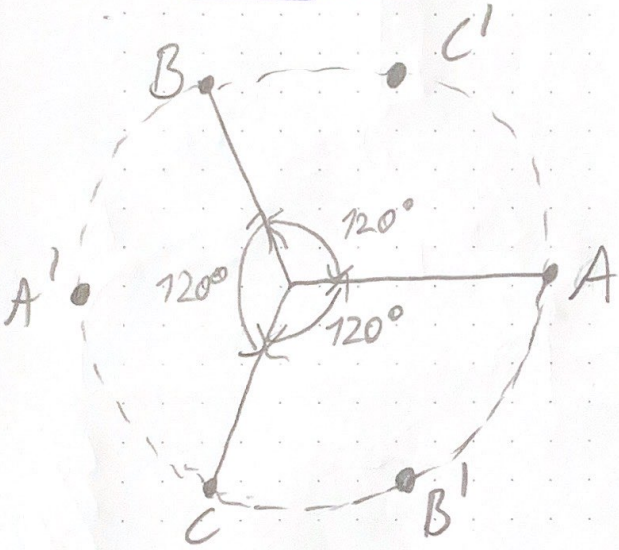
THREE PHASE SYSTEM

★ NIKOLA TESLA

Three Phase Voltage Generation



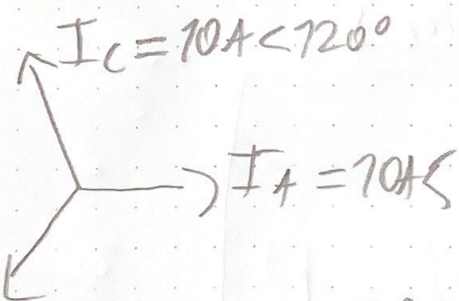
$E_{AA'}$ is at $0°$

$E_{BB'}$ is at $-120°$

$E_{CC'}$ is at $120°$

Basic Three Phase Circuit Connection

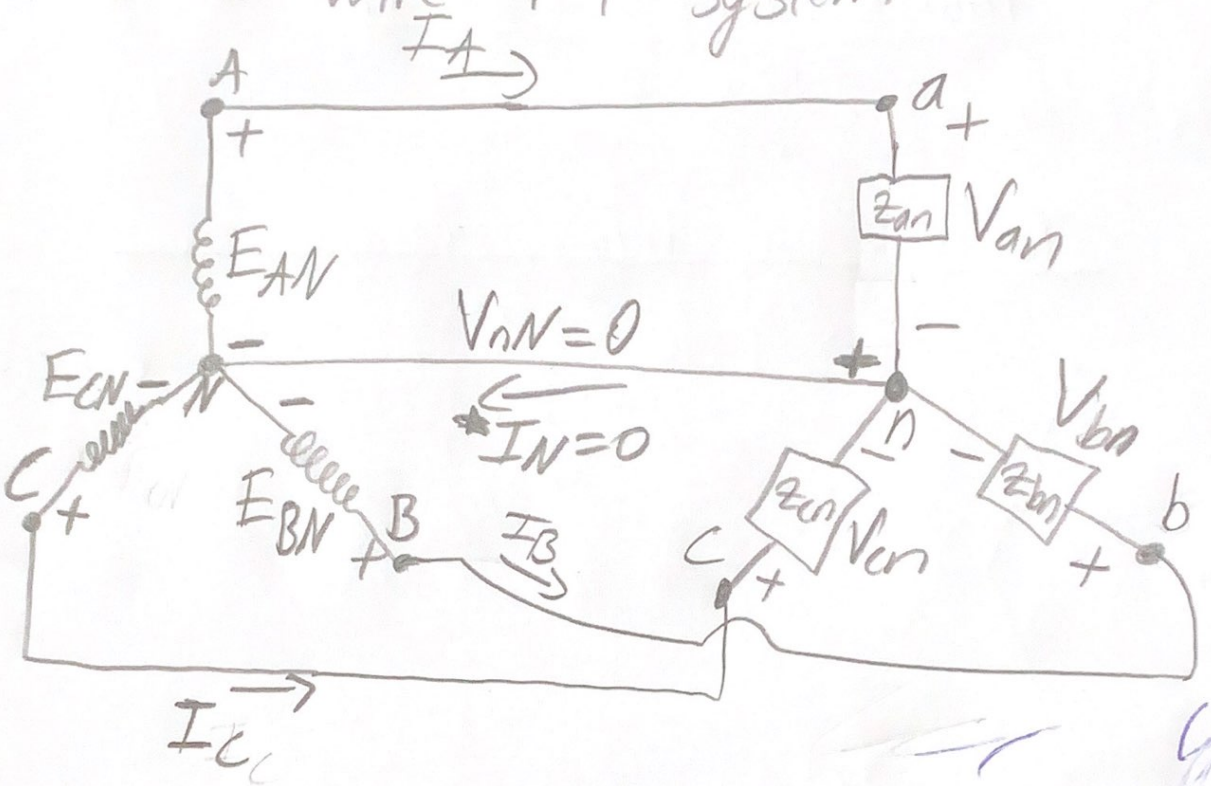
Four Wire and Three Wire system



current form a balanced set

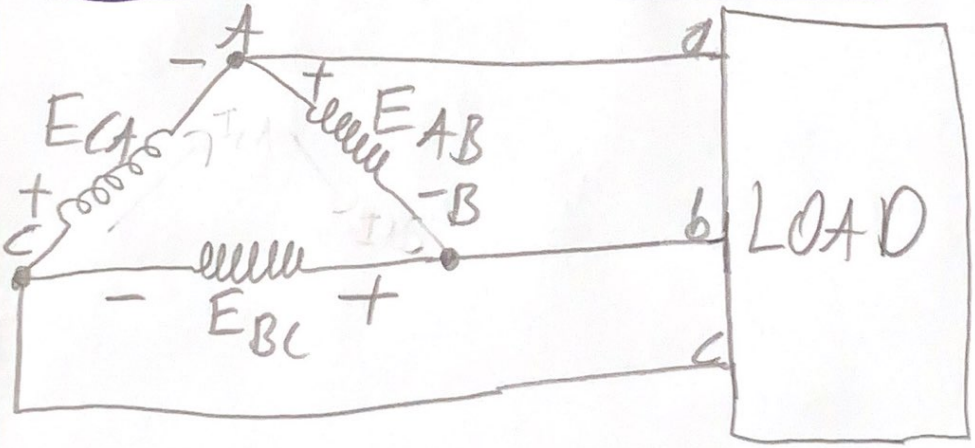
Note: E_{AN}, E_{BN}, E_{CN} they are known as "line to neutral voltages"

* Four-wire Y-Y system



* 3 wire olsun istersek nötr wire çıkacak

Delta-Connected Generators



Phase Sequence

1- ABC phase sequence } reversed
2- ACB " "

Phase Voltages

Line (also called line to line) voltages are between lines.

