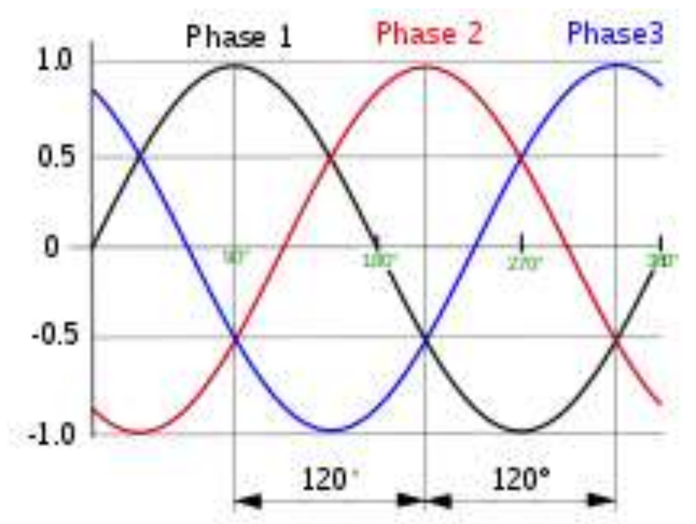
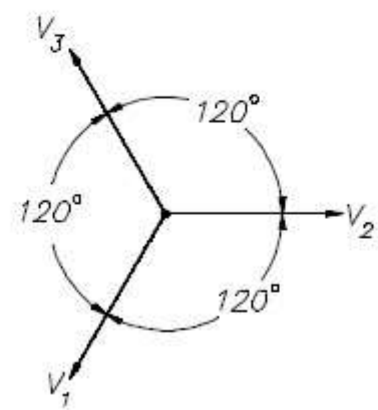
THREE PHASE SUPPLY

THREE PHASE SUPPLY

- In Three Phase Generator there are three identical binding which are 120° electrical apart from each other. Therefore, Three Phase Generator produce three voltages of the same magnitude and direction.
- Three-phase electric power is a common method of alternating current electric power generation, transmission, and distribution.
- It is a type of polyphase system and is the most common method used by electrical grids worldwide to transfer power.
- It is also used to power large motors and other heavy loads.

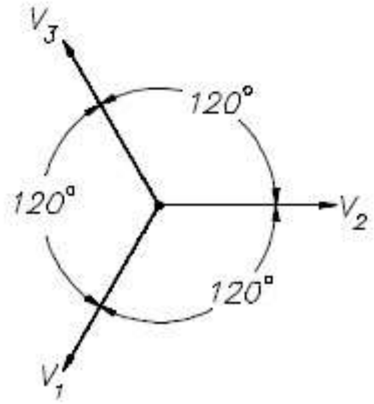




Three Phase Supply

THREE PHASE SUPPLY

- $V_1 = V_m \sin\omega t \implies V_1 = |V_{ph}|\angle 0^\circ$
- $V_2 = V_m \sin(\omega t - 120^\circ) \implies V_2 = |V_{ph}|\angle -120^\circ$
- $V_3 = V_m \sin(\omega t - 240^\circ) \implies V_2 = |V_{ph}|\angle -240^\circ$

