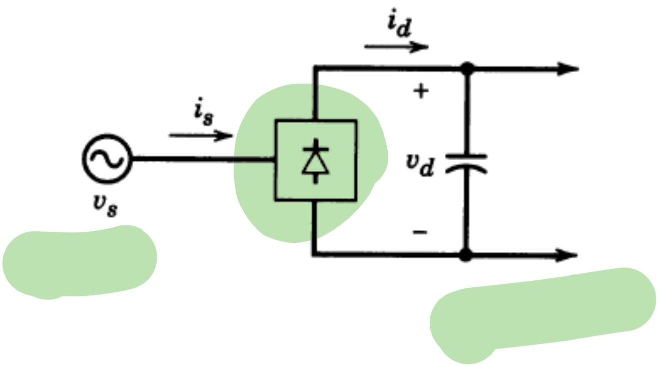
Rectificadores de línea no controlados

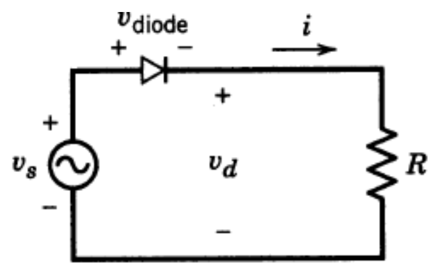
Generalidades

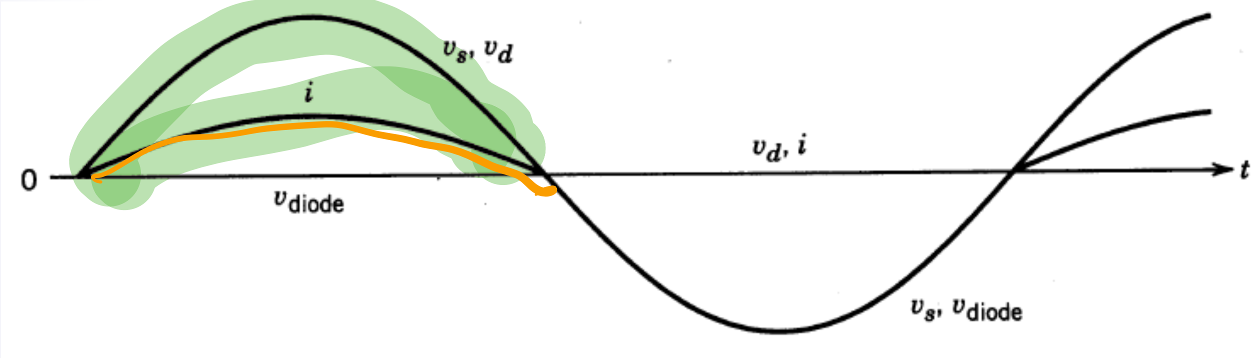
Diagrama de un rectificador de línea



Ejemplos sencillos

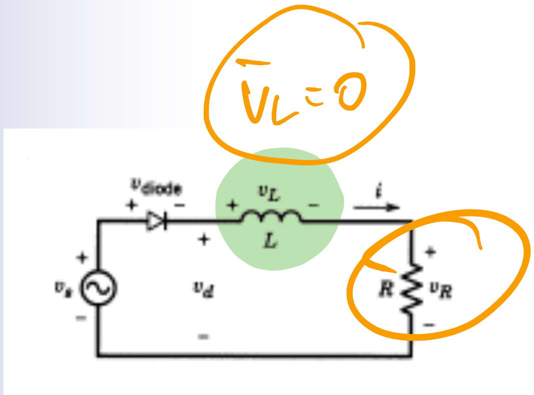
Rectificador monofásico de media onda – Carga Resistiva

