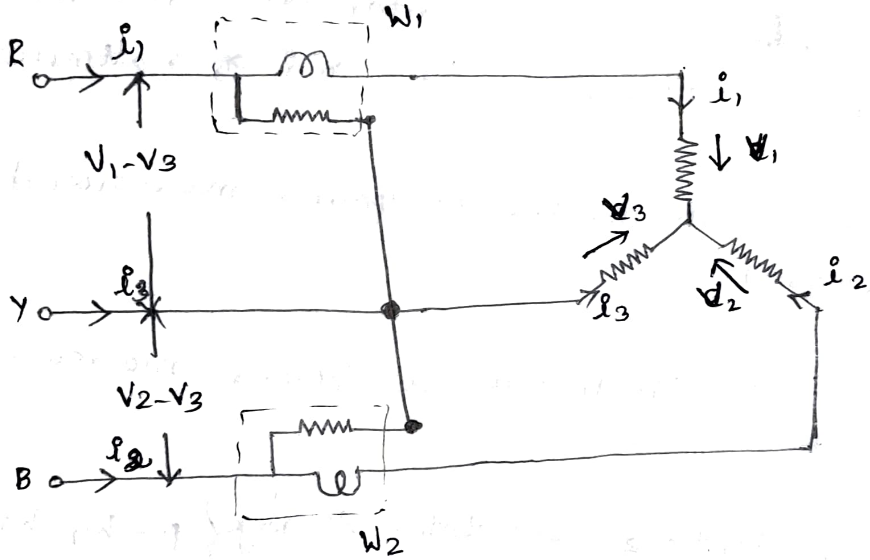
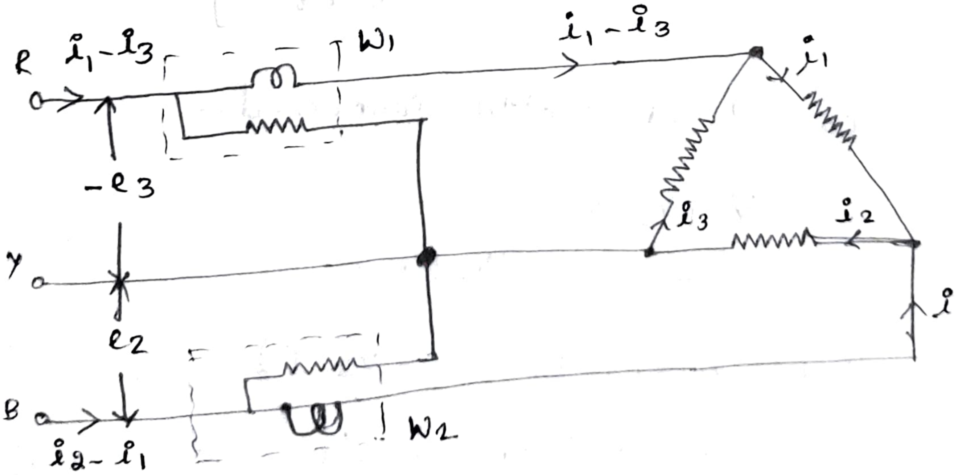
method :-

→ This method is applied usually for measuring the electrical Power in 3-phase, 3-wire circuit. The load may be balanced (or) unbalanced. It may connected either in delta (or) star

→ The current coils of 2-Wattmeters are inserted in two of the lines and voltage coil of each Wattmeter is connected from it's own current coil to the line in which no Wattmeter has been connected. The connections of Wattmeter in this method are shown below,





* The Instantaneous power, $P = V_1 . i_1 + V_2 . i_2 + V_3 . i_3$ — (1)

$\therefore i_1 + i_2 + i_3 = 0$

(or) $i_3 = -(i_1 + i_2)$

sub $i_3 = -(i_1 + i_2)$

$$P = V_1 . i_1 + V_2 . i_2 - V_3 . (i_1 + i_2)$$

$$P = i_1 (V_1 - V_3) + i_2 (V_2 - V_3)$$

i_1 = Instantaneous current flowing through the current coil of Wattmeter

$(V_1 - V_3)$ = the Instantaneous Potential difference across voltage coil of Wattmeter-1

