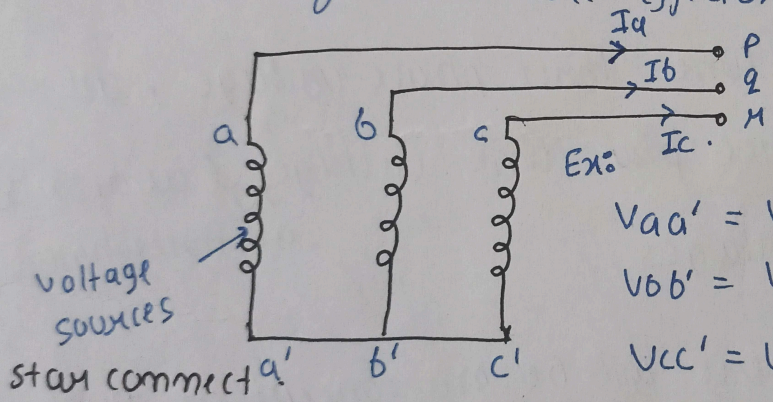
3 Phase (Φ) System.

The main advantages of 3phase system over single phase is

1) A three phase machine has a smaller size than a single phase machine of same power output.

2) The conductor material required to transmit a given power at a given voltage over a given distance by a three phase system is less than that by an equipment single phase system.

3) Since three-phase supply produces a rotating magnetic field three-phase motors are simpler in construction, smaller in size, start more conveniently, have uniform torque, run more smoothly and more efficient than single phase motors



Ex:

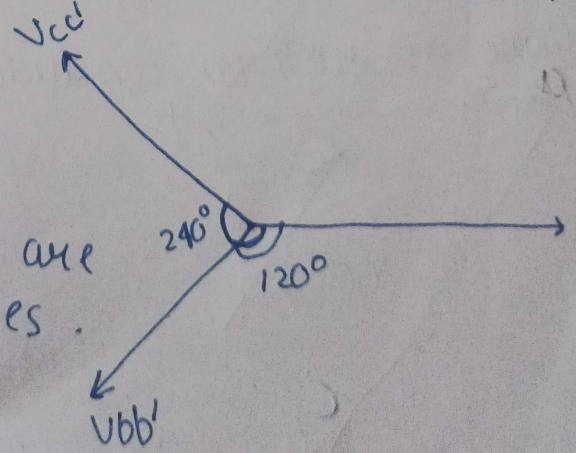
$V_{aa'} = V_m \sin\omega t$.

$V_{bb'} = V_m \sin(\omega t - 120)$

$V_{cc'} = V_m \sin(\omega t - 240)$.

If $I_a = 100$ A
$I_b = -75$A
$I_c = -25$A hence the circuit completes

These are called balanced voltages.



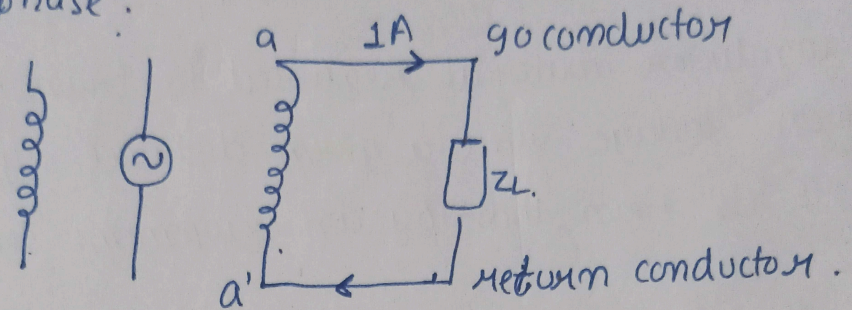
voltage b/w p & q is.

line voltage. V_p, V_q, V_r are line voltages.

I_a, I_b, I_c are line current

voltage b/w a & a', b & b', c & c' are phase voltages.