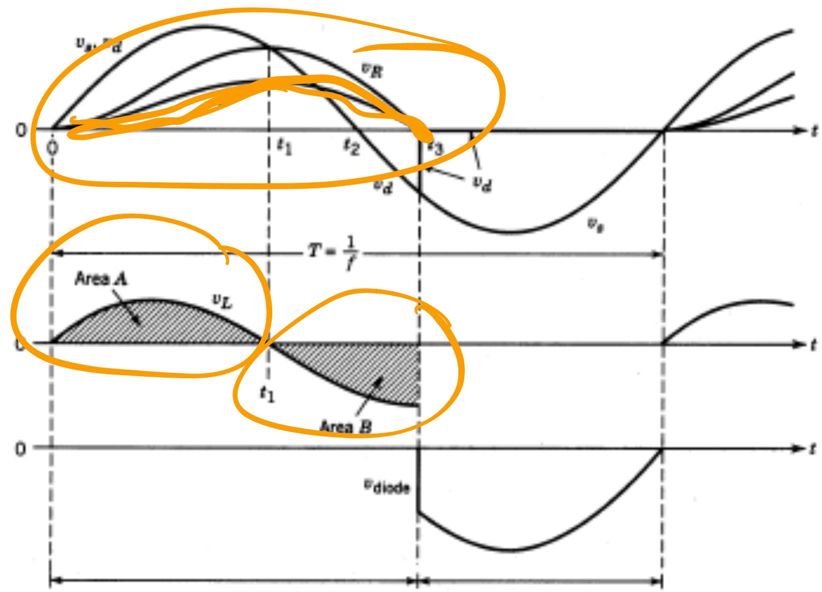


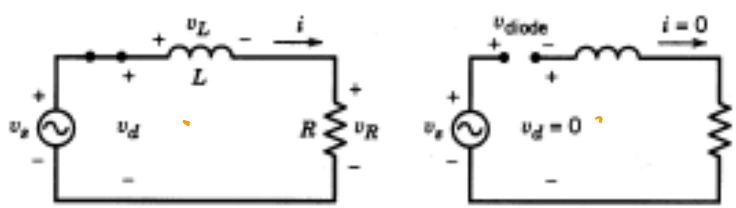


Ejemplos sencillos

Rectificador monofásico de media onda – Carga Inductiva



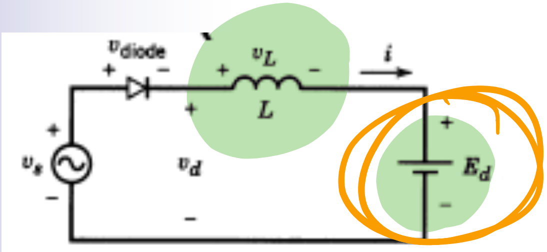


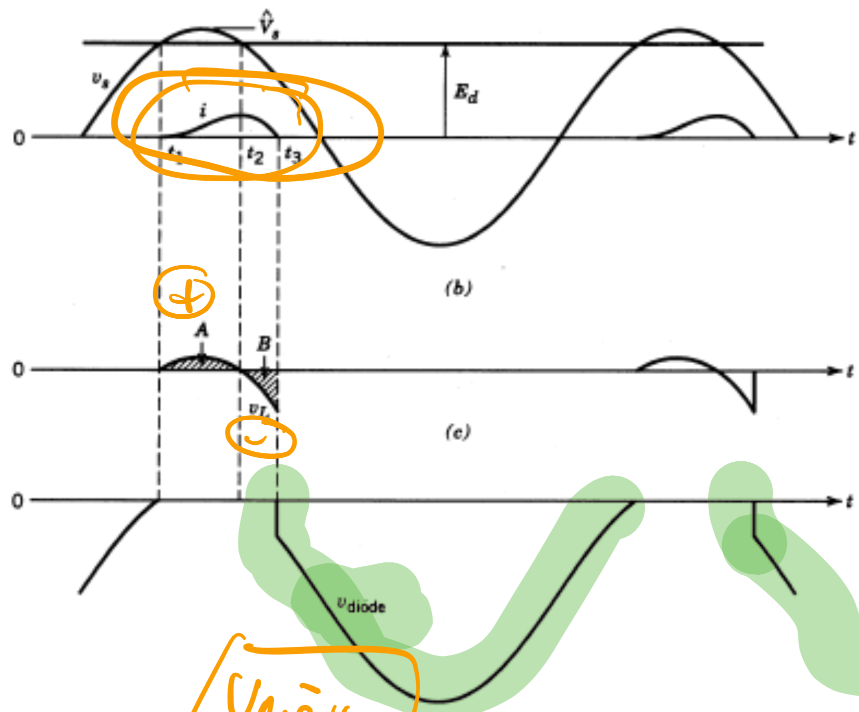


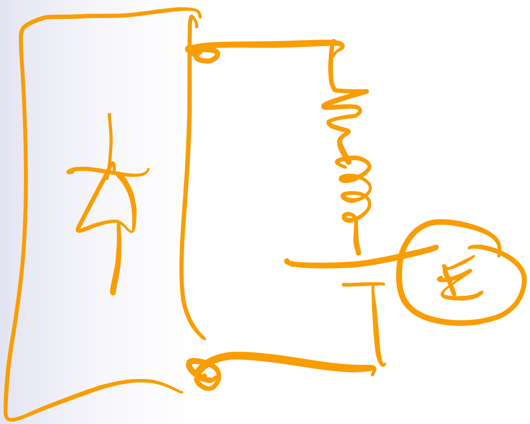
Fuente: Mohan

Ejemplos sencillos

Rectificador monofásico – Carga con tensión contra-electromotriz

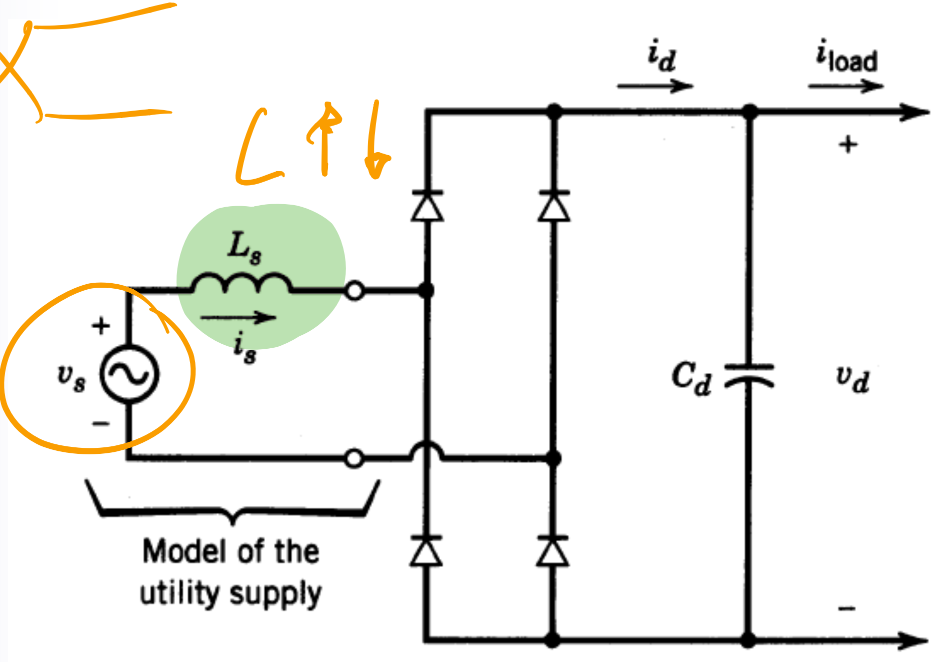






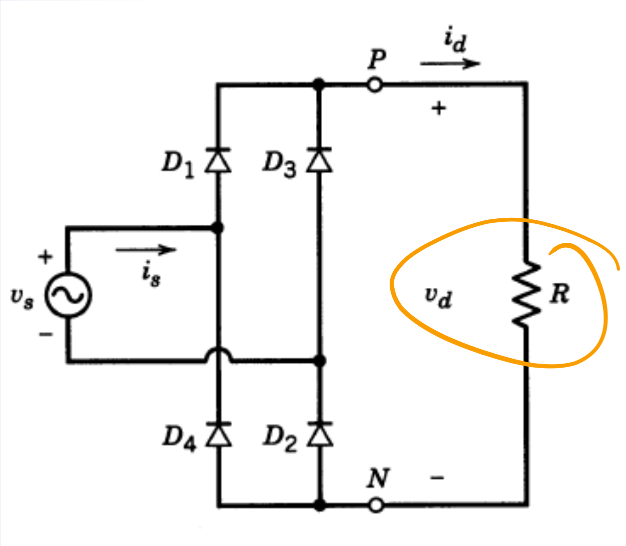
Rectificador monofásico de onda completa

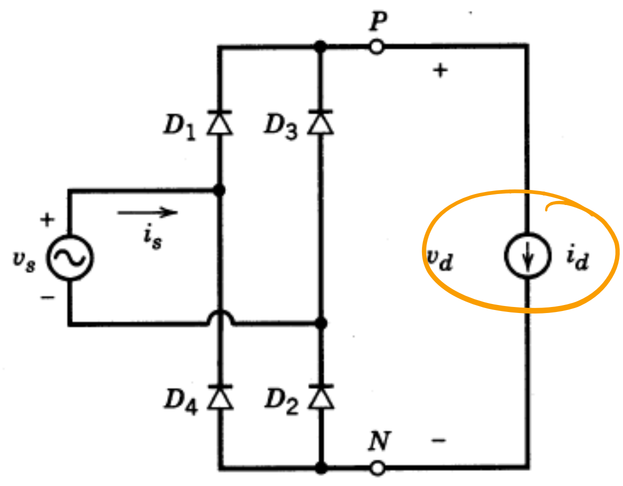
Rectificador monofásico de onda completa



Rectificador monofásico de onda completa

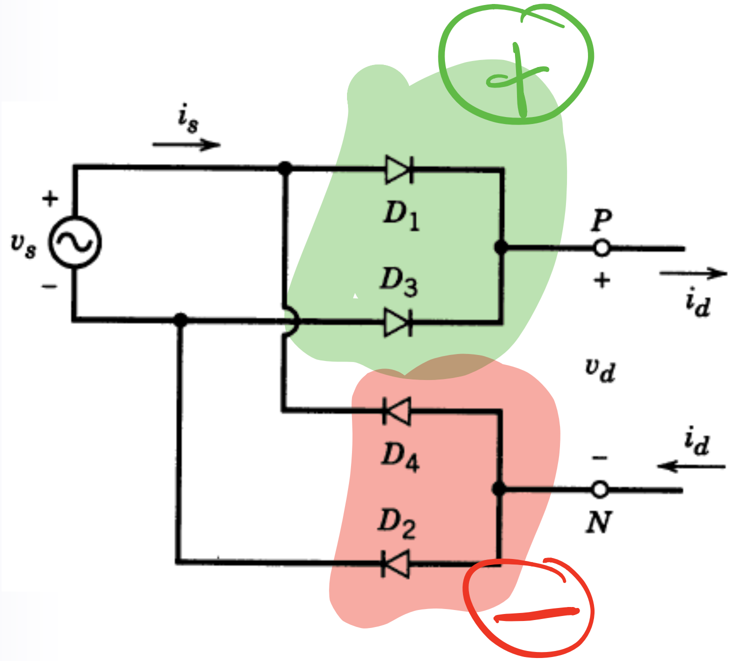
Rectificador monofásico de onda completa. Análisis