* E_{AB}, E_{BC}, E_{CA} are line to line voltages at the generator
* V_{ab}, V_{bc} + V_{ca} line voltages at load

Phase Voltages defined line to neveral thus,

* V_{an}, V_{bn}, V_{cn} phase voltage

for Δ load, phases are defined from line to line thus,

* V_{ab}, V_{bc}, V_{ca} are phase voltages for Δ

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Line Currents

I_a, I_b, I_c, and I_A, I_B, I_C

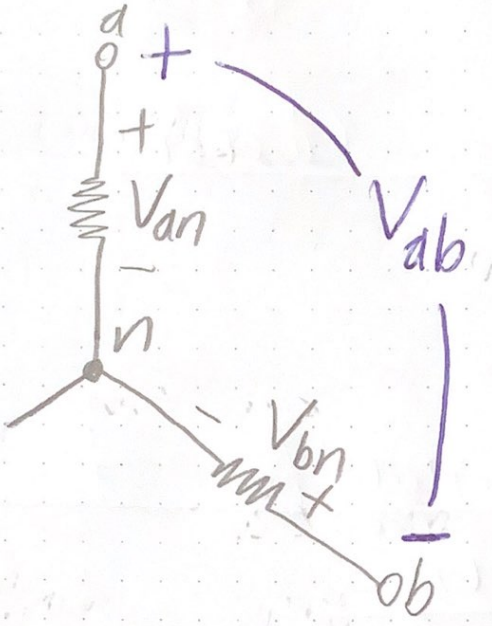
Phase currents

for Y load I_a, I_b, I_c pass through phase impedances and therefore phase currents.

for the Δ load I_{ab}, I_{bc}, I_{ca} are phase current

* For Y load, phase current and line currents are same thing.