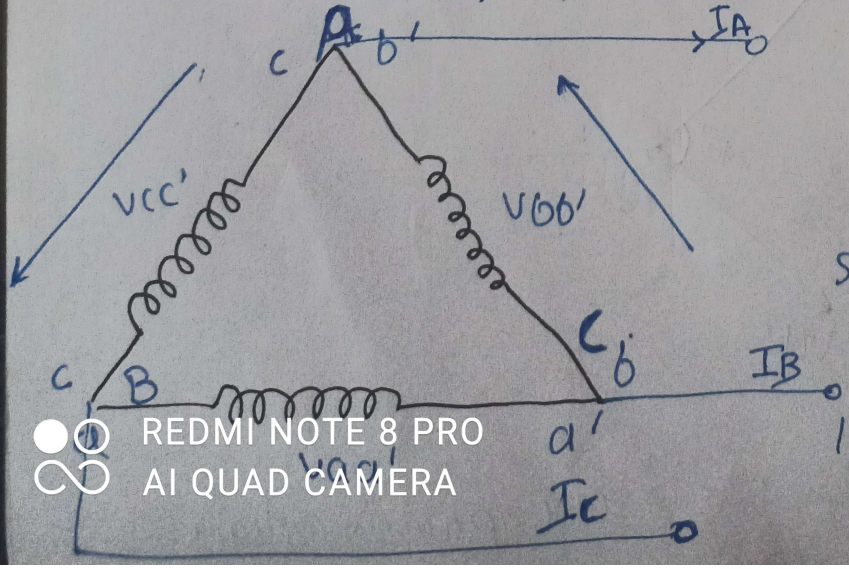
Hence we say
line voltages & phase voltages are totally different.
Current in a & a', b & b', c & c' are phase current.
Here phase current & line current are same
like in single phase.



there are 4 wire & in 3 phase we have.
3 wire hence one advantage is also we have copper/
conducting material saving.

The phasor sum of all three phase voltage, all
three phase current, all three line voltages & currents
all three line
will be zero in balanced voltages.

Hence in 3 phase system there will be no concept of go &
return conductor here if 1 circuit behaves a go conductor
other will behave as return conductor.



Similarly for delta
system. we see these extended
wire I_A, I_B, I_C are
line currents, soon.

line voltage & phase voltage are same in delta system but line current & phase current will be different..

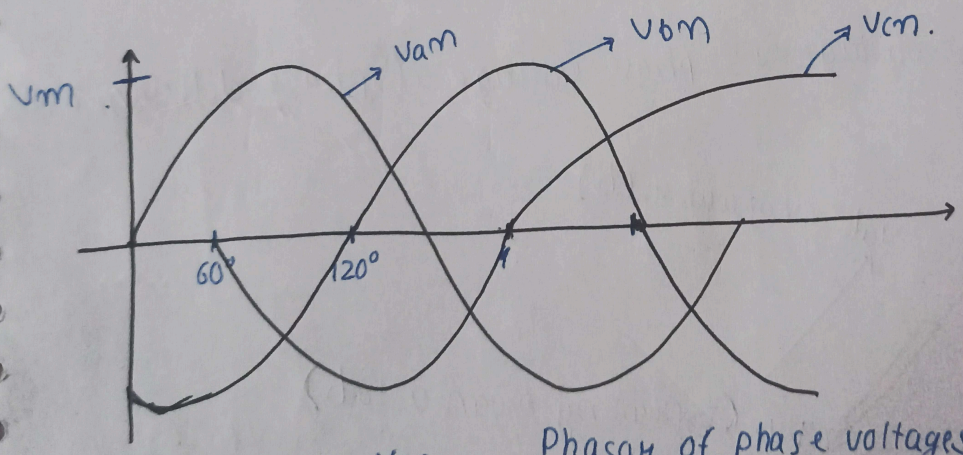
- In star system the line voltage $= \sqrt{3}$ phase voltage & phase difference b/w line voltage & phase voltage is 30° while line current and phase are same.
- In delta system $I_L = \sqrt{3} I_P \angle -30°$ & line voltage & phase voltage are same.
- In star system, the line voltage is difference of two phase voltage. while in star system the line current is difference of two phase current. [Difference taken is phasor diff]