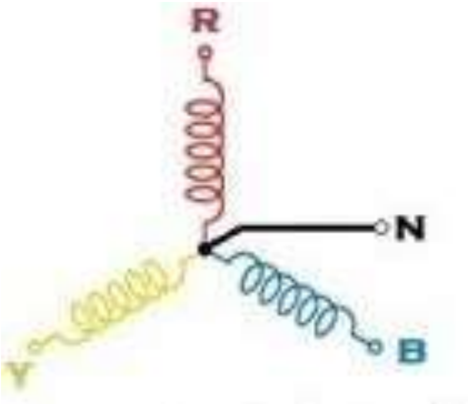


Three Phase Supply

Advantages of Three Phase System over Single Phase System

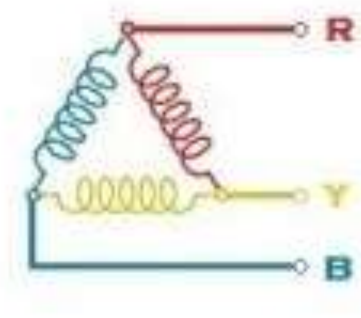
- The amount of conducting material required to transfer a given amount of power is minimum in a three-phase system.
- The instantaneous power in a three-phase system never falls to zero resulting in smoother and better operating characteristics of the load.
- Three-phase supply is required by three-phase induction motors which are widely used in industry because of their ruggedness, longer life, higher torque, low initial and maintenance costs.
- Domestic as well as industrial and commercial power can be supplied from the same three-phase distribution system.
- Three-phase system has better voltage regulation. For a given size of the machine, the power generated by a three-phase alternator is higher.
- Three-phase equipment (motors, transformers, etc.) weighs less than single-phase equipment of the same power rating.
- They have a wide range of voltages and can be used for single-phase loads.
- Three-phase equipment is smaller in size, weighs less, and is more efficient than single-phase equipment.

Star connection



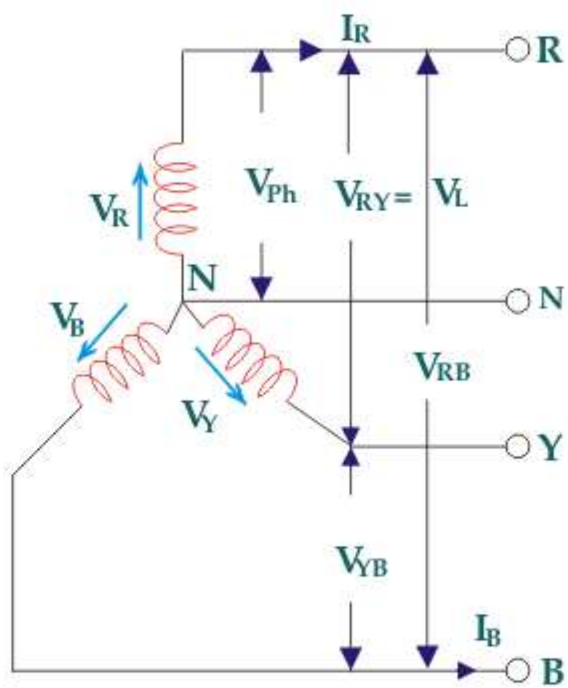
- In STAR connection, the starting or finishing ends (Similar ends) of three coils are connected together to form the neutral point. A common wire is taken out from the neutral point which is called Neutral.
- Three phase four wire system is derived from Star Connections **(3-Phase, 4 Wires System**) We may Also derived 3 Phase 3 Wire System from Star Connection

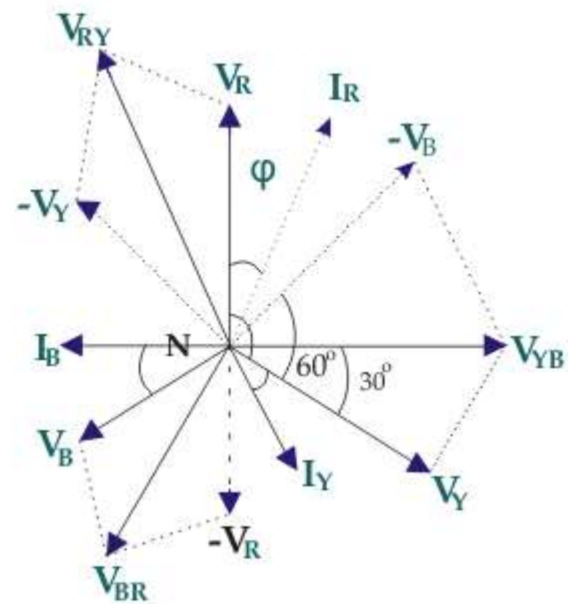
Delta Connection



- In DELTA connection, the opposite ends of three coils are connected together. In other words, the end of each coil is connected with the start of another coil, and three wires are taken out from the coil joints.
- No Neutral Point in Delta Connection.
- Three phase three wire system is derived from Delta Connections **(3-Phase, 3 Wires System)**

Phase voltage and line voltage in star connected system





Phase voltage and line voltage in star connected system

- Phase voltage. Voltage measured between the two terminals of the coil is called phase voltage.
- Line Voltage. Voltage measured between the two outer terminals of the two coils is known as line voltage and the current flowing in the main leads is known as line current
- Suppose due to load impedance the current lags the applied voltage in each phase of the system by an angle φ. As we have considered that the system is perfectly balanced, the magnitude of current and voltage of each phase is the same.
- In the balanced star system, magnitude of phase voltage in each phase is V_{ph}. $\therefore V_R = V_Y = V_B = V_{ph}$

In the star connection, line current is same as phase current. The magnitude of this current is same in all three phases i.e. I_L.

