

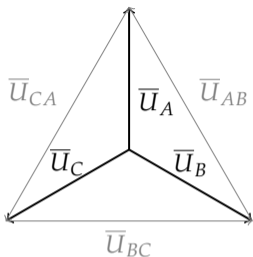
Sistemas Trifásicos

Teoría de Circuitos II

Oscar Perpiñán Lamigueiro

- ① Generadores
- ② Receptores
- ③ Potencia en Sistemas Trifásicos
- ④ Compensación de Reactiva
- ⑤ Medida de Potencia en Sistemas Trifásicos
- ⑥ Conversión de Fuentes Reales
- ⑦ Estudio generalizado de los sistemas trifásicos

Tensiones de Fase y Línea



Tensiones de **Fase**: U_A, U_B, U_C

Tensiones de **Línea**: U_{AB}, U_{BC}, U_{CA}

$$\bar{U}_{AB} = \bar{U}_A - \bar{U}_B$$

$$\bar{U}_{BC} = \bar{U}_B - \bar{U}_C$$

$$\bar{U}_{CA} = \bar{U}_C - \bar{U}_A$$

$$\bar{U}_{AB} + \bar{U}_{BC} + \bar{U}_{CA} = 0$$

Tensiones de Fase y Línea

$$\bar{U}_A = U_f / \theta_f$$

$$\bar{U}_B = U_f / \theta_f - 120^\circ$$

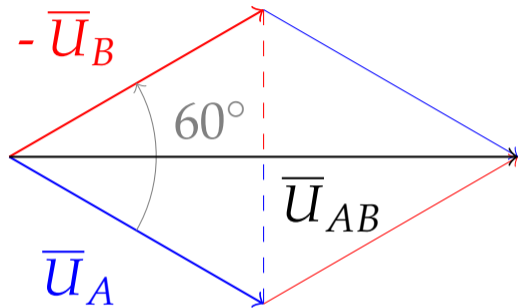
$$\bar{U}_{AB} = \bar{U}_A - \bar{U}_B =$$

$$= U_f / \theta_f - U_f / \theta_f - 120^\circ =$$

$$= U_f / \theta_f + U_f / \theta_f + 60^\circ$$

$$= 2 \cdot U_f \cdot \cos(30) / \theta_f + 30^\circ =$$

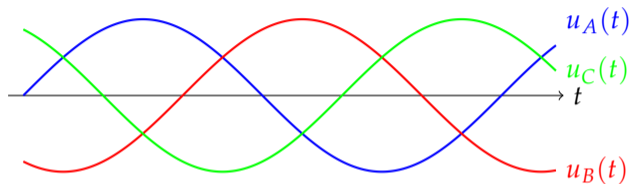
$$= \sqrt{3} U_f / \theta_f + 30^\circ$$



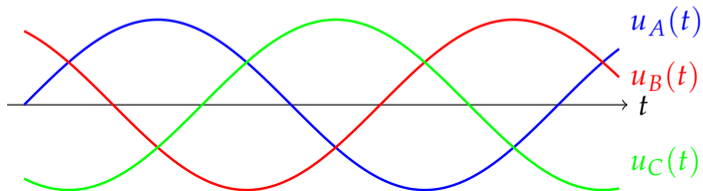
$$U = \sqrt{3} \cdot U_f$$
$$\theta_l = \theta_f + 30^\circ$$

Secuencia de Fases

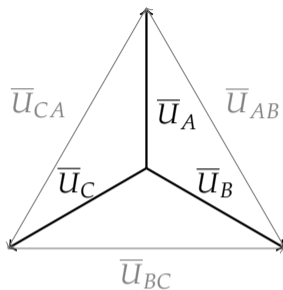
- ▶ Sentido en el que ocurren los máximos de cada fase.
- ▶ Secuencia de Fases Directa (**SFD**): ABC



- ▶ Secuencia de Fases Inversa (**SFI**): ACB



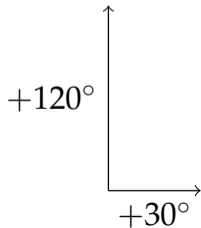
Secuencia de Fases Directa (SFD)



$$\bar{U}_A = \frac{U}{\sqrt{3}} \angle 90^\circ$$

$$\bar{U}_B = \frac{U}{\sqrt{3}} \angle -30^\circ$$

$$\bar{U}_C = \frac{U}{\sqrt{3}} \angle -150^\circ$$

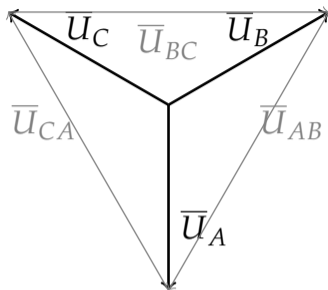


$$\bar{U}_{AB} = U \angle 120^\circ$$

$$\bar{U}_{BC} = U \angle 0^\circ$$

$$\bar{U}_{CA} = U \angle -120^\circ$$

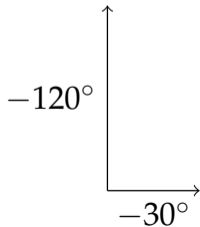
Secuencia de Fases Inversa (SFI)



$$\bar{U}_A = \frac{U}{\sqrt{3}} \angle -90^\circ$$

$$\bar{U}_B = \frac{U}{\sqrt{3}} \angle 30^\circ$$

$$\bar{U}_C = \frac{U}{\sqrt{3}} \angle 150^\circ$$



$$\bar{U}_{AB} = U \angle -120^\circ$$

$$\bar{U}_{BC} = U \angle 0^\circ$$

$$\bar{U}_{CA} = U \angle 120^\circ$$

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Tipos de Receptores

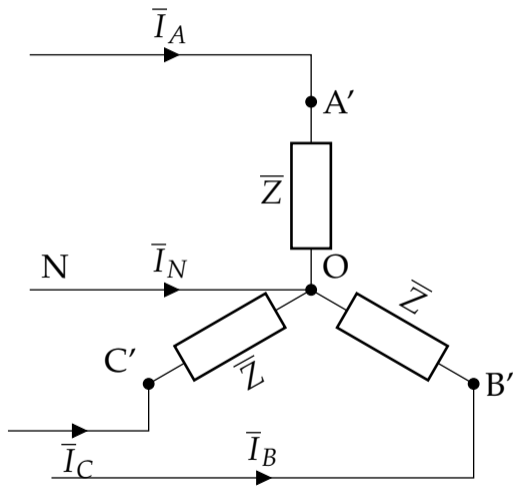
Conexión

- ▶ **Estrella** (punto común) Y
- ▶ **Triángulo** Δ

Impedancias

- ▶ **Equilibrado** (las tres impedancias son idénticas en módulo **y** fase).
- ▶ **Desequilibrado**

Receptor en Estrella Equilibrado



$$\bar{I}_A = \frac{\bar{U}_A}{\bar{Z}} = \frac{U_f}{Z} \angle \pm 90^\circ - \theta$$

$$\bar{I}_B = \frac{\bar{U}_B}{\bar{Z}} = \frac{U_f}{Z} \angle \mp 30^\circ - \theta$$

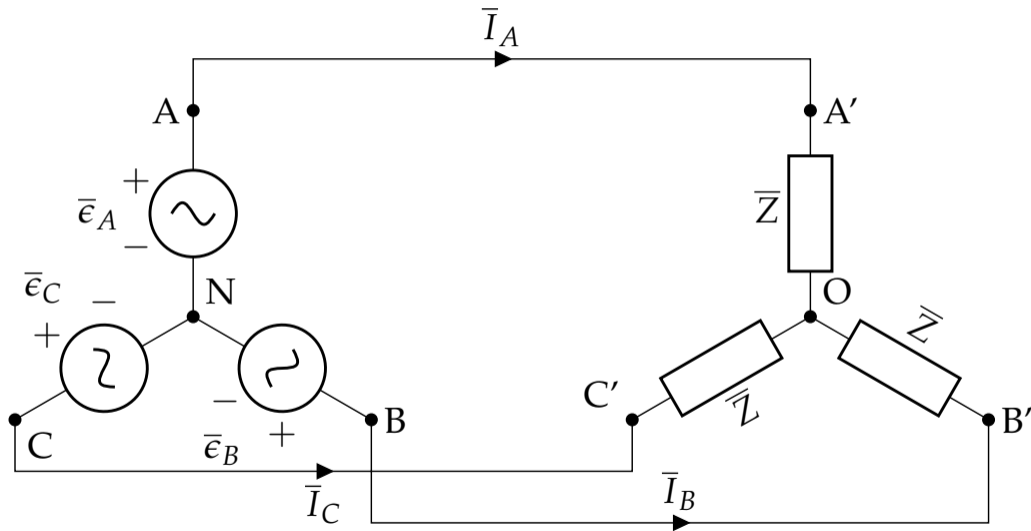
$$\bar{I}_C = \frac{\bar{U}_C}{\bar{Z}} = \frac{U_f}{Z} \angle \mp 150^\circ - \theta$$