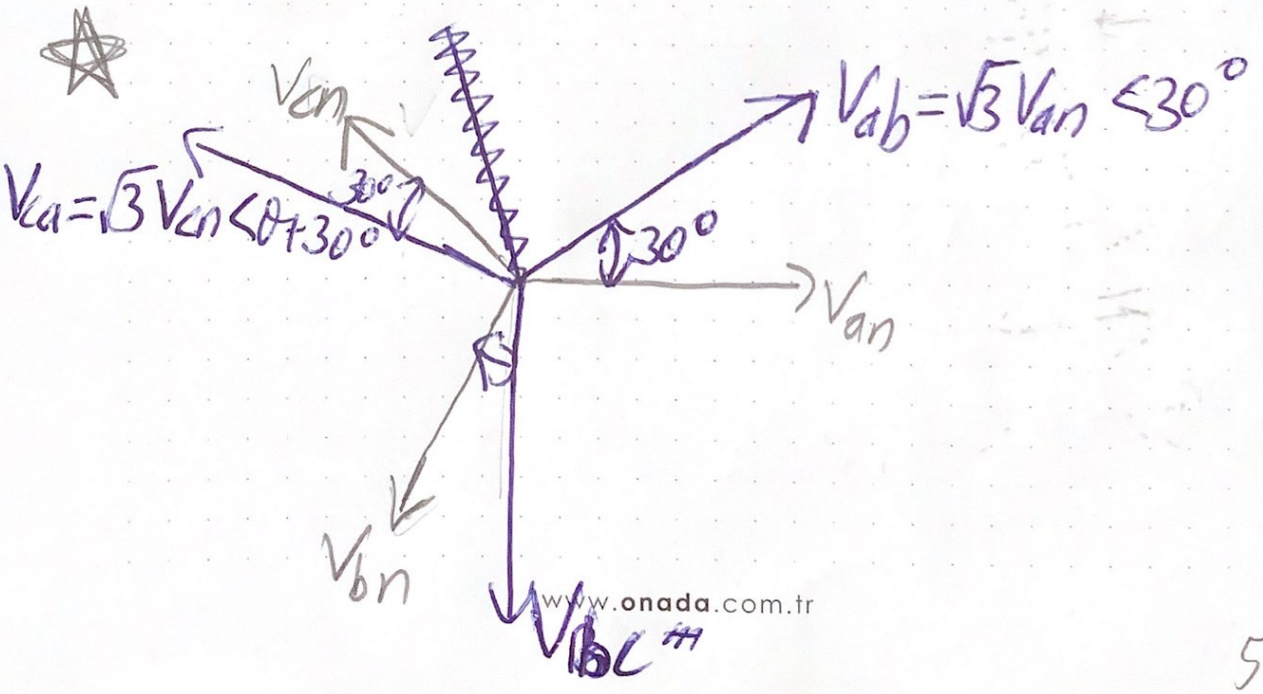
Line and phase voltages for a Y circuit



★ $V_{ab} = V_{an} - V_{bn}$

★ $V_{ab} = \sqrt{3} V_{an} \angle 30°$

★



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* $V_{an} = \frac{V_{ab}}{\sqrt{3} \angle 30^\circ}$ $E_{AN} = \frac{E_{AB}}{\sqrt{3} \angle 30^\circ}$

