



MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent institution of MAHE, Manipal)



Basic Electrical Technology

[ELE 105 I]

Three Phase AC Circuits

L24 – Power Associated with Three Phase System

Topics Covered

Power in 3 phase system: active, reactive and apparent.

Power measurement

Three Phase Power

I. Star Connected Load

Complex Power,

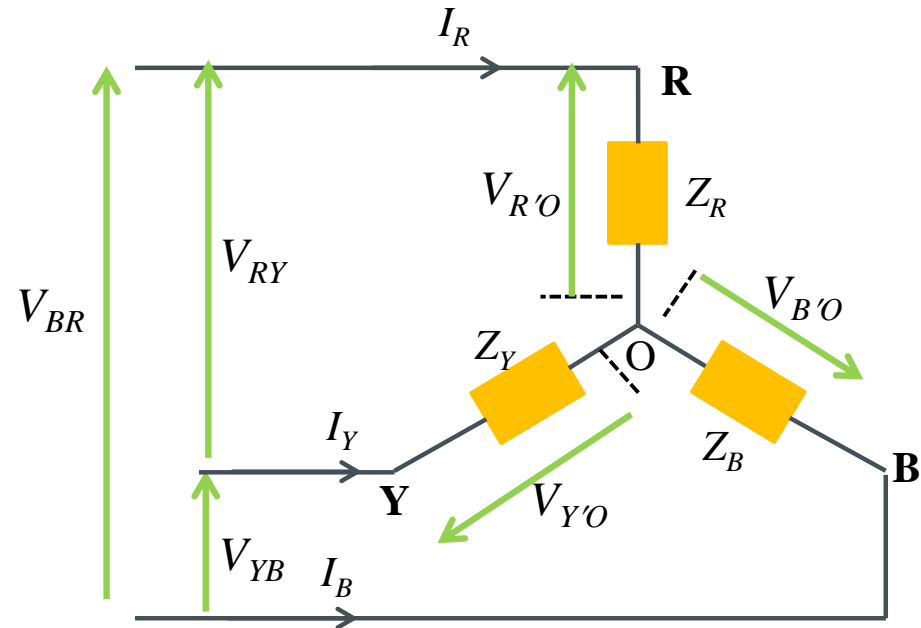
$$S = V_{R'O} I_R^* + V_{Y'O} I_Y^* + V_{B'O} I_B^*$$

Active Power,

$$P = V_{R'O} I_R \cos \angle(V_{R'O} \& I_R) + V_{Y'O} I_Y \cos \angle(V_{Y'O} \& I_Y) + V_{B'O} I_B \cos \angle(V_{B'O} \& I_B)$$

Reactive Power,

$$Q = V_{R'O} I_R \sin \angle(V_{R'O} \& I_R) + V_{Y'O} I_Y \sin \angle(V_{Y'O} \& I_Y) + V_{B'O} I_B \sin \angle(V_{B'O} \& I_B)$$



For Balanced Load,

Complex Power, $S = \sqrt{3} V_L I_L^*$

Active Power, $P = \sqrt{3} V_L I_L \cos \angle \pm \theta$

Reactive Power, $Q = \sqrt{3} V_L I_L \sin \angle \pm \theta$

Apparent Power, $S = \sqrt{3} V_L I_L$

Three Phase Power...