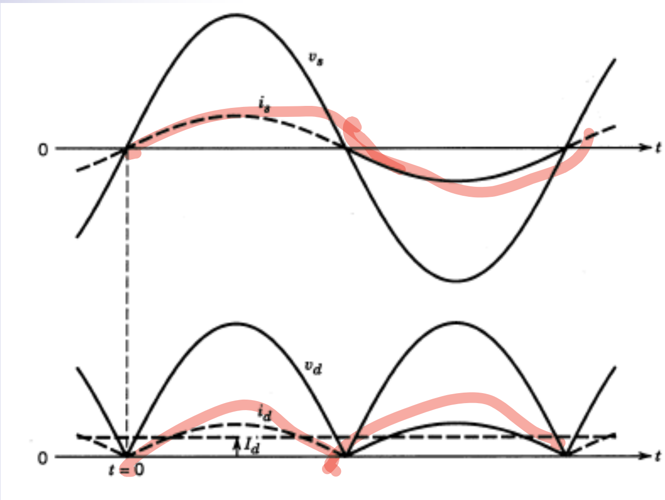
Ls = 0

Rectificador monofásico de onda completa. Análisis

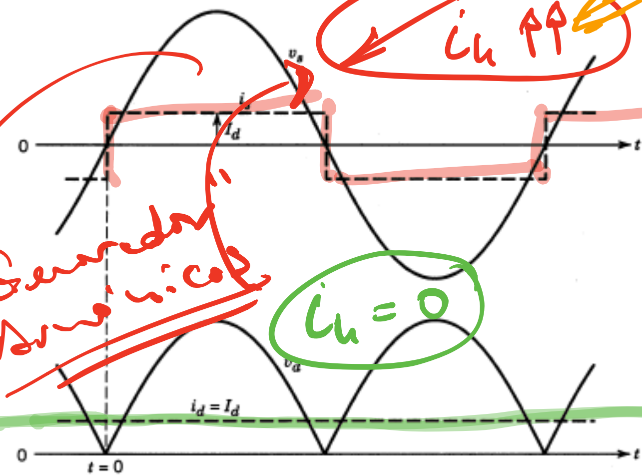


Rectificador monofásico de onda completa

Rectificador monofásico de onda completa. Análisis



Carga Resistiva



Carga Inductiva

i_n ↑↑

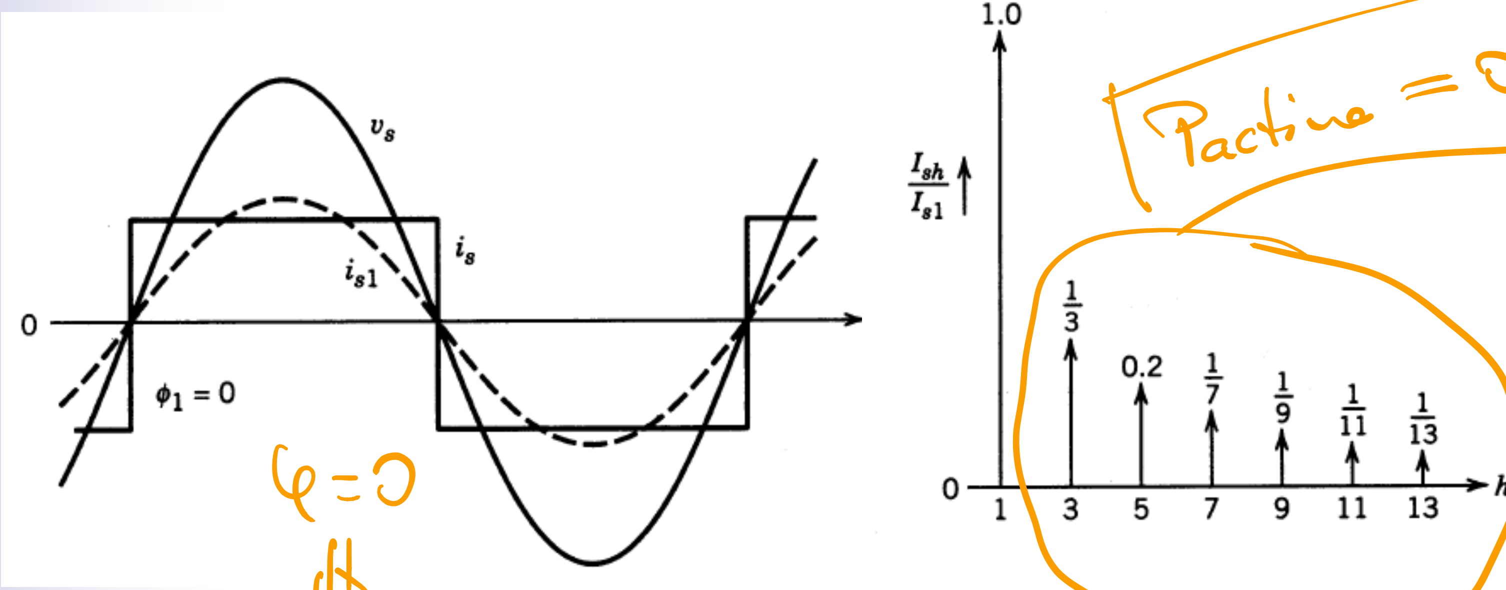
"Generador Armónicos"

$i_n = 0$

$$P_{in} = V_{1ef}\, I_{1ef} \cos\varphi_1 + \cancel{V_{2ef}\, I_{2ef} \cos\varphi_2} + \ldots$$

Rectificador monofásico de onda completa

Corriente de entrada. Corriente cte a la salida



$P_{activa} = 0$

$\varphi = 0$

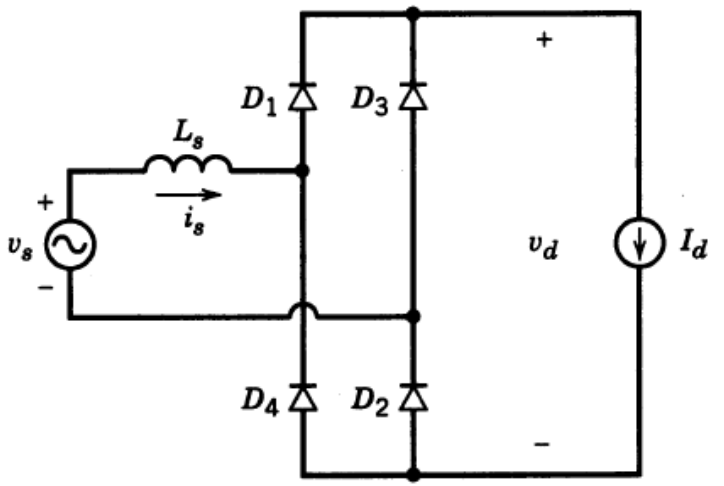
$\Downarrow$

$FP \neq 1$

$FP < 1$ $\Leftarrow$ $S > P$

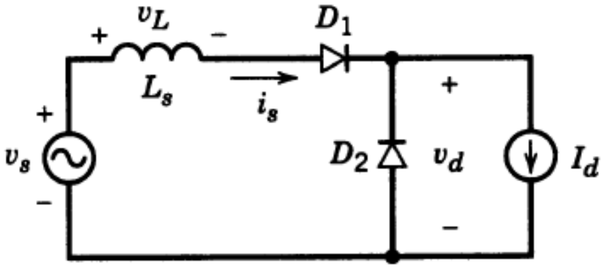
Rectificador monofásico de onda completa

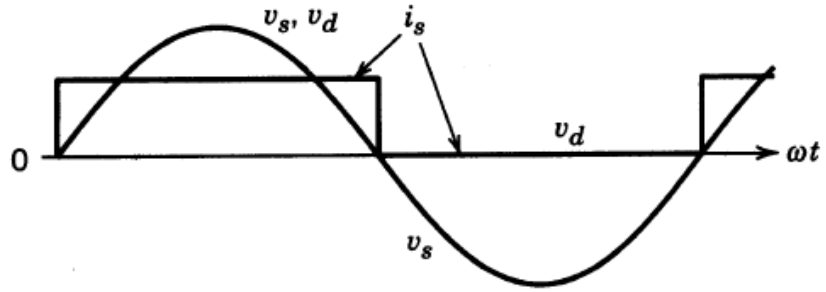
Efecto Ls



Rectificador monofásico de onda completa

Caso sencillo. Efecto Ls

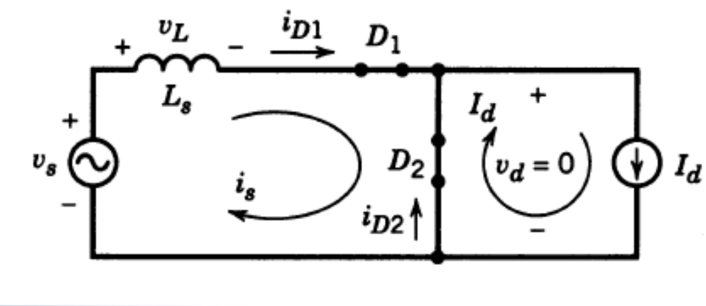




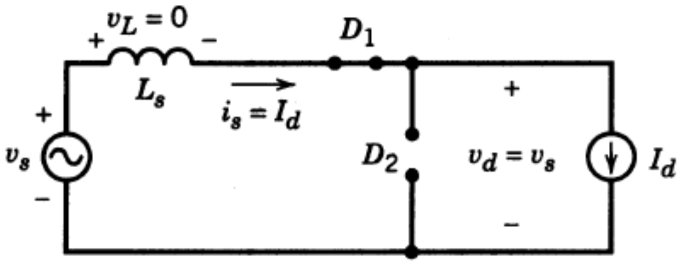
Rectificador monofásico de onda completa