$i_1 . (V_1 - V_3)$ = Instantaneous power measured by Wattmeter-1

$i_2 (V_2 - V_3)$ = Instantaneous Power measured by Wattmeter-2

$\therefore P = W_1 + W_2$ (or) total Average Power $\}$ $P = W_1 + W_2$

Case (b) :- Load - Delta connected :-

$V_1 + V_2 + V_3 = 0$

(or) $V_1 = -(V_2 + V_3)$

$$\therefore P = V_1 . i_1 + V_2 . i_2 + V_3 . i_3$$

$$= -(V_2 + V_3) . i_1 + V_2 . i_2 + V_3 . i_3$$

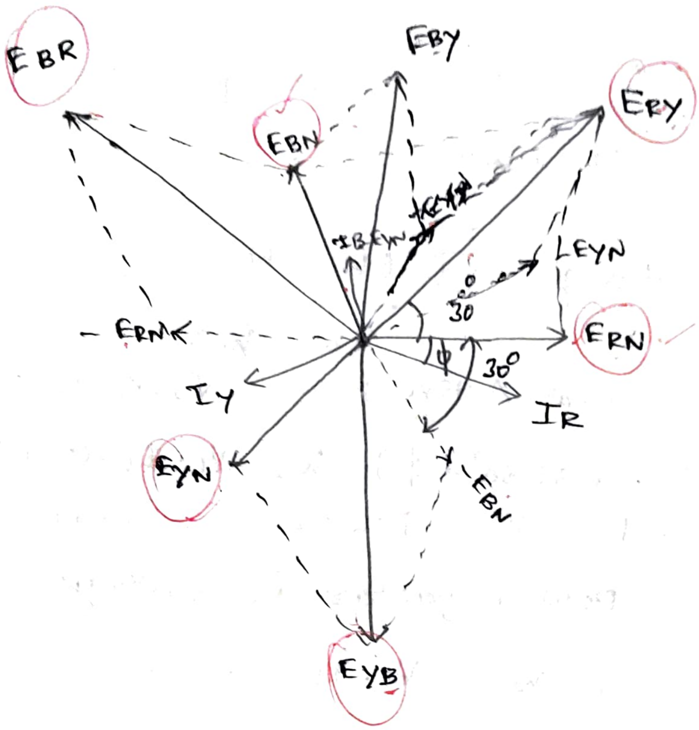
$$P = -V_3 (i_1 - i_3) + V_2 (i_2 - i_1)$$

$\therefore$ $-e_3$ - Instantaneous potential difference across the voltage coil of Wattmeter-1

$\therefore (I_1 - I_3)$ - current flowing through Wattmeter-1

$\therefore$ Total Instantaneous power, $P = W_1 + W_2$

* phasor diagram:-



$\cos(90° - \phi) = \sin\phi$

$\cancel{\sin\phi}$
$\cos\phi = \sin(90° + \phi)$

→ Reading of Wattmeter-1 = W_1

$\therefore W_1 = V_{RY} \cdot I_R \cdot \cos(30° + \phi)$

$W_1 = V_L \cdot I_L \cdot \cos(30° + \phi)$ —— (1)

→ Reading of Wattmeter-2 = W_2

$\therefore W_2 = V_{BR} \cdot I_B \cdot \cos(30° - \phi)$

$W_2 = V_L \cdot I_L \cdot \cos(30° - \phi)$ —— (2)

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

$= V_L \cdot I_L [(\cos 30° + \cos\phi) + \cancel{V_L I_L} \cdot \cos 30° - \cos\phi]$

$= V_L \cdot I_L [2 \cos 30°$

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

$W_1 - W_2 = \cancel{\ } \cdot W_L \cdot I_L \cdot \sin\phi$

$$\therefore \frac{\cancel{W_2 - W_1}}{W_2 + W_1} = \frac{\cancel{V_L \cdot I_L \cdot \sin\phi}}{\sqrt{3} \cdot V_L \cdot I_L \cdot \cos\phi}$$

$$\sqrt{3} \cdot (W_2 - W_1) = \cancel{V_P}\ \sqrt{3} \cdot V_L \cdot I_L \cdot \sin\phi$$

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

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

$W_1 + W_2$ = TOTAL Active power $= \sqrt{3} \cdot V_L \cdot I_L \cdot \cos\phi$

$W_1 = V_L \cdot I_L \cdot \cos(30^\circ + \phi)$, $W_2 = V_L \cdot I_L \cdot \cos(30^\circ - \phi)$

