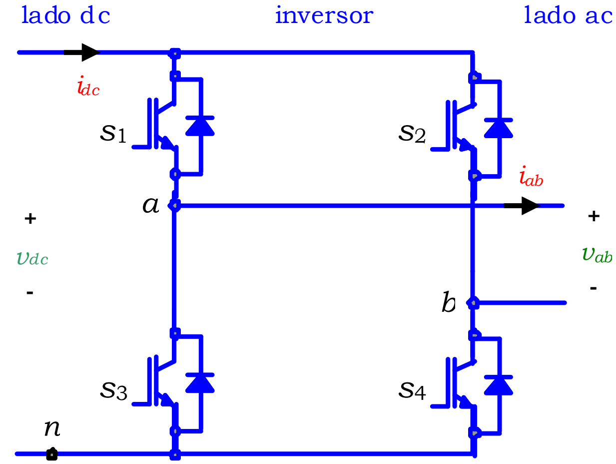
Inversor de Voltaje Monofásico

Problema Estudiar el inversor de voltaje con Modulación SPWM.



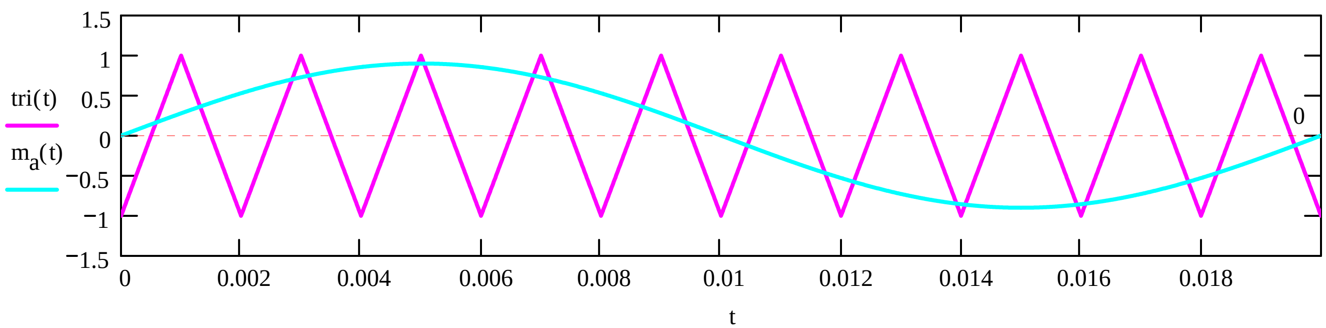
La moduladora es, $M := 0.9$ $\omega_s := 2\cdot\pi\cdot 50$ $f_M := 0$ $m_a(t) := M\cdot\sin(\omega_s\cdot t + f_M)$

La triangular es, $f_{n\_tr} := 10$ $per := 1$

$$tri(t) := \frac{2}{\pi}\cdot\operatorname{asin}\left(\sin\left(f_{n\_tr}\cdot\omega_s\cdot t + f_M\cdot f_{n\_tr} - \frac{\pi}{2}\right)\right)$$

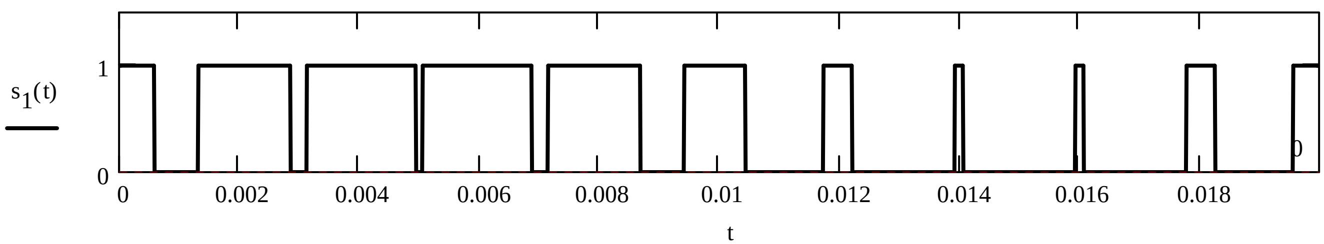
Se la función, $s_1(t) := \text{if}(m_a(t) > tri(t), 1, 0)$ $s_3(t) := \text{if}(m_a(t) > tri(t), 0, 1)$

$n_f := f_{n\_tr}\cdot 4\cdot 50\cdot per$ $n := 0 .. n_f$ $t_f := .02\cdot per$ $t := 0, \frac{t_f}{n_f} .. t_f$



Cuando la función s_1 vale 1 se enciende el switch 1 y cuando vale 0 se enciende el switch 3.