3 phase voltages

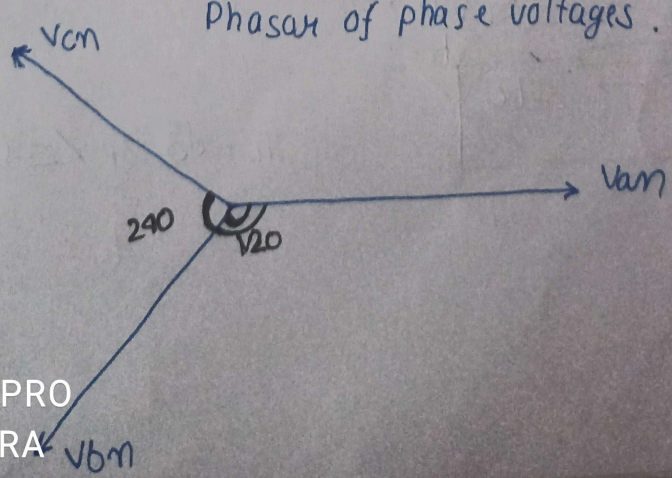
$V_{an} = V_m \sin \omega t$ $\quad \overline{V_{an}} = V \angle 0$

$V_{bn} = V_m \sin(\omega t - 120)$ $\quad \overline{V_{bn}} = V \angle -120$

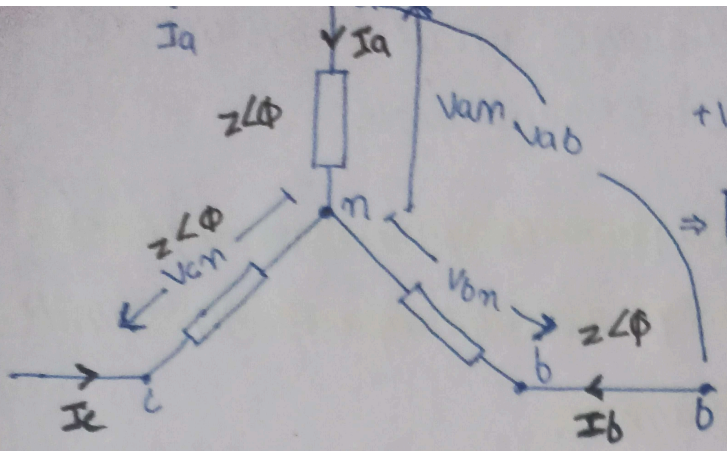
$V_{cn} = V_m \sin(\omega t - 240)$ $\quad \overline{V_{cn}} = V \angle -240$.



$\frac{V_m}{\sqrt{2}} = V$



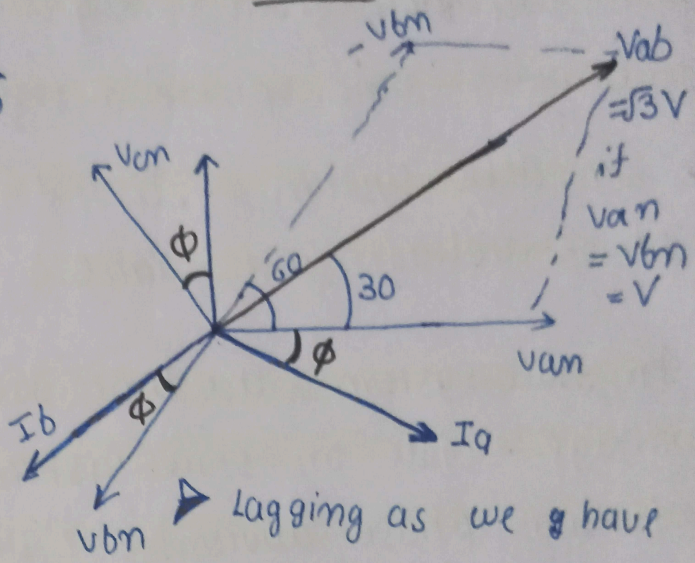
Phasor of phase voltages.



