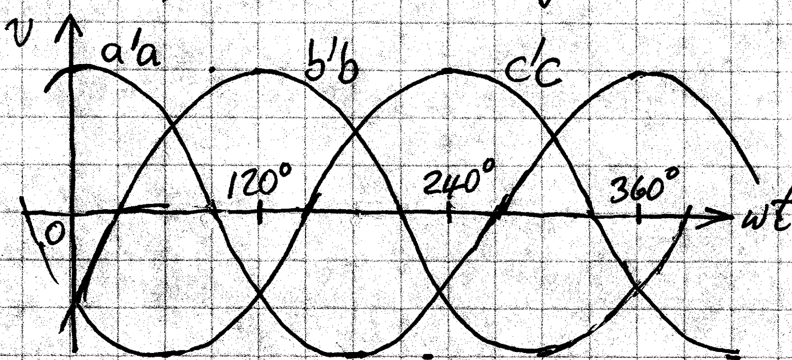
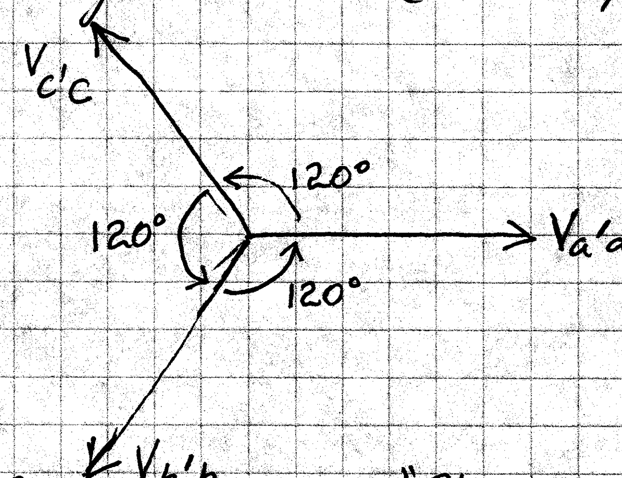
ECE 241 Lecture 17 THREE PHASE CIRCUITS

3-ϕ Generation Figs 7.25/26 3 windings on armature 120° apart.



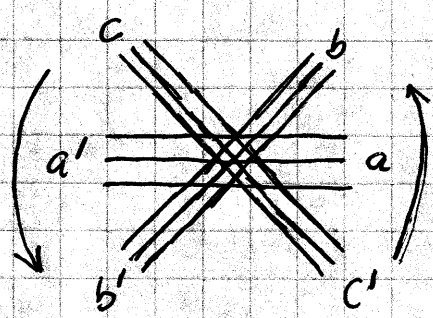


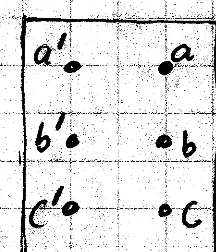
$V_{a'a} = \sqrt{2}\,V \cos\omega t$ $\quad \mathbb{V}_{a'a} = V\angle 0^\circ$

$V_{b'b} = \sqrt{2}\,V \cos(\omega t - 120^\circ)$ $\quad \mathbb{V}_{b'b} = V\angle -120^\circ$

$V_{c'c} = \sqrt{2}\,V \cos(\omega t - 240^\circ)$ $\quad \mathbb{V}_{c'c} = V\angle -240^\circ$

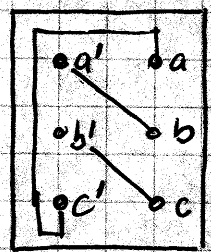
"Phase rotation" is abc

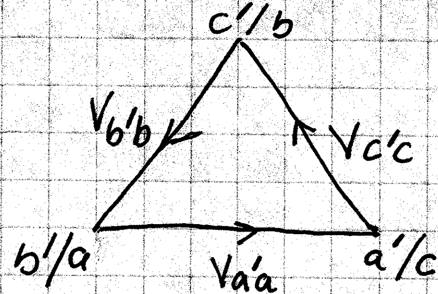




One can connect single-phase 120V loads across each phase a'a, etc. But needs 6 wires to supply multiple loads. Y & Δ connections help with 3 wires.