$s_2(t) := s_3(t)$ $s_4(t) := s_1(t)$



Los voltajes se pueden escribir como,

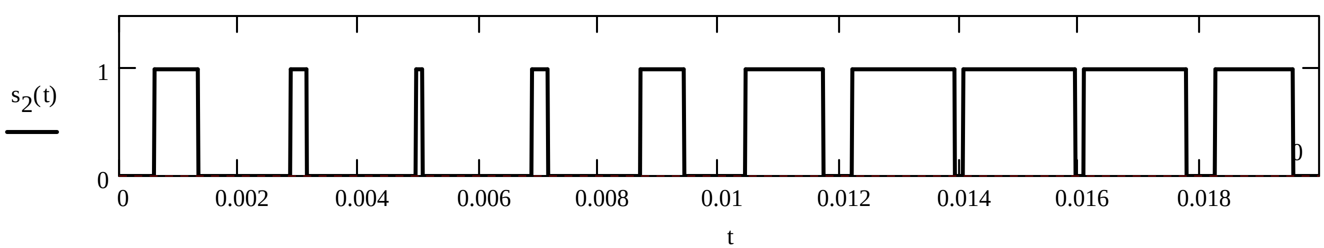
$v_{an}(t) = s_1(t)\cdot v_{dc}(t)$ $v_{bn}(t) = s_2(t)\cdot v_{dc}(t)$

$v_{ab}(t) = v_{an}(t) - v_{bn}(t)$

$v_{ab}(t) = s_1(t)\cdot v_{dc}(t) - s_2(t)\cdot v_{dc}(t)$

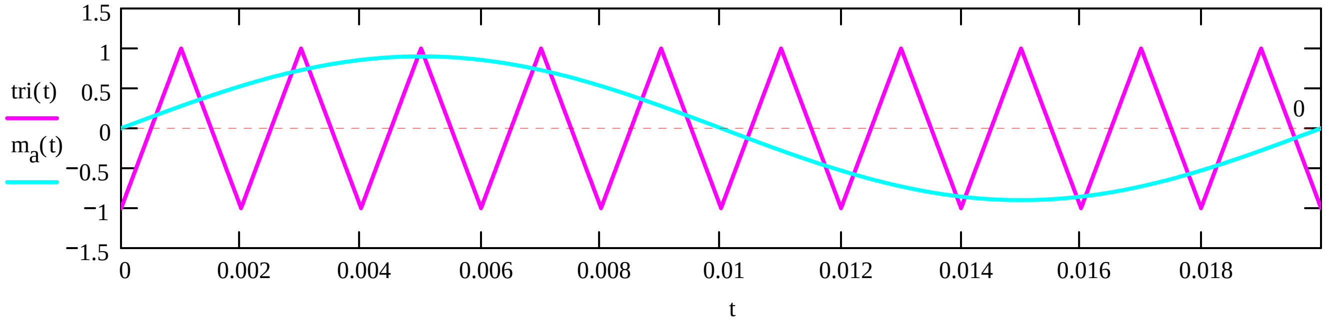
$v_{ab}(t) = (s_1(t) - s_2(t))\cdot v_{dc}(t)$