$+V_{an} - V_{ab} - V_{bn} = 0$

$\Rightarrow \boxed{V_{ab} = V_{an} - V_{bn}}$

Method 1:



Lagging as we have given $z \angle \phi$ ϕ is positive which is inductive circuit

Method :2

$V_{ab} = V\angle 0 - V\angle -120$

$= V\sin\omega t - V\sin(\omega t - 120°)$

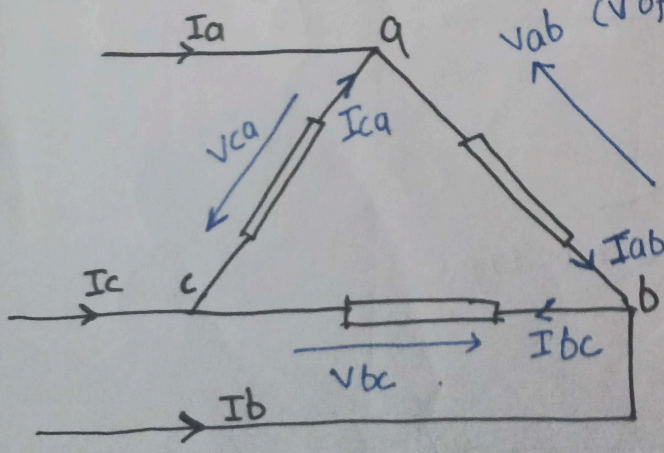
$= 2V\cos(\omega t - 60°)\sin 60°$

$= 2V \times \frac{\sqrt{3}}{2} \cos(150° - \omega t)$

$V_{ab} = \sqrt{3}V \sin(\omega t + 30°)$

Similarly we can do it for V_{ca} & V_{bc} also.

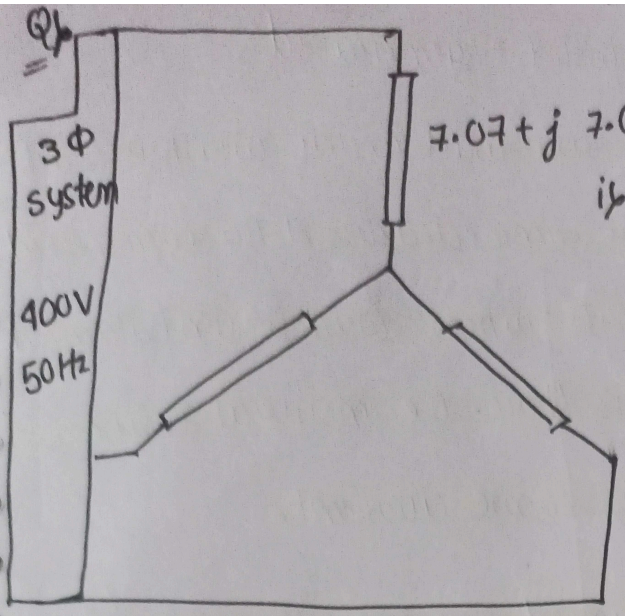
Hence it proves line voltage $= \sqrt{3}$ phase voltage & phase difference b/w is 30°.



$I_L = \sqrt{3}\, I_P \angle -30°$

Delta System

Q)



i) Calculate the phase current and the line current drawn by the load.

➤ If it is not given quantities given are considered as line quantities.

i) $I_{an} = \frac{V_{an}}{z} = \frac{400}{\sqrt{3} \times 7.07\sqrt{2}} = \frac{\frac{400\angle 0}{\sqrt{3}}}{9.998\angle 45^\circ}$.

$I_{an} = 23.09 \angle -45^\circ$ A.

Line current will be same.

ii) If load is delta system.

$I_{ab} = \frac{V_{ab}}{z} = \frac{400\angle 0}{10\angle 45} = 40\angle -45^\circ$ A.