Currents for a Wye Circuit

$I_a = V_{an} / Z_{an}$

Line And Phase Currents for A Delta Circuit

$I_{ab} = V_{ab} / Z_{ab}$

$I_a = I_{ab} - I_{ca}$

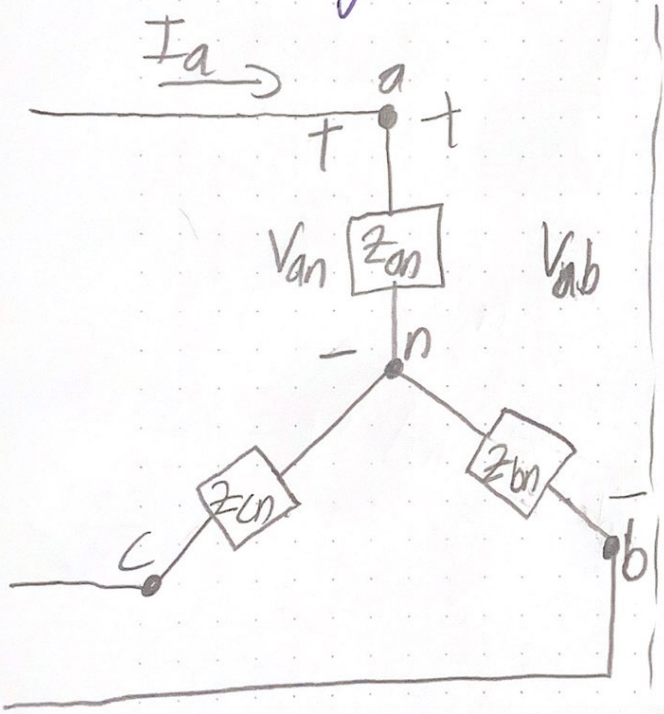
$I_a = \sqrt{3} I_{ab} \angle -30^\circ$

$I_{ab} = \frac{I_a}{\sqrt{3} \angle -30^\circ}$

Single phase equivalent

★ $Z_Y = Z_\Delta / 3$

Summary of Relationships (Balanced System). All Voltages and Currents Are Balanced

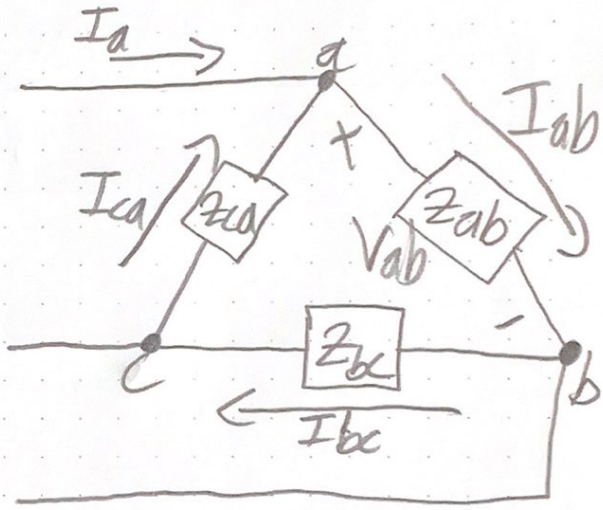


$V_{ab} = \sqrt{3} V_{an} \angle 30°$

$I_a = V_{an} / Z_{an}$

$Z_{an} = Z_{bn} = Z_{cn}$

a) Y connection



$I_a = \sqrt{3} I_{ab} \angle -30°$

$I_{ab} = V_{ab} / Z_{ab}$

$Z_{ab} = Z_{bc} = Z_{ca}$

b) Δ connection

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Generator $E_{AB} = \sqrt{3} E_{AN} \angle 30°$