∴ $$I_R = I_Y = I_B = I_L,$$

Where, I_R is line current of R phase, I_Y is line current of Y phase and I_B is line current of B phase.

So, phase current, I_{ph} of each phase is same as line current IL in star connected system.

∴ $$I_R = I_Y = I_B = I_L = I_{ph}.$$

The voltage across R and Y terminal of the star connected circuit is V_{RY}.
The voltage across Y and B terminal of the star connected circuit is V_{YBR}.
From the diagram, it is found that

$$V_{RY} = V_R + (-V_Y)$$

Similarly, $$V_{YB} = V_Y + (-V_B)$$

And, $$V_{BR} = V_B + (-V_R)$$

Now, as angle between V_R and V_Y is 120^o(electrical), the angle between V_R and $-V_Y$ is $180^o - 120^o = 60^o$(electrical).

$$\begin{aligned} V_L = |V_{RY}| &= \sqrt{V_R^2 + V_Y^2 + 2V_R V_Y \cos 60^o} \\ &= \sqrt{V_{ph}^2 + V_{ph}^2 + 2V_{ph}V_{ph} \times \frac{1}{2}} \\ &= \sqrt{3}V_{ph} \\ \therefore V_L &= \sqrt{3}V_{ph} \end{aligned}$$

Thus, for the star-connected system line
Voltage = √3 × phase voltage.
Line current = Phase current

As, the angle between voltage and current per phase is φ, the electric power per phase is

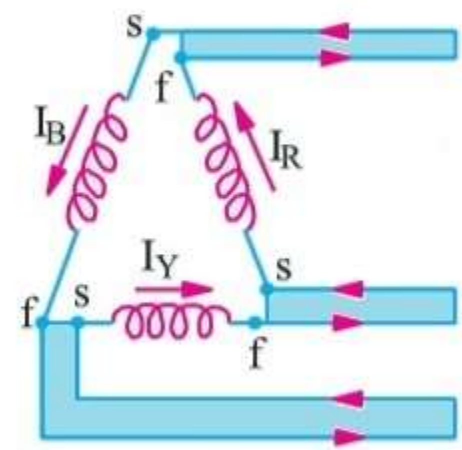
$$V_{ph}I_{ph}cos\phi = \frac{V_L}{\sqrt{3}}I_L\cos\phi$$

So the total power of three phase system

$$3 \times \frac{V_L}{\sqrt{3}}I_L\cos\phi = \sqrt{3}V_LI_L\cos\phi$$

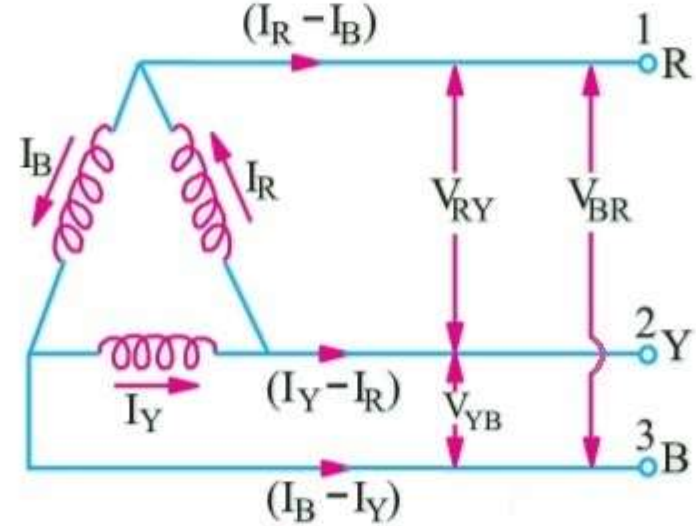
Delta Connection (Δ)

- In this system of interconnection, the starting ends of the three phases or coils are connected to the finishing ends of the coil.
- The starting end of the first coil is connected to the finishing end of the second coil and so on (for all three coils) and it looks like a closed mesh or circuit as shown in figure.