$I_L = 40 \times \sqrt{3} \angle -75^\circ$

➤ $P_{3\phi} = 3 V_p I_p \cos\phi$

➤ $Q_{3\phi} = 3 V_p I_p \sin\phi$

➤ $S = 3 V_p I_p$.

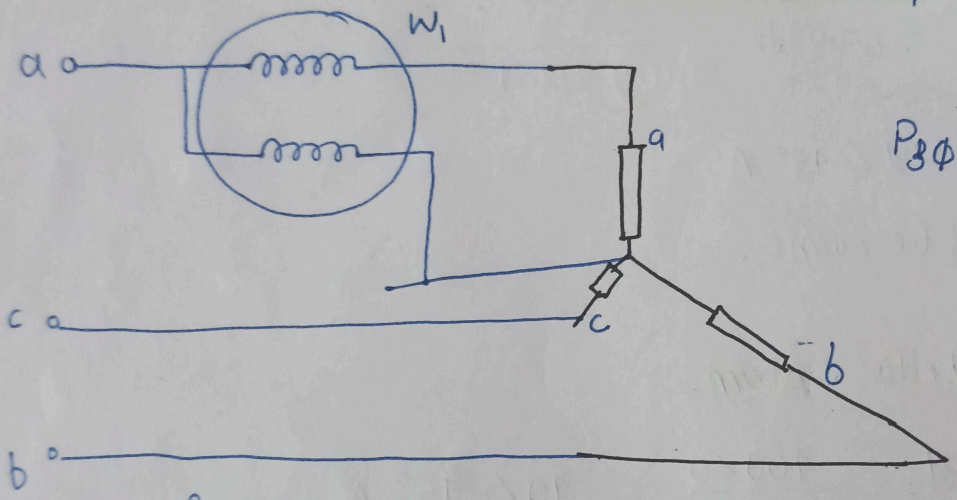
➤ 3 PHASE POWER

i) We can measure the 3 phase power by 1 watt meter conditions are load must be balanced and neutral pt is should

be there otherwise artificially it will be generated.

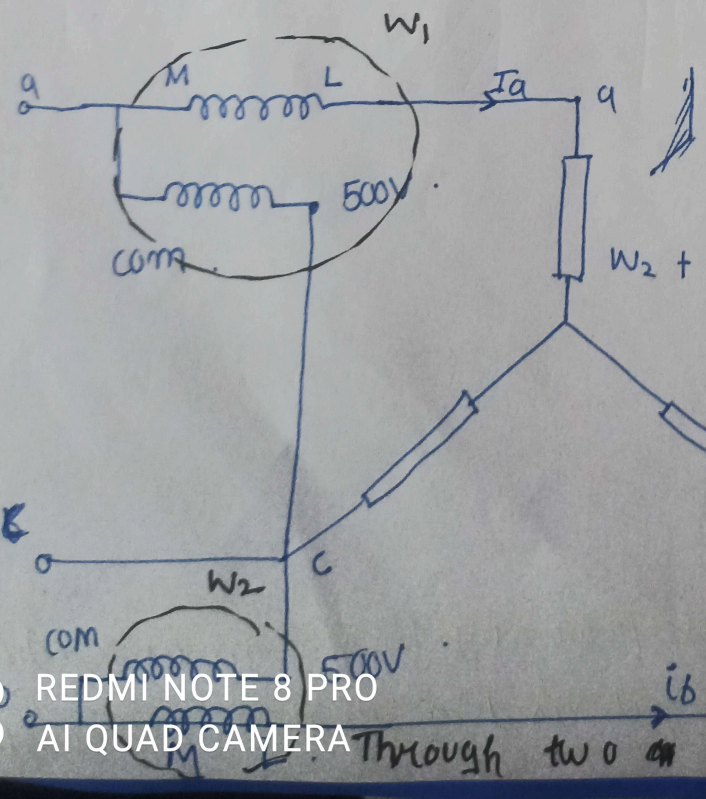
iii) we can measure the power by two watt meter weather load is balanced or unbalanced, load is star connected or delta connected. and but there is one condition it fails when load is unbalanced and three phase four wire system is there. i.e neutral wire is there and neutral wire is carrying some current.

iii) In three phase four wire unbalanced system three watt meters are needed to measure total 3 phase power.



