Three-Phase Power Measurement

Wattmeter is the instrument used for power measurement. Fig. 1 shows a wattmeter (W) and its connection with a single-phase load. It has two coils, one is called as current coil (cc) and the other is the voltage coil (vc). The current coil is connected in series and the voltage coil is connected across the load or supply whose power is intended to be measured.

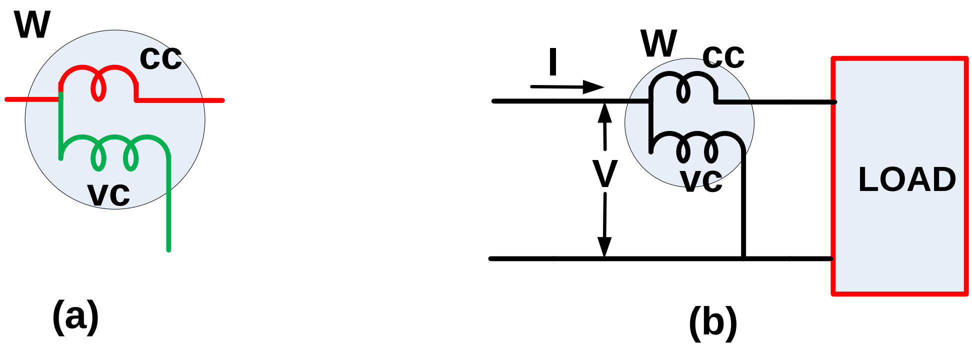

Fig. 1

For a three-phase system three wattmeters are required. Three-phase power can also be measured using two wattmeters. In addition to real power, the power factor and the reactive power can be estimated from the readings of the two wattmeters. Two wattmeter method for measurement of three-phase power is depicted in Fig. 2.

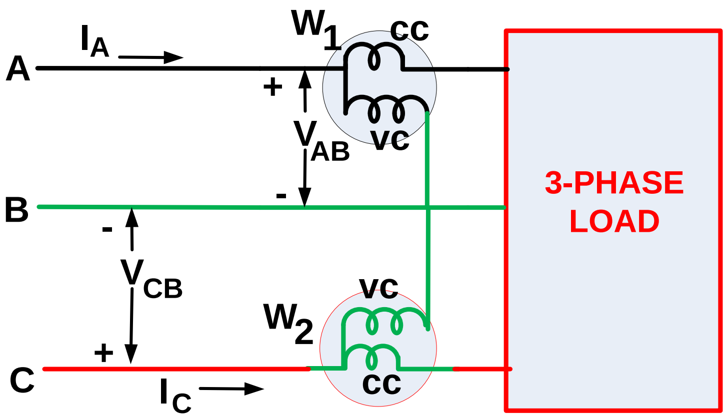

Fig. 2

The current I_A flows through the current coil of **W**$_1$ and V_{AB} is the voltage sensed by the voltage coil of **W**$_1$. Similarly, I_C flows through the current coil of **W**$_2$ and V_{CB} is the voltage across its voltage coil. From Fig. 3, one can see phase angles between the line voltages and the currents.

$$W_1 = V_{AB}I_A\cos(30^0 + \theta) = V_L I_L \cos(30^0 + \theta)$$
$$W_2 = V_{CB}I_c\cos(30^0 - \theta) = V_L I_L \cos(30^0 - \theta)$$
$$W_1 + W_2 = V_L I_L\{\cos(30^0 + \theta) + \cos(30^0 - \theta)\}$$
$$= V_L I_L\{2\cos 30^0 . \cos\theta\}$$
$$= V_L I_L\left\{2 \times \frac{\sqrt{3}}{2} \cdot \cos\theta\right\}$$
$$= \sqrt{3} V_L I_L \cos\theta = P = \ Total\ Power$$

$$W_2 - W_1 = V_L I_L sin\theta \qquad \tan\theta = \sqrt{3}(\frac{W_2 - W_1}{W_1 + W_2})$$

Power Factor = $cos[\tan^{-1}\left\{\sqrt{3}(\frac{W2\ \ -W_1}{W_1 + W_2})\right\}]$

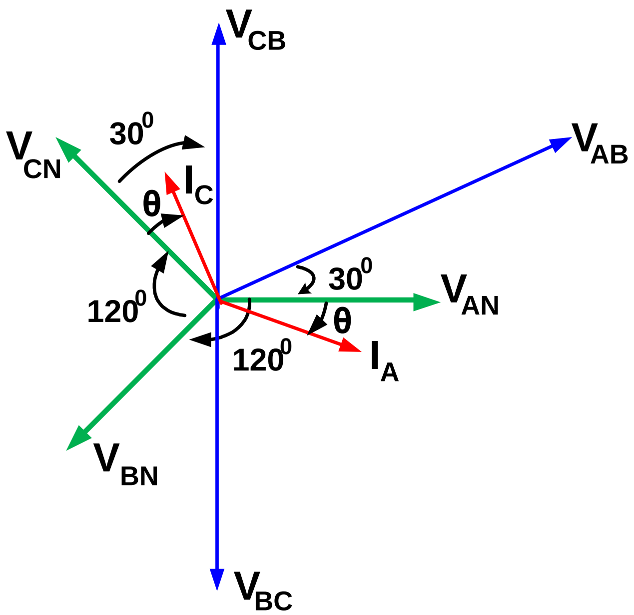

Fig. 3

Example: A 440 volt, 3-phase line supplies to an inductive delta connected load. Two wattmeter method is employed to measure the 3-phase power. If the two wattmeter readings are $W_1 = 15\ KW$ and $W_2 = 5\ KW$, find

(a) The line current

(b) The power factor

(c) Load resistance per phase and

(d) Load reactance per phase.

Solution:

12. Real power consumed by the load = $\boldsymbol{W_1 + W_2 = 15\ KW + 5\ KW = 20\ KW}$

    Reactive power consumed by the inductive load = $\sqrt{\mathbf{3}}\ \times (\boldsymbol{W_1 - W_2}) = \mathbf{17.32}\ \boldsymbol{kW}$

    (a) Line current = $\frac{\mathbf{20+}\boldsymbol{j}\mathbf{17.32}}{\sqrt{\mathbf{3}}\ \times\mathbf{440}} = \mathbf{34.71\angle 40.89^0}$

    (b) Power factor = $\mathbf{cos}\left(\mathbf{tan^{-1}}\left(\frac{\sqrt{3}\ (W_1 - W_2)}{\mathbf{W1 + W2}}\right)\right) = \mathbf{0.7559}$

    (c) Load resistance per phase = $\boldsymbol{R_{ph}} = \frac{\boldsymbol{real\ power\ consumed}}{|I_L|^2} = \frac{\mathbf{20}\ \boldsymbol{kW}}{\mathbf{34.71^2}} = \mathbf{16.6}\ \Omega$

    (d) Load reactance per phase = $\boldsymbol{X_{ph}} = \frac{\boldsymbol{reactive\ power\ consumed}}{|I_L|^2} = \frac{\mathbf{17.32}\ \boldsymbol{kW}}{\mathbf{34.71^2}} = \mathbf{14.376}\ \Omega$