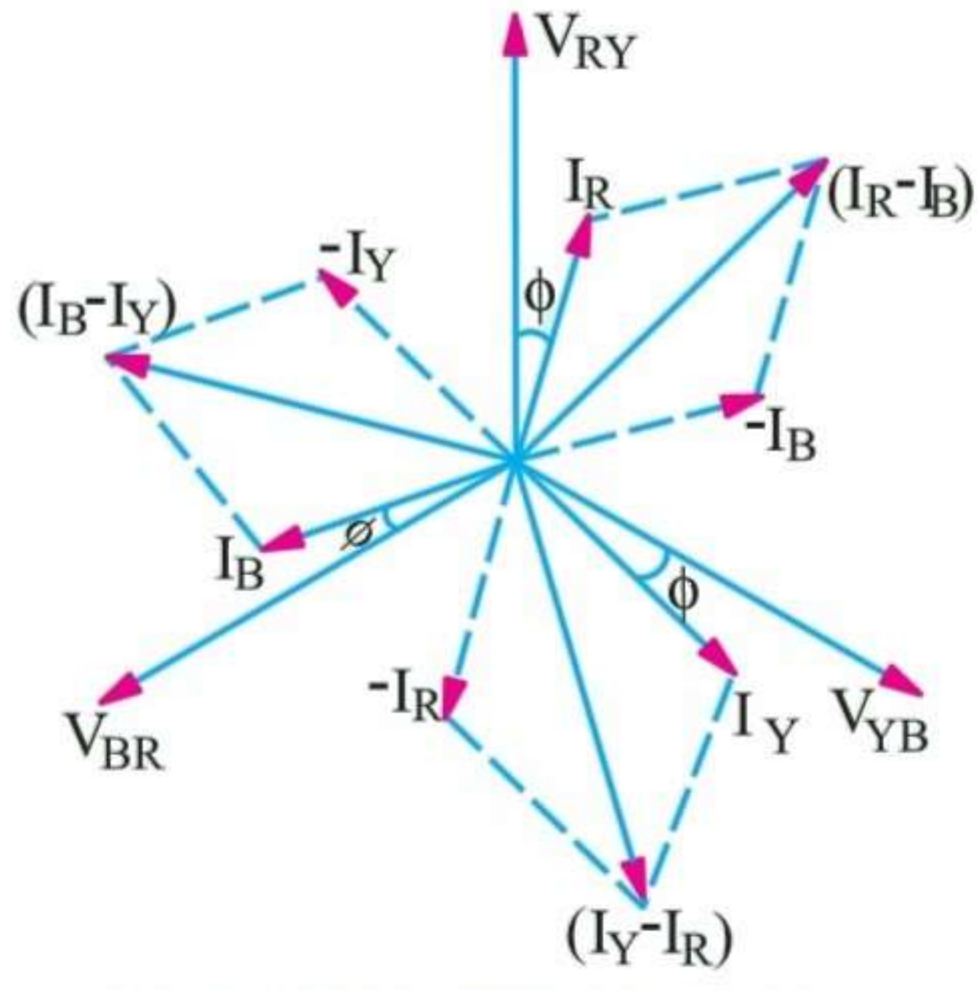


Delta Connection (Δ)

- In more clear words, all three coils are connected in series to form a close mesh or circuit. Three wires are taken out from three junctions and the all outgoing currents from junction assumed to be positive.
- In Delta connection, the three windings interconnection looks like a short circuit, but this is not true, if the system is balanced, then the value of the algebraic sum of all voltages around the mesh is zero.
- When a terminal is open, then there is no chance of flowing currents with basic frequency around the closed mesh.



Line & Phase Voltages and Line & Phase Current in Delta Connection



Line Voltages and Phase Voltages in Delta Connection

In delta connection there is only one phase winding between two terminals (i.e. there is one phase winding between two wires). Therefore,

the voltage between (any pair of) two lines is equal to the phase voltage of the phase winding which is connected between two lines

The phase sequence is R → Y → B

therefore, the direction of voltage from R phase towards Y phase is positive (+), and the voltage of R phase is leading by 120°from Y phase voltage. Likewise, the voltage of Y phase is leading by 120° from the phase voltage of B and its direction is positive from Y towards B.

