Basic Electrical Technology

[ELE 1051]

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

1. Star Connected Load

Complex Power,

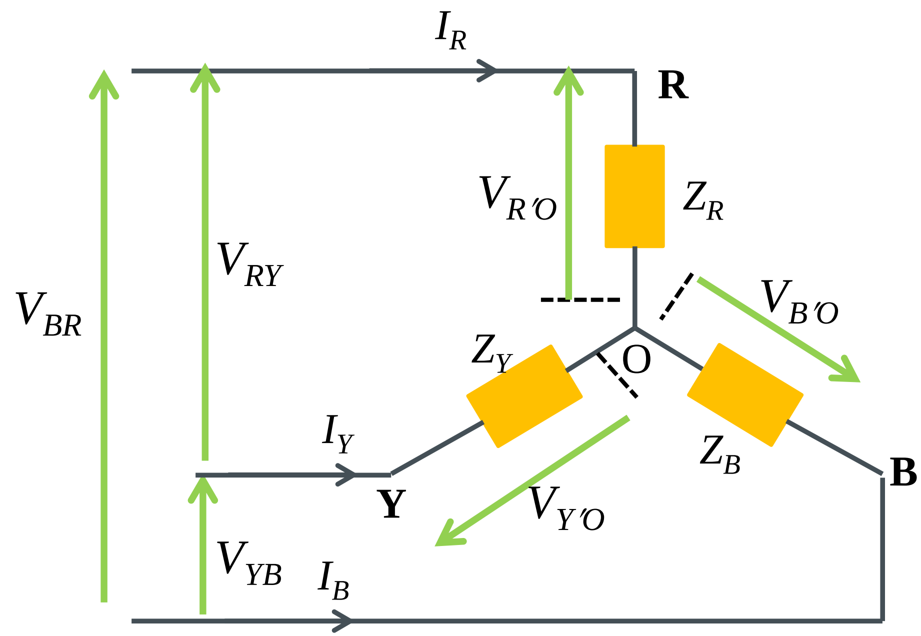
$$S = V_{R'O} I_R^* + V_{Y'O} I_Y^* + V_{B'O} I_B^*$$

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…

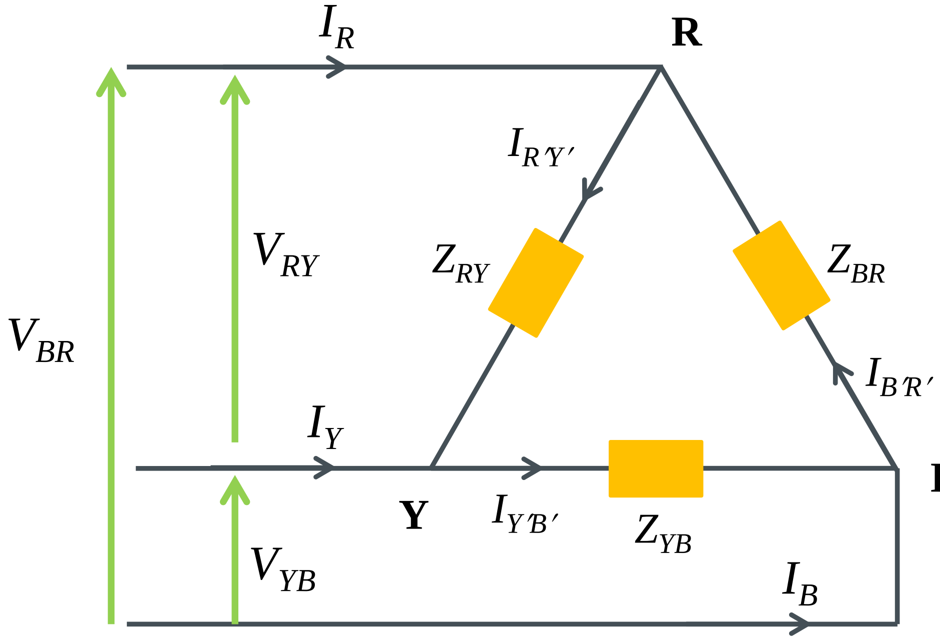
2. Delta Connected Load

Complex Power,

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

Active Power,

$$P = V_{RY}\, I_{R'Y'}\, Cos\angle(\, V_{RY}\, \&\, I_{RY})$$
$$+ V_{YB}\, I_{Y'B'}\, Cos\angle(\, V_{YB}\, \&\, I_{YB})$$
$$+ V_{BR}\, I_{B'R'}\, Cos\angle(\, V_{BR}\, \&\, I_{BR})$$



