Sistemas Trifásicos

Teoría de Circuitos II

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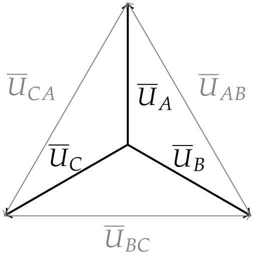
1. Generadores
2. Receptores
3. Potencia en Sistemas Trifásicos
4. Compensación de Reactiva
5. Medida de Potencia en Sistemas Trifásicos
6. Conversión de Fuentes Reales
7. Estudio generalizado de los sistemas trifásicos

Tensiones de Fase y Línea



Tensiones de **Fase**: U_A, U_B, U_C
Tensiones de **Línea**: U_{AB}, U_{BC}, U_{CA}

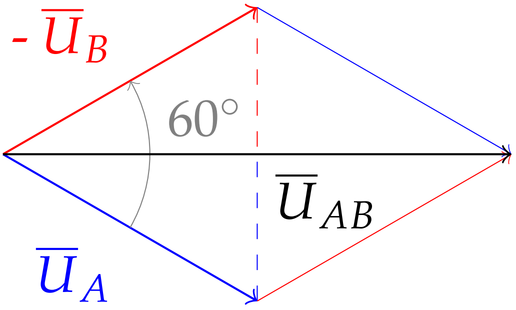
$$\overline{U}_{AB} = \overline{U}_A - \overline{U}_B$$
$$\overline{U}_{BC} = \overline{U}_B - \overline{U}_C$$
$$\overline{U}_{CA} = \overline{U}_C - \overline{U}_A$$

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

Tensiones de Fase y Línea

$$\overline{U}_A = U_f \angle \theta_f$$
$$\overline{U}_B = U_f \angle \theta_f - 120^\circ$$

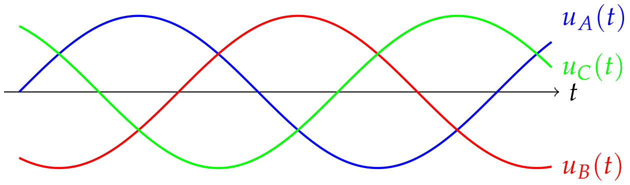
$$\begin{aligned}\overline{U}_{AB} &= \overline{U}_A - \overline{U}_B = \\ &= U_f \angle \theta_f - U_f \angle \theta_f - 120^\circ = \\ &= U_f \angle \theta_f + U_f \angle \theta_f + 60^\circ \\ &= 2 \cdot U_f \cdot \cos(30) \angle \theta_f + 30^\circ = \\ &= \sqrt{3} U_f \angle \theta_f + 30^\circ\end{aligned}$$



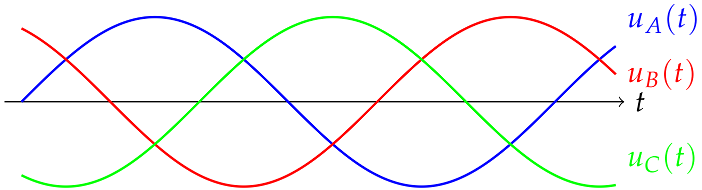
$$\boxed{\begin{aligned} U &= \sqrt{3} \cdot U_f \\ \theta_l &= \theta_f + 30^\circ \end{aligned}}$$

Secuencia de Fases

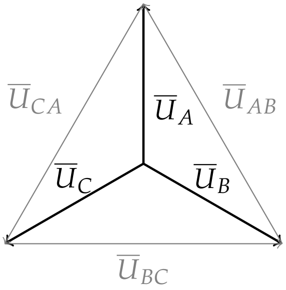
- Sentido en el que ocurren los máximos de cada fase.
- Secuencia de Fases Directa (**SFD**): ABC



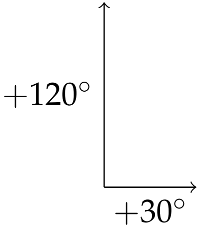
- Secuencia de Fases Inversa (**SFI**): ACB



Secuencia de Fases Directa (SFD)

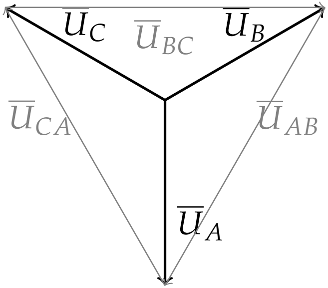


$$\overline{U}_A = \frac{U}{\sqrt{3}} \underline{/90^\circ}$$
$$\overline{U}_B = \frac{U}{\sqrt{3}} \underline{/-30^\circ}$$
$$\overline{U}_C = \frac{U}{\sqrt{3}} \underline{/-150^\circ}$$

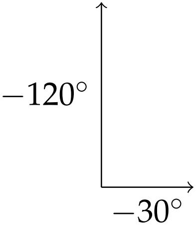


$$\overline{U}_{AB} = U\underline{/120^\circ}$$
$$\overline{U}_{BC} = U\underline{/0^\circ}$$
$$\overline{U}_{CA} = U\underline{/-120^\circ}$$

Secuencia de Fases Inversa (SFI)



$$\overline{U}_A = \frac{U}{\sqrt{3}}\angle{-90^\circ}$$
$$\overline{U}_B = \frac{U}{\sqrt{3}}\angle{30^\circ}$$
$$\overline{U}_C = \frac{U}{\sqrt{3}}\angle{150^\circ}$$



$$\overline{U}_{AB} = U\angle{-120^\circ}$$
$$\overline{U}_{BC} = U\angle{0^\circ}$$
$$\overline{U}_{CA} = U\angle{120^\circ}$$

Tipos de Receptores

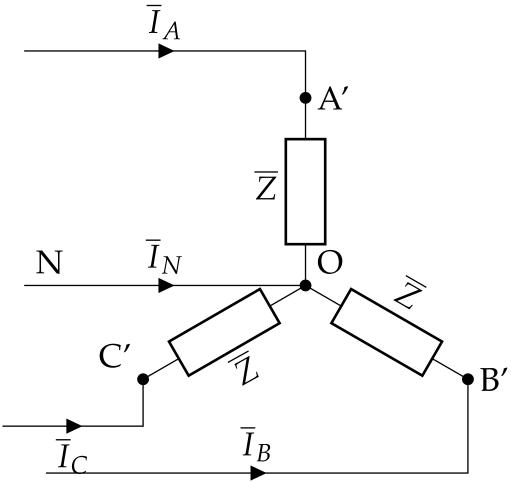
Conexión

- **Estrella** (punto común) Y
- **Triángulo** $\triangle$

Impedancias

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

Receptor en Estrella Equilibrado



$$\bar{I}_A = \frac{\overline{U}_A}{\overline{Z}} = \frac{U_f}{Z} \underline{/\pm 90^\circ - \varphi}$$

$$\bar{I}_B = \frac{\overline{U}_B}{\overline{Z}} = \frac{U_f}{Z} \underline{/\mp 30^\circ - \varphi}$$

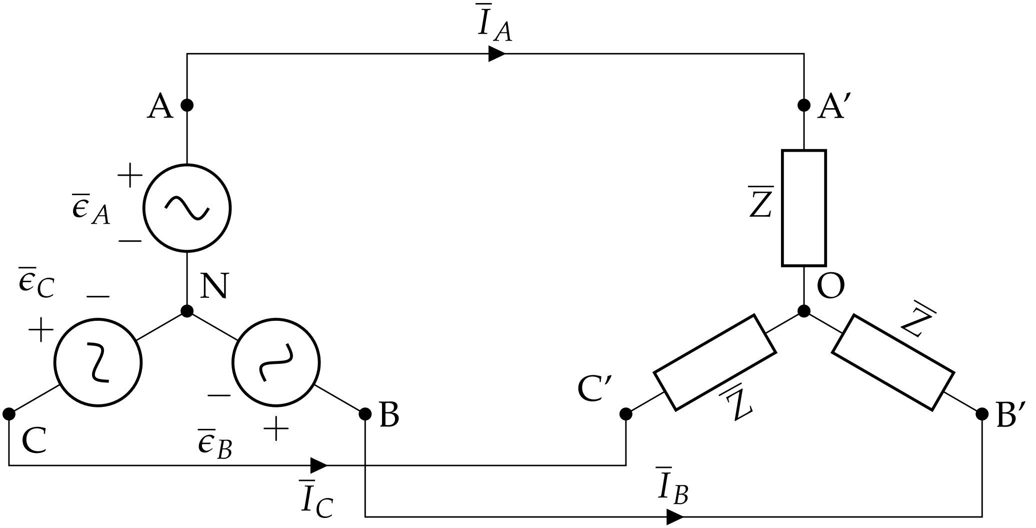
$$\bar{I}_C = \frac{\overline{U}_C}{\overline{Z}} = \frac{U_f}{Z} \underline{/\mp 150^\circ - \varphi}$$