$P_{3\phi} = 3W_1$

Through one watt meter.



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

$W_2 + W_1 = (V_a - V_c)\, i_a + (V_b - V_c)\, i_b$

$= V_a i_a - V_c i_a + V_b i_b - V_c i_b$

$= V_a i_a + V_b i_b - V_c (i_a + i_b)$

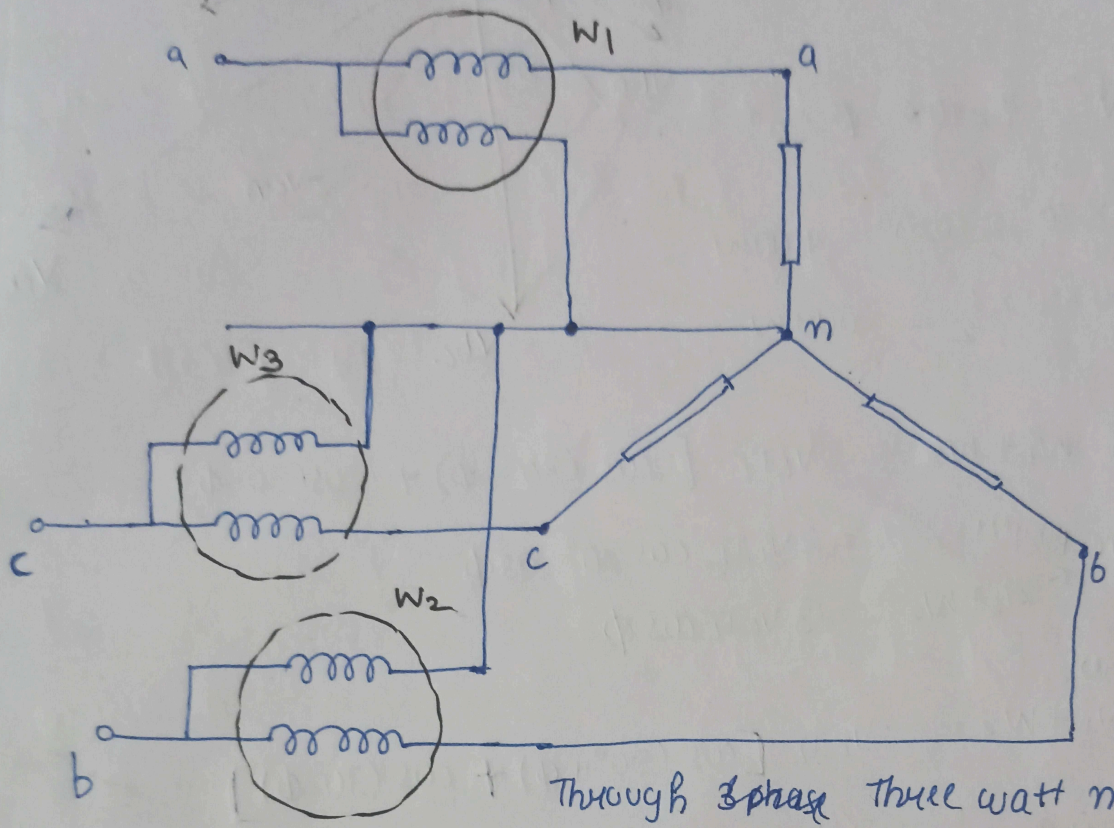
Through two watt meter.