Reactive Power,

$$Q = V_{RY}\, I_{R'Y'}\, Sin\angle(\, V_{RY}\, \&\, I_{RY})$$
$$+ V_{YB}\, I_{Y'B'}\, Sin\angle(\, V_{YB}\, \&\, I_{YB})$$
$$+ V_{BR}\, I_{B'R'}\, Sin\angle(\, V_{BR}\, \&\, I_{BR})$$

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-1

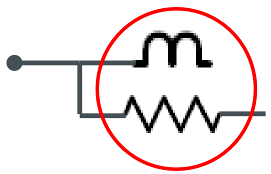
A balanced star connected load of 8+j6 Ω per phase is connected to a 3 phase, 415V supply. Find the line currents, power factor, power, reactive volt amperes and total volt amperes.

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

Power is measured using Wattmeter



It has a current coil connected in series & Potential coil connected in parallel

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Measurement of 3 Ph. Active Power

1. Balanced Load (Star Connected) using 1 Wattmeter

Wattmeter Reading,

$$W_1 = V_{R'O}\, I_R\, Cos\angle(\, V_{R'O}\ \&\ I_R)$$

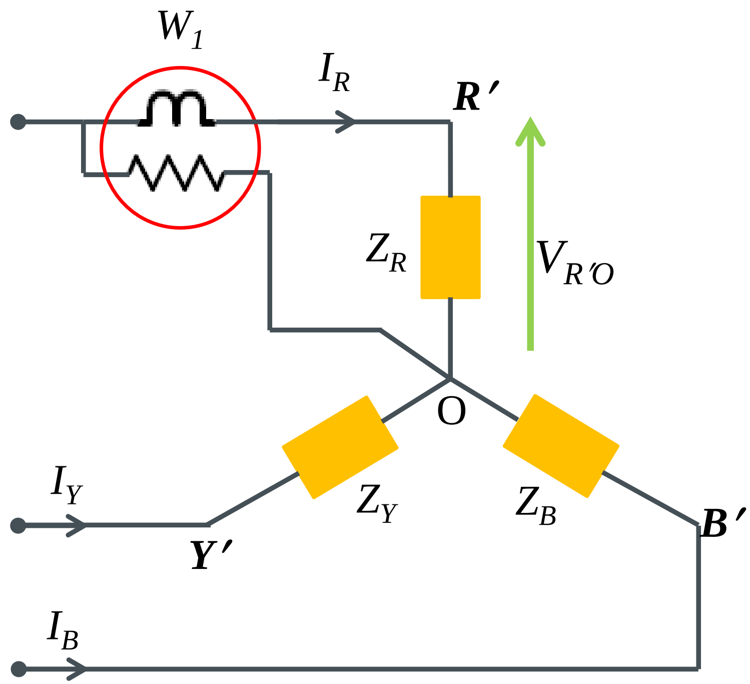