- If the line voltage between;
- Line 1 and Line 2 = V_{RY}
- Line 2 and Line 3 = V_{YB}
- Line 3 and Line 1 = V_{BR}
- Then, we see that V_{RY} leads V_{YB} by 120° and V_{YB} leads V_{BR} by 120°.
- Let's suppose,
- $V_{RY} = V_{YB} = V_{BR} = V_L$ …………… (Line Voltage)
- Then
- $V_L = V_{PH}$
- I.e. in Delta connection, the Line Voltage is equal to the Phase Voltage.

Line Currents and Phase Currents in Delta Connection

- The total current of each Line is equal to the vector difference between two phase currents flowing through that line. i.e.;

  Current in Line 1= $I_1 = I_R - I_B$

  Current in Line 2 =$I_2 = I_Y - I_R$

  Current in Line 3 =$I_3 = I_B - I_Y$
- The current of Line 1 can be found by determining the vector difference between I_R and I_B and we can do that by increasing the I_B Vector in reverse, so that, I_R and I_B makes a parallelogram.
- The diagonal of that parallelogram shows the vector difference of I_R and I_B which is equal to Current in Line 1= I_1. Moreover, by reversing the vector of I_B, it may indicate as ($-I_B$), therefore, the angle between I_R and $-I_B$ (I_B, when reversed = $-I_B$) is 60°.

  If, $I_R = I_Y = I_B = I_{PH}$ …. The phase currents

Line Currents and Phase Currents in Delta Connection

- The current flowing in Line 1 would be;

I_L or $I_1 = 2 \times I_{PH} \times \text{Cos}\ (60°/2)$
$= 2 \times I_{PH} \times \text{Cos}\ 30°$
$= 2 \times I_{PH} \times (\sqrt{3}/2)$ …… Since $\text{Cos}\ 30° = \sqrt{3}/2$
$= \sqrt{3}\ I_{PH}$

i.e. In Delta Connection, The Line current is √3 times of Phase Current

- Similarly, we can find the reaming two Line currents as same as above. i.e.,
- $I_2 = I_Y – I_R$ … Vector Difference $= \sqrt{3}\ I_{PH}$
- $I_3 = I_B – I_Y$ … Vector difference $= \sqrt{3}\ I_{PH}$

Line Currents and Phase Currents in Delta Connection

As, all the Line current are equal in magnitude i.e.

$$I_1 = I_2 = I_3 = I_L$$

Hence

$$IL = \sqrt{3}\ I_{PH}$$

- It is seen from the fig above that;
- The Line Currents are 120° apart from each other
- Line currents are lagging by 30° from their corresponding Phase Currents
- The angle Φ between line currents and respective line voltages is (30°+Φ), i.e. each line current is lagging by (30°+Φ) from the corresponding line voltage.

Power in Delta Connection

We know that the power of each phase

$$\text{Power / Phase} = V_{PH\,x}\, I_{PH} \times \text{Cos}\Phi$$

And the total power of three phases;

$$\text{Total Power} = P = 3 \times V_{PH\,x}\, I_{PH} \times \text{Cos}\Phi \;\ldots..\; (1)$$

We know that the values of Phase Current and Phase Voltage in Delta Connection;

$I_{PH} = I_L / /\sqrt{3}$ ..... (From IL = $\sqrt{3}\, I_{PH}$)

$V_{PH} = V_L$

Putting these values in power eq……. (1)

$P = 3 \times V_L \times (I_L/\sqrt{3}) \times \text{Cos}\Phi$ …… ($I_{PH} = I_L / /\sqrt{3}$)

$P = \sqrt{3} \times\sqrt{3} \times V_L \times (I_L/\sqrt{3}) \times \text{Cos}\Phi$ …{ $3 = \sqrt{3}\times\sqrt{3}$ }