2. Delta Connected Load

Complex Power,

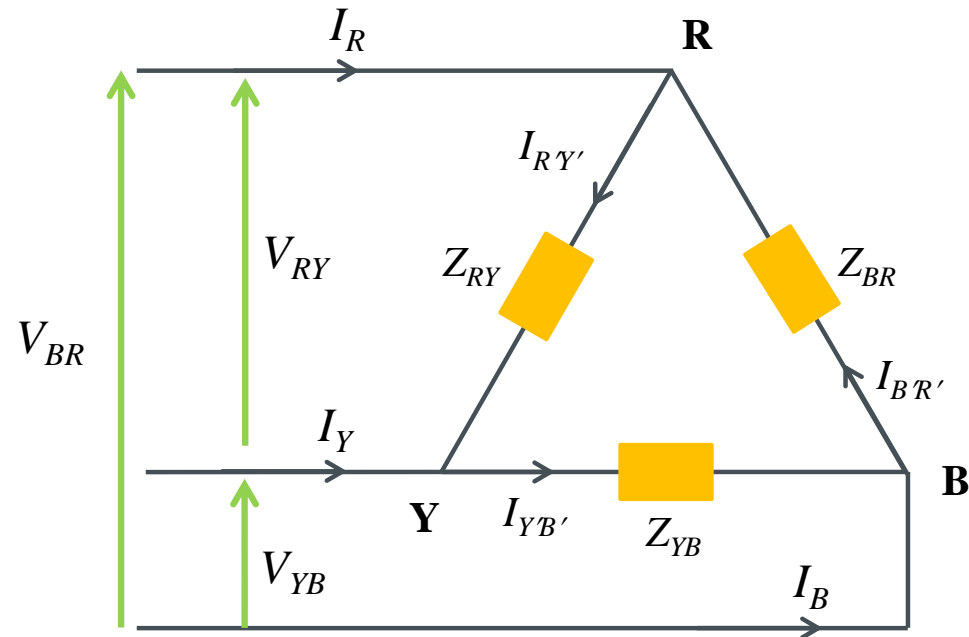
$$S = V_{RY} I_{R'Y'}^* + V_{YB} I_{Y'B'}^* + V_{BR} I_{B'R'}^*$$

Active Power,

$$\begin{aligned} P = & V_{RY} I_{R'Y'} \cos \angle(V_{RY} \& I_{RY}) \\ & + V_{YB} I_{Y'B'} \cos \angle(V_{YB} \& I_{YB}) \\ & + V_{BR} I_{B'R'} \cos \angle(V_{BR} \& I_{BR}) \end{aligned}$$

Reactive Power,

$$\begin{aligned} Q = & V_{RY} I_{R'Y'} \sin \angle(V_{RY} \& I_Y) \\ & + V_{YB} I_{Y'B'} \sin \angle(V_{YB} \& I_{YB}) \\ & + V_{BR} I_{B'R'} \sin \angle(V_{BR} \& I_{BR}) \end{aligned}$$



For Balanced Load,

Complex Power, $S = 3 V_{ph} I_{ph}^*$

Active Power, $P = \sqrt{3} V_L I_L \cos \angle \pm \theta$

Reactive Power, $Q = \sqrt{3} V_L I_L \sin \angle \pm \theta$

Apparent Power, $S = \sqrt{3} V_L I_L$

Exercise- I

A balanced star connected load of $8+j6 \Omega$ per phase is connected to a 3 phase, 415V supply. Find the line currents, power factor, power, reactive volt amperes and total volt amperes.

Exercise-2

A star connected load is supplied from a symmetrical three phase, 440V system. The branch impedances of the load are $Z_R = 5 \angle 30^\circ \Omega$, $Z_Y = 10 \angle 45^\circ \Omega$, $Z_B = 10 \angle 60^\circ \Omega$. Find the active power supplied by the source.