$$|\bar{I}_A| = |\bar{I}_B| = |\bar{I}_C| = \frac{U_f}{Z}$$

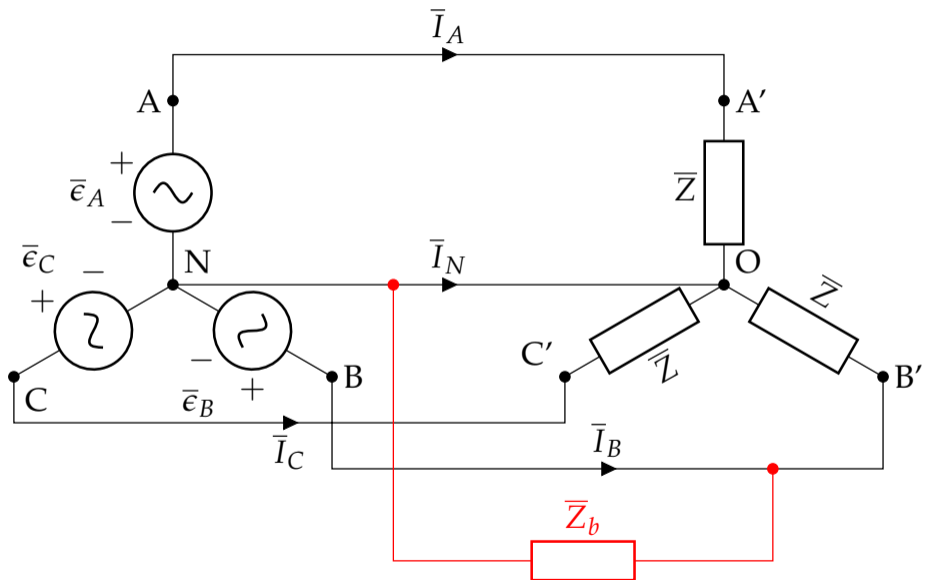
$$\bar{I}_A + \bar{I}_B + \bar{I}_C + \bar{I}_N = 0$$

$$\bar{I}_A + \bar{I}_B + \bar{I}_C = 0 \rightarrow \boxed{\bar{I}_N = 0}$$

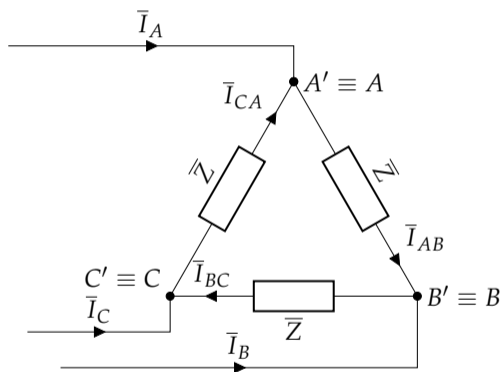
Receptor en Estrella Equilibrado



Receptor en Estrella con Carga Monofásica



Receptor en Triángulo Equilibrado



$$\bar{I}_{AB} = \frac{\bar{U}_{AB}}{\bar{Z}} = \frac{U}{Z} \angle \pm 120^\circ - \theta$$

$$\bar{I}_{BC} = \frac{\bar{U}_{BC}}{\bar{Z}} = \frac{U}{Z} \angle 0 - \theta$$

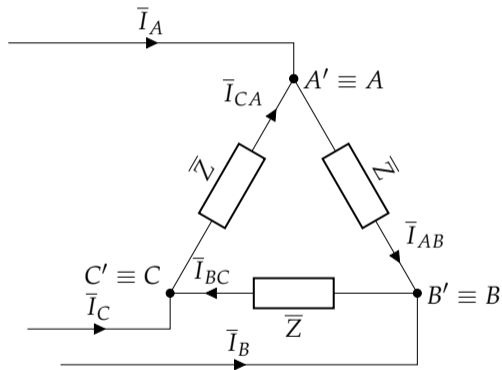
$$\bar{I}_{CA} = \frac{\bar{U}_{CA}}{\bar{Z}} = \frac{U}{Z} \angle \mp 120^\circ - \theta$$

$$\bar{I}_{AB} + \bar{I}_{BC} + \bar{I}_{CA} = 0$$

Corriente de Fase:

$$I_f = |\bar{I}_{AB}| = |\bar{I}_{BC}| = |\bar{I}_{CA}| = \frac{U}{Z}$$

Receptor en Triángulo Equilibrado



$$\bar{I}_A = \bar{I}_{AB} - \bar{I}_{CA} = \sqrt{3} \cdot \frac{U}{Z} \angle \pm 90^\circ - \theta$$

$$\bar{I}_B = \bar{I}_{BC} - \bar{I}_{AB} = \sqrt{3} \cdot \frac{U}{Z} \angle \mp 30^\circ - \theta$$

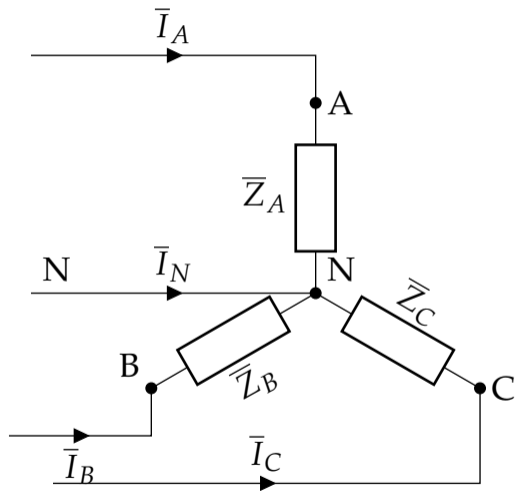
$$\bar{I}_C = \bar{I}_{CA} - \bar{I}_{BC} = \sqrt{3} \cdot \frac{U}{Z} \angle \mp 150^\circ - \theta$$

Corriente de Línea:

$$I = |\bar{I}_A| = |\bar{I}_B| = |\bar{I}_C| = \sqrt{3} \cdot \frac{U}{Z}$$

$$I = \sqrt{3} \cdot I_f$$

Receptor en Estrella Desequilibrado con Neutro



$$\bar{I}_A = \frac{\bar{U}_A}{\bar{Z}_A}$$

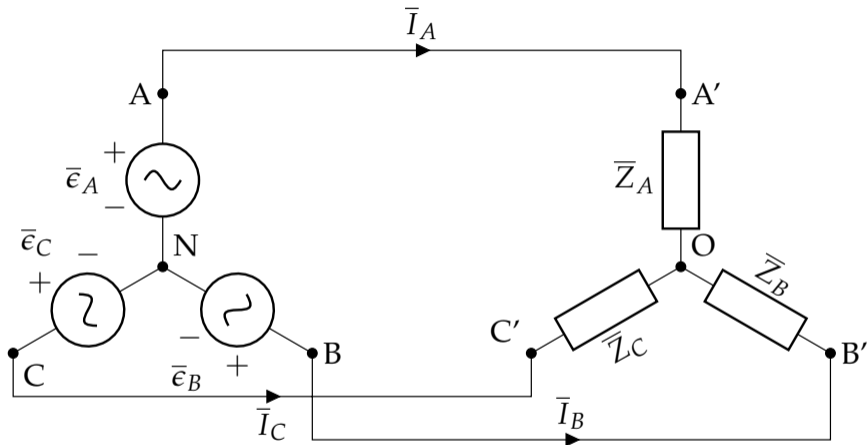
$$\bar{I}_B = \frac{\bar{U}_B}{\bar{Z}_B}$$

$$\bar{I}_C = \frac{\bar{U}_C}{\bar{Z}_C}$$

$$\bar{I}_A + \bar{I}_B + \bar{I}_C + \bar{I}_N = 0$$

$$\bar{I}_A + \bar{I}_B + \bar{I}_C \neq 0 \rightarrow \boxed{\bar{I}_N \neq 0}$$

Receptor en Estrella Desequilibrado sin Neutro



$$\bar{U}_N \neq \bar{U}_O$$

Método del desplazamiento del neutro

Ecuaciones del receptor:

$$\bar{U}_{A'O} = \bar{I}_A \cdot \bar{Z}_A$$

$$\bar{U}_{B'O} = \bar{I}_B \cdot \bar{Z}_B$$

$$\bar{U}_{C'O} = \bar{I}_C \cdot \bar{Z}_C$$

Ecuación del nudo O:

$$\bar{I}_A + \bar{I}_B + \bar{I}_C = 0$$

Método del desplazamiento del neutro

Relacionamos las tensiones en el receptor con las tensiones del generador:

$$\bar{U}_{A'O} = \bar{U}_{AN} - \bar{U}_{ON}$$

$$\bar{U}_{B'O} = \bar{U}_{BN} - \bar{U}_{ON}$$

$$\bar{U}_{C'O} = \bar{U}_{CN} - \bar{U}_{ON}$$

Despejamos las corrientes teniendo en cuenta estas relaciones:

$$\bar{I}_A = \frac{\bar{U}_{AN} - \bar{U}_{ON}}{\bar{Z}_A}$$

$$\bar{I}_B = \frac{\bar{U}_{BN} - \bar{U}_{ON}}{\bar{Z}_B}$$

$$\bar{I}_C = \frac{\bar{U}_{CN} - \bar{U}_{ON}}{\bar{Z}_C}$$

Método del desplazamiento del neutro

Finalmente, usando la ecuación del nudo O despejamos la tensión U_{ON} (tensión de desplazamiento del neutro)*:

$$\bar{U}_{ON} = \frac{\bar{U}_{AN} \cdot \bar{Y}_A + \bar{U}_{BN} \cdot \bar{Y}_B + \bar{U}_{CN} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C}$$