Caso sencillo. Efecto Ls

Circuito durante conmutación

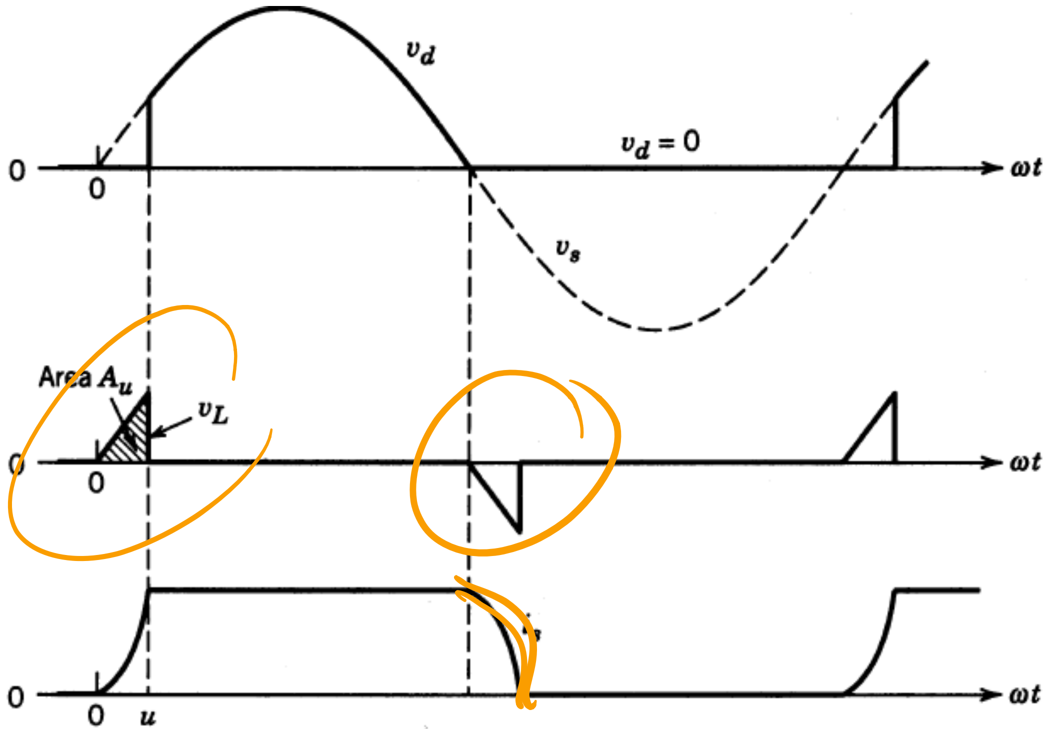


Circuito después de la conmutación



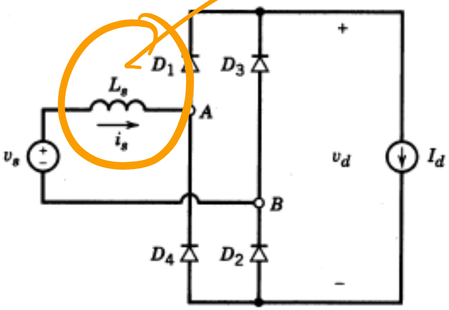
Rectificador monofásico de onda completa

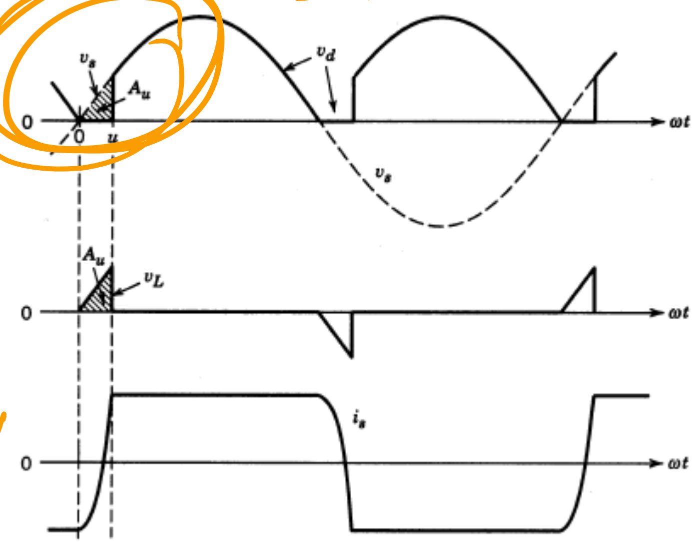
Caso sencillo. Forma de onda de comutación de corriente



Rectificador monofásico de onda completa

Caso sencillo. Forma de onda de comutación de corriente





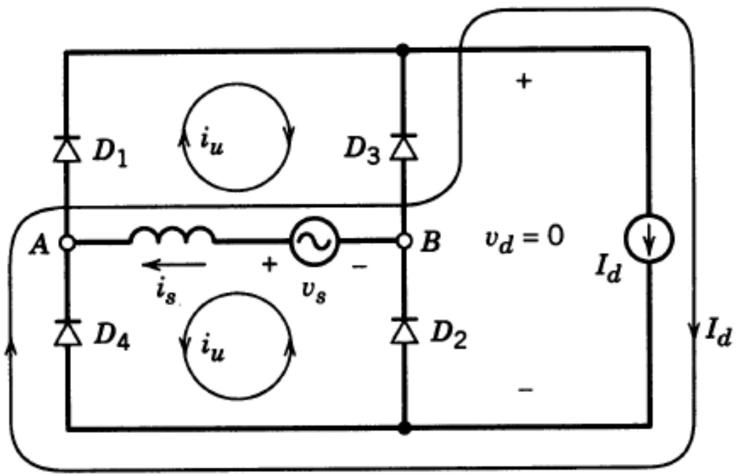
$\bar{V}_0 <$ calculado

$\bar{V}_0$ (L...)

V

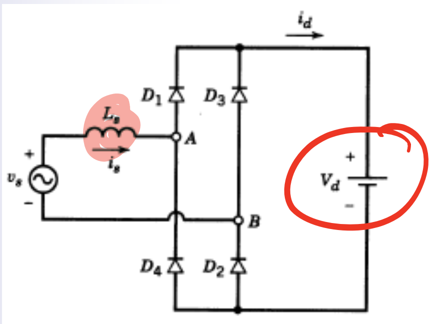
Rectificador monofásico de onda completa

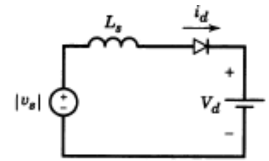
Lazos para el análisis



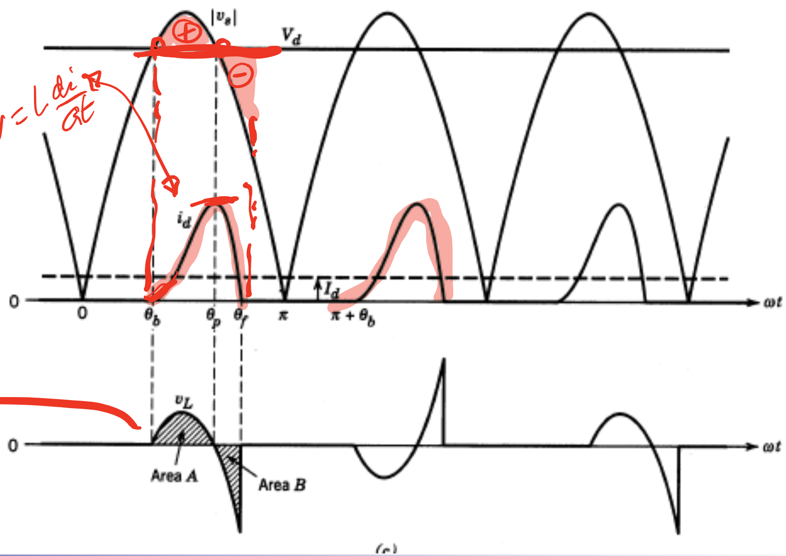
Rectificador monofásico de onda completa