$W_2 - W_1$ = Reactive Power $= \sqrt{3} \cdot V_L \cdot I_L \cdot \sin\phi$

(i) $\phi = 0^\circ$, power factor is unity

$$W_1 = W_2 = V_L \cdot I_L \cdot \cos 30^\circ$$

Readings of both Wattmeter are equal in magnitude

(ii) $\phi = 60^\circ$, power factor is $= 0.5$ and $\phi < 60^\circ > 0.5$

$$W_1 = V_L \cdot I_L \cdot \cos(30^\circ + 60^\circ) = V_L \cdot I_L \cdot \cos 90^\circ = 0$$

$$W_2 = V_L \cdot I_L \cdot \cos(30^\circ - 60^\circ) = \frac{\sqrt{3}}{2} V_L \cdot I_L$$

(iii) $90^\circ > \phi > 60^\circ$ | $W_1 = 0$, W_2 = Read the total power

$W_2 = +ve$, ($W_1 = -ve$)

Power factor < 0.5

(iv) $\phi = 90^\circ$,

$$W_1 = V_L \cdot I_L \cdot \sin 30^\circ$$

$$W_2 = -V_L \cdot I_L \cdot \sin 30^\circ$$

$$W_1 + W_2 = 0$$

* In 2-Wattmeter method, total Reactive power can also be found

$\therefore$ Total Reactive power $= \sqrt{3}\, V_L . I_L . \sin\phi$

$= \sqrt{3}\,(W_2 - W_1)$

* power factor calculations:-

(a) $V = 277\sqrt{2} \sin(377t + 30^\circ)\, V$

$i = 5.1\sqrt{2} \sin(377t - 10^\circ) A$

$\theta = (30^\circ - (-10^\circ)) = 40^\circ$

$p.f = \cos\phi = \cos 40^\circ = 0.766 \}$; $P = 277 \times \cos\phi$

(b) $V = 679 . \sin(377t + 50^\circ)\, V$

$i = 13 . \cos(377t + 10^\circ) A$

$\cos x = \sin(x + 90^\circ)$

$i = 13 . \sin(377t + 90^\circ + 10^\circ)$

$i = 13 . \sin(377t + 100^\circ) A$ $[\because \cos x = \sin(x + 90^\circ)]$

$\theta = (50^\circ - 100^\circ) = -50^\circ$

$P.F = \cos(-50^\circ) = 0.643$

$P = \frac{679}{\sqrt{2}} \times \frac{13}{\sqrt{2}} \times 0.643 = 2.84 kW$

(c) $V = -170 . \sin(377t - 30^\circ)\, V$ $[\because -\sin x = \sin(x \pm 180^\circ)]$

$i = 8.1 . \cos(377t + 30^\circ) A$ $V = +170 . \sin(377t + 150^\circ)$

$\cos x = \sin(x + 90^\circ)$

$i = 8.1 \sin(377t + 120^\circ) A$

$\therefore \theta = (+150^\circ - (-120^\circ)) = (270^\circ)$

$\cos\phi = \cos 270^\circ =$

(d) $V = V_m . \sin\omega t$, $I = I_m . \sin(\omega t - 45^\circ)$

$\theta = (0 - (-45^\circ))$

$\theta = 45^\circ$

$\cos\phi = \cos 45^\circ = \frac{1}{\sqrt{2}} = 0.707$ (lagging)

Problem-1:- The two Wattmeter method is used to measure a power in a three-phase load. The Wattmeter Readings are 400 W and -35 W. Calculate

(i) Total active power, (ii) power factor, and

(iii) Reactive power

$W_2 = 400W$
$W_1 = -35$

1. Total Active power $= W_1 + W_2 = 400 + (-35) = 365W$

2. $\tan\phi = \sqrt{3}\dfrac{[W_2 - W_1]}{W_2 + W_1} = \sqrt{3}\dfrac{[400 - \overset{(-35)}{\cancel{400}}]}{400 + (-35)}$

$\tan\phi = 2.064$

$\phi = 64.15^0$

$\cos\phi = 0.4359$

3. Reactive power $= \sqrt{3}(W_2 - W_1) = \sqrt{3}.V_L.I_L.\sin\phi$

$W_2 - W_1 = V_L.I_L.\sin\phi$

$\therefore W_2 - W_1 = 435$

$\therefore$ Reactive power $= \sqrt{3} \times 435 = 753.44VAR$

Problem-2:- The input power to a three-phase load is 10 KW at 0.8 p.f. Two Wattmeters are connected to measure the power, find the individual readings of the Wattmeters