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

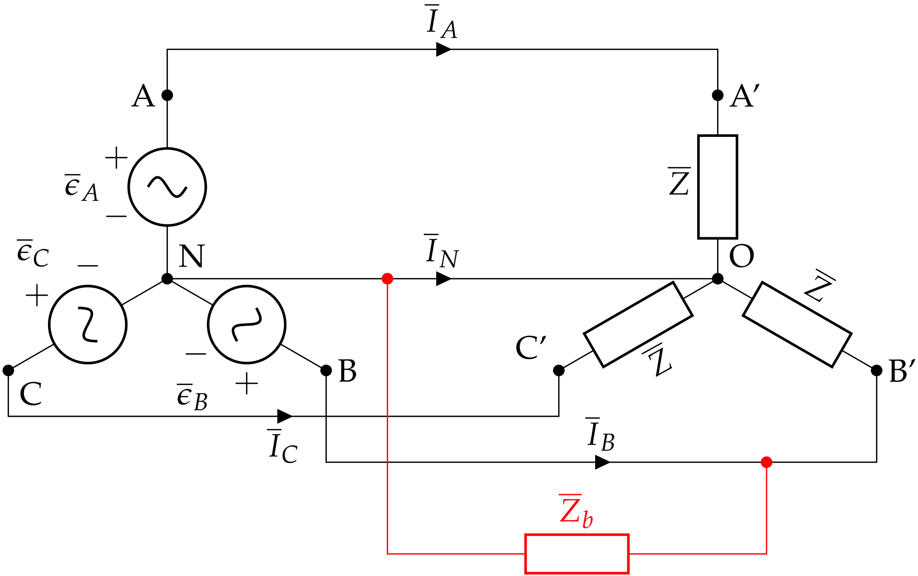
$$\bar{I}_A + \bar{I}_B + \bar{I}_C + \bar{I}_N = 0$$

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

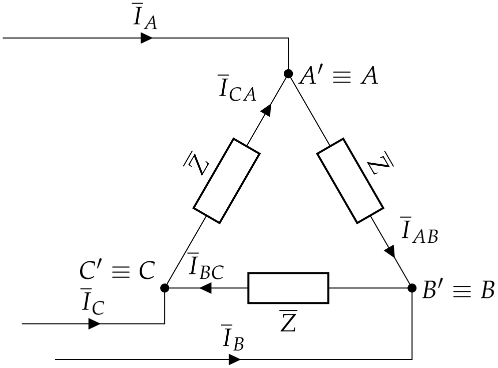
Receptor en Estrella Equilibrado



Receptor en Estrella con Carga Monofásica



Receptor en Triángulo Equilibrado



$$\bar{I}_{AB} = \frac{\overline{U}_{AB}}{\overline{Z}} = \frac{U}{Z}\underline{/\pm 120^\circ - \varphi}$$

$$\bar{I}_{BC} = \frac{\overline{U}_{BC}}{\overline{Z}} = \frac{U}{Z}\underline{/0 - \varphi}$$

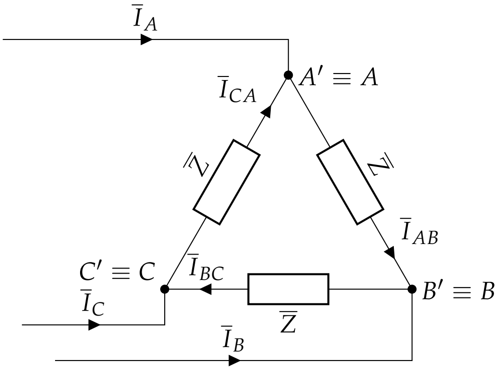
$$\bar{I}_{CA} = \frac{\overline{U}_{CA}}{\overline{Z}} = \frac{U}{Z}\underline{/\mp 120^\circ - \varphi}$$

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

Corriente de Fase:

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

Receptor en Triángulo Equilibrado



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

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

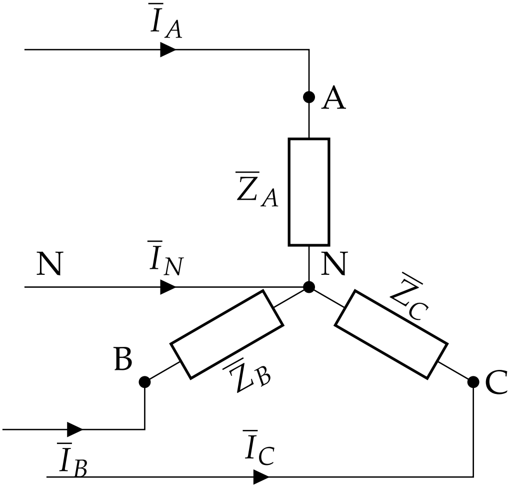
$$\bar{I}_C = \bar{I}_{CA} - \bar{I}_{BC} = \sqrt{3} \cdot \frac{U}{Z} \underline{/\mp 150^\circ - \varphi}$$

Corriente de Línea:

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

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

Receptor en Estrella Desequilibrado con Neutro



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

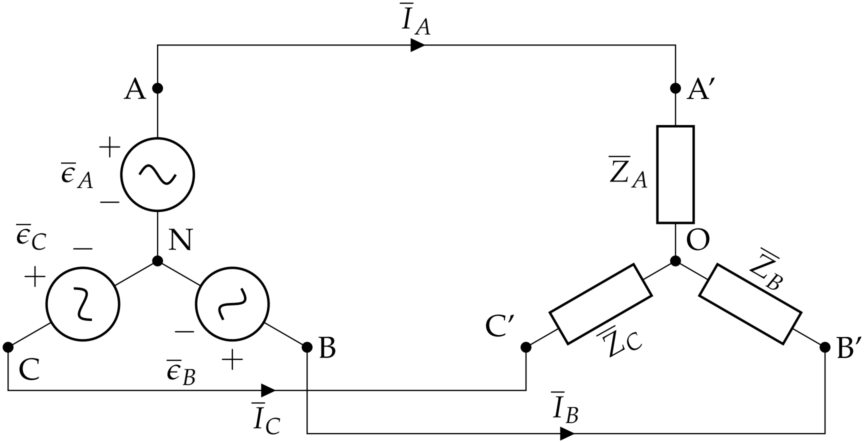
$$\overline{I}_B = \frac{\overline{U}_B}{\overline{Z}_B}$$

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

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

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

Receptor en Estrella Desequilibrado sin Neutro



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

Método del desplazamiento del neutro

Ecuaciones del receptor:

$$\overline{U}_{A'O} = \overline{I}_A \cdot \overline{Z}_A$$
$$\overline{U}_{B'O} = \overline{I}_B \cdot \overline{Z}_B$$
$$\overline{U}_{C'O} = \overline{I}_C \cdot \overline{Z}_C$$

Ecuación del nudo O:

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

Método del desplazamiento del neutro

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

$$\overline{U}_{A'O} = \overline{U}_{AN} - \overline{U}_{ON}$$
$$\overline{U}_{B'O} = \overline{U}_{BN} - \overline{U}_{ON}$$
$$\overline{U}_{C'O} = \overline{U}_{CN} - \overline{U}_{ON}$$

Despejamos las corrientes teniendo en cuenta estas relaciones:

$$\bar{I}_A = \frac{\overline{U}_{AN} - \overline{U}_{ON}}{\overline{Z}_A}$$
$$\bar{I}_B = \frac{\overline{U}_{BN} - \overline{U}_{ON}}{\overline{Z}_B}$$
$$\bar{I}_C = \frac{\overline{U}_{CN} - \overline{U}_{ON}}{\overline{Z}_C}$$