Measurement of 3 Ph.Active Power

I. Star Connected Load using 2 Wattmeter's

Wattmeter Reading,

$$W_1 = v_{RY} i_R = (v_{R'O} - v_{Y'O}) i_R$$

$$W_2 = v_{BY} i_B = (v_{B'O} - v_{Y'O}) i_B$$

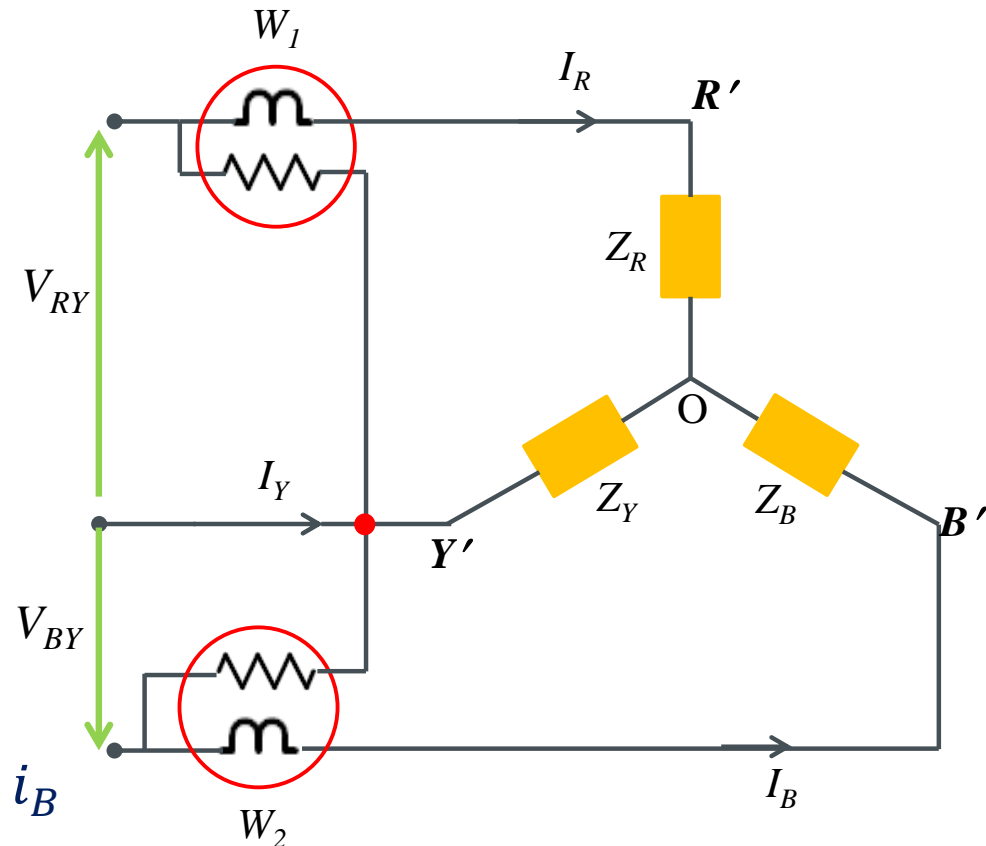
Total Active Power,

$$= W_1 + W_2$$

$$= (v_{R'O} - v_{Y'O}) i_R + (v_{B'O} - v_{Y'O}) i_B$$

$$= v_{R'O} i_R - v_{Y'O} (i_R + i_B) + v_{B'O} i_B$$

$$= v_{R'O} i_R + v_{Y'O} i_Y + v_{B'O} i_B \quad \text{Since, } i_R + i_Y + i_B = 0$$