Una vez calculada esta tensión \bar{U}_{ON} se pueden calcular las corrientes de línea:

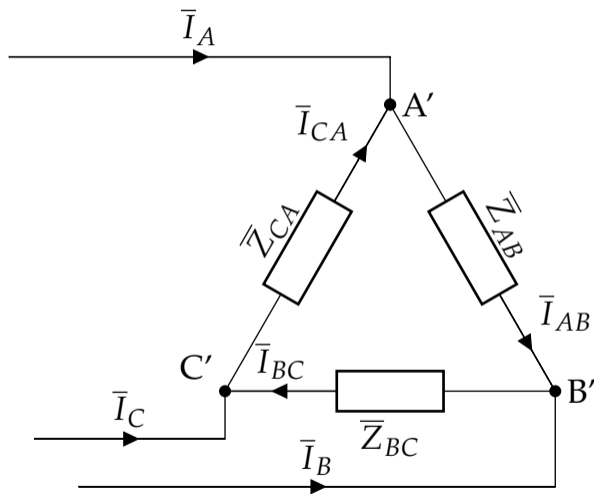
$$\bar{I}_A = (\bar{U}_{AN} - \bar{U}_{ON}) \cdot \bar{Y}_A$$

$$\bar{I}_B = (\bar{U}_{BN} - \bar{U}_{ON}) \cdot \bar{Y}_B$$

$$\bar{I}_C = (\bar{U}_{CN} - \bar{U}_{ON}) \cdot \bar{Y}_C$$

*Se puede llegar a este mismo resultado aplicando el teorema de Millman.

Receptor en Triángulo Desequilibrado



$$\bar{I}_{AB} = \frac{\bar{U}_{AB}}{\bar{Z}_{AB}}$$

$$\bar{I}_{BC} = \frac{\bar{U}_{BC}}{\bar{Z}_{BC}}$$

$$\bar{I}_{CA} = \frac{\bar{U}_{CA}}{\bar{Z}_{CA}}$$

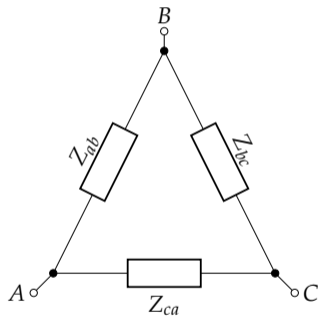
$$\bar{I}_A = \bar{I}_{AB} - \bar{I}_{CA}$$

$$\bar{I}_B = \bar{I}_{BC} - \bar{I}_{AB}$$

$$\bar{I}_C = \bar{I}_{CA} - \bar{I}_{BC}$$

Transformación de receptores

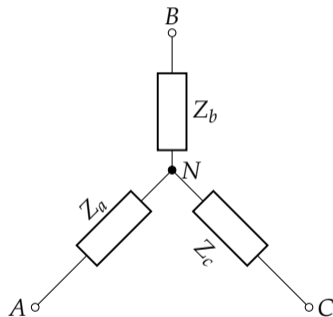
Triángulo a Estrella



$$\bar{Z}_a = \frac{\bar{Z}_{ab} \cdot \bar{Z}_{ca}}{\bar{Z}_{ab} + \bar{Z}_{bc} + \bar{Z}_{ca}}$$

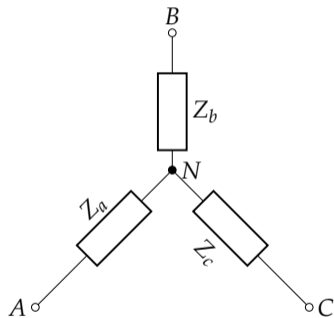
$$\bar{Z}_b = \frac{\bar{Z}_{bc} \cdot \bar{Z}_{ab}}{\bar{Z}_{ab} + \bar{Z}_{bc} + \bar{Z}_{ca}}$$

$$\bar{Z}_c = \frac{\bar{Z}_{ca} \cdot \bar{Z}_{bc}}{\bar{Z}_{ab} + \bar{Z}_{bc} + \bar{Z}_{ca}}$$



Transformación de receptores

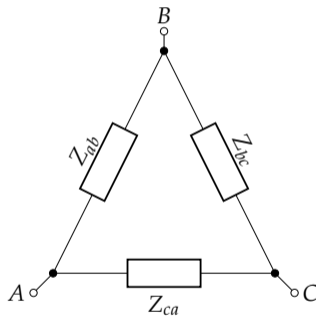
Estrella a Triángulo



$$\bar{Y}_{ab} = \frac{\bar{Y}_a \bar{Y}_b}{\bar{Y}_a + \bar{Y}_b + \bar{Y}_c}$$

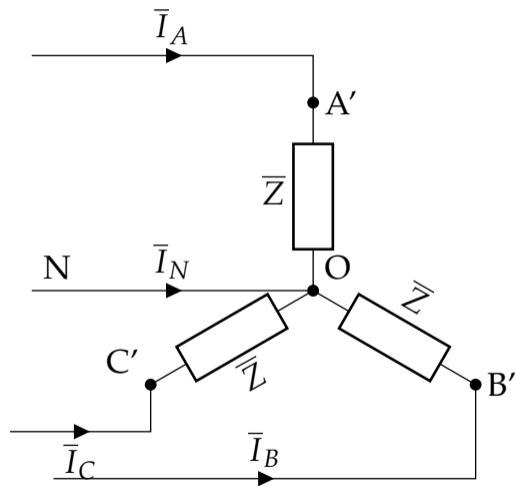
$$\bar{Y}_{bc} = \frac{\bar{Y}_b \bar{Y}_c}{\bar{Y}_a + \bar{Y}_b + \bar{Y}_c}$$

$$\bar{Y}_{ca} = \frac{\bar{Y}_c \bar{Y}_a}{\bar{Y}_a + \bar{Y}_b + \bar{Y}_c}$$



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Receptor en Estrella Equilibrado



