2 \Rightarrow V_{bn}$ & $I_b$. , $V_{bn} = (100/\sqrt{3})\angle -150$.

$w_3 \Rightarrow V_{cn}$ & $I_c$. , $V_{cn} = (100/\sqrt{3})\angle 90$

$$\frac{\frac{100}{\sqrt{3}}\angle -30 - V_N}{-j10} + \frac{\frac{100}{\sqrt{3}}\angle -150 - V_N}{j10} + \frac{\frac{100}{\sqrt{3}}\angle 90 - V_N}{10} = 0.$$

→ find $V_N$ then find $I_a$, $I_b$, $I_c$.

* $I_a = 19.32\angle 15$.
* $I_b = 19.32\angle 16.2$.
* $I_c = 10\angle -90$.

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$w_1: P_1 = V_{an} * I_a * \cos(\theta_{V_{an}} - \phi_{I_a})$

$= \frac{100}{\sqrt{3}} * 19.32 * \cos(-30-15) = 788.7\,w$

$w_2: P_2 = V_{bn} * I_b * \cos(\theta - \phi)$

$= \frac{100}{\sqrt{3}} * 19.32 * \cos(-150-165)$

$= 788.7\,w$

$w_3: P_3 = V_{cn} * I_c * \cos(\theta - \phi)$

$= \frac{100}{\sqrt{3}} * 10 * \cos(90+90)$

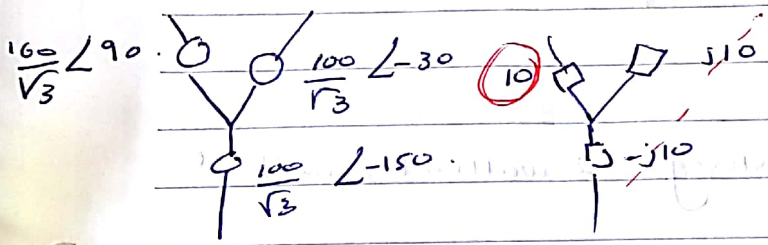
$= -577.4\,w$

total power supplied by the source is:

$P_{3\phi} = P_1 + P_2 + P_3$

$= w_1 + w_2 + w_3$

$= 788.7 + 788.7 - 577.4 = \underline{\underline{1000\ w}}$



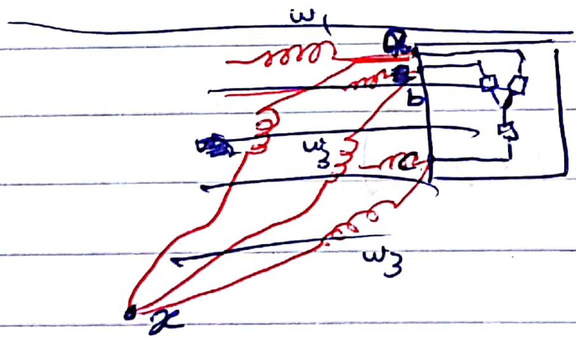

Real power only on $10\,\Omega$

$P_{3\phi} = (I_c)^2 * R$

$= (10)^2 * 10$

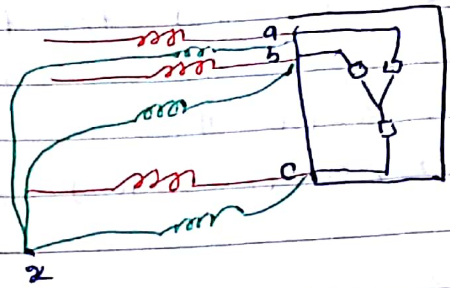
$= 1000\ w$ #

## The two watt meter method :-



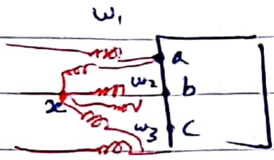
## The Two wattmeter method:

x: what if x is chosen such that x is put on one of phases

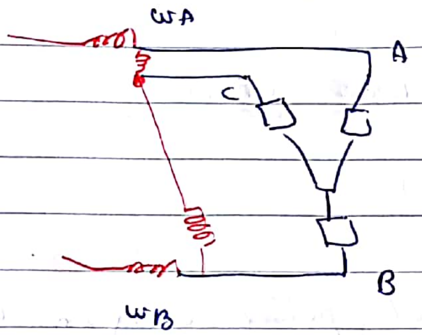



↓

Zero = $w_2$ ←



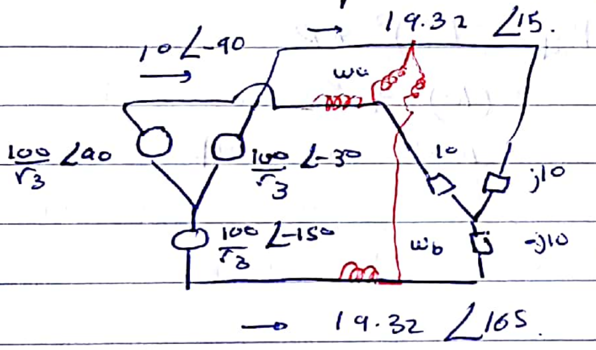

علينا الاكتفاء ب
Two wattmeters.