Rectificador con lado de continua





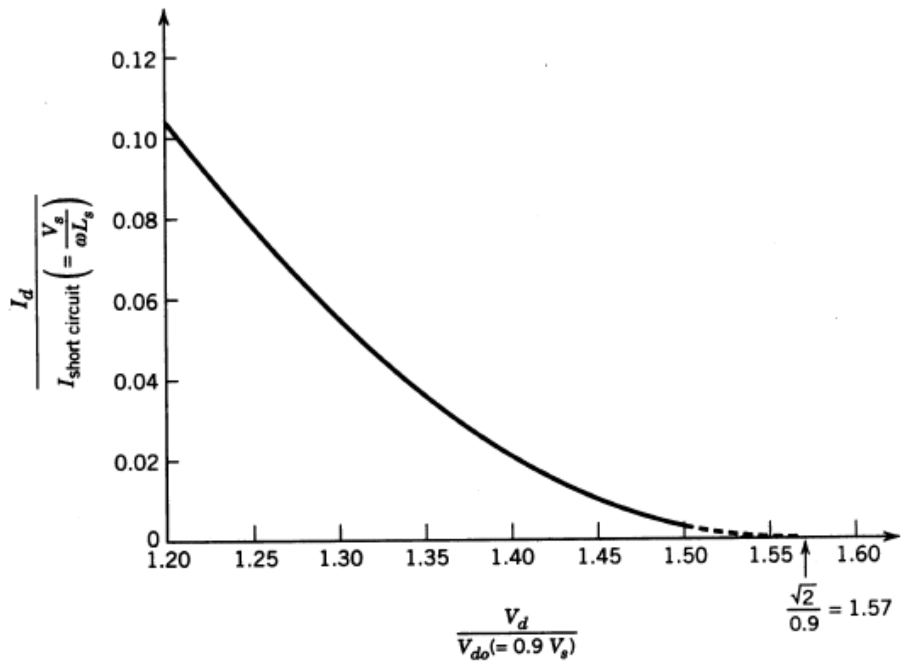
$v = L \frac{di}{dt}$



$\boxed{\overline{V_L} = 0}$

Rectificador monofásico de onda completa

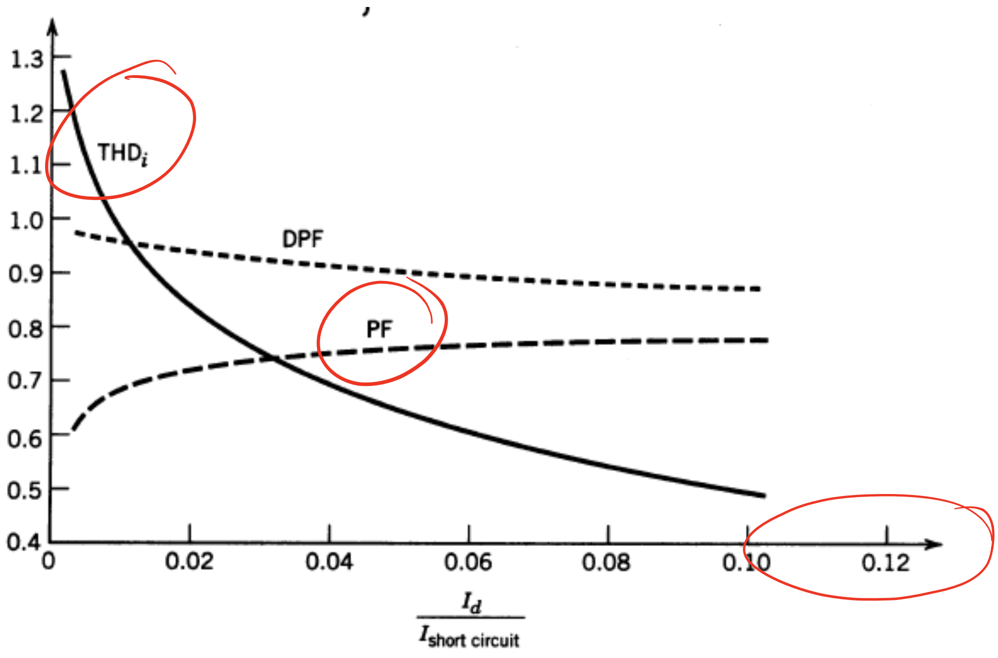
Relación tensión-corriente



Corriente cero corresponde a tensión DC igual al pico de tensión de entrada

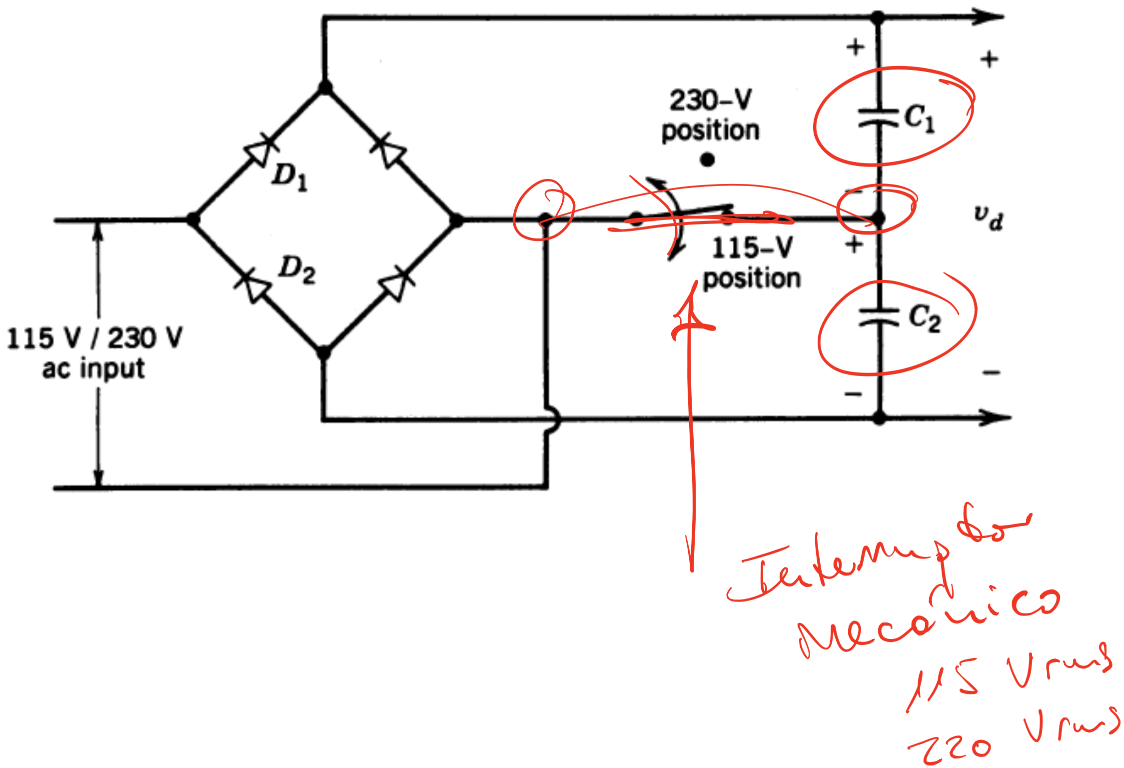
Rectificador monofásico de onda completa