$P = \sqrt{3} \times V_L \times I_L \times \text{Cos}\Phi$ …

Power in Delta Connection,

$P = 3 \times V_{PH\,x}\, I_{PH} \times \text{Cos}\Phi$ …. or

$P = \sqrt{3} \times V_L \times I_L \times \text{Cos}\Phi$

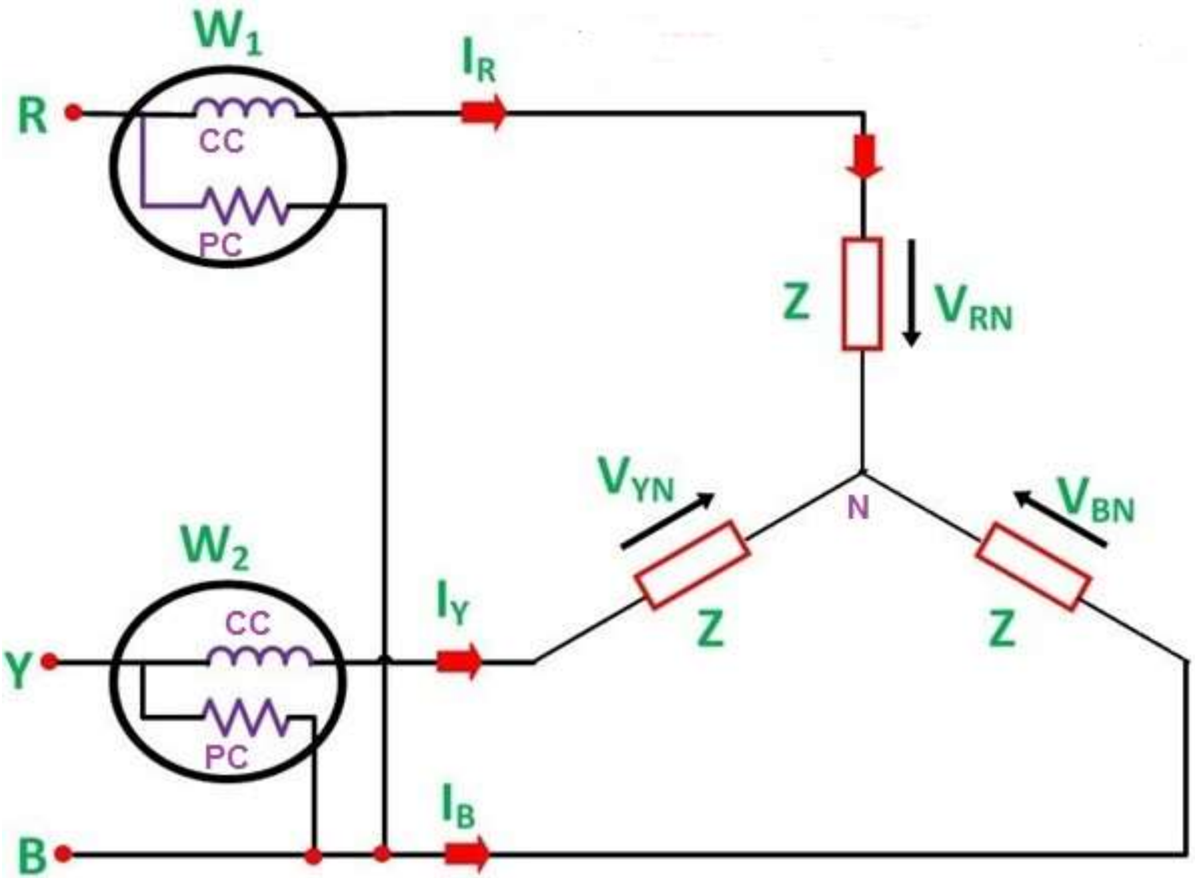
Measurement of Three Phase Power

- There are three methods which are used for the measurement of three phase power in three phase circuits. The three methods are:
- Three Wattmeter Method
- Two Wattmeter Method
- Single Wattmeter Method

Two Wattmeter Method

- In two wattmeter method, a three phase balanced voltage is to a balanced three phase load
- where the current in each phase is assumed lagging by an angle of Ø behind the corresponding phase voltage.
-