$$= V_{Ph}\, I_{Ph}\, Cos\theta$$

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

2. Balanced Load (Delta Connected) using 1 Wattmeter

Wattmeter Reading,

$$W_1 = V_{R'Y'}\, I_{R'Y'}\, Cos\angle(\, V_{R'Y'}\ \&\ I_{R'Y'})$$

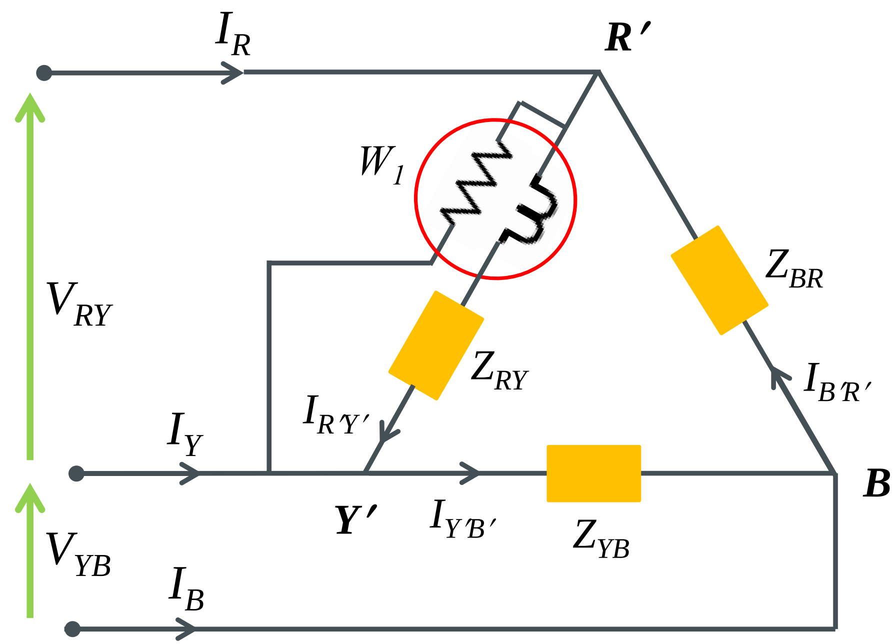
$$= V_L\, I_{Ph}\, Cos\theta$$

Total active power consumed,

$$= 3 \times W_1$$

$$= 3 \times V_L\, I_{Ph}\, Cos\theta$$

$$= \sqrt{3} \times V_L\, I_L\, Cos\theta$$



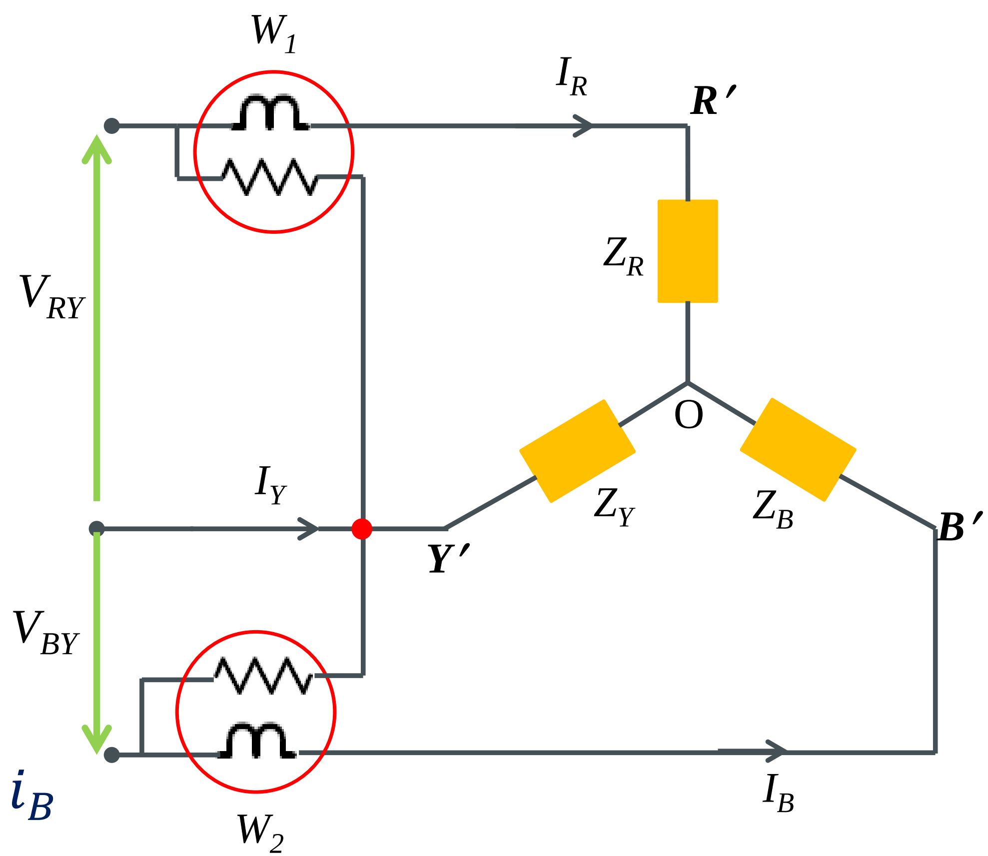
Measurement of 3 Ph. Active Power

3. 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,

$$= W_1 + W_2$$

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

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

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

Measurement of 3 Ph. Active Power

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

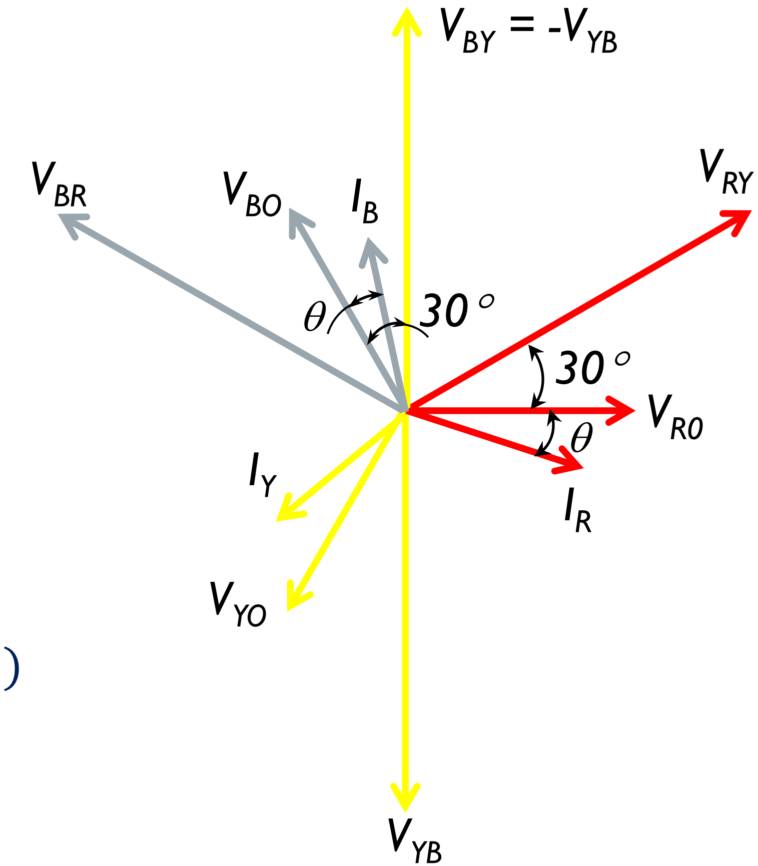
Wattmeter Reading,

$$W_1 = V_{RY}\, I_R\, Cos\angle(\,V_{RY}\,\&\,I_R)$$
$$= V_L\, I_L\, Cos(30° + \theta)$$

$$W_2 = V_{BY}\, I_B\, Cos\angle(\,V_{BY}\,\&\,I_B)$$
$$= V_L\, I_L\, Cos(30° - \theta)$$

Total active power consumed,

$$P = W_1 + W_2$$
$$= V_L\, I_L\, Cos(30° + \theta) + V_L\, I_L\, Cos(30° - \theta)$$
$$= \sqrt{3} \times V_L\, I_L\, Cos\theta$$



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,

$$\frac{W_2 - W_1}{W_2 + W_1} = \frac{Sin\ \theta}{\sqrt{3} \times Cos\ \theta}$$

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

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

Exercise-3

Three identical impedances of (8+j6) Ω are connected in delta across a symmetrical 3 phase, 3 wire 400V 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.*

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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.