Método del desplazamiento del neutro

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

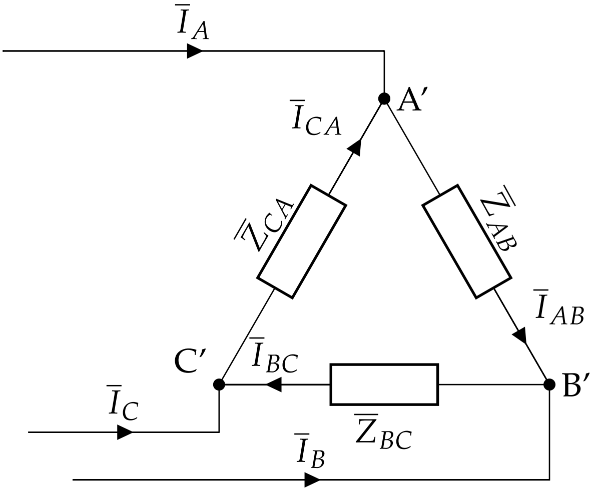
$$\boxed{\overline{U}_{ON} = \frac{\overline{U}_{AN} \cdot \overline{Y}_A + \overline{U}_{BN} \cdot \overline{Y}_B + \overline{U}_{CN} \cdot \overline{Y}_C}{\overline{Y}_A + \overline{Y}_B + \overline{Y}_C}}$$

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

$$\begin{aligned} \bar{I}_A &= (\overline{U}_{AN} - \overline{U}_{ON}) \cdot \overline{Y}_A \\ \bar{I}_B &= (\overline{U}_{BN} - \overline{U}_{ON}) \cdot \overline{Y}_B \\ \bar{I}_C &= (\overline{U}_{CN} - \overline{U}_{ON}) \cdot \overline{Y}_C \end{aligned}$$

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

Receptor en Triángulo Desequilibrado



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

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

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

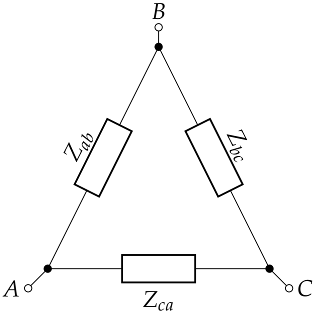
$$\overline{I}_A = \overline{I}_{AB} - \overline{I}_{CA}$$

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

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

Transformación de receptores

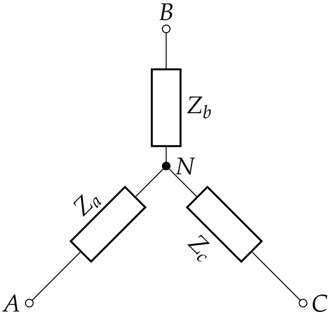
Triángulo a Estrella



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

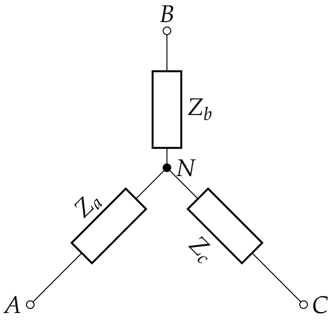
$$\overline{Z}_b = \frac{\overline{Z}_{bc} \cdot \overline{Z}_{ab}}{\overline{Z}_{ab} + \overline{Z}_{bc} + \overline{Z}_{ca}}$$

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



Transformación de receptores

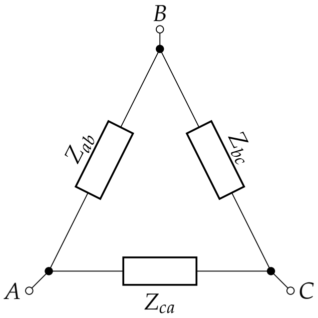
Estrella a Triángulo



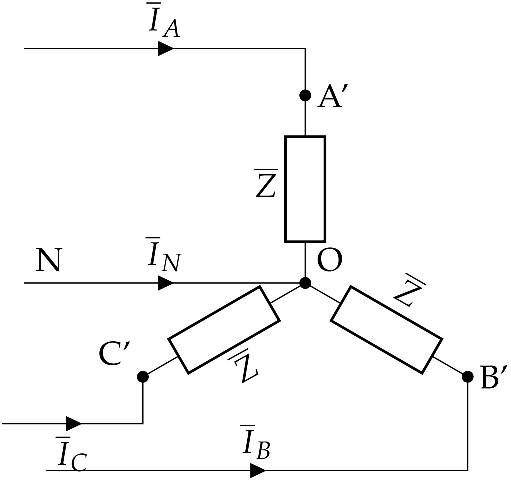
$$\overline{Y}_{ab} = \frac{\overline{Y}_a \overline{Y}_b}{\overline{Y}_a + \overline{Y}_b + \overline{Y}_c}$$

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

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



Receptor en Estrella Equilibrado

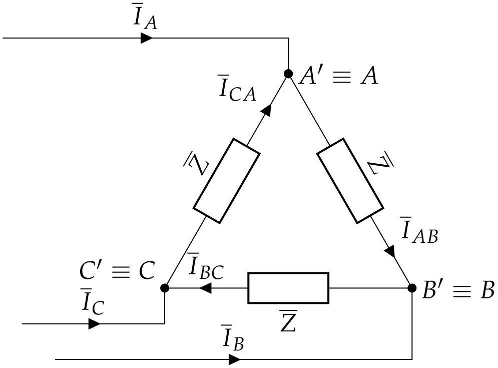


$$P = 3 \cdot P_Z = 3 \cdot U_Z I_Z \cos(\varphi)$$
$$Q = 3 \cdot Q_Z = 3 \cdot U_Z I_Z \sin(\varphi)$$

$$I_Z = I$$
$$U_Z = U_F$$

$$P = 3U_F I \cos(\varphi) = \sqrt{3} UI \cos(\varphi)$$
$$Q = 3U_F I \sin(\varphi) = \sqrt{3} UI \sin(\varphi)$$
$$S = \sqrt{P^2 + Q^2} = \sqrt{3} UI$$

Receptor en Triángulo Equilibrado

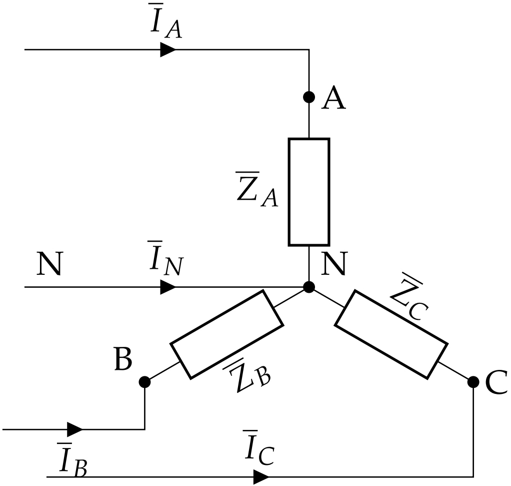


$$P = 3 \cdot P_Z = 3 \cdot U_Z I_Z \cos(\varphi)$$
$$Q = 3 \cdot Q_Z = 3 \cdot U_Z I_Z \sin(\varphi)$$

$$I_Z = I_F$$
$$U_Z = U$$

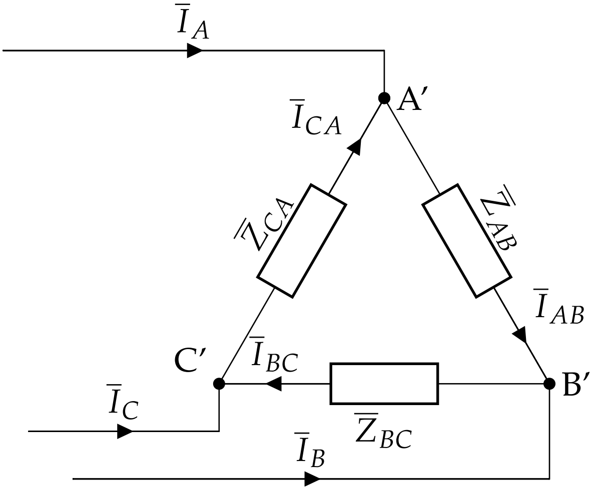
$$P = 3UI_F \cos(\varphi) = \sqrt{3}UI \cos(\varphi)$$
$$Q = 3UI_F \sin(\varphi) = \sqrt{3}UI \sin(\varphi)$$
$$S = \sqrt{P^2 + Q^2} = \sqrt{3}UI$$

Receptor en Estrella Desequilibrado



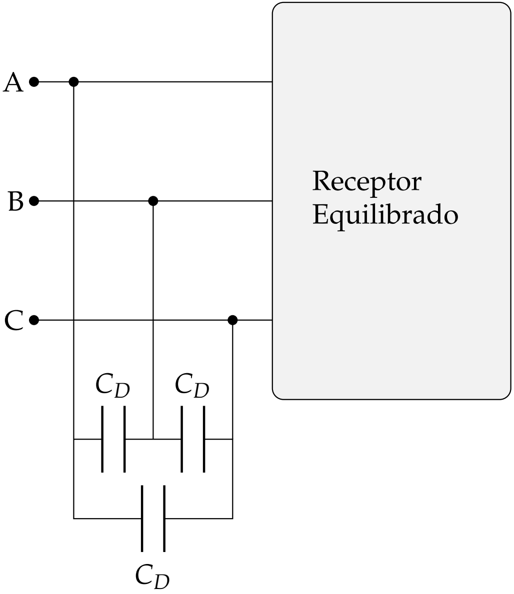
$$P = P_A + P_B + P_C$$
$$Q = Q_A + Q_B + Q_C$$
$$\overline{S} = P + jQ$$