$$P = 3 \cdot P_Z = 3 \cdot U_Z I_Z \cos(\theta)$$

$$Q = 3 \cdot Q_Z = 3 \cdot U_Z I_Z \sin(\theta)$$

$$I_Z = I$$

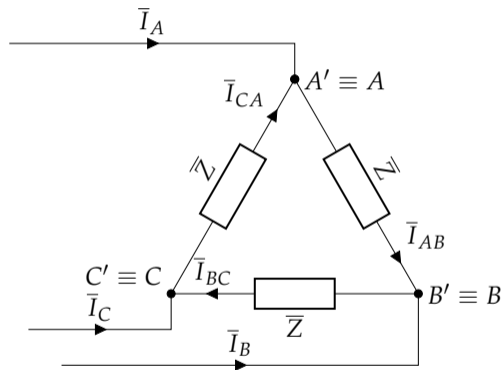
$$U_Z = U_F$$

$$P = 3U_F I \cos(\theta) = \sqrt{3}UI \cos(\theta)$$

$$Q = 3U_F I \sin(\theta) = \sqrt{3}UI \sin(\theta)$$

$$S = \sqrt{P^2 + Q^2} = \sqrt{3}UI$$

Receptor en Triángulo Equilibrado



$$P = 3 \cdot P_Z = 3 \cdot U_Z I_Z \cos(\theta)$$

$$Q = 3 \cdot Q_Z = 3 \cdot U_Z I_Z \sin(\theta)$$

$$I_Z = I_F$$

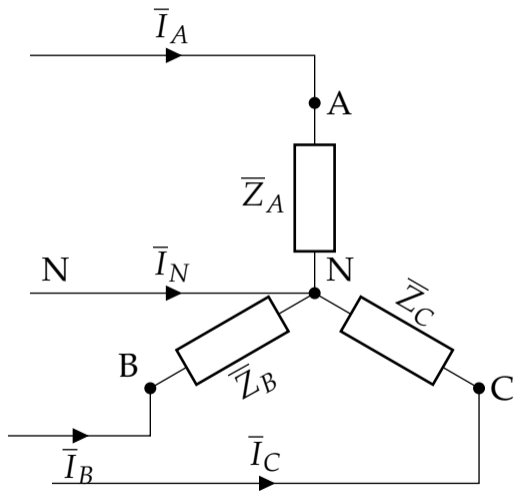
$$U_Z = U$$

$$P = 3UI_F \cos(\theta) = \sqrt{3}UI \cos(\theta)$$

$$Q = 3UI_F \sin(\theta) = \sqrt{3}UI \sin(\theta)$$

$$S = \sqrt{P^2 + Q^2} = \sqrt{3}UI$$

Receptor en Estrella Desequilibrado

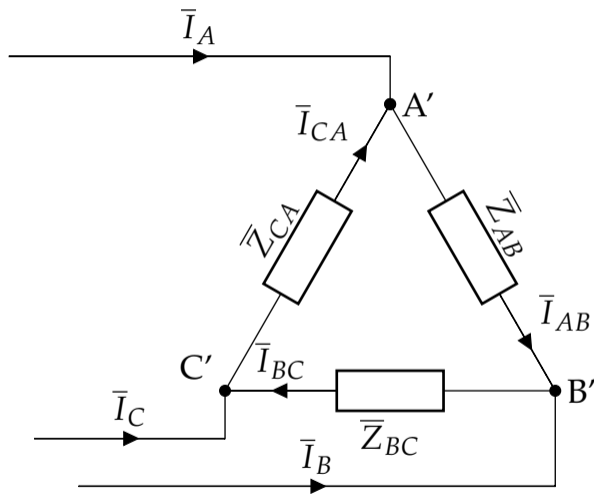


$$P = P_A + P_B + P_C$$

$$Q = Q_A + Q_B + Q_C$$

$$\bar{S} = P + jQ$$

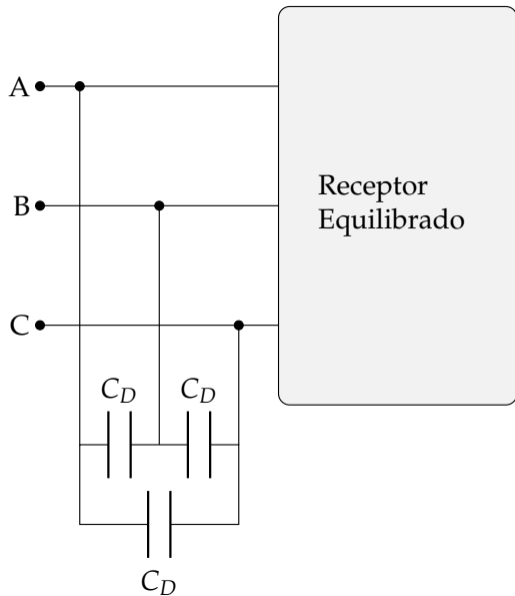
Receptor en Triángulo Desequilibrado



$$P = P_{AB} + P_{BC} + P_{CA}$$
$$Q = Q_{AB} + Q_{BC} + Q_{CA}$$
$$\bar{S} = P + jQ$$

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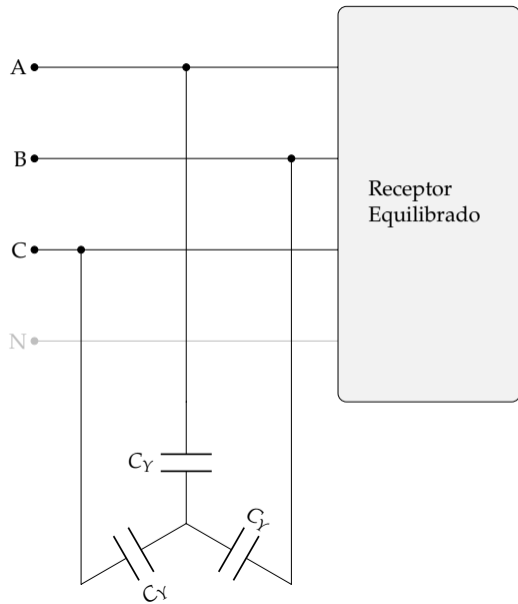
Conexión en Triángulo



$$\begin{aligned} Q &= P \tan \theta \\ Q' &= P \tan \theta' = \\ &= Q - Q_c \\ Q_c &= 3 \cdot \omega C_{\Delta} \cdot U^2 \end{aligned}$$

$$C_{\Delta} = \frac{P(\tan \theta - \tan \theta')}{3\omega U^2}$$

Conexión en Estrella



$$Q = P \tan \theta$$

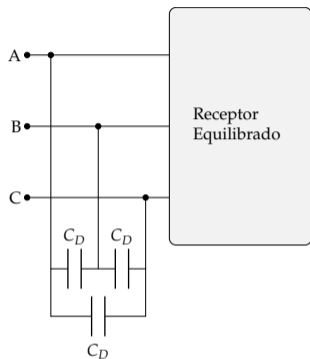
$$Q' = P \tan \theta' =$$

$$= Q - Q_c$$

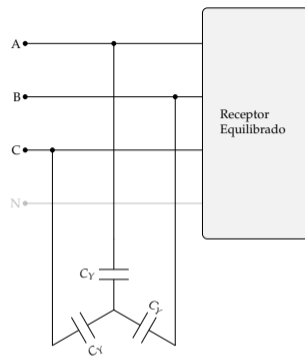
$$Q_c = 3 \cdot \omega C_Y \cdot U_f^2$$

$$C_Y = \frac{P(\tan \theta - \tan \theta')}{\omega U^2}$$

Comparación Estrella-Triángulo



$$C_{\Delta} = \frac{P(\tan \theta - \tan \theta')}{3\omega U^2}$$

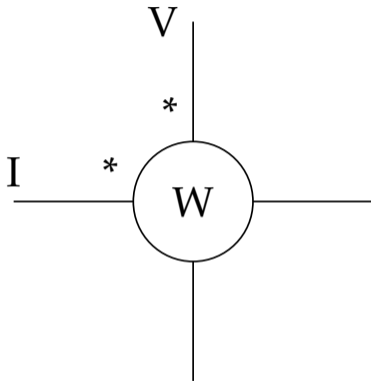


$$C_Y = \frac{P(\tan \theta - \tan \theta')}{\omega U^2}$$

Dado que $C_Y = 3 \cdot C_{\Delta}$ la **configuración recomendada** es **triángulo**.

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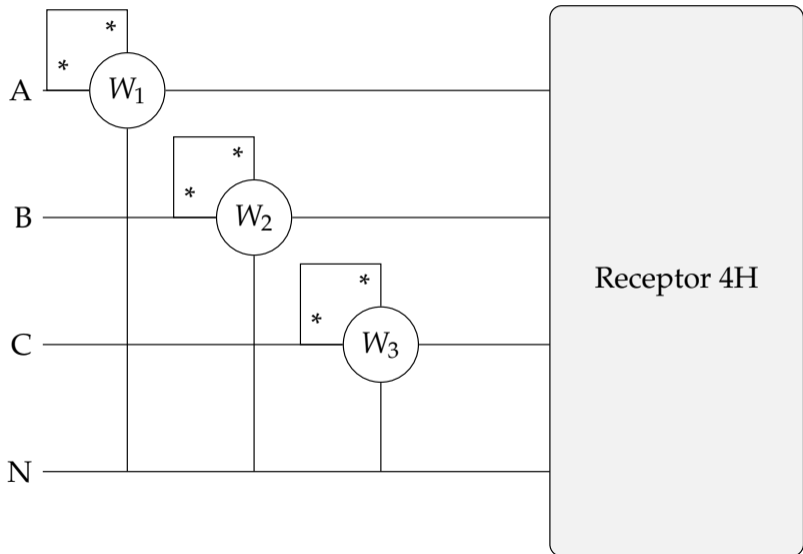
Recordatorio: vatímetro



Vatímetro: equipo de medida de 4 terminales (1 par para tensión, 1 par para corriente)

$$W = \Re(\bar{U} \cdot \bar{I}^*)$$

Sistema de 4 Hilos



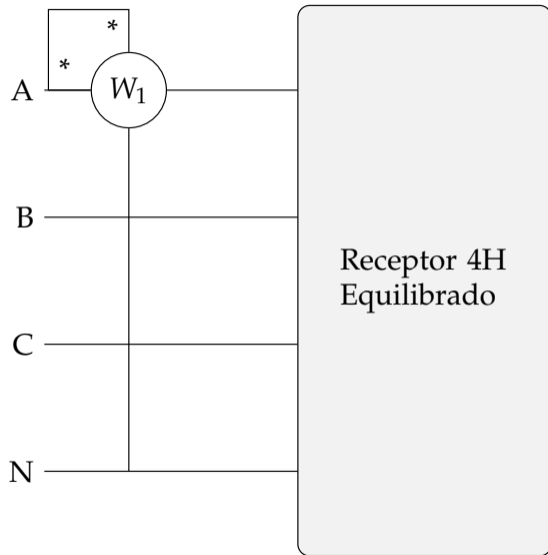
$$W_1 = \Re(\bar{U}_A \cdot \bar{I}_A^*) = P_A$$

$$W_2 = \Re(\bar{U}_B \cdot \bar{I}_B^*) = P_B$$

$$W_3 = \Re(\bar{U}_C \cdot \bar{I}_C^*) = P_C$$

$$P = W_1 + W_2 + W_3$$

Sistema de 4 Hilos Equilibrado



$$P_A = P_B = P_C$$

$$P = 3 \cdot W_1$$

Sistema de 3 Hilos Equilibrado (SFD)

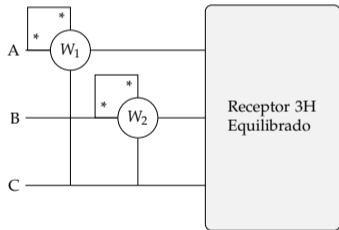
$$(ABC) :: A \triangleright B \triangleright C \implies \{AB, BC, CA\}$$

$$W_1 = UI \cos(\theta - 30^\circ)$$

$$P = W_1 + W_2$$

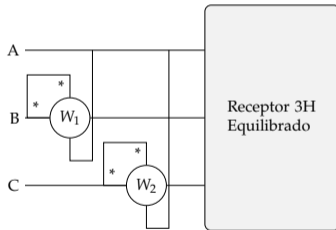
$$W_2 = UI \cos(\theta + 30^\circ)$$

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



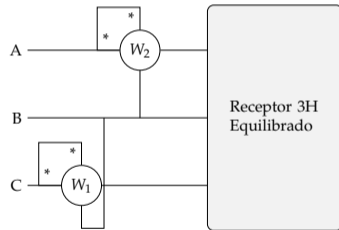
$W_1 : AC \notin SFD$

$W_2 : BC \in SFD$



$W_1 : BA \notin SFD$

$W_2 : CA \in SFD$



$W_1 : CB \notin SFD$

$W_2 : AB \in SFD$

Sistema de 3 Hilos Equilibrado (SFI)