DELTA CONNECTION





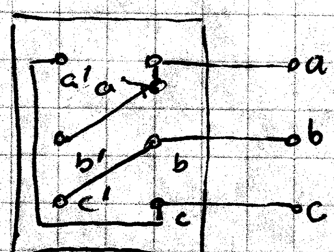
eg. $V_{a'b} = V_{a'a} + V_{c'c} + V_{b'b}$

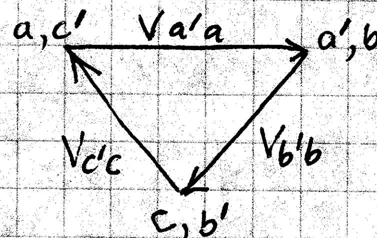
$= V_{a'a} + V_{b'b} + V_{c'c} = 0$

as expected since $V_{a'b} = 0$

3 single-ϕ wires ; lab weightings

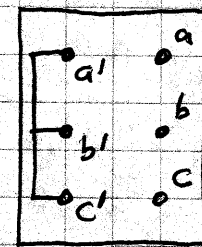
Alternative

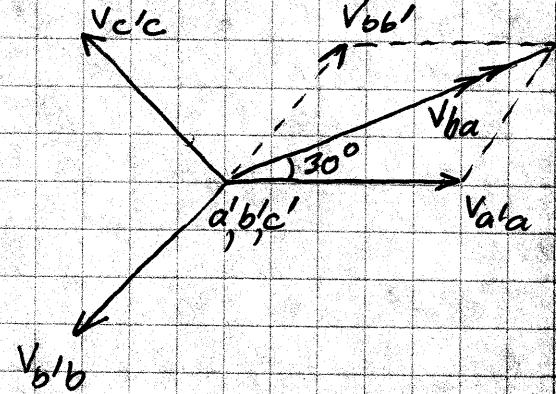




Δ Typically used in residential areas

WYE CONNECTION





Line-to-line voltages:

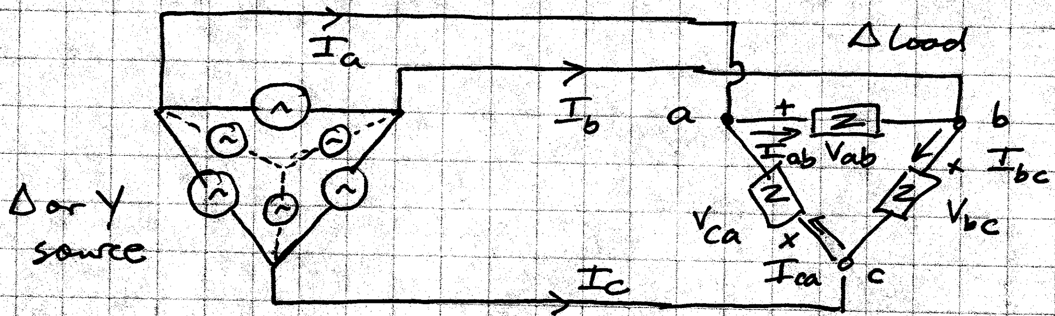
$\hat{V}_{ba} = \hat{V}_{a'a} - V_{b'b} = V_{a'a} + V_{bb'}$

$= 2 V_{a'a} \cos 30°$

$= \sqrt{3}\, V_{a'a} \angle 30°$

In general, $V_{line} = \sqrt{3}\, V_{phase} \angle 30°$

DELTA CIRCUITS : Delta Load, Δ or Y source



Balanced Load

Take $\hat{V}_{ab}$ as phasor reference

Δ "phase" voltages V_{ab}, V_{bc}, V_{ca} = "line" voltages

Phase currents $$I_{ab} = \frac{V_{ab}}{Z_{ab}} = \frac{V\angle 0^\circ}{Z\angle\theta_z} = \frac{V}{Z}\angle -\theta_z$$

$$I_{bc} = \frac{V_{bc}}{Z_{bc}} = \frac{V\angle -120^\circ}{Z\angle\theta_z} = \frac{V}{Z}\angle -120^\circ - \theta_z$$

$$I_{ca} = \frac{V_{ca}}{Z_{ca}} = \frac{V\angle -240^\circ}{Z\angle\theta_z} = \frac{V}{Z}\angle -240^\circ - \theta_z$$