Receptor en Triángulo Desequilibrado



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

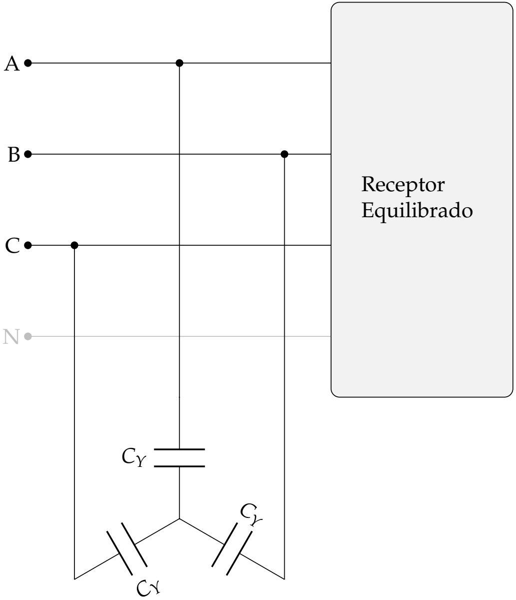
Conexión en Triángulo



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

$$
\boxed{C_\triangle = \frac{P(\tan \varphi - \tan \varphi')}{3\omega U^2}}
$$

Conexión en Estrella



$$Q = P \tan\varphi$$

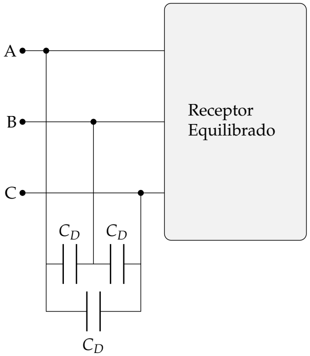
$$Q' = P \tan\varphi' =$$

$$= Q - Q_c$$

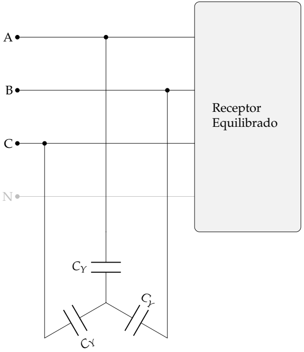
$$Q_c = 3 \cdot \omega C_Y \cdot U_f^2$$

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

Comparación Estrella-Triángulo



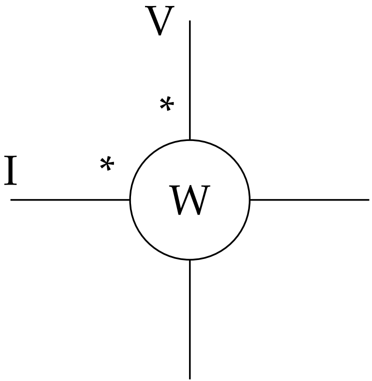
$$C_{\triangle} = \boxed{\frac{P(\tan\varphi - \tan\varphi')}{3\omega U^2}}$$



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

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

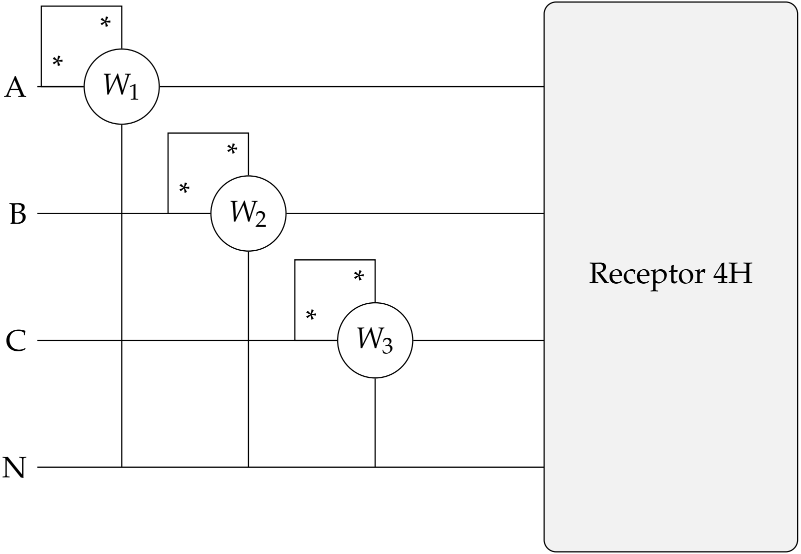
Recordatorio: vatímetro



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

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

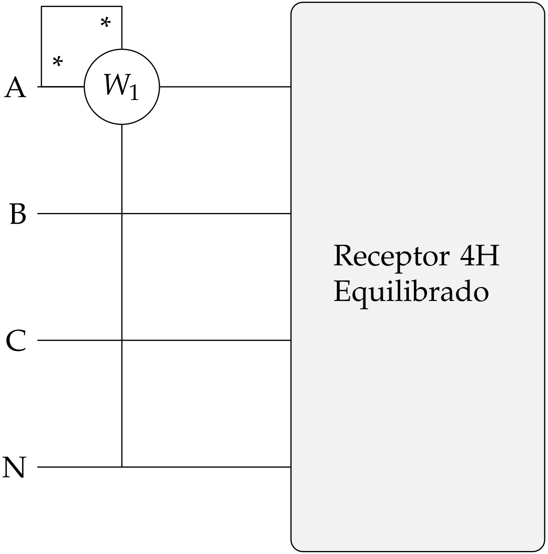
Sistema de 4 Hilos



$$W_1 = \Re(\overline{U}_A \cdot \overline{I}_A^*) = P_A$$
$$W_2 = \Re(\overline{U}_B \cdot \overline{I}_B^*) = P_B$$
$$W_3 = \Re(\overline{U}_C \cdot \overline{I}_C^*) = P_C$$

$$\boxed{P = W_1 + W_2 + W_3}$$

Sistema de 4 Hilos Equilibrado



$$P_A = P_B = P_C$$

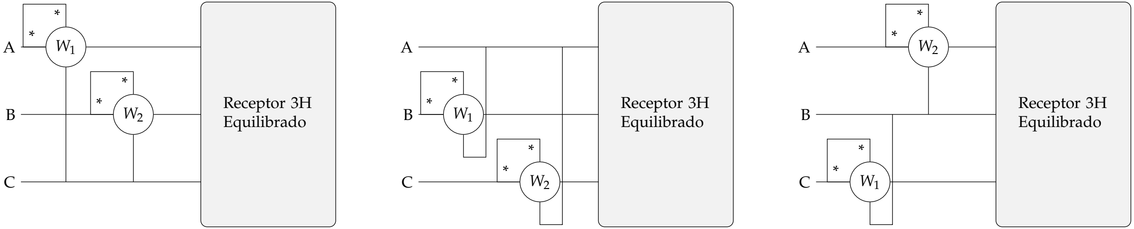
$$\boxed{P = 3 \cdot W_1}$$

Sistema de 3 Hilos Equilibrado (SFD)

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

$$W_1 = UI\cos(\varphi - 30^\circ) \qquad P = W_1 + W_2$$

$$W_2 = UI\cos(\varphi + 30^\circ) \qquad Q = \sqrt{3}(W_1 - W_2)$$



$$W_1 : AC \notin SFD \qquad W_1 : BA \notin SFD \qquad W_1 : CB \notin SFD$$

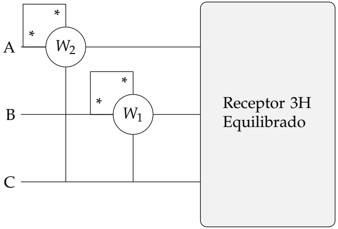
$$W_2 : BC \in SFD \qquad W_2 : CA \in SFD \qquad W_2 : AB \in SFD$$

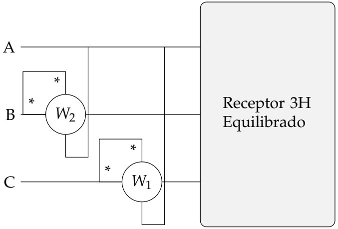
Sistema de 3 Hilos Equilibrado (SFI)