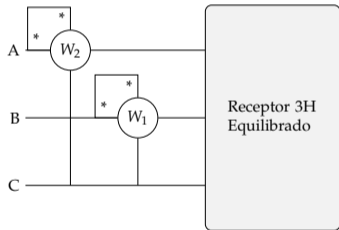
$$(ACB) :: A \triangleright C \triangleright B \implies \{AC, CB, BA\}$$

$$W_1 = UI \cos(\theta - 30^\circ)$$

$$P = W_1 + W_2$$

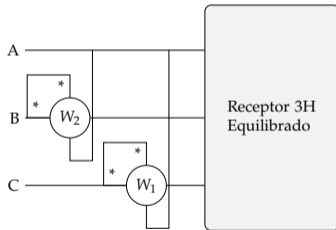
$$W_2 = UI \cos(\theta + 30^\circ)$$

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



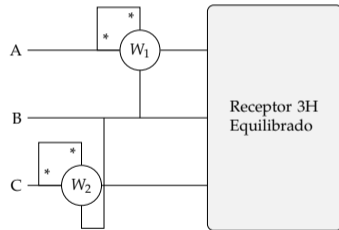
$W_1 : BC \notin SFI$

$W_2 : AC \in SFI$



$W_1 : CA \notin SFI$

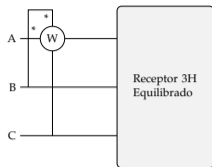
$W_2 : BA \in SFI$



$W_1 : AB \notin SFI$

$W_2 : CB \in SFI$

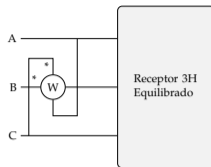
Conexiones para medida de reactiva



$$W = \Re(\bar{U}_{BC} \cdot \bar{I}_A^*)$$

$BC \in SFD$

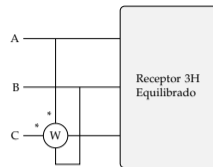
$BC \notin SFI$



$$W = \Re(\bar{U}_{CA} \cdot \bar{I}_B^*)$$

$CA \in SFD$

$CA \notin SFI$



$$W = \Re(\bar{U}_{AB} \cdot \bar{I}_C^*)$$

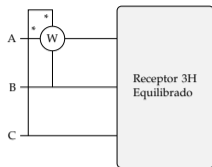
$AB \in SFD$

$AB \notin SFI$

$$SFD \rightarrow W = \frac{Q}{\sqrt{3}}$$

$$SFI \rightarrow W = -\frac{Q}{\sqrt{3}}$$

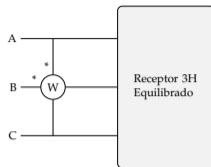
Conexiones para medida de reactiva



$$W = \Re(\bar{U}_{CB} \cdot \bar{I}_A^*)$$

$CB \notin SFD$

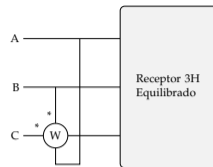
$CB \in SFI$



$$W = \Re(\bar{U}_{AC} \cdot \bar{I}_B^*)$$

$AC \notin SFD$

$AC \in SFI$



$$W = \Re(\bar{U}_{BA} \cdot \bar{I}_C^*)$$

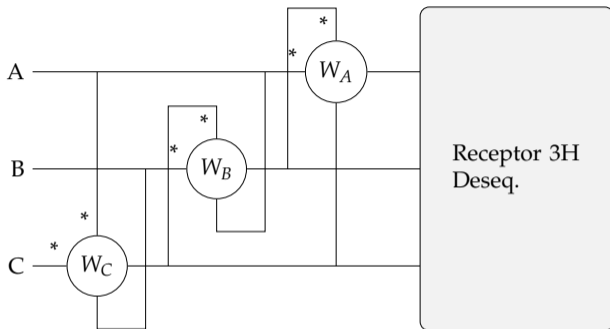
$BA \notin SFD$

$BA \in SFI$

$$SFD \rightarrow W = -\frac{Q}{\sqrt{3}}$$

$$SFI \rightarrow W = \frac{Q}{\sqrt{3}}$$

Medida de la reactiva con receptor desequilibrado



$$W_A = \Re(\bar{U}_{BC} \cdot \bar{I}_A^*)$$

$$W_B = \Re(\bar{U}_{CA} \cdot \bar{I}_B^*)$$

$$W_C = \Re(\bar{U}_{AB} \cdot \bar{I}_C^*)$$

$$\bar{U}_{AB} = \pm\sqrt{3} \cdot \bar{U}_C \cdot e^{j\pi/2}$$

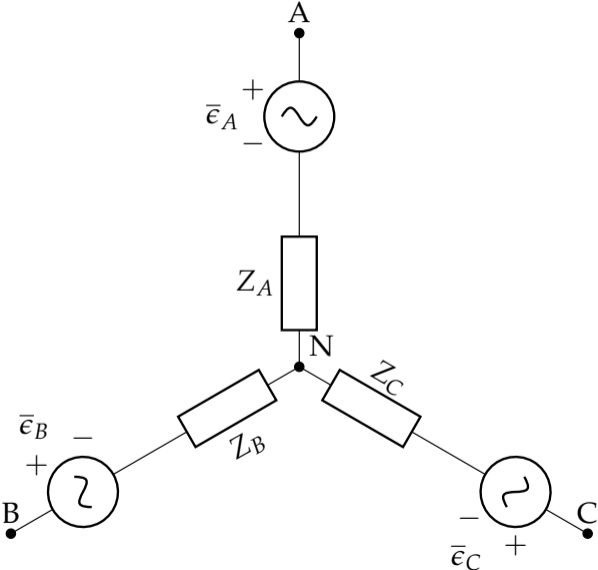
$$\bar{U}_{BC} = \pm\sqrt{3} \cdot \bar{U}_A \cdot e^{j\pi/2}$$

$$\bar{U}_{CA} = \pm\sqrt{3} \cdot \bar{U}_B \cdot e^{j\pi/2}$$

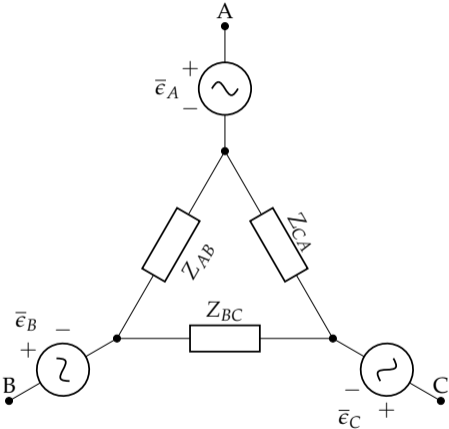
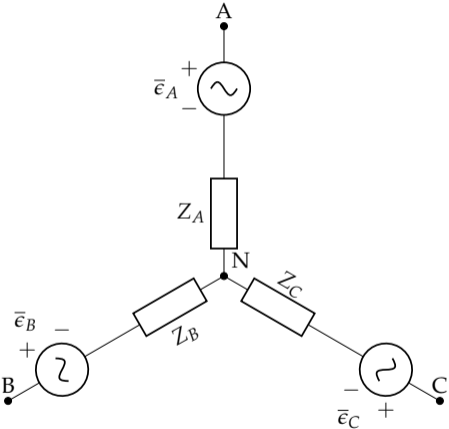
$$W_A + W_B + W_C = \pm Q / \sqrt{3}$$

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- ⑥ Conversión de Fuentes Reales**
- ⑦ Estudio generalizado de los sistemas trifásicos

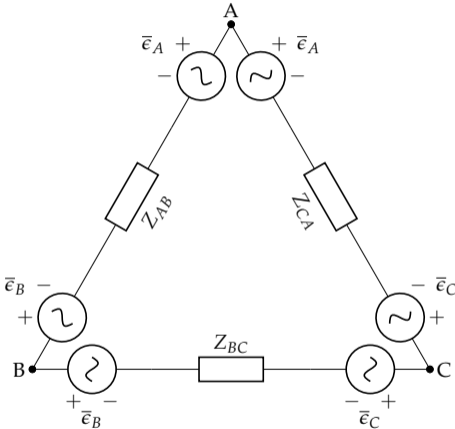
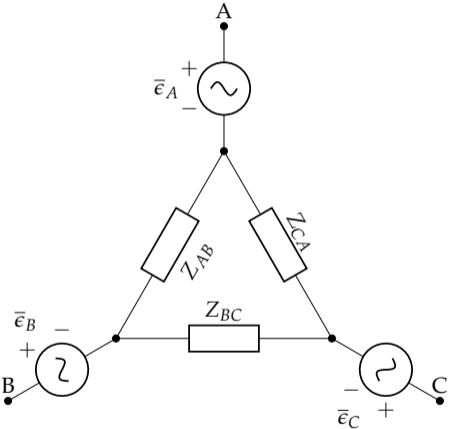
Estrella a Triángulo