Efecto de la corriente de salida en F.P , D.A.T



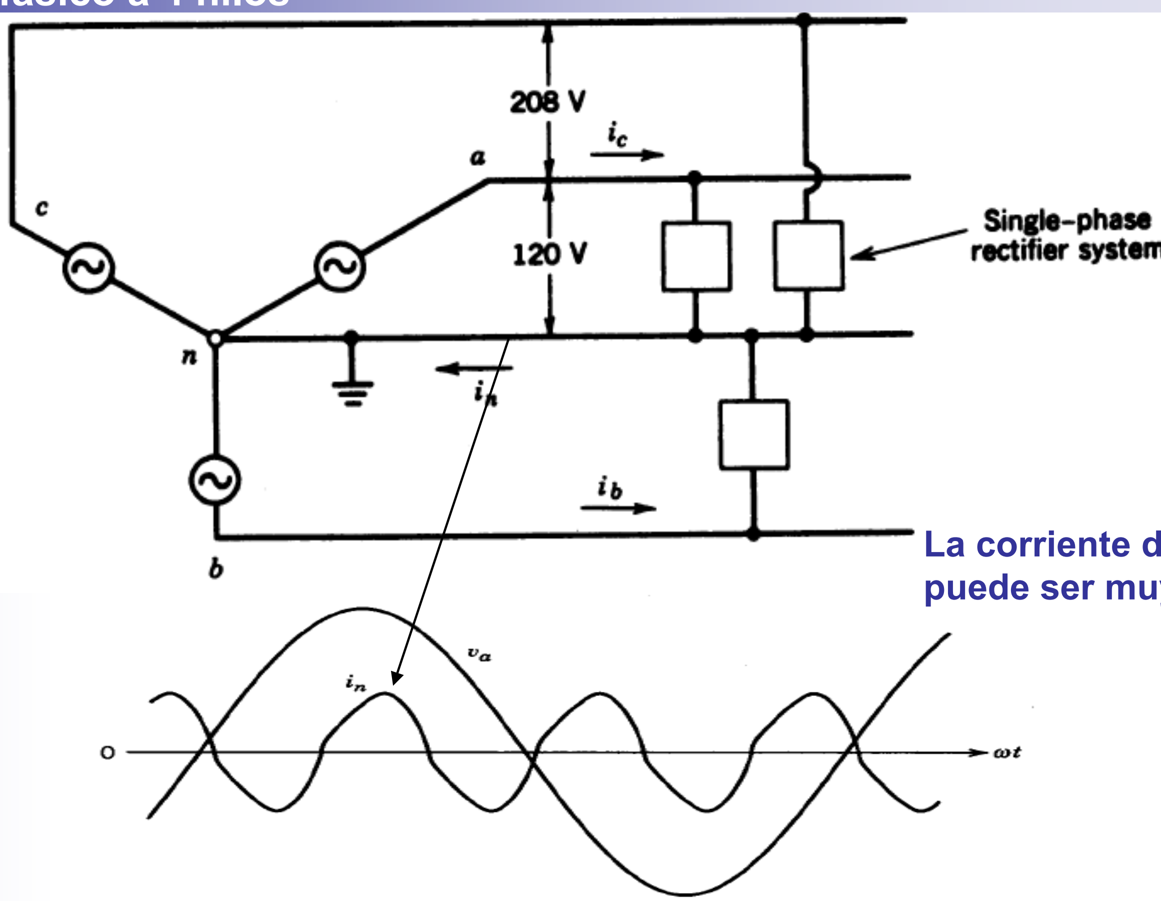
Rectificador doblador de tensión

Rectificador doblador de tensión



Rectificador trifásico

Sistema trifásico a 4 hilos



La corriente de neutro puede ser muy elevada

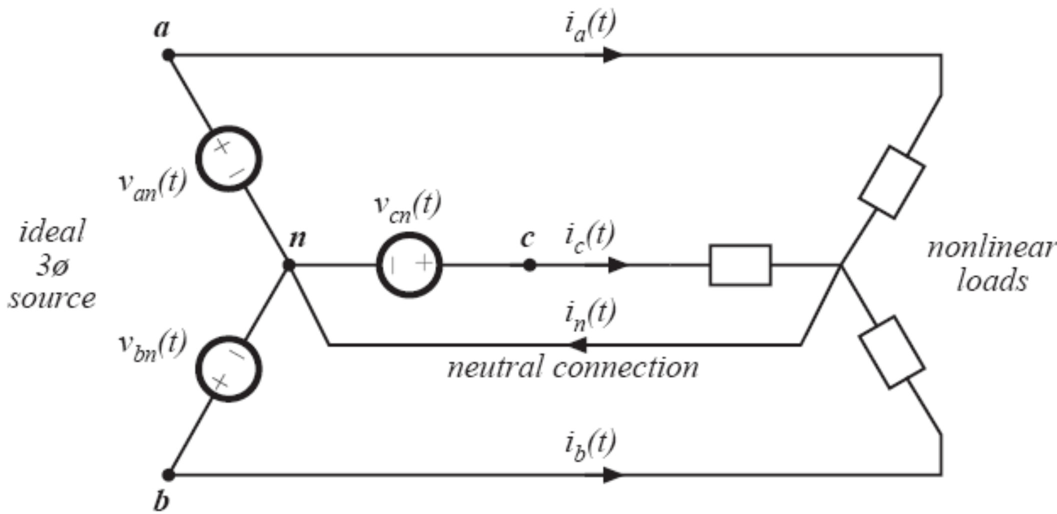
16.5. Harmonic currents in three phase systems

The presence of harmonic currents can also lead to some special problems in three-phase systems:

- In a four-wire three-phase system, harmonic currents can lead to large currents in the neutral conductors, which may easily exceed the conductor rms current rating
- Power factor correction capacitors may experience significantly increased rms currents, causing them to fail

In this section, these problems are examined, and the properties of harmonic current flow in three-phase systems are derived:

- Harmonic neutral currents in 3ø four-wire networks
- Harmonic neutral voltages in 3ø three-wire wye-connected loads



Fourier series of line currents and voltages:

$$i_a(t) = I_{a0} + \sum_{k=1}^{\infty} I_{ak} \cos(k\omega t - \theta_{ak})$$

$$i_b(t) = I_{b0} + \sum_{k=1}^{\infty} I_{bk} \cos(k(\omega t - 120^\circ) - \theta_{bk})$$

$$i_c(t) = I_{c0} + \sum_{k=1}^{\infty} I_{ck} \cos(k(\omega t + 120^\circ) - \theta_{ck})$$

$$v_{an}(t) = V_m \cos(\omega t)$$

$$v_{bn}(t) = V_m \cos(\omega t - 120^\circ)$$

$$v_{cn}(t) = V_m \cos(\omega t + 120^\circ)$$

Corriente por neutro

$$i_n(t) = I_{a0} + I_{b0} + I_{c0} +$$
$$\sum_{k=1}^{\infty} \left[I_{ak} \cos(k\omega t - \theta_{ak}) + I_{bk} \cos(k(\omega t - 120^\circ) - \theta_{bk}) + I_{ck} \cos(k(\omega t + 120^\circ) - \theta_{ck}) \right]$$

If the load is unbalanced, then there is nothing more to say. The neutral connection may contain currents having spectrum similar to the line currents.

In the balanced case, $I_{ak} = I_{bk} = I_{ck} = I_k$ and $\theta_{ak} = \theta_{bk} = \theta_{ck} = \theta_k$, for all k; i.e., the harmonics of the three phases all have equal amplitudes and phase shifts. The neutral current is then

$$i_n(t) = 3I_0 + \sum_{k=3,6,9,\cdots}^{\infty} 3I_k \cos(k\omega t - \theta_k)$$

Corriente por neutro

$$i_n(t) = 3I_0 + \sum_{k=3,6,9,\cdots}^{\infty} 3I_k \cos(k\omega t - \theta_k)$$

- Fundamental and most harmonics cancel out
- Triplen (triple-n, or 0, 3, 6, 9, ...) harmonics do not cancel out, but add. Dc components also add.
- Rms neutral current is

$$i_{n,\,rms} = 3\sqrt{I_0^2 + \sum_{k=3,6,9,\cdots}^{\infty} \frac{I_k^2}{2}}$$

Corriente por neutro

A balanced nonlinear load produces line currents containing fundamental and 20% third harmonic: $i_{an}(t) = I_1 \cos(\omega t - \theta_1) + 0.2\, I_1 \cos(3\omega t - \theta_3)$. Find the rms neutral current, and compare its amplitude to the rms line current amplitude.

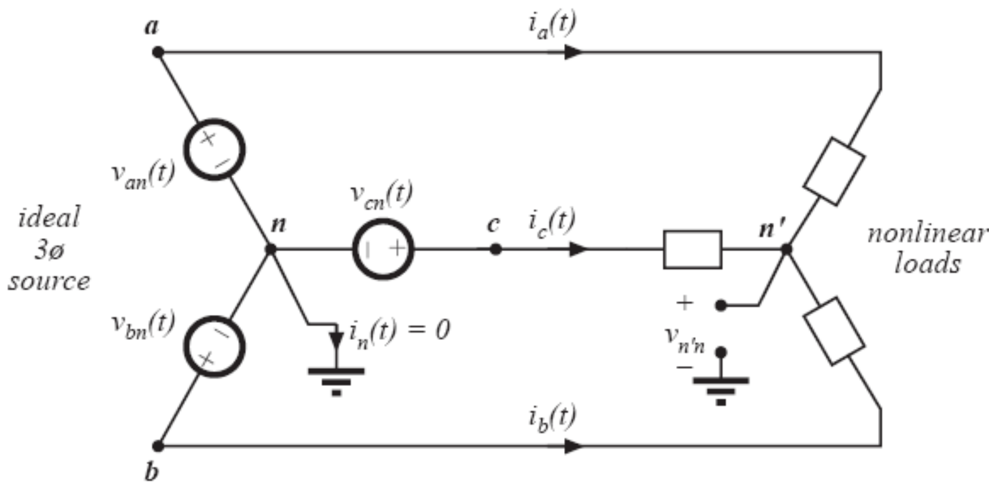
Solution

$$i_{n,\,rms} = 3\sqrt{\frac{(0.2I_1)^2}{2}} = \frac{0.6\, I_1}{\sqrt{2}}$$

$$i_{1,\,rms} = \sqrt{\frac{I_1^2 + (0.2I_1)^2}{2}} = \frac{I_1}{\sqrt{2}}\sqrt{1+0.04} \approx \frac{I_1}{\sqrt{2}}$$

- The neutral current magnitude is 60% of the line current magnitude!
- The triplen harmonics in the three phases add, such that 20% third harmonic leads to 60% third harmonic neutral current.
- Yet the presence of the third harmonic has very little effect on the rms value of the line current. Significant unexpected neutral current flows.

Wye-connected nonlinear load, no neutral connection:



Tres hilos

If the load is balanced, then it is still true that

$$i_n(t) = 3I_0 + \sum_{k=3,6,9,\cdots}^{\infty} 3I_k \cos(k\omega t - \theta_k)$$

But $i_n(t) = 0$, since there is no neutral connection.