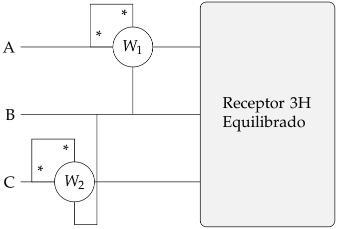
$$\boxed{(ACB) :: A \triangleright C \triangleright B \Longrightarrow \{AC, CB, BA\}}$$

$$W_1 = UI\cos(\varphi - 30^\circ) \qquad P = W_1 + W_2$$

$$W_2 = UI\cos(\varphi + 30^\circ) \qquad Q = \sqrt{3}(W_1 - W_2)$$



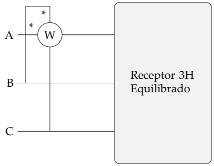


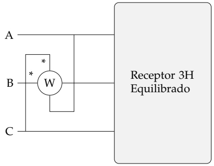


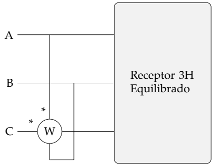
$$W_1 : BC \notin SFI \qquad W_1 : CA \notin SFI \qquad W_1 : AB \notin SFI$$

$$W_2 : AC \in SFI \qquad W_2 : BA \in SFI \qquad W_2 : CB \in SFI$$

Conexiones para medida de reactiva







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

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

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

$$BC \in SFD$$
$$BC \notin SFI$$

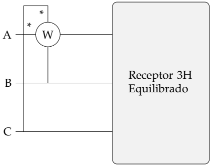
$$CA \in SFD$$
$$CA \notin SFI$$

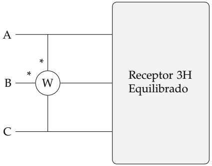
$$AB \in SFD$$
$$AB \notin SFI$$

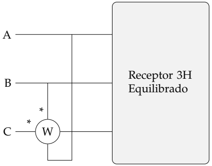
$$SFD \rightarrow \boxed{W = \frac{Q}{\sqrt{3}}}$$

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

Conexiones para medida de reactiva







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

$$CB \notin SFD$$

$$CB \in SFI$$

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

$$AC \notin SFD$$

$$AC \in SFI$$

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

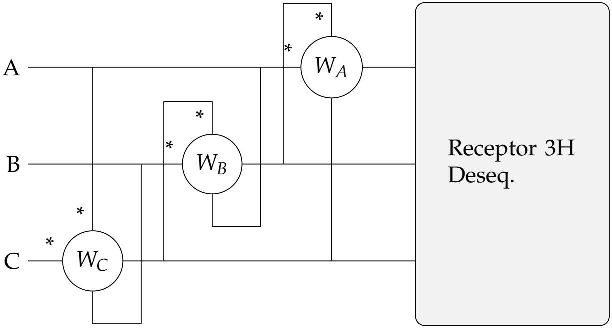
$$BA \notin SFD$$

$$BA \in SFI$$

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

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

Medida de la reactiva con receptor desequilibrado

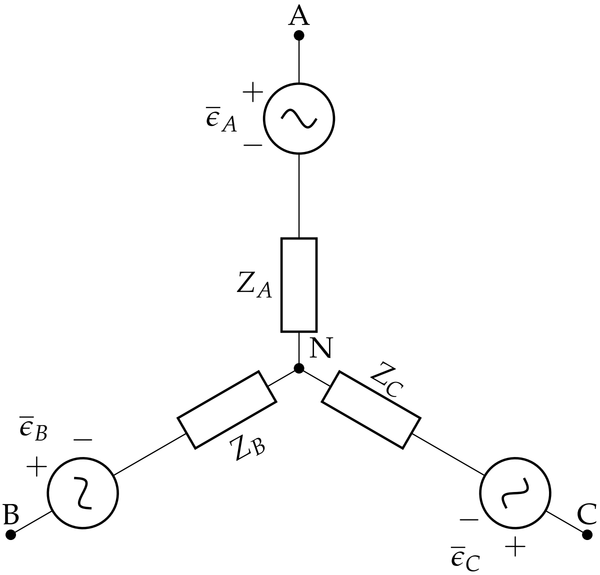


$$W_A = \Re(\overline{U}_{BC} \cdot \overline{I}_A^*)$$
$$W_B = \Re(\overline{U}_{CA} \cdot \overline{I}_B^*)$$
$$W_C = \Re(\overline{U}_{AB} \cdot \overline{I}_C^*)$$

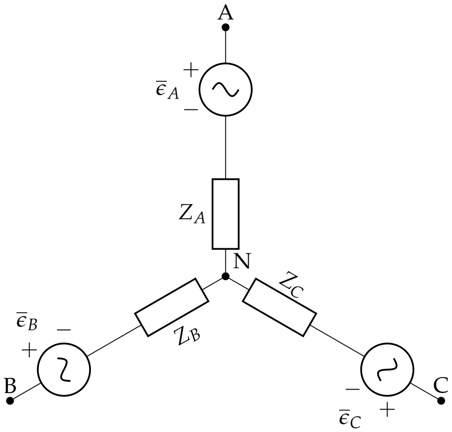
$$\overline{U}_{AB} = \pm\sqrt{3} \cdot \overline{U}_C \cdot e^{j\pi/2}$$
$$\overline{U}_{BC} = \pm\sqrt{3} \cdot \overline{U}_A \cdot e^{j\pi/2}$$
$$\overline{U}_{CA} = \pm\sqrt{3} \cdot \overline{U}_B \cdot e^{j\pi/2}$$

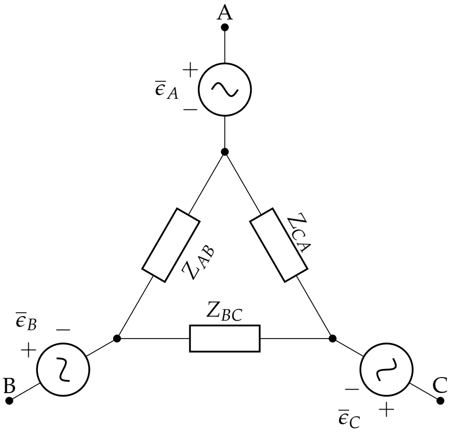
$$\boxed{W_A + W_B + W_C = \pm Q/\sqrt{3}}$$