Power In A Balanced System Wye load

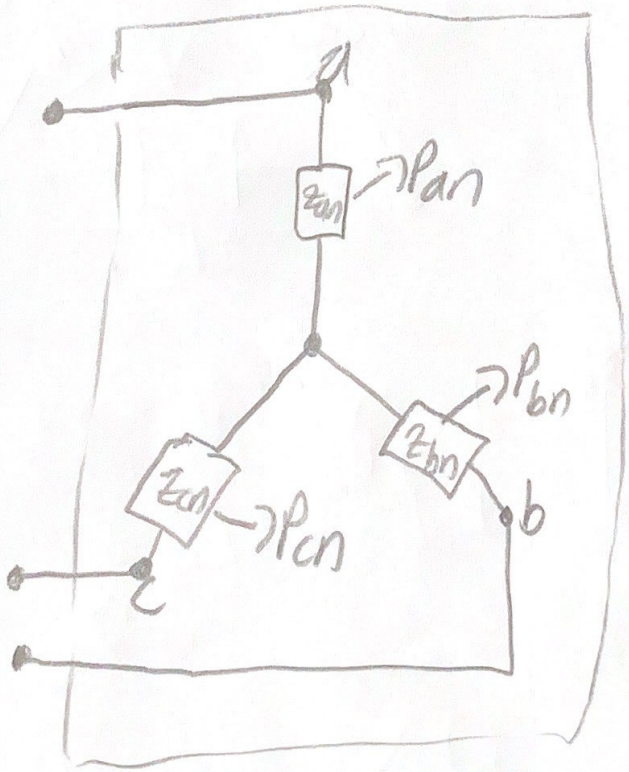
The power per phase

★ $P_\phi = I_\phi V_\phi \cos\theta_\phi$ (W)

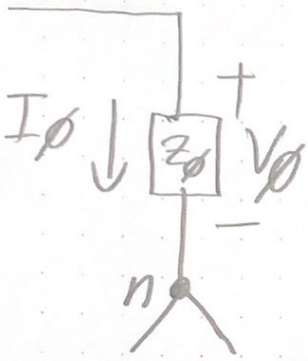
θ_ϕ is the angle of Z_ϕ.

Total power is

★ $P_{total} = 3P_\phi = 3V_\phi I_\phi \cos\theta_\phi$ (W)



$P_T = P_{an} + P_{bn} + P_{cn} = 3P_\phi$



$P_\phi = V_\phi I_\phi \cos\theta_\phi$

θ_ϕ : angle of Z_ϕ

! For a balanced Y, $\boxed{P_\phi = P_{an} = P_{bn} = P_{cn}}$

★ $P_T = \sqrt{3} \cdot V_L \cdot I_L \cdot \cos\theta_\phi$ (W)

★ $P_\phi = I_\phi^2 R_\phi = V_R^2 / R_\phi$ (W)

★ $P_T = 3 I_\phi^2 R_\phi = 3 V_R^2 / R_\phi$ (W)

Reactive Power to a Balanced Wye Load

$$Q_\phi = V_\phi I_\phi \sin\theta_\phi \ (VAR)$$
$$= I_\phi^2 X_\phi = V_\phi^2 / X_\phi \ (VAR)$$

$$Q_T = \sqrt{3}\, V_L I_L \sin\theta_\phi \ (VAR)$$

X_ϕ: reactive component

Z_ϕ V_X is the voltage across it.