Two Wattmeter Method



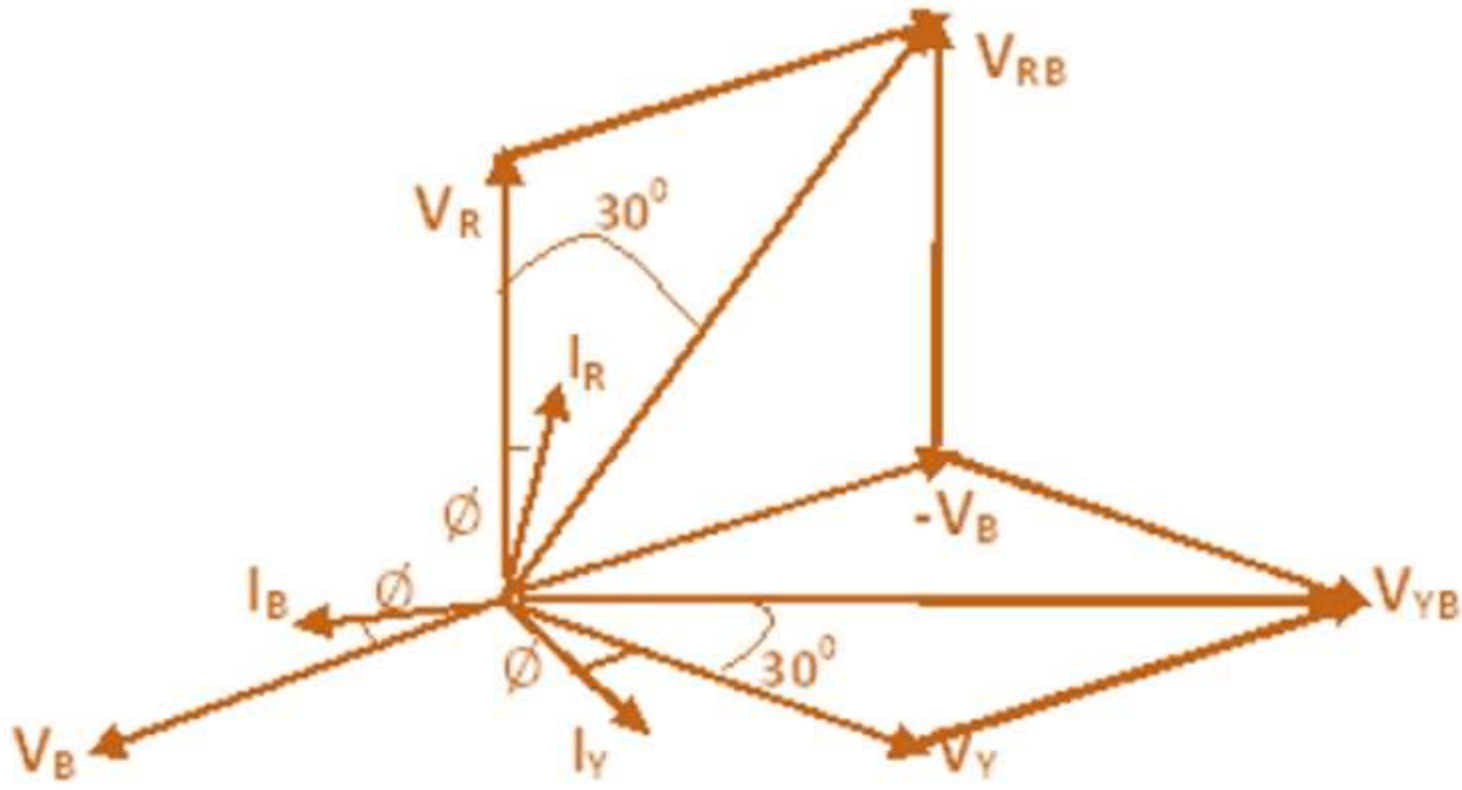
Two Wattmeter Method

- From the figure, it is obvious that current through the Current Coil (CC) of Wattmeter $W_1 = I_R$

current though Current Coil of wattmeter $W_2 = I_B$

whereas the potential difference of Pressure Coil (PC) of wattmeter $W_1 = V_{RB}$ (Line Voltage) and potential difference seen by Pressure Coil of wattmeter $W_2 = V_{BY}$.