Estrella a Triángulo

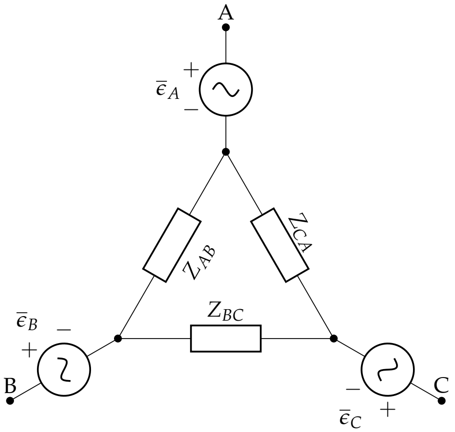


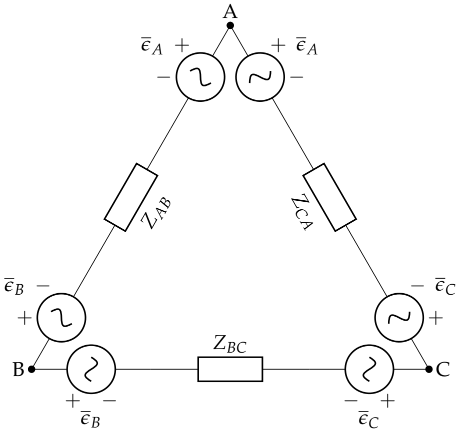
Transformamos impedancia



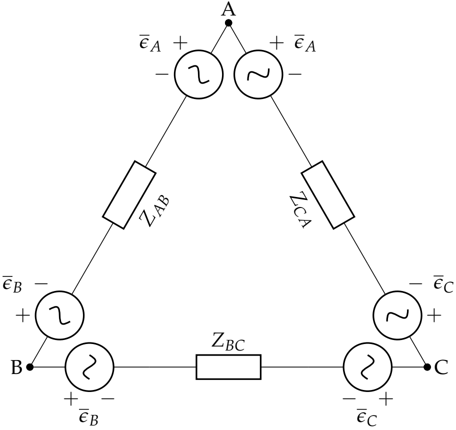


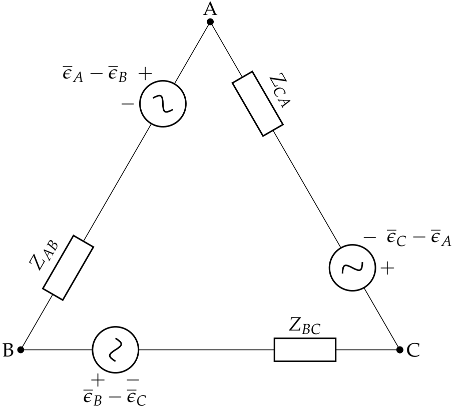
Aplicamos movilidad de fuentes



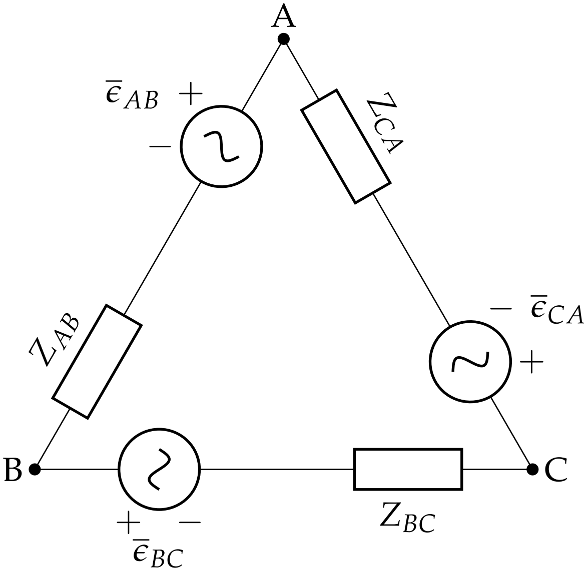


Asociamos fuentes

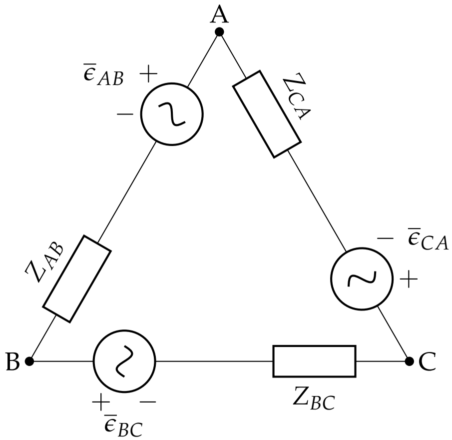


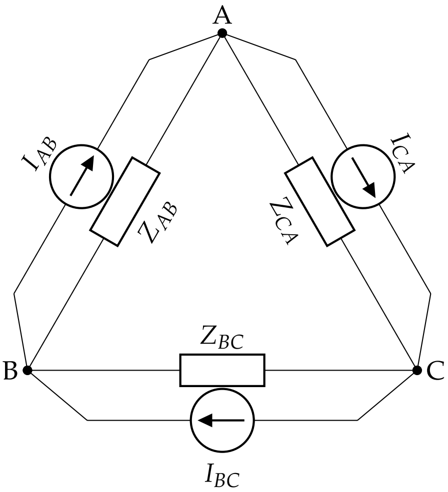


Triángulo a Estrella

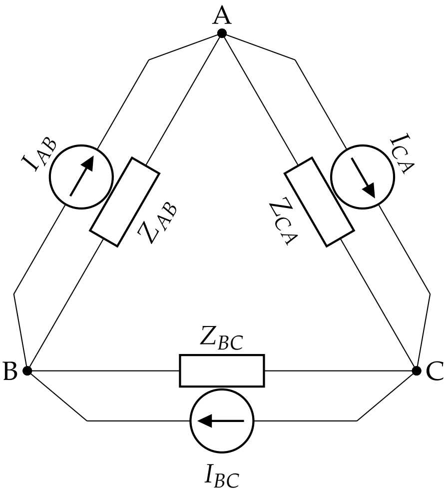


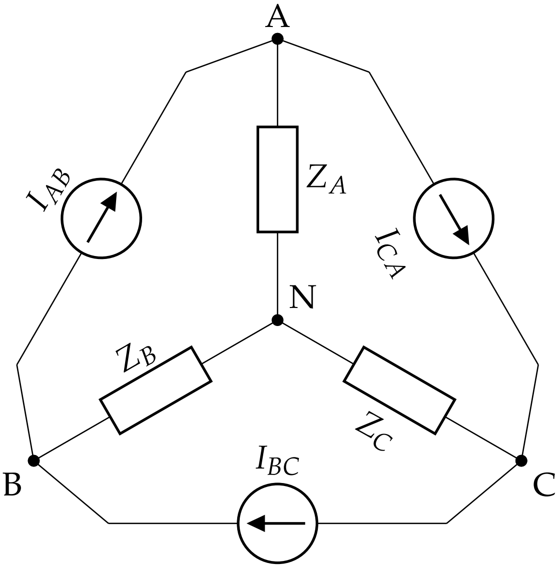
Transformamos fuentes



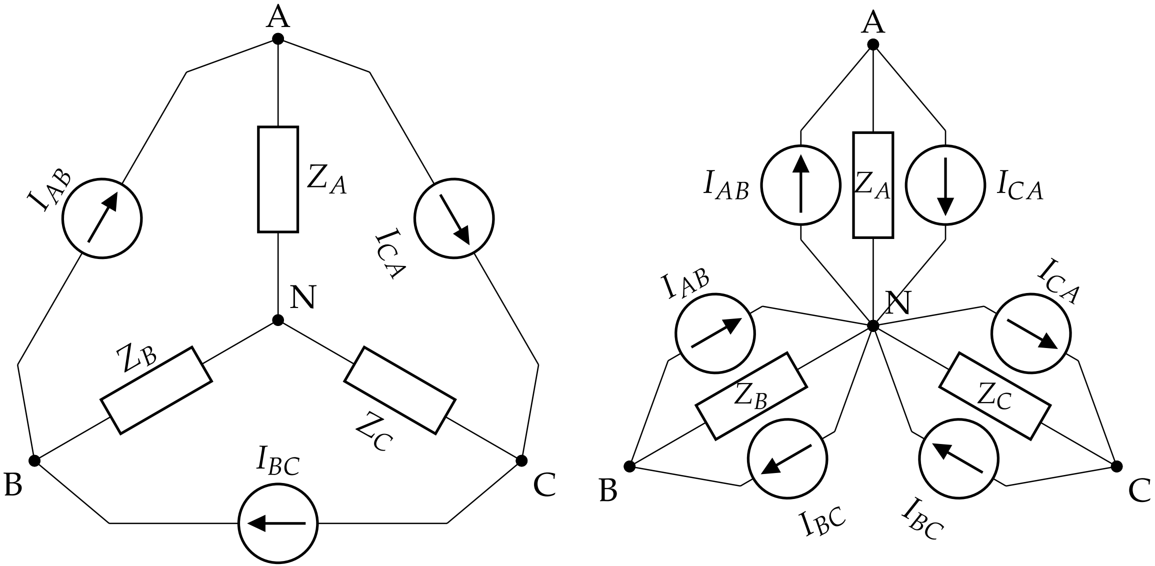


Transformamos impedancias

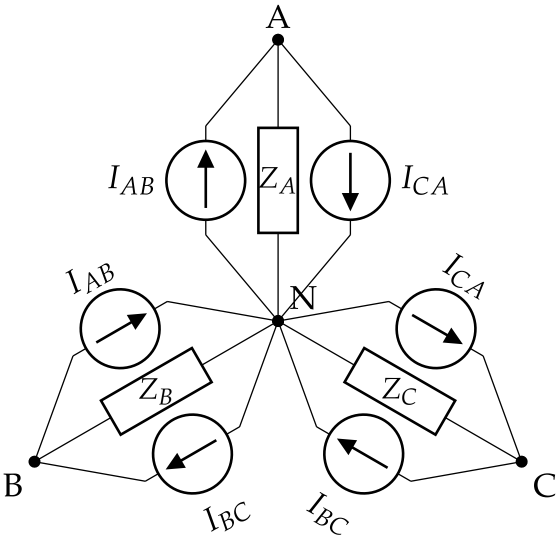


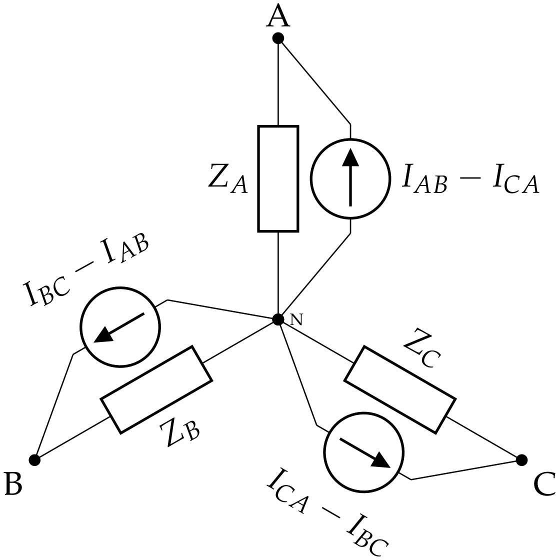


Aplicamos movilidad de fuentes

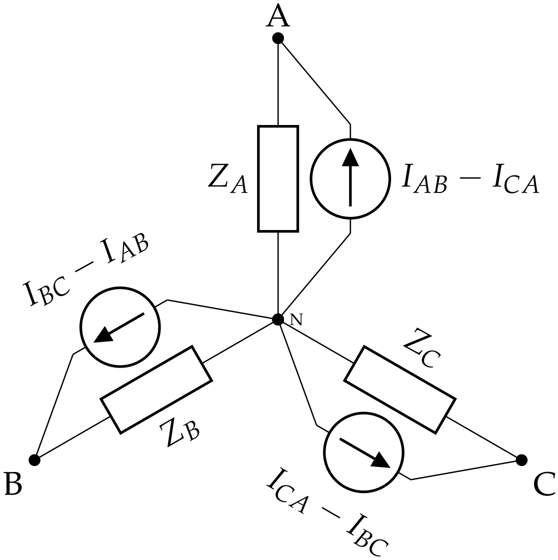


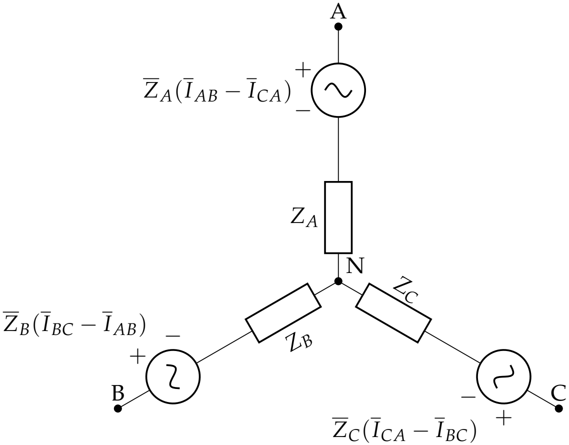
Asociamos fuentes



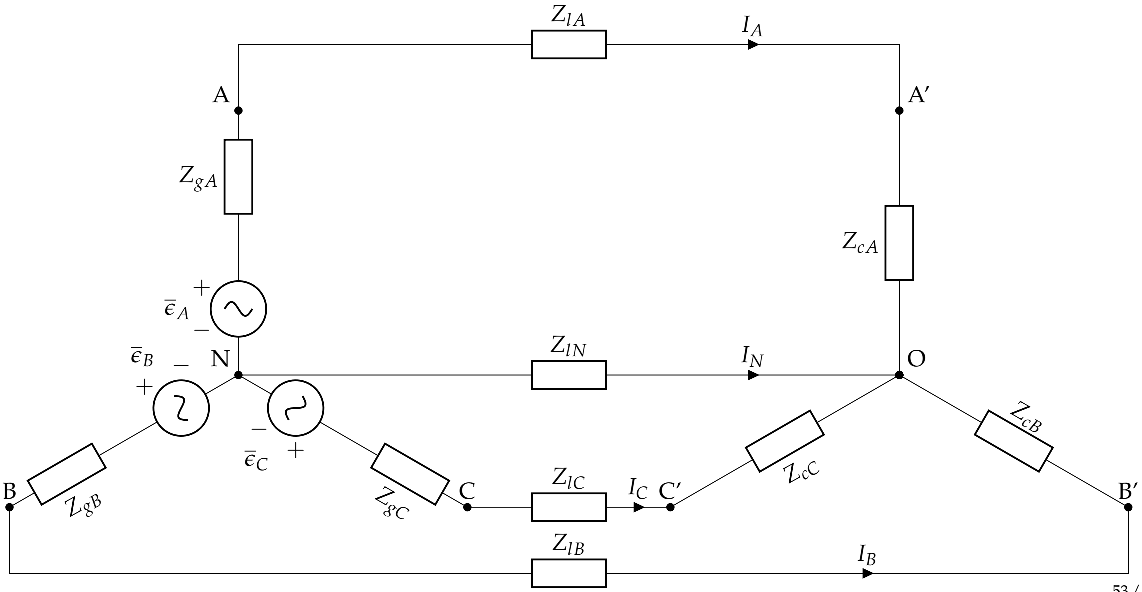