From. KCL and previous conditions Read

$$i_a + i_b + i_c = 0$$

$$i_a + i_b = -i_c$$

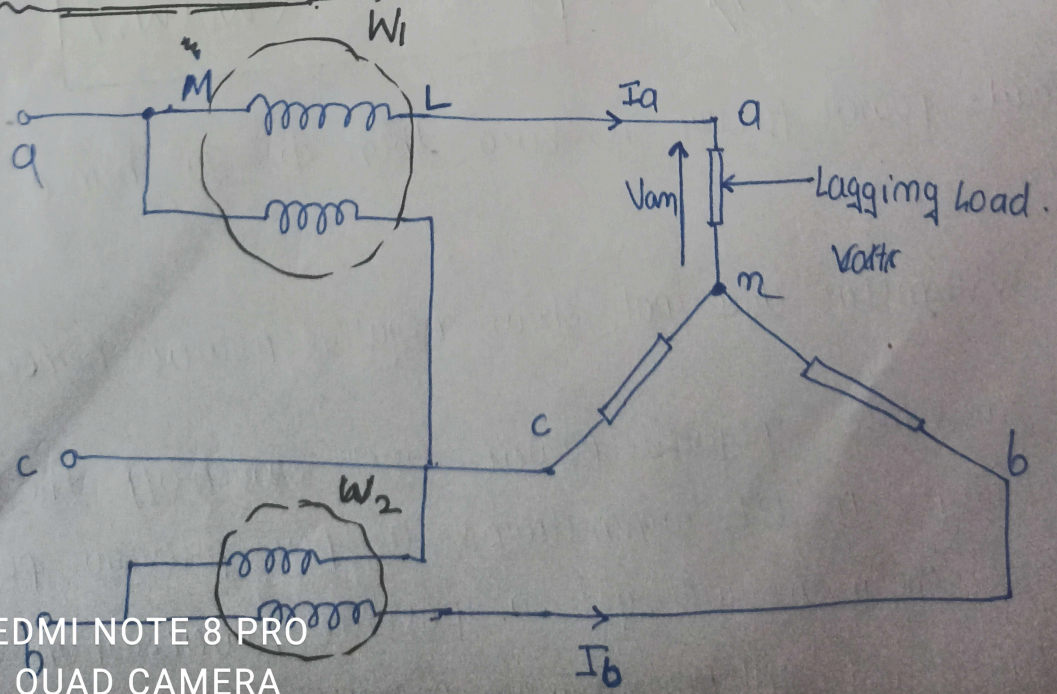
$$W_1 + W_2 = V_a i_a + V_b i_b + V_c i_c$$



Through 3phase Three watt meter.

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

TWO PHASE METHOD

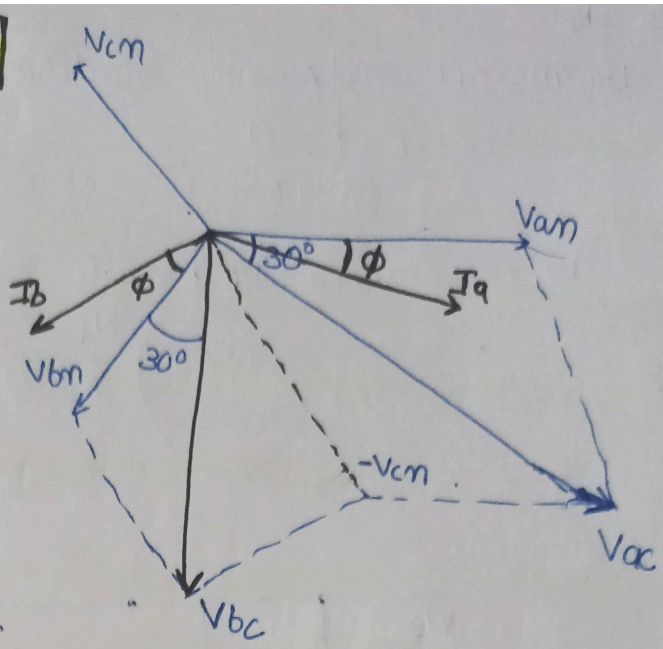


$W_1 = V_{ac} I_a V_L I_L \cos(30° + \phi)$

$W_1 = V_{ac} I_a \cos(30° - \phi)$

$W_2 = V_L I_L \cos(30° + \phi)$

$W_2 = V_{bc} I_b \cos(30° + \phi)$



Ex: 400 V $i = 10$ A $\phi = 30°$

$W_1 = 400 \times 10 \times \cos 0° = 4000 W$

$W_2 = 400 \times 10 \times \frac{1}{2} = 2000 W$

Now $W_1 + W_2 = V_L I_L [\cos(30° + \phi) + \cos(30 - \phi)]$

Total Active power $= 2 V_L I_L \cos 30° \cos\phi$

$W_1 + W_2 = \sqrt{3} V_L I_L \cos\phi$

Total Reactive power.