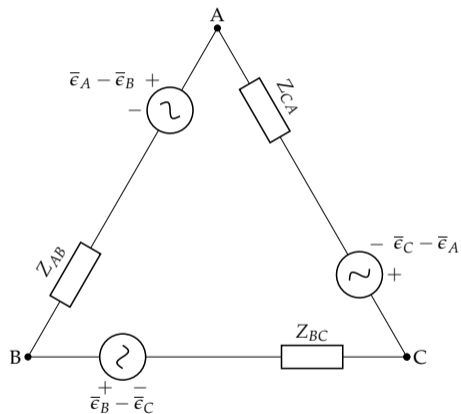
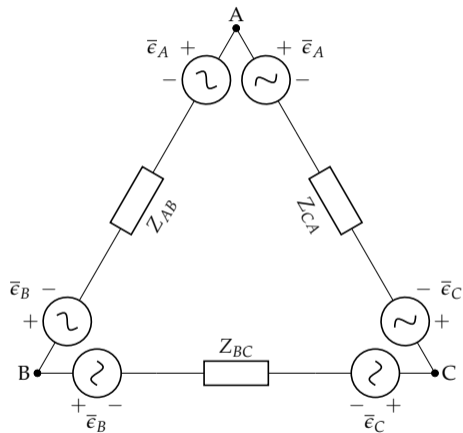
Transformamos impedancia



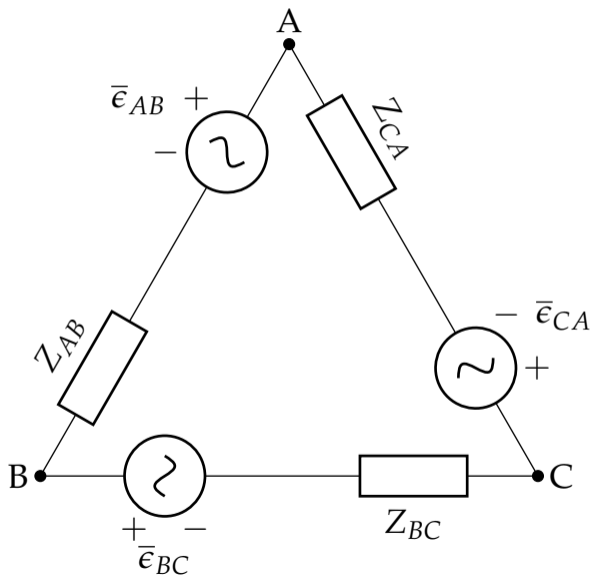
Aplicamos movilidad de fuentes



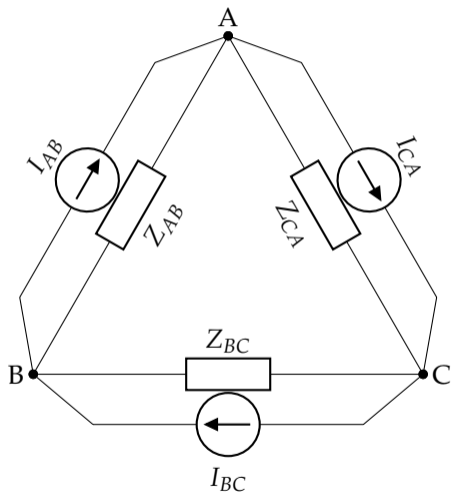
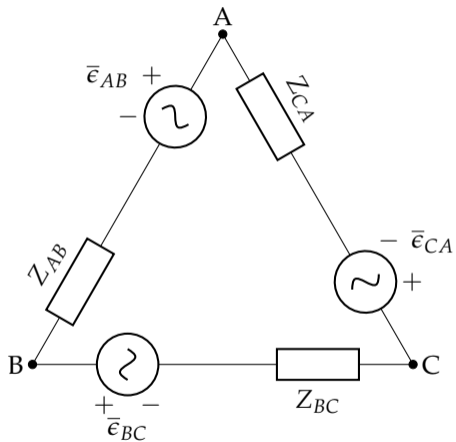
Asociamos fuentes



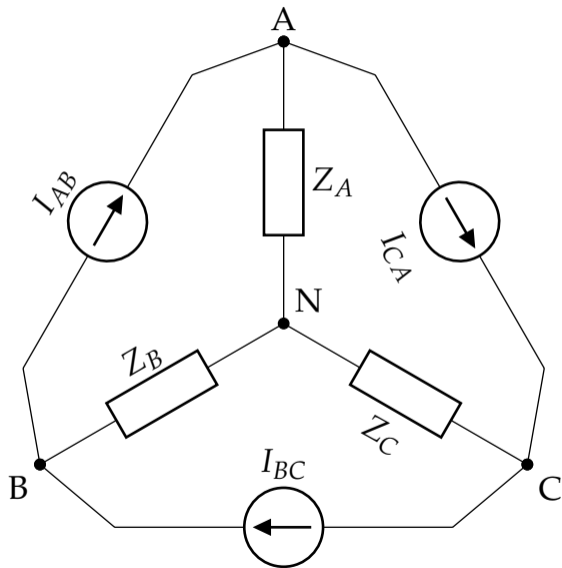
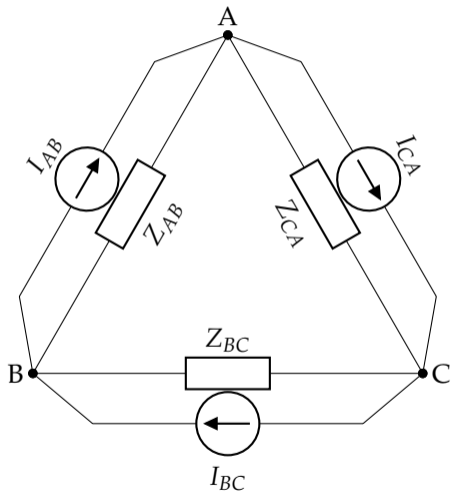
Triângulo a Estrela



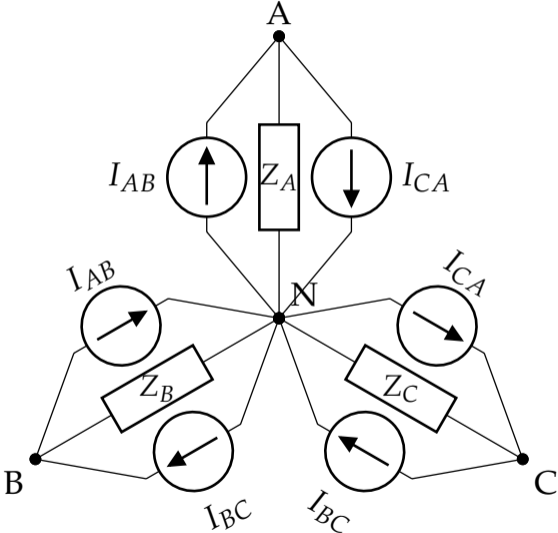
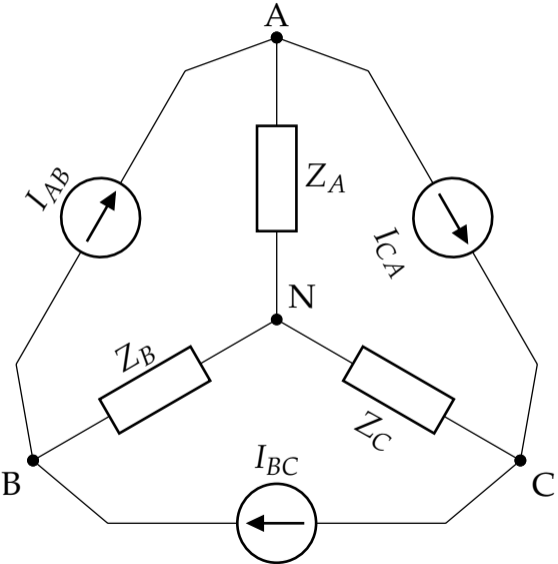
Transformamos fuentes



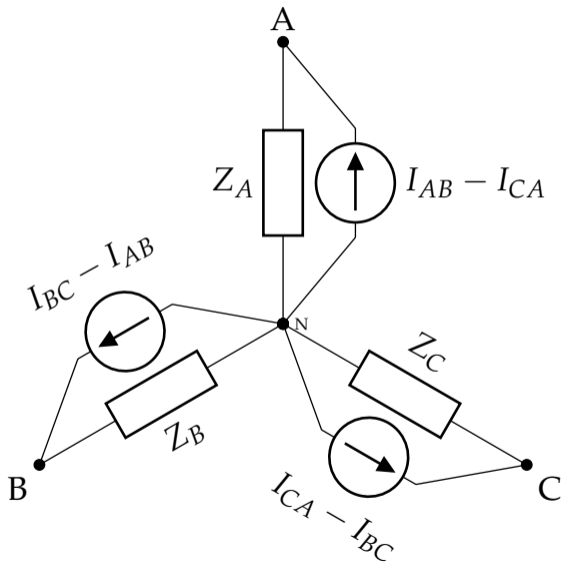
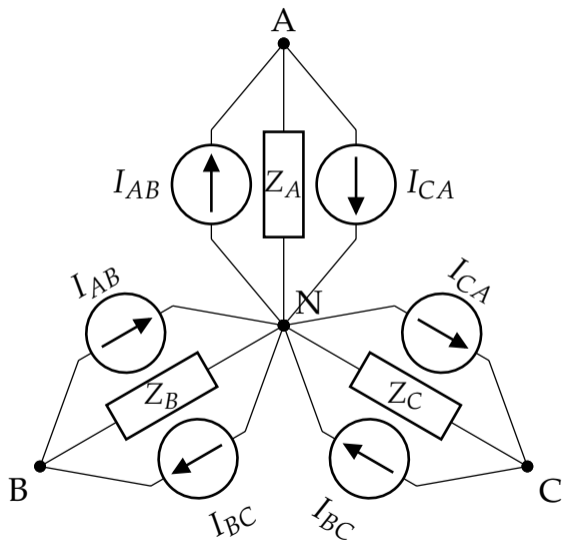
Transformamos impedancias