$W_A \Rightarrow V_{AC}, I_a.$

$W_B \Rightarrow V_{BC}, I_b.$

* Solve the previous exp. using 2 wattmeter method




$w_a : V_{ca}, I_c$

$w_b \Rightarrow V_{ba}, I_b.$

$V_{AB} = \sqrt3 V_{an} \angle 30$

$V_{ab} = 100 \angle 0$ .. $(V_{ba} = -V_{ab} = 100 \angle 180)$

$V_{bc} = 100 \angle -120$

$V_{ca} = 100 \angle 120$

$w_a : P_a : |V_{ca}||I_c| \cos(\theta_{V_{ca}} - \phi_{I_c}) = 100 * 10 * \cos(120+90) = -886$

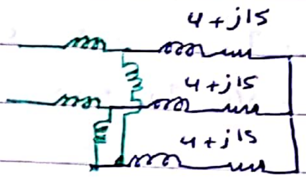
$w_b : P_b : |V_{ba}||I_b| \cos(\theta_{V_{ba}} - \phi_{I_b}) = 100 * 19.32 \cos(180-165)$

$= 1886$ w

$1886 - 886 = 1000$ w #

* Given that $V_{AB} = 230\angle 0$
→ find the reading of each wattmeter.
& the total power supplied to the load.

$W_A : V_{AC} : I_A$.
$W_B : V_{BC}, I_B$.




$V_{AB} = 230\angle 0$
$V_{BC} = 230\angle -120$
$V_{CA} = 230\angle 120$, $V_{AC} = 230\angle 120-180$

$$I_a = \frac{V_{AN}}{4+j15} = \frac{(V_{AB}/\sqrt{3})\angle -30}{4+j15} = \frac{\frac{230}{\sqrt{3}}\angle -30}{4+j15} = 8.554\angle -105.1^\circ$$

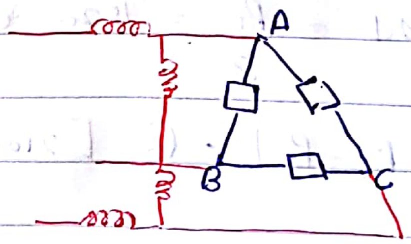
$I_b = 8.554\angle -106-120$
$I_c = 8.554\angle -105.1+120$

$w_1 : p_1 = 230 * 8.554\cos(-60+105.1) = 1389\ w$
$w_2 : p_2 = 230 * 8.554\cos(-120+125.1) = -512\ w$.

$P_T = P_1 + P_2 = 876.5\ w$

شيك $P_T = 3|I|^2R = 3*(8.554)^2*4\ w$ #

# How to calculate the pF from the reading of wattmeter.




$W_A = |V_{AB}||I_A|\cos(\theta_{V_{AB}} - \phi_{I_A})$
$= |V_{LL}||I_L|\cos(\theta_{V_{AB}} - \phi_{I_A})$

$W_B = |V_{CB}||I_C|\cos(\theta_{V_{CB}} - \phi_{I_C})$
$= |V_{LL}||I_L|\cos(\theta_{V_{CB}} - \phi_{I_C})$

⇒ Consider inductive load (voltage leads current.)

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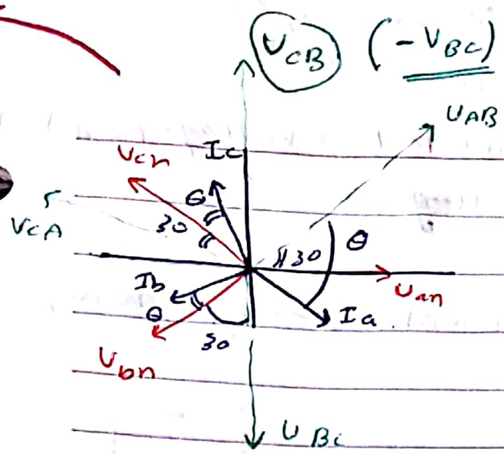