Transformamos fuentes

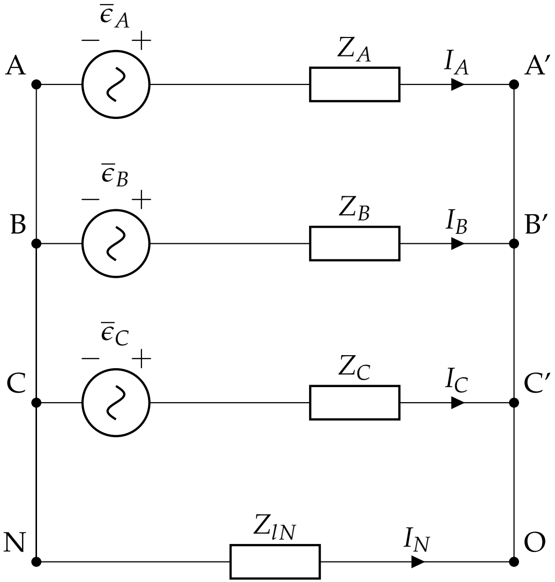




Planteamiento del sistema

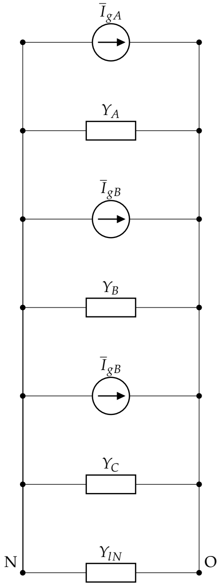


Agrupamos impedancias de generador, línea y receptor



$$
\begin{aligned}
\overline{Z}_A &= \overline{Z}_{gA} + \overline{Z}_{lA} + \overline{Z}_{cA} \\
\overline{Z}_B &= \overline{Z}_{gB} + \overline{Z}_{lB} + \overline{Z}_{cB} \\
\overline{Z}_C &= \overline{Z}_{gC} + \overline{Z}_{lC} + \overline{Z}_{cC}
\end{aligned}
$$

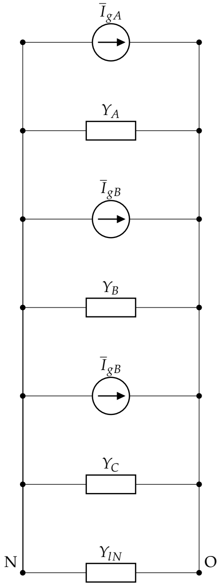
Conversión de fuentes



$$\bar{I}_{gA} = \bar{\epsilon}_A \cdot \overline{Y}_A$$
$$\bar{I}_{gB} = \bar{\epsilon}_B \cdot \overline{Y}_B$$
$$\bar{I}_{gC} = \bar{\epsilon}_C \cdot \overline{Y}_C$$

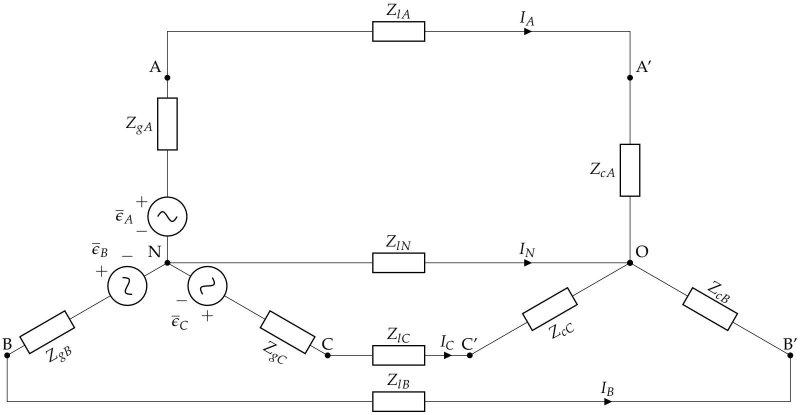
$$\overline{U}_{ON} = \frac{\bar{I}_{gA} + \bar{I}_{gB} + \bar{I}_{gC}}{\overline{Y}_A + \overline{Y}_B + \overline{Y}_C + \overline{Y}_{lN}}$$