$W_1 - W_2 = V_L I_L [\cos(30° + \phi) - \cos(30 - \phi)]$

$\sqrt{3}|W_1 - W_2| = \sqrt{3} V_L I_L \sin\phi$ $= 2 V_L I_L \sin 30° \sin\phi = V_L I_L \sin\phi$

$\tan\phi = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$

→ If the load's power factor is zero then $\phi = 90°$ hence.

$W_1 = -W_2$

→ Practical wattmeter does not show negative power Hence

→ Now to measure negative power. first switch off the source then interchange M & L connections as per previous page figure. Hence now we will get a positive power when source will still be negative power actually

$W_1 = V_L I_L \cos(30-\phi)$

$W_2 = V_L I_L \cos(30+\phi)$

Case I

If $\phi = 0$ means power factor is unity W_1 & W_2 both are positive and equal.

Case II

If $\phi = 0° - 60°$ mean $\cos\phi = [1, 0.5)$ $W_1 \neq W_2$ but both will be positive.

Case III

$\phi = 60°$ $W_2 = 0$ $W_1 = + \frac{\sqrt{3}}{2} V_L I_L$.

Case IV

$\phi > 60°$ mean $\cos\phi < 0.5$ $W_1 \neq W_2$ also one wattmeter reading is negative.

Case V

$\phi = 90°$ means $\cos\phi = 90°$ $W_1 = -W_2$.

Q) The Input power to a 3ϕ motor was measured by 2 watt meter method. The reading were 5.2kW & 1.7kW, the later reading was obtained after reversal of current coil connections. The line voltage was 400v. Calculate a) The Total power b) The power factor c) The line current.

Total power = $5.2 - 1.7 = 3.5$kW

$$\tan\phi = \sqrt{3}\,\frac{[5.2+1.7]}{(5.2-1.7)} = \sqrt{3} \times \frac{6.9}{3.5} = \sqrt{3} \times \frac{69}{35} = 3.414$$

$\phi = 73.67°$

$\cos\phi = \cos(73.67) = 0.281$

$1000 \times 3.5 = 400 \times I_L \times 0.281 \times \sqrt{3}$

$$I_L = \frac{3500}{4 \times 0.281 \times \sqrt{3}} = \frac{35}{4 \times 0.281 \times \sqrt{3}}$$

$I_L = 17.98\ A$ Ans

Q) Each phase of a 3 phase of a delta connected load consists of an impedence $Z_p = 40\angle 30°$. The line voltage is 400 V at 50 Hz Determine.

↳ Reference is current hence this is lagging load.

a) Power factor

b) Phase currents & Line currents

c) Power consumed by phase impedence & total 3phase power

d) The reading of the two wattmeter used to measure the total 3 phase power.

a) $\cos 30° = \frac{1.732}{2} = 0.866$

b) $I_p = \frac{400}{40\angle 30°} = 10\angle -30°\ A.$

$|I_L| = \sqrt{3}|I_p| = \therefore \sqrt{3} \times 10 = 10\sqrt{3}\ A.$

c) $P_{3\phi} = 3 \times V_p I_p \cos\phi = 3 \times 400 \times 10 \times \frac{\sqrt{3}}{2}$

$= 6000\sqrt{3}\ W$

d) $W_1 = V_L I_L \cos(30° - \phi) = 400 \times 10\sqrt{3} \times \cos 0° = 4000\sqrt{3}\ W$

$W_2 = 400 \times 10\sqrt{3} \times \cos 60° = 2000\sqrt{3}\ W$ Ans