$$P_A = V_{LL} I_L \cos(30+\theta)$$

$$P_B = V_{LL} I_L \cos(30-\theta)$$

$$\frac{P_A}{P_B} = \frac{\cancel{|V_{LL}|}\cancel{|I_L|}\cos(30+\theta)}{\cancel{|V_{LL}|}\cancel{|I_L|}\cos(30-\theta)}$$

$$\frac{P_A}{P_B} = \frac{\cos 30\cos\theta - \sin 30\sin\theta}{\cos 30\cos\theta + \sin 30\sin\theta}$$

$$= \left(\frac{\frac{\sqrt{3}}{2}\cos\theta - \frac{1}{2}\sin\theta}{\frac{\sqrt{3}}{2}\cos\theta + \frac{1}{2}\sin\theta}\right) * \frac{2}{2} * \frac{\cos\theta}{\cos\theta}$$

$$\frac{P_A}{P_B} = \frac{\sqrt{3} - \tan\theta}{\sqrt{3} + \tan\theta}$$

$$P_A(\sqrt{3} + \tan\theta) = P_B(\sqrt{3} - \tan\theta)$$

$$P_A\sqrt{3} + P_A\tan\theta = P_B\sqrt{3} - P_B\tan\theta$$

$$\tan\theta\,[P_A + P_B] = \sqrt{3}\,[P_B - P_A]$$

$$\tan\theta = \frac{\sqrt{3}\,[P_B - P_A]}{[P_A - P_B]}$$

$$\rightarrow \tan\theta = \frac{\sqrt{3}\,[P_2 - P_1]}{[P_1 + P_2]}$$

- $P_2 = P_1$ (Resistive load)
- $P_2 > P_1$ (Inductive load)
- $P_2 < P_1$ (Capacitive load)

* واحد من الثلاثيات
يكون عادي والتاني
معكوس .

$P_1$ ← العادي

~~العكس~~

$P_2$ ← المعكوس

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$P_T = P_1 + P_2 = V_{LL} * I_L * \cos(30+\theta) + V_{LL} I_L \cos(30-\theta)$

$= V_{LL} I_L \cos 30 \cos\theta - V_{LL} I_L \cancel{\sin 30 \sin\theta} + V_{LL} I_L \cos 30 \cos\theta$

$+ V_{LL} I_L \cancel{\sin 30} \sin\theta$

$= 2 V_{LL} I_L \cos 30 \cos\theta = \boxed{\sqrt{3} V_{LL} I_L \cos\theta.} \equiv P_T$

$\rightarrow \sqrt{3}[P_2 - P_1] = \sqrt{3} V_{LL} I_L \cos(30-\theta) - \sqrt{3} V_{LL} I_L \cos(30+\theta)$

$= \sqrt{3} V_{LL} \cancel{I_L \cos 30 \cos\theta} + \sqrt{3} V_{LL} I_L \sin 30 \sin\theta$

$- \cancel{\sqrt{3} V_{LL} I_L \cos 30 \cos\theta} + \sqrt{3} V_{LL} I_L \sin 30 \sin\theta.$

$= \sqrt{3} V_{LL} I_L \sin\theta = Q_T$

#

$$P_T = P_2 + P_1$$
$$Q_T = \sqrt{3}[P_2 - P_1]$$
$$|S| = \sqrt{P_2^2 + P_1^2}$$
$$\tan\theta = \frac{Q_T}{P_T} = \frac{\sqrt{3}[P_2 - P_1]}{[P_2 + P_1]}.$$

**Ex.** Tow wattmeters produce readings $P_1 = 1560$, $P_2 = 2100$ w when connected to $3\phi$ load, find :

[1] $P_T = P_1 + P_2$

$= 1560 + 2100 = 3660$ w.

if the load is Balanced.

$P_{1\phi} = \frac{P_T}{3} = 1220$ w.

[2] $Q_T = \sqrt{3}[P_2 - P_1] = \sqrt{3}[2100 - 1560] = 935$ VAR.

if the load is Balanced.

$Q_{1\phi} = \frac{Q_T}{3} = 311.67$ VAR.