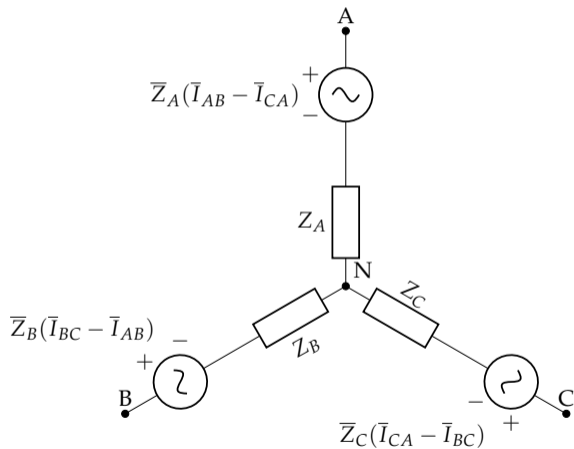
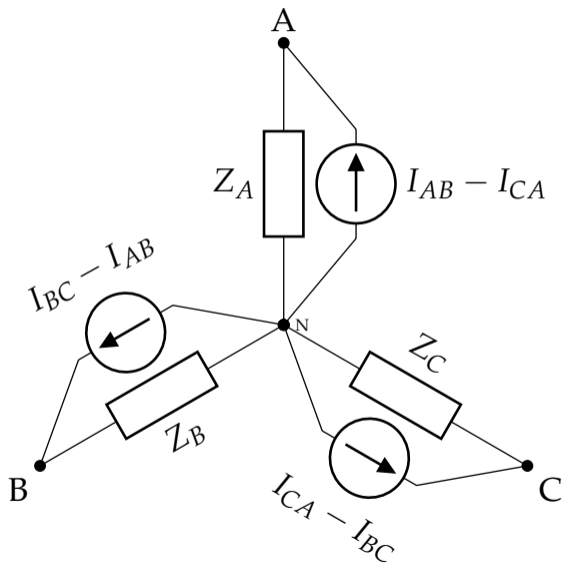
Aplicamos movilidad de fuentes



Asociamos fuentes

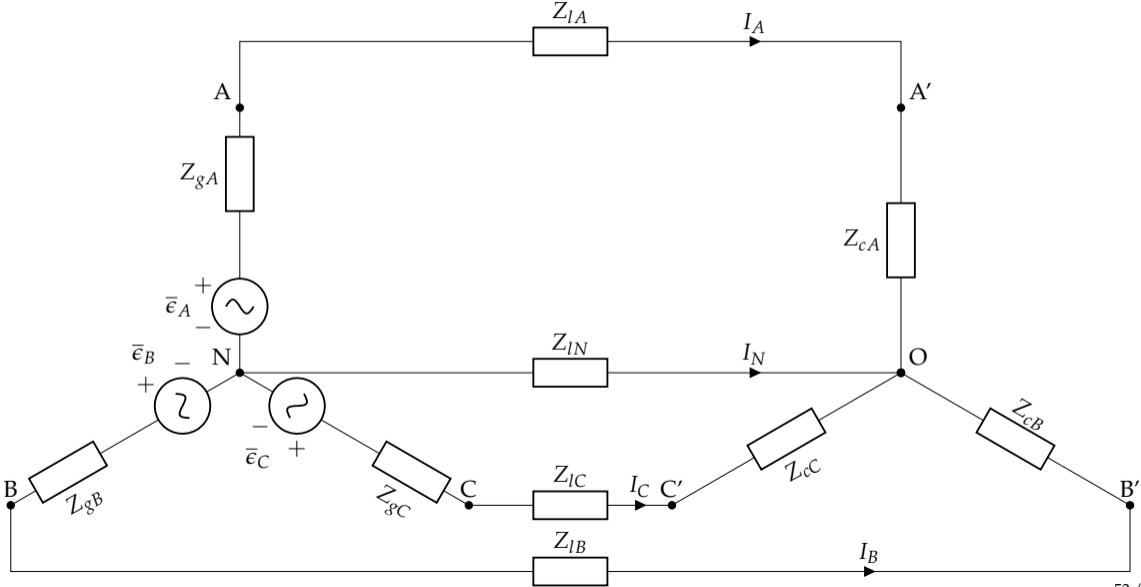


Transformamos fuentes

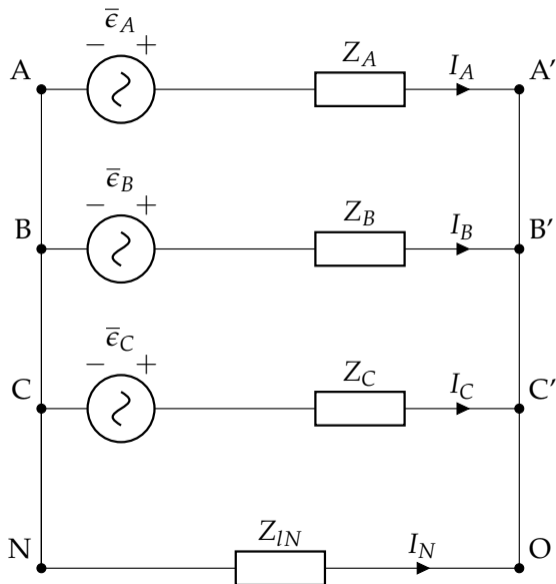


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Planteamiento del sistema



Agrupamos impedancias de generador, línea y receptor

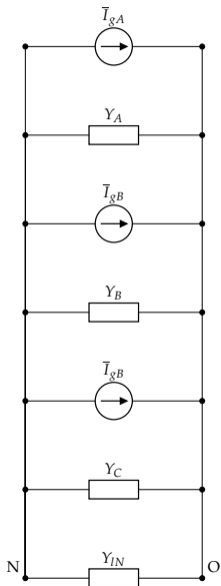


$$\bar{Z}_A = \bar{Z}_{gA} + \bar{Z}_{lA} + \bar{Z}_{cA}$$

$$\bar{Z}_B = \bar{Z}_{gB} + \bar{Z}_{lB} + \bar{Z}_{cB}$$

$$\bar{Z}_C = \bar{Z}_{gC} + \bar{Z}_{lC} + \bar{Z}_{cC}$$

Conversión de fuentes



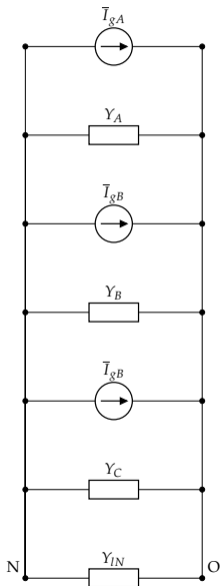
$$\bar{I}_{gA} = \bar{\epsilon}_A \cdot \bar{Y}_A$$

$$\bar{I}_{gB} = \bar{\epsilon}_B \cdot \bar{Y}_B$$

$$\bar{I}_{gC} = \bar{\epsilon}_C \cdot \bar{Y}_C$$

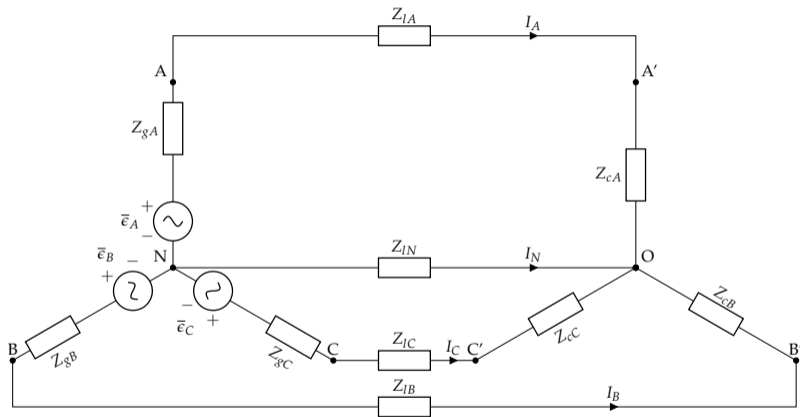
$$\bar{U}_{ON} = \frac{\bar{I}_{gA} + \bar{I}_{gB} + \bar{I}_{gC}}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C + \bar{Y}_{IN}}$$

Tensión de desplazamiento del neutro



$$\bar{U}_{ON} = \frac{\bar{\epsilon}_{gA} \cdot \bar{Y}_A + \bar{\epsilon}_{gB} \cdot \bar{Y}_B + \bar{\epsilon}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C + \bar{Y}_{IN}}$$

Cálculo de corrientes



$$\bar{I}_A = \frac{\bar{e}_A - \bar{U}_{ON}}{\bar{Z}_{gA} + \bar{Z}_{lA} + \bar{Z}_{cA}}$$

$$\bar{I}_B = \frac{\bar{e}_B - \bar{U}_{ON}}{\bar{Z}_{gB} + \bar{Z}_{lB} + \bar{Z}_{cB}}$$

$$\bar{I}_C = \frac{\bar{e}_C - \bar{U}_{ON}}{\bar{Z}_{gC} + \bar{Z}_{lC} + \bar{Z}_{cC}}$$

$$\bar{I}_N = -\bar{I}_A - \bar{I}_B - \bar{I}_C$$

Aplicación a sistemas equilibrados

La suma de las fuerzas electromotrices es 0

$$\bar{\epsilon}_{gA} + \bar{\epsilon}_{gB} + \bar{\epsilon}_{gC} = 0$$

Las tres impedancias son iguales

$$\bar{Y}_A = \bar{Y}_B = \bar{Y}_C$$

Por tanto,

$$\bar{U}_{ON} = \frac{3 \cdot \bar{Y} \cdot (\bar{\epsilon}_{gA} + \bar{\epsilon}_{gB} + \bar{\epsilon}_{gC})}{3 \cdot \bar{Y} + \bar{Y}_{IN}} = 0$$

Este resultado es independiente de la existencia del neutro y de su impedancia.