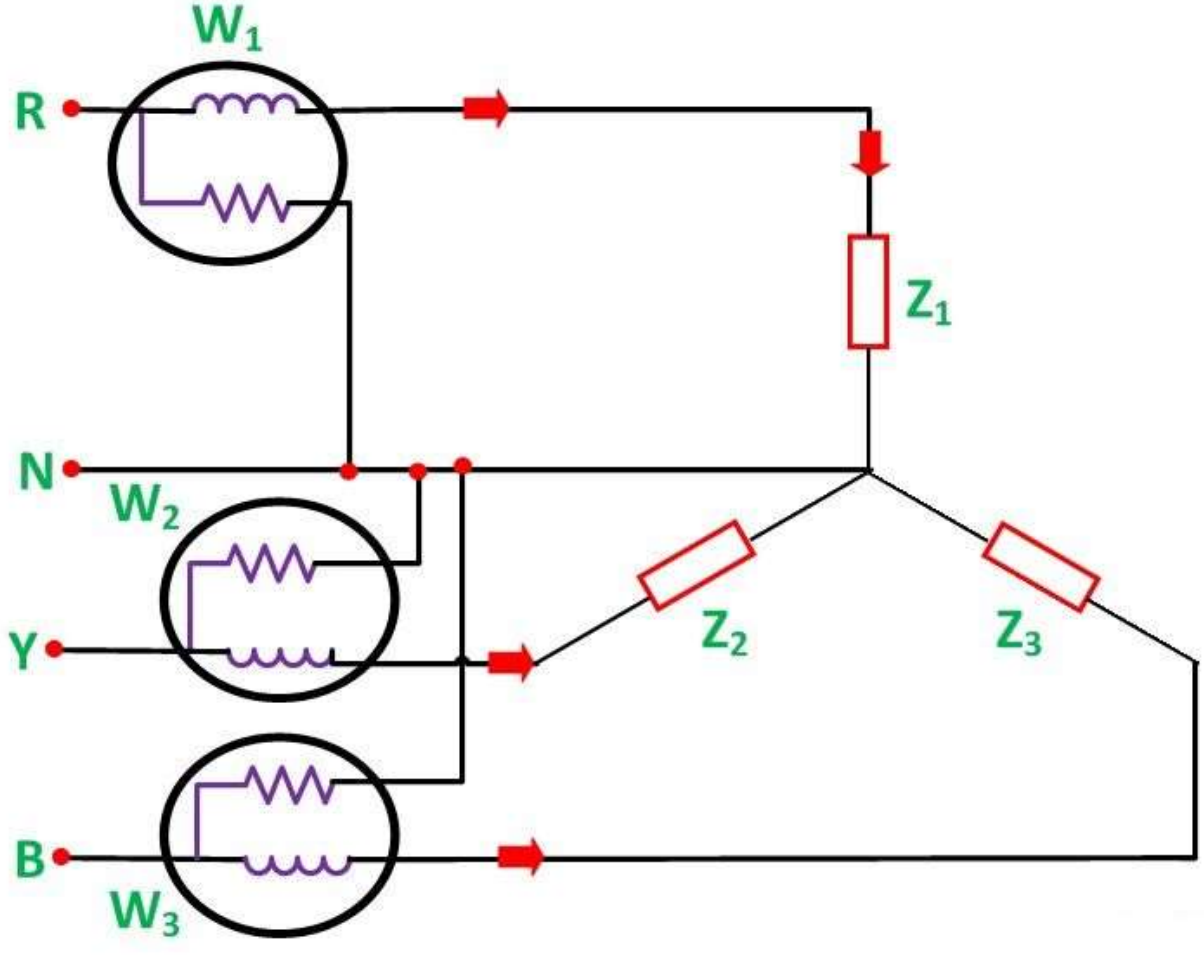
The phasor diagram of the above circuit is drawn by taking VR as reference phasor as shown below.



Three-Wattmeter Method of Three Phase Power Measurement

- Three Wattmeter method is employed to measure power in a 3 phase, 4 wire system.However, this method can also be employed in a 3 phase, 3 wire delta connected load, where power consumed by each load is required to be determined separately.
- The connections for star connected loads for measuring power by Three wattmeter method is shown below.

Three-Wattmeter Method of Three Phase Power Measurement



Three-Wattmeter Method of Three Phase Power Measurement

- The pressure coil of all the Three wattmeters namely W_1, W_2 and W_3 are connected to a common terminal known as the neutral point. The product of the phase current and line voltage represents as phase power and is recorded by individual wattmeter.
- The total power in a Three wattmeter method of power measurement is given by the algebraic sum of the readings of Three wattmeters. i.e.

Total power $P = W_1 + W_2 + W_3$

Where,

$W_1 = V_1 I_1$
$W_2 = V_2 I_2$
$W_3 = V_3 I_3$