Measurement of 3 Ph.Active Power

2. Balanced Load (Star Connected) using 2 Wattmeter's

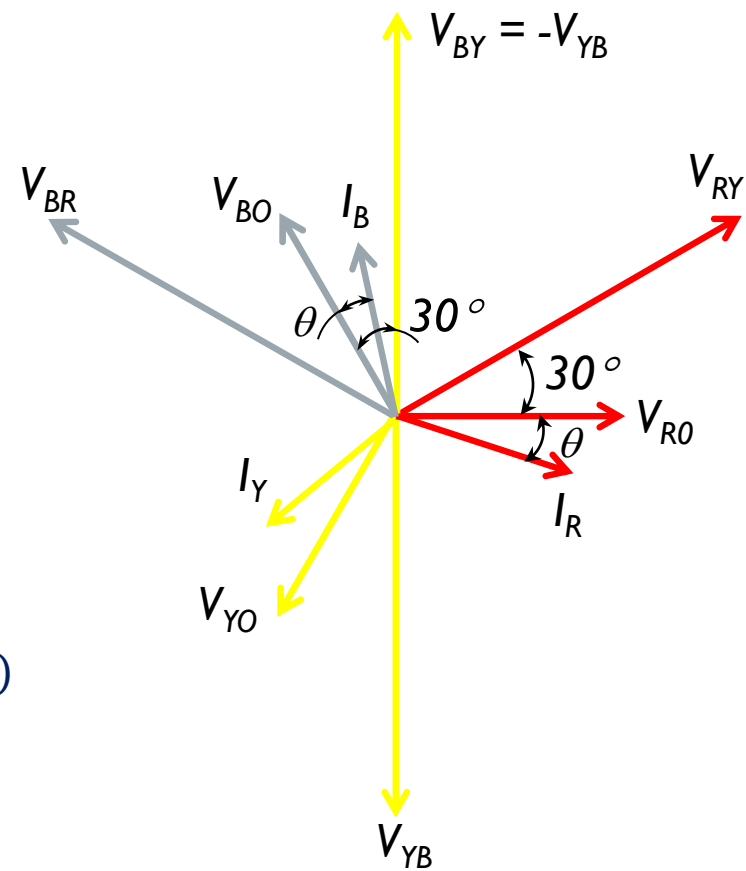
Wattmeter Reading,

$$\begin{aligned} W_1 &= V_{RY} I_R \cos \angle (V_{RY} \& I_R) \\ &= V_L I_L \cos(30^\circ + \theta) \end{aligned}$$

$$\begin{aligned} W_2 &= V_{BY} I_B \cos \angle (V_{BY} \& I_B) \\ &= V_L I_L \cos(30^\circ - \theta) \end{aligned}$$

Total active power consumed,

$$\begin{aligned} P &= W_1 + W_2 \\ &= V_L I_L \cos(30^\circ + \theta) + V_L I_L \cos(30^\circ - \theta) \\ &= \sqrt{3} \times V_L I_L \cos \theta \end{aligned}$$



Meas. of 3 Ph.Active Power...

Summation of two wattmeters,

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

Difference in the reading of two wattmeters,

$$W_2 - W_1 = V_L \times I_L \times \sin \theta$$

Hence,

$$\frac{W_2 - W_1}{W_2 + W_1} = \frac{\sin \theta}{\sqrt{3} \times \cos \theta}$$

$$\theta = \tan^{-1} \left[\sqrt{3} \times \frac{W_2 - W_1}{W_2 + W_1} \right]$$

$$\text{Power factor of the Balanced Load} = \cos \theta = \cos \left\{ \tan^{-1} \left[\sqrt{3} \times \frac{W_2 - W_1}{W_2 + W_1} \right] \right\}$$