$W_1 + W_2 = 10 \times 10^3 = 10000$ ——— (1)

$\phi = \cos^{-1}(0.8) = 36.80^0$

$\tan\phi = 0.75 = \dfrac{\sqrt{3}[W_2 - W_1]}{[W_2 + W_1]}$

$0.75[W_2 + W_1] = \sqrt{3}W_2 - \sqrt{3}W_1$

$\dfrac{0.75}{\sqrt{3}}[W_2 + W_1] = W_2 - W_1$

0.43×1000

$\cancel{0.43W_2 + 0.43W_1} = W_2 - W_1$

$\cancel{0.57}$ $4300 = W_2 - W_1$ ——— (2)

$W_2 = 7.165$ KW

$W_1 = 2.835$ KW

problem-3:- The readings are $-3000W$ and $8000W$, load capacitive

(1) Input power = $W_1 + W_2$ = $-3000 + 8000 = 5000W$

(2) $\tan\phi = \sqrt{3}\dfrac{[W_2 - W_1]}{[W_1 + W_2]} = \sqrt{3}\dfrac{[8000-(-3000)]}{[8000+(-3000)]} = 3.81$

(3) $\phi = 75.29°$ (lead) ; $\cos\phi = 0.25$

problem-4:- $I_L = 17A$, $V_L = 440$, Wattmeter reading = 4488 VAR

$\cos\phi = 0.8$

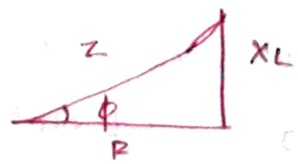
Problem-5:- The power consumed in a three phase balanced-star connected load is 2kW at a power factor of 0.8 lagging. The supply voltage is 400V, 50 Hz. calculate the resistance and reactance of each phase

$\therefore$ Power consumed = 2KW

$W_1 + W_2 = 2\times10^3 = \sqrt{3}V_L \cdot I_L \cdot \cos\phi$

$I_L = \dfrac{2000}{\sqrt{3}\times400\times0.8} = 3.6\text{ A}$

$\therefore Z_{ph} = \dfrac{V_{ph}}{I_{ph}} = \dfrac{\frac{400}{\sqrt{3}}}{3.6} = 64.15\text{ A}$



$\therefore \cos\phi = \frac{R}{Z}$; $R = Z \cdot \cos\phi$

$= 64.15 \times 0.8 = 51.32\ \Omega$

$\sin\phi = \frac{X_L}{Z}$; $X_{ph} = Z \cdot \sin\phi$

$= 64.15 \times 0.6 = 38.5\ \Omega$

Problem-6 :- Two Wattmeters to measure power 5 kW, Pf - unity. If the p.f - charged to 0.707 lagging, calulate total input power, calulate the readings of two Wattmeters

$$W_1 + W_2 = 10\,kW \quad \text{— (1)}$$

$$\tan\theta = \frac{\sqrt{3}\,[W_2 - W_1]}{[W_1 + W_2]} \qquad \cos\phi = 0.707$$

$$\phi = 45^\circ$$

$$W_2 - W_1 = \frac{10}{\sqrt{3}} = 5.773\,kW \quad \text{— (2)}$$

$$W_2 = 7.886\,kW$$

$$W_1 = 2.113\,kW$$

Problem-7 :- The input power to a 1.6 kV, 50 Hz three-phase motor is measured by using two Wattmeter method. The motor is running at full-load and full-load efficiency is 86%. The readings are 255 kW and 85 kW, respectively. Determine, (1) Input power, (2) power factor, (3) line current and (4) output power

(1) Input power $= W_1 + W_2 = 340\,kW$

(2) $$\tan\theta = \sqrt{3}\,\frac{[W_2 - W_1]}{[W_2 + W_1]} = 0.866$$

$$\cos\phi = 0.756 \text{ (lag)}$$

(3) Line current :-

$$1.6\times10^3 = V_L . I_L . \cos\phi = W_1 + W_2$$

$$I_L = \frac{\cancel{1.6\times10^3}\; W_1 + W_2}{\sqrt{3}.V_L.\cos\phi}$$

$$= 162.28\,A$$

(4). Output power :-

Output = Input × Efficiency

= 340 × 0.86 = 292.40 (kW)