[3] $PF = \cos\left[\tan^{-1}\left[\frac{\sqrt{3}[2100 - 1560]}{2100 + 1560}\right]\right]$

$= 0.9689$ lagging ($P_2 > P_1$)

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$\angle 0 \rightarrow$ بحسبها دا ما بدي

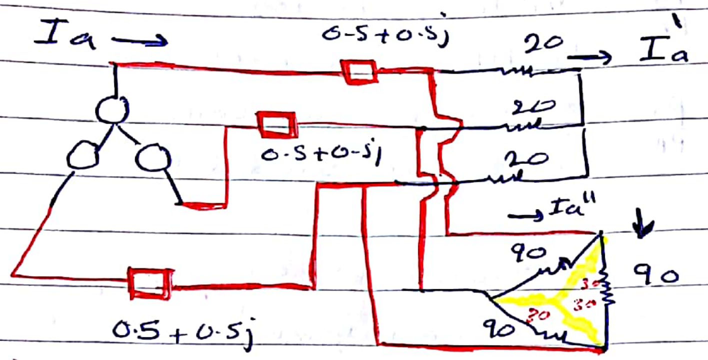
RMS.

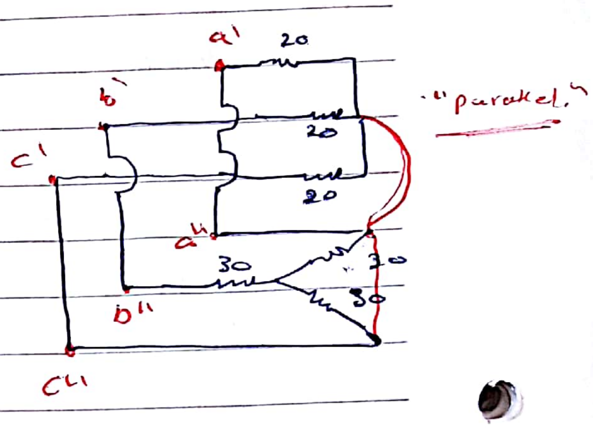
line to line voltage (اذا ما حدد)

Example:-

Voltage of generator = 208 volt.

Find the line currents & phase currents (any where)




"parallel"

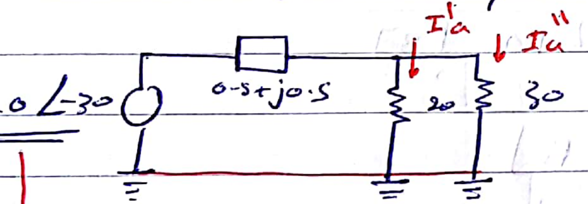
*** convert Δ to Y.**

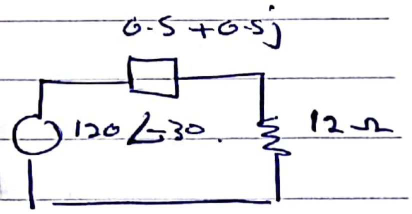
$Z_Y = \frac{1}{3} Z_\Delta$ (balanced load)

$= 30\ \Omega$

*** then single phase equivelant circuit.**

( take phase A).




Take $V_{AB}$ as our reference

$V_{AB} = 208\angle 0$.

$V_{AN} = \frac{V_{AB}}{\sqrt{3}} \angle -30 = 120\angle -30$

$I_a = \frac{120\angle -30}{12+0.5+0.5j}$

$I'_a = \frac{30}{50} I_a$.

$I''_a = \frac{20}{50} I_a$

Current division.

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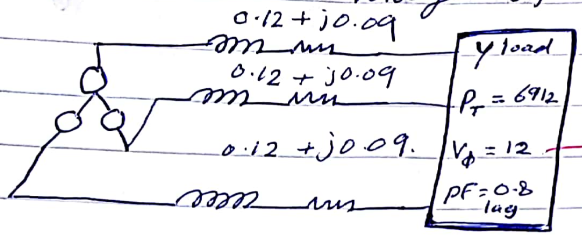
Ex.

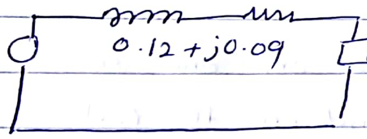
Find the line voltage of the source side.




$\rightarrow$ phase to neutral voltage.

$\rightarrow$ single phase eq. CCT.

* Take $U_{AN}$ as our reference.




120 volt.

2304 Ω

PF = 0.8.

* $P = U \cdot I * PF$.

$2304 = |120| |I| * 0.8$

$|I| = 24\ A$.

$I = 24 \angle -36.84$ (lagging)

$U_{an} = 120 \angle 0 + (0.12 + j0.09) * (24 \angle -36.84)$

$\therefore = 123.6 \angle 0.$

$U_{ab} = \sqrt{3} * 123.6 \angle +30 = 214.1 \angle 30^\circ$ volt.