Measurement of 3 Ph.Active Power

3. Balanced Load (Star Connected) using 1 Wattmeter

Wattmeter Reading,

$$W_1 = V_{R'O} I_R \cos \angle (V_{R'O} \text{ \& } I_R)$$

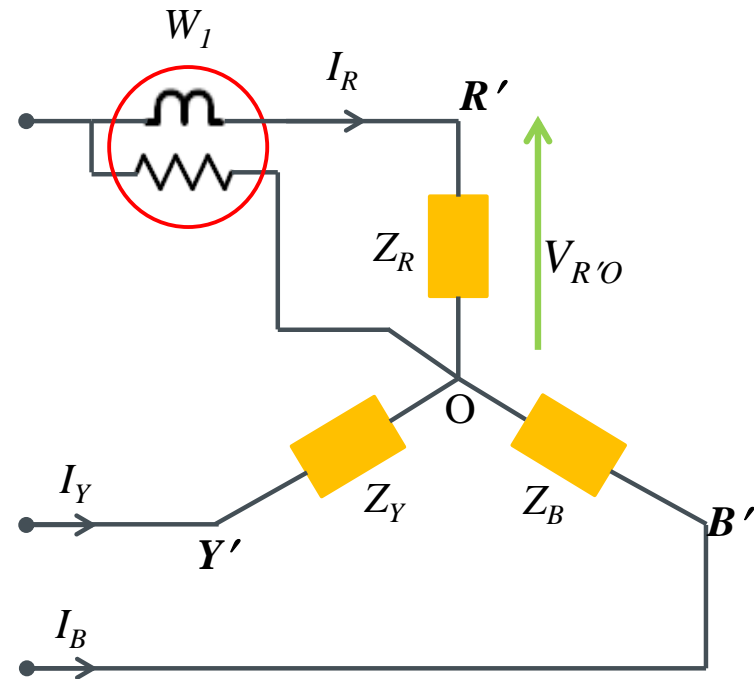
$$= V_{Ph} I_{Ph} \cos \theta$$

Total active power consumed,

$$= 3 \times W_1$$

$$= 3 \times V_{Ph} I_{Ph} \cos \theta$$

$$= \sqrt{3} \times V_L I_L \cos \theta$$



Measurement of 3 Ph.Active Power

4. Balanced Load (Delta Connected) using 1 Wattmeter

Wattmeter Reading,

$$W_1 = V_{R'Y'} I_{R'Y'} \cos \angle (V_{R'Y'} \text{ \& } I_{R'Y'})$$

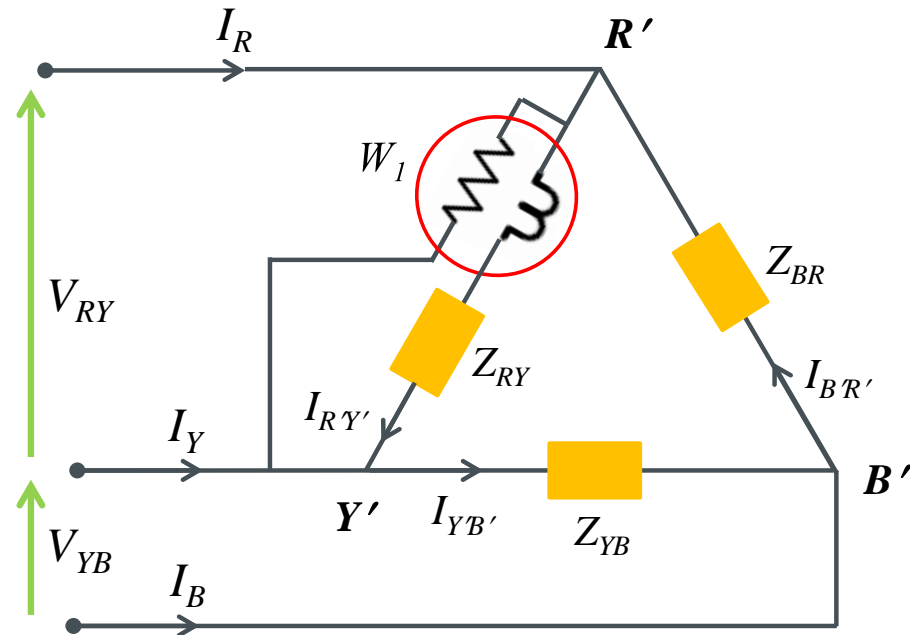
$$= V_L I_{Ph} \cos \theta$$

Total active power consumed,

$$= 3 \times W_1$$

$$= 3 \times V_L I_{Ph} \cos \theta$$

$$= \sqrt{3} \times V_L I_L \cos \theta$$



Exercise-3

Three identical impedances of $(8+j6) \Omega$ are connected in delta across a symmetrical 3 phase, 3 wire 400 V system. Calculate the power factor using wattmeter readings.

Exercise-4

Three loads $Z_R = 5 \angle 30^\circ \Omega$, $Z_Y = 10 \angle 45^\circ \Omega$, $Z_B = 10 \angle 60^\circ \Omega$ are connected in Star to R, Y and B Phase respectively. The current coils of the two wattmeters are connected in R & Y lines. If the supply voltage is 415V, 50 Hz, determine the reading of the two wattmeters. Assume the phase sequence is RBY.

Summary

Measurement of Active Power for a three phase Star/Delta connected balanced/unbalanced load can be performed by using two wattmeters.

For a balanced Load, the Load Power factor can be measured by using one or two wattmeter method.

Measurement of power for a balanced Star/Delta load can be performed using one wattmeter.