Aplicación a sistemas desequilibrados

- ▶ Sistemas con neutro de impedancia no nula

$$\bar{U}_{ON} = \frac{\bar{\epsilon}_{gA} \cdot \bar{Y}_A + \bar{\epsilon}_{gB} \cdot \bar{Y}_B + \bar{\epsilon}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C + \bar{Y}_{IN}}$$

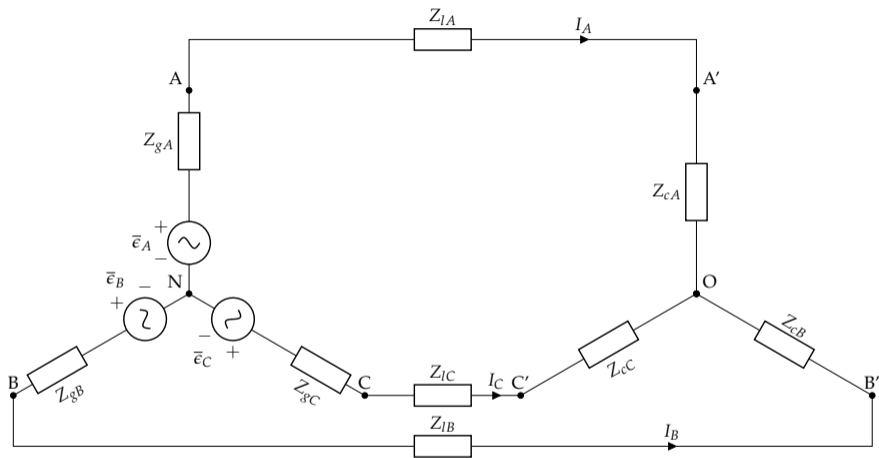
- ▶ Sistemas con neutro de impedancia nula ($\bar{Z}_{IN} = 0$, $\bar{Y}_{IN} \rightarrow \infty$)

$$\bar{U}_{ON} = \frac{\bar{\epsilon}_{gA} \cdot \bar{Y}_A + \bar{\epsilon}_{gB} \cdot \bar{Y}_B + \bar{\epsilon}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C + \bar{Y}_{IN}} = 0$$

- ▶ Sistemas sin neutro ($\bar{Z}_{IN} \rightarrow \infty$, $\bar{Y}_{IN} = 0$)

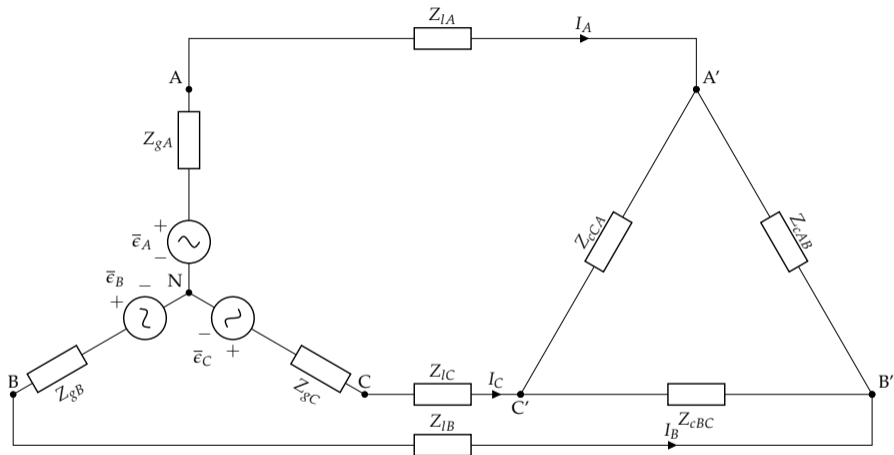
$$\bar{U}_{ON} = \frac{\bar{\epsilon}_{gA} \cdot \bar{Y}_A + \bar{\epsilon}_{gB} \cdot \bar{Y}_B + \bar{\epsilon}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C}$$

Sistema sin neutro



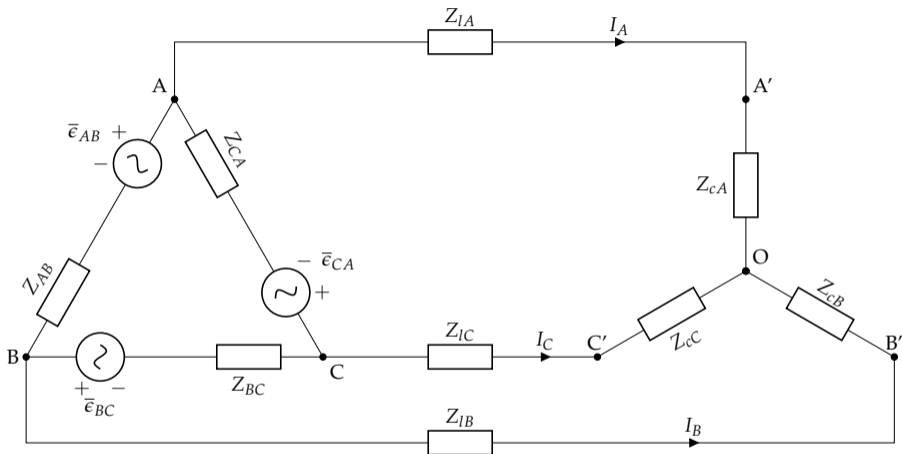
$$Z_{lN} \rightarrow \infty \} \longrightarrow \bar{U}_{ON} = \frac{\bar{e}_{gA} \cdot \bar{Y}_A + \bar{e}_{gB} \cdot \bar{Y}_B + \bar{e}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C}$$

Receptor en triángulo



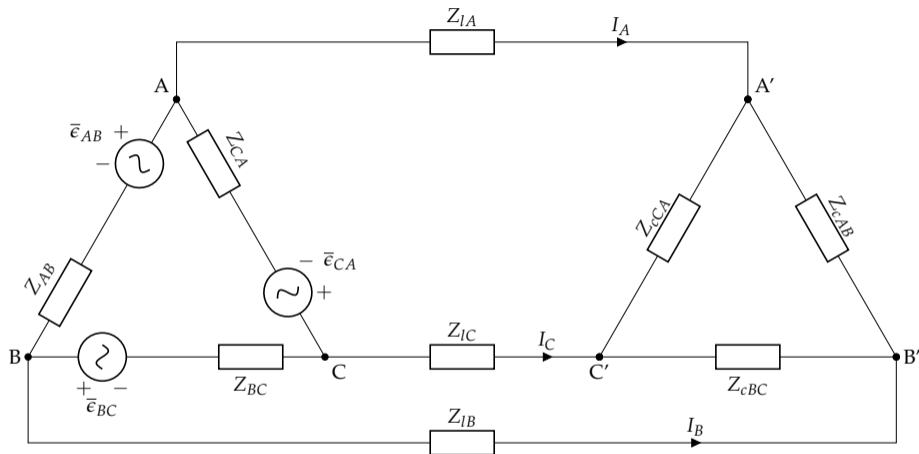
$$\left. \begin{array}{l} \text{Transformación de Receptor} \\ Z_{lN} \rightarrow \infty \end{array} \right\} \rightarrow \bar{U}_{ON} = \frac{\bar{e}_{gA} \cdot \bar{Y}_A + \bar{e}_{gB} \cdot \bar{Y}_B + \bar{e}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C}$$

Generador en triángulo



$$\left. \begin{array}{l} \text{Transformación de Generador} \\ Z_{IN} \rightarrow \infty \end{array} \right\} \rightarrow \bar{U}_{ON} = \frac{\bar{e}_{gA} \cdot \bar{Y}_A + \bar{e}_{gB} \cdot \bar{Y}_B + \bar{e}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C}$$

Generador y Receptor en triángulo



Transformación de Generador }
 Transformación de Receptor }
 $Z_{IN} \rightarrow \infty$

$$\rightarrow \bar{U}_{ON} = \frac{\bar{e}_{gA} \cdot \bar{Y}_A + \bar{e}_{gB} \cdot \bar{Y}_B + \bar{e}_{gC} \cdot \bar{Y}_C}{\bar{Y}_A + \bar{Y}_B + \bar{Y}_C}$$