Tensión de desplazamiento del neutro



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

Cálculo de corrientes



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

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

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

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

Aplicación a sistemas equilibrados

La suma de las fuerzas electromotrices es 0

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

Las tres impedancias son iguales

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

Por tanto,

$$\overline{U}_{ON} = \frac{3 \cdot \overline{Y} \cdot \left(\overline{\epsilon}_{gA} + \overline{\epsilon}_{gB} + \overline{\epsilon}_{gC}\right)}{3 \cdot \overline{Y} + \overline{Y}_{lN}} = 0$$

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

Aplicación a sistemas desequilibrados

- Sistemas con neutro de impedancia no nula

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

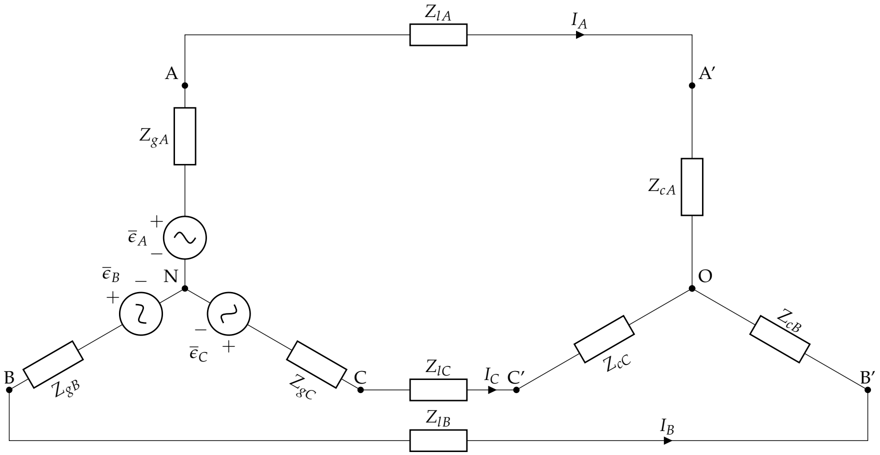
- Sistemas con neutro de impedancia nula ($\overline{Z}_{lN} = 0, \quad \overline{Y}_{lN} \to \infty$)

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

- Sistemas sin neutro ($\overline{Z}_{lN} \to \infty, \quad \overline{Y}_{lN} = 0$)

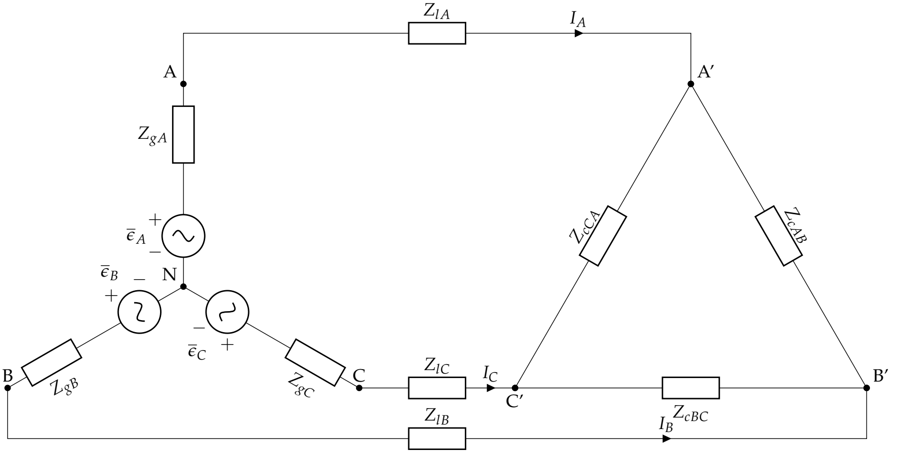
$$\overline{U}_{ON} = \frac{\overline{\epsilon}_{gA} \cdot \overline{Y}_A + \overline{\epsilon}_{gB} \cdot \overline{Y}_B + \overline{\epsilon}_{gC} \cdot \overline{Y}_C}{\overline{Y}_A + \overline{Y}_B + \overline{Y}_C}$$

Sistema sin neutro



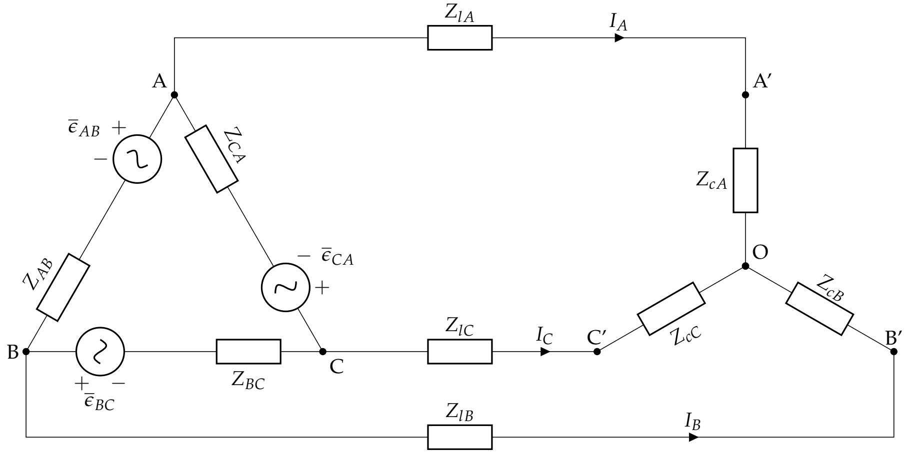
$$Z_{lN} \to \infty\} \longrightarrow \overline{U}_{ON} = \frac{\overline{\epsilon}_{gA} \cdot \overline{Y}_A + \overline{\epsilon}_{gB} \cdot \overline{Y}_B + \overline{\epsilon}_{gC} \cdot \overline{Y}_C}{\overline{Y}_A + \overline{Y}_B + \overline{Y}_C}$$

Receptor en triángulo



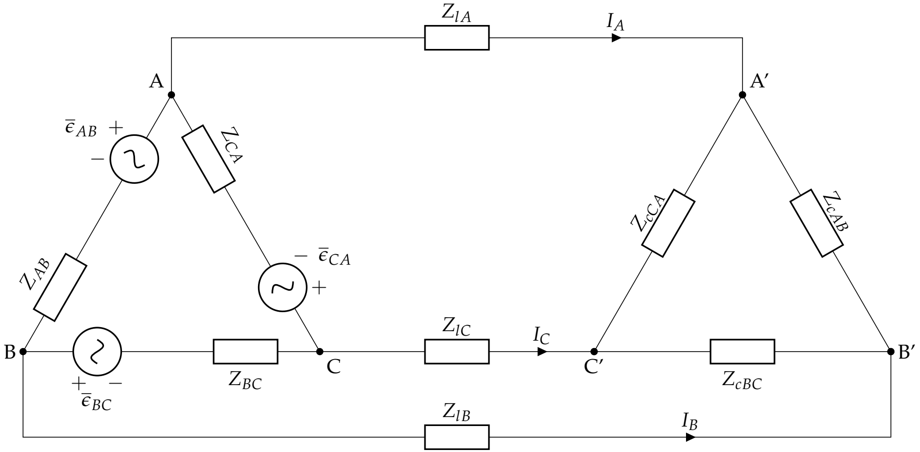
$$\left.\begin{array}{l}\text{Transformación de Receptor}\\ Z_{lN} \to \infty\end{array}\right\} \longrightarrow \overline{U}_{ON} = \frac{\overline{\epsilon}_{gA} \cdot \overline{Y}_A + \overline{\epsilon}_{gB} \cdot \overline{Y}_B + \overline{\epsilon}_{gC} \cdot \overline{Y}_C}{\overline{Y}_A + \overline{Y}_B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

Generador en triángulo



$$\left.\begin{array}{l}\text{Transformación de Generador}\\ Z_{lN} \to \infty\end{array}\right\} \longrightarrow \overline{U}_{ON} = \frac{\overline{\epsilon}_{gA} \cdot \overline{Y}_A + \overline{\epsilon}_{gB} \cdot \overline{Y}_B + \overline{\epsilon}_{gC} \cdot \overline{Y}_C}{\overline{Y}_A + \overline{Y}_B + \overline{Y}_C}$$

Generador y Receptor en triángulo



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