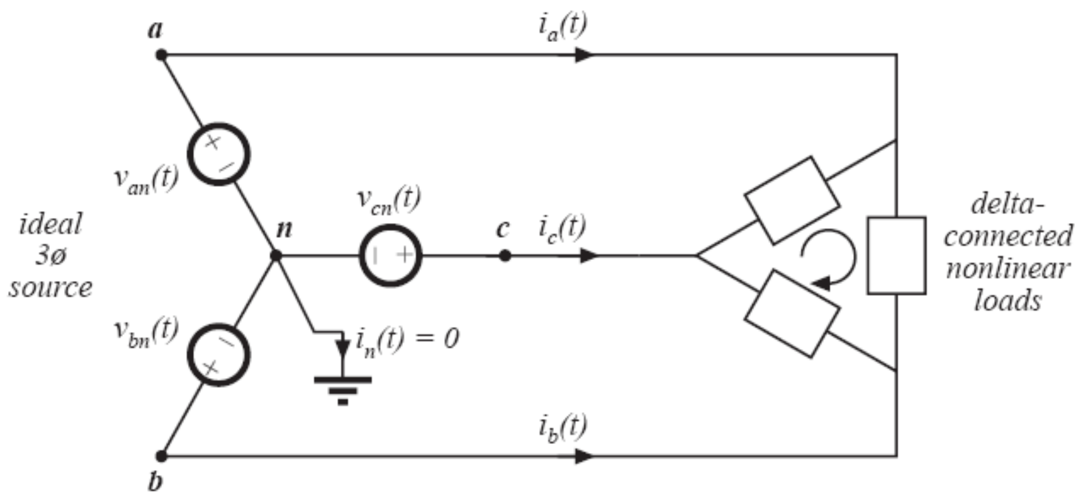
So the ac line currents cannot contain dc or triplen harmonics.

What happens:

> A voltage is induced at the load neutral point, that causes the line current dc and triplen harmonics to become zero.
>
> The load neutral point voltage contains dc and triplen harmonics.

With an unbalanced load, the line currents can still contain dc and triplen harmonics.

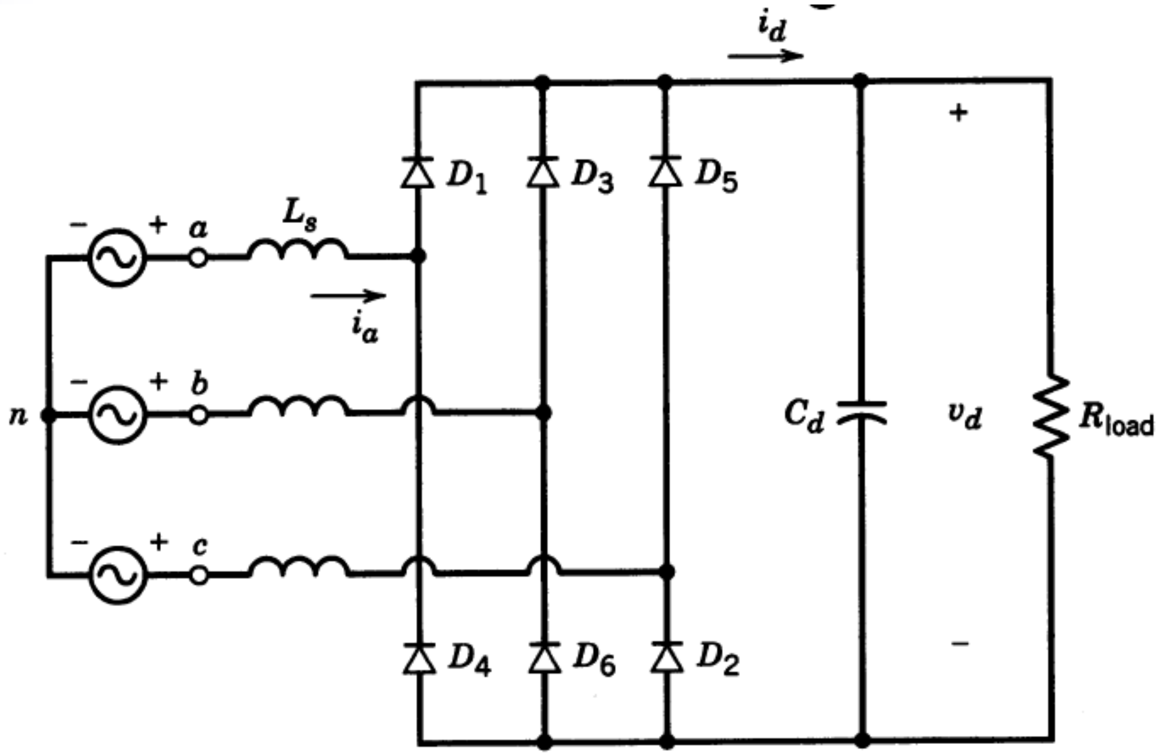
Conexión en triángulo



- There is again no neutral connection, so the ac line currents contain no dc or triplen harmonics
- The load currents may contain dc and triplen harmonics: with a balanced nonlinear load, these circulate around the delta.