Apparent Power

$$S_\phi = V_\phi I_\phi = I_\phi^2 Z_\phi = \frac{V_\phi^2}{Z_\phi} \ (VA)$$

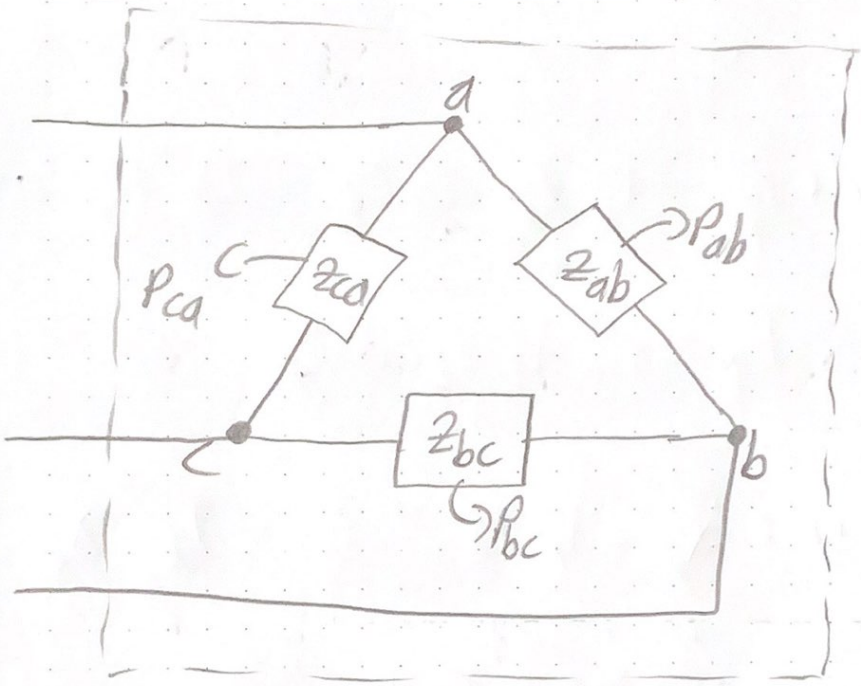
$$S_T = \sqrt{3}\, V_L I_L \ (VA)$$

Power Factor

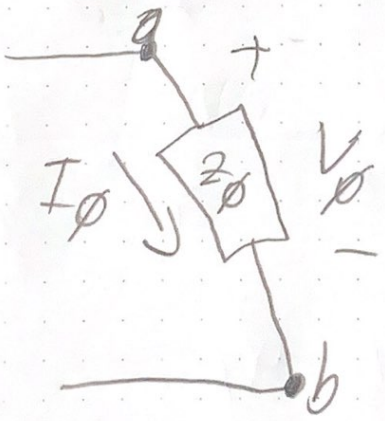
$$F_p = \cos\theta_\phi = P_T / S_T = P_\phi / S_\phi$$

Power to balanced delta (Δ) load

★ $P_\phi = V_\phi I_\phi \cos\theta_\phi$ (W)



$$P_T = P_{ab} + P_{bc} + P_{ca} = 3P_\phi$$



! $P_\phi = P_{ab} = P_{bc} = P_{ca}$ for balanced Δ system.

$$P_\phi = V_\phi I_\phi \cos\theta_\phi$$

↳ angle of load impedance(Z)

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SUMMARY

of power formulas for balanced Wye and delta circuit

active power: $P_\phi = V_\phi I_\phi \cos\theta_\phi = I_\phi^2 R_\phi = \frac{V_R^2}{R_\phi}$

$$P_T = \sqrt{3}\, V_L I_L \cos\theta_\phi$$

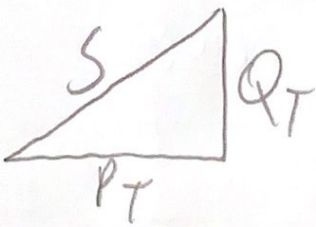
reactive power: $Q_\phi = V_\phi I_\phi \sin\theta_\phi = I_\phi^2 X_\phi = \frac{V_X^2}{X_\phi}$

$$Q_T = \sqrt{3}\, V_L I_L \sin\theta_\phi$$

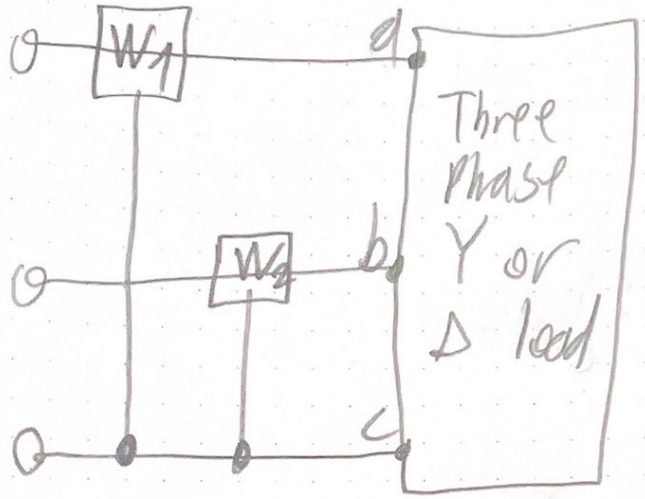
apperant power: $S_\phi = V_\phi I_\phi = I_\phi^2 Z_\phi = \frac{V_\phi^2}{Z_\phi}$

power factor: $F_p = \cos\theta_\phi = \frac{P_T}{S_T} = \frac{P_\phi}{S_\phi}$

power triangle: $S_T = P_T + jQ_T$



Two Wattmeter Methode



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$$\tan\theta_{\phi} = \sqrt{3}\left(\frac{P_h - P_e}{P_h + P_e}\right)$$

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