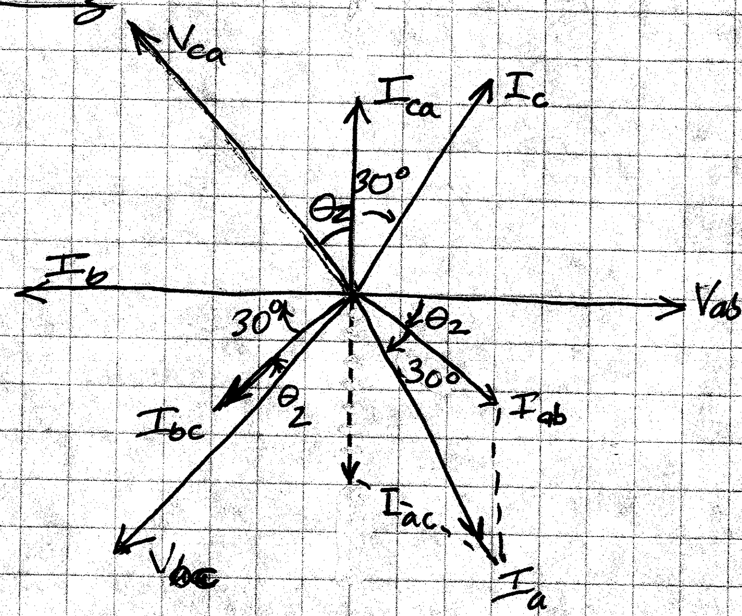
Line currents ≠ Phase currents

$$I_a = I_{ab} + I_{ac} = I_{ab} - I_{ca} \quad \text{(See fig.)}$$

$$I_{ac} = -I_{ca}$$

$$\therefore I_a = 2 I_{ab} \cos 30^\circ \angle -\theta_z - 30^\circ$$
$$= \sqrt{3}\, I_{ab} \angle -30^\circ \quad \text{\& } \|^s\ I_b, I_c$$

So $I_{line} = \sqrt{3}\ I_{phase} \angle -30^\circ$



3ϕ POWER

Total power $= \sum$ 3 equal phase powers

$$P_{total} = 3P_p = 3\underbrace{V_p I_p}_{\text{Phase voltages and currents}} \underbrace{\cos\theta}_{\text{power factor of load}}$$

Easier to measure line voltage, power, etc, rather than phase voltages

Note: θ is not the angle between line voltage and line current.

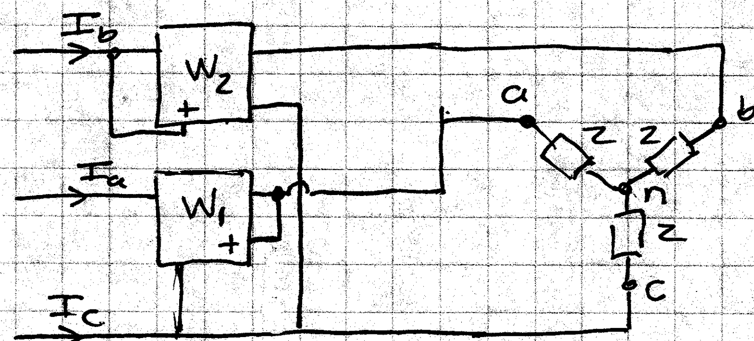
For Δ load, $V_\ell = V_p$ & $I_\ell = \sqrt{3}\, I_p$

$$\therefore P_\Delta = 3 V_p I_p \cos\theta = 3 V_\ell \frac{I_\ell}{\sqrt{3}} \cos\theta = \sqrt{3}\, V_\ell I_\ell \cos\theta$$

For Y load: $V_\ell = \sqrt{3}\, V_p$ & $I_\ell = I_p$

$$\text{So } P_Y = 3 V_p I_p \cos\theta = 3 \frac{V_\ell}{\sqrt{3}} I_\ell \cos\theta = \sqrt{3}\, V_\ell I_\ell \cos\theta$$

Power Measurement



$W_1 = I_a V_{ac} \cos\theta_1$

$W_2 = I_b V_{bc} \cos\theta_2$

Connect 3 wattmeters:
But define line c as reference $\therefore$ W_3 wattmeter measures potential difference.

For numbers in Example 11
where $P_{tot} = 3420$ W
$W_1 + W_2 = 3420$ W.

Hence, eliminate W_3 since senses zero voltage to ref.

Assignment 8 (c) P 7.36 P 7.40 P 7.48