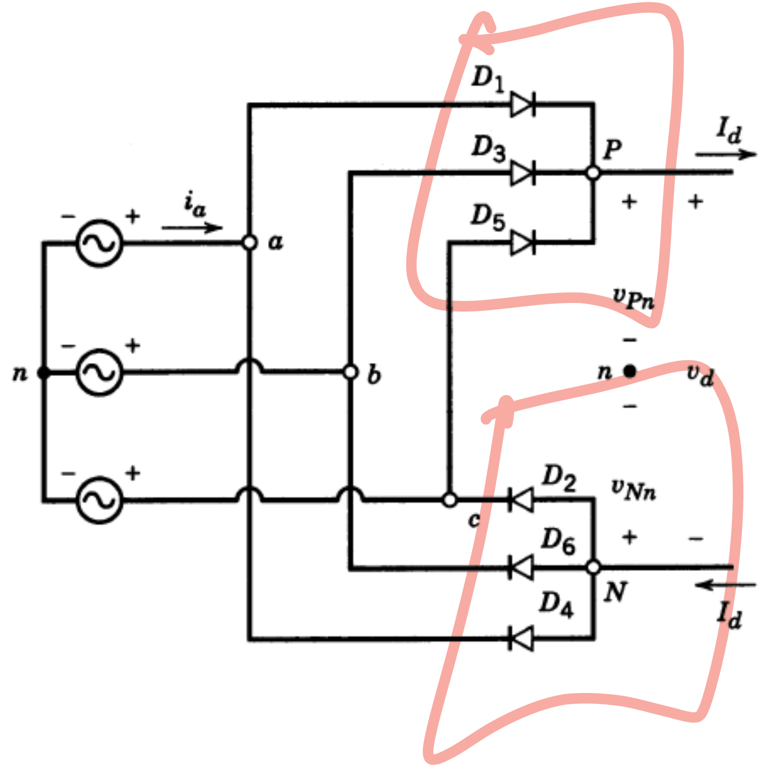
Rectificador trifásico

Rectificador trifásico de onda completa



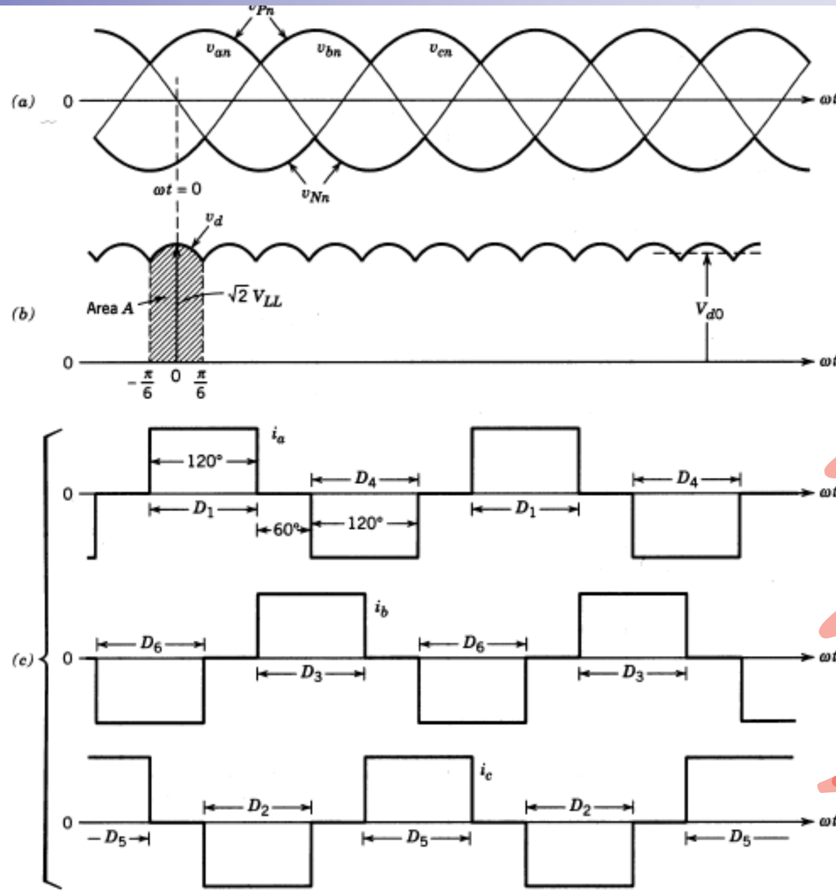
Rectificador trifásico

Rectificador trifásico de onda completa

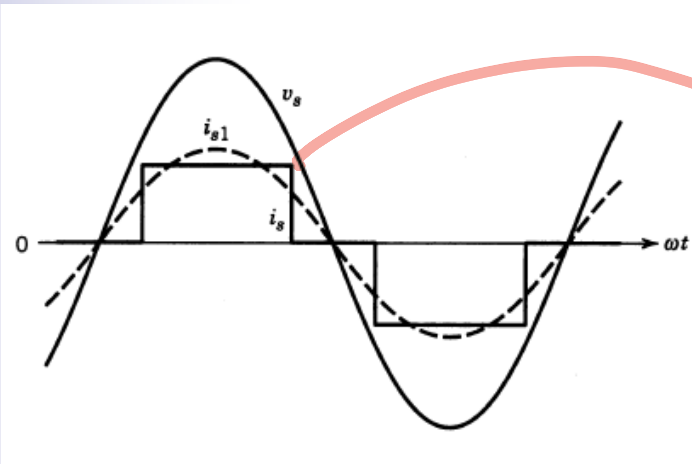


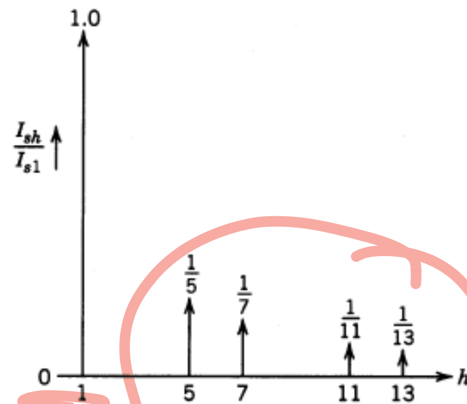
Rectificador trifásico

Formas de onda



Corriente de línea



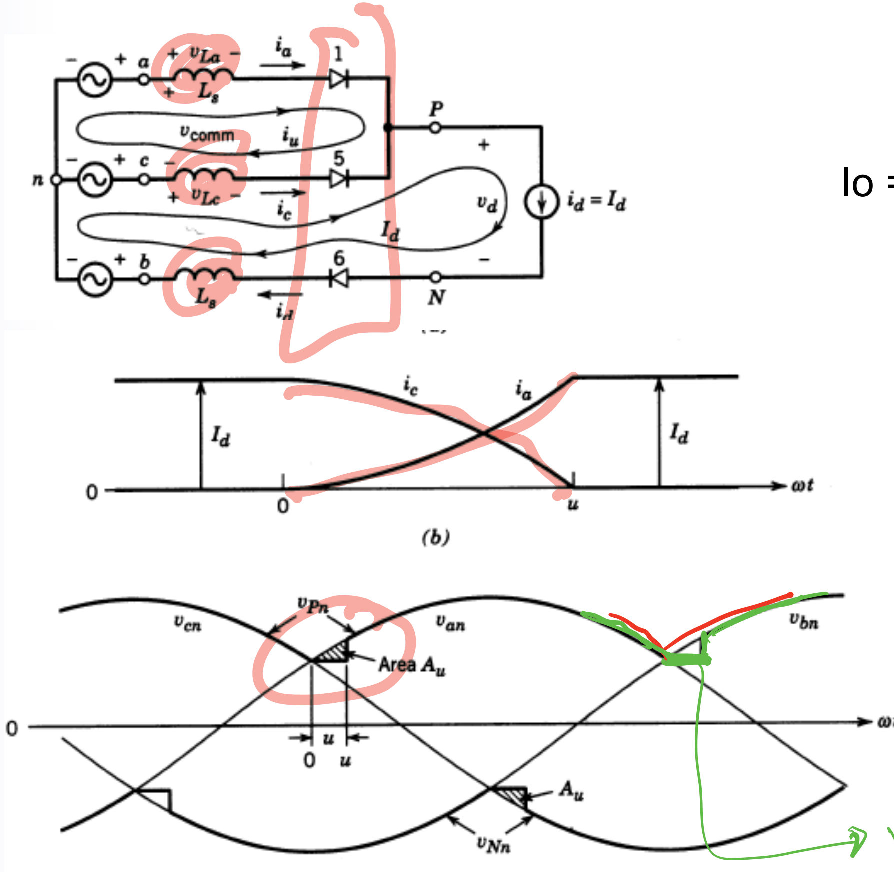


F.P < 1

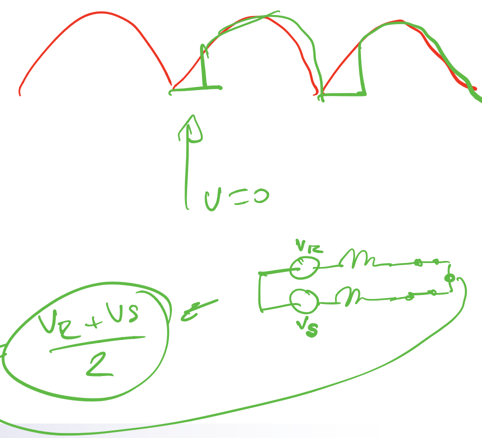
Ls = 0
Corriente de carga constante

Rectificador trifásico

Conmutación de corriente

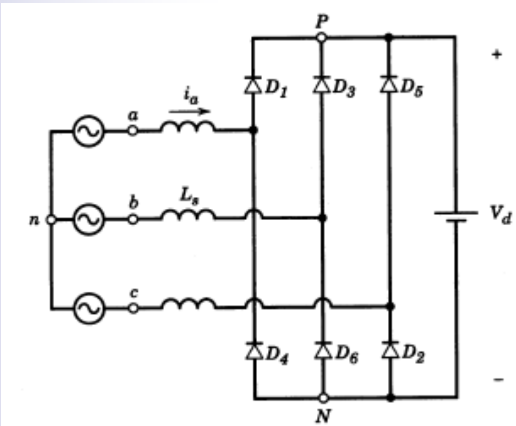


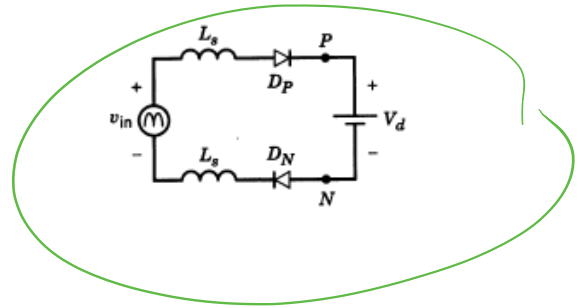
Io = constante

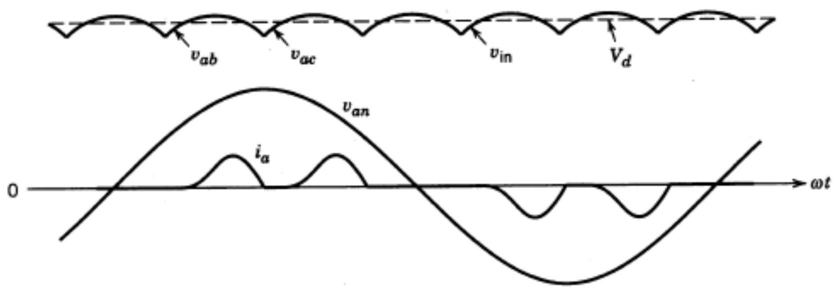


Rectificador trifásico

Rectificador con condensador grande a la salida







Rectificador trifásico

F.P., DAT y FD en función de la carga