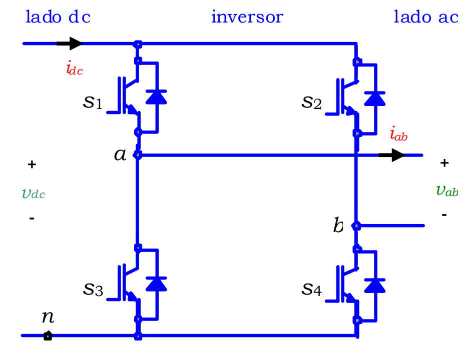
$v_{ab}(t) = s_{ab}(t)\cdot v_{dc}(t)$

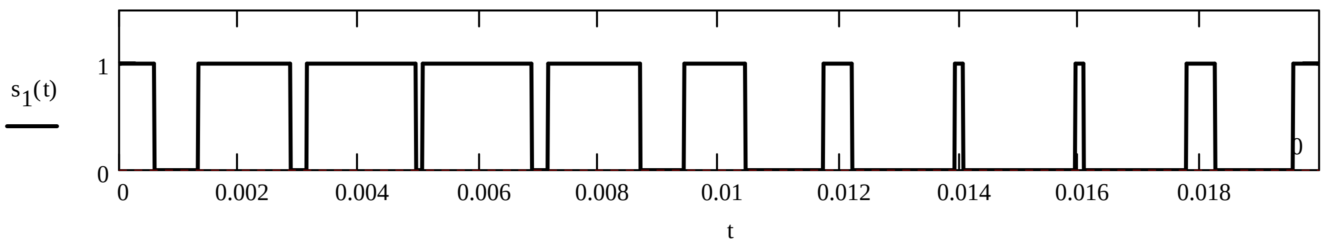


Se define la función de conmutación como,

$s_{ab}(t) := s_1(t) - s_2(t)$

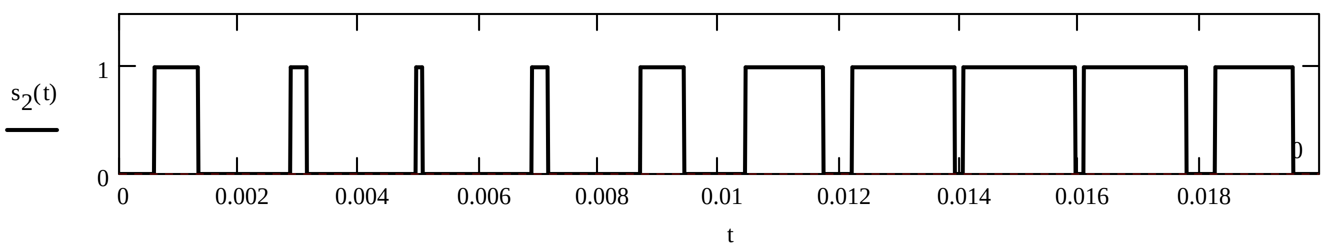






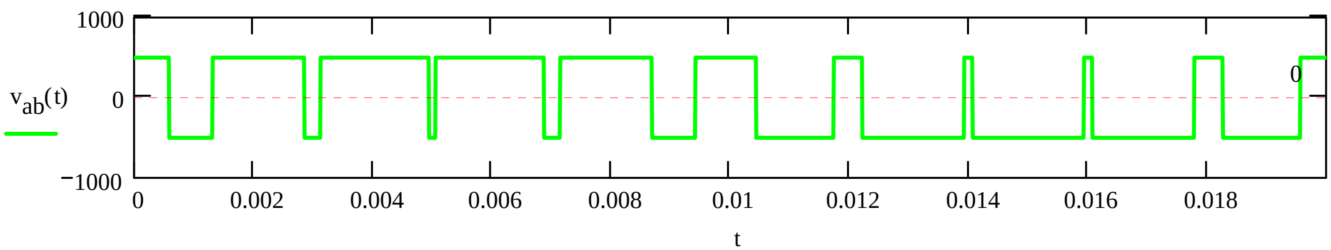
$s_{ab}(t) := s_1(t) - s_2(t)$

$V_{dc} := 500$



$v_{dc}(t) := V_{dc}$

$v_{ab}(t) := s_{ab}(t) \cdot v_{dc}(t)$



$N := 1024$

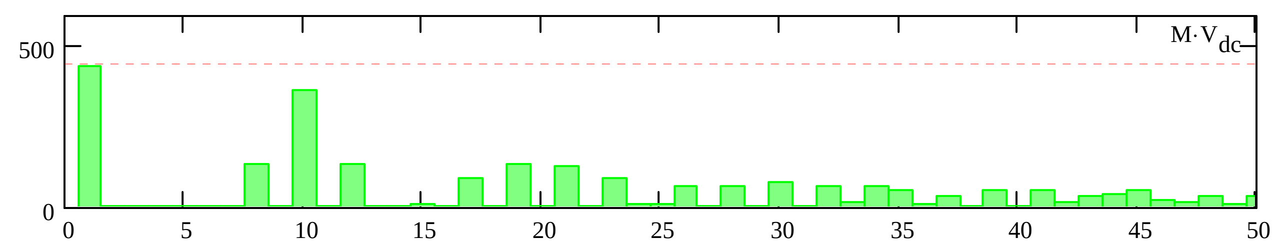
$m := 1 .. N$

$x_m := v_{ab}\left(\frac{m}{N} \cdot t_f\right)$

$xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2) \cdot xf_{m \cdot per}$

FFT de v_{ab}



La fundamental del voltaje ac es igual a MV_{dc} y no hay componentes de frecuencia hasta f_{n_tr} / 2.

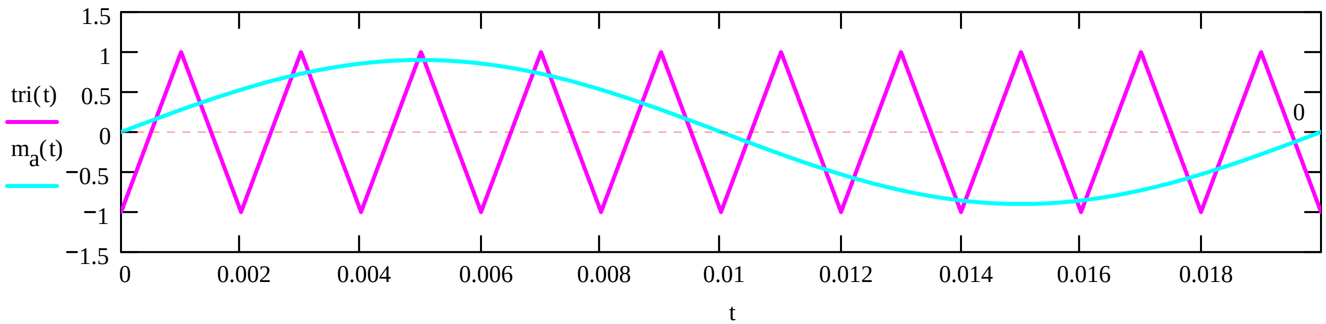
$v_{ab1}(t) = V_{dc} \cdot m_a(t)$

$f \leq \frac{f_{n\_tr}}{2}$

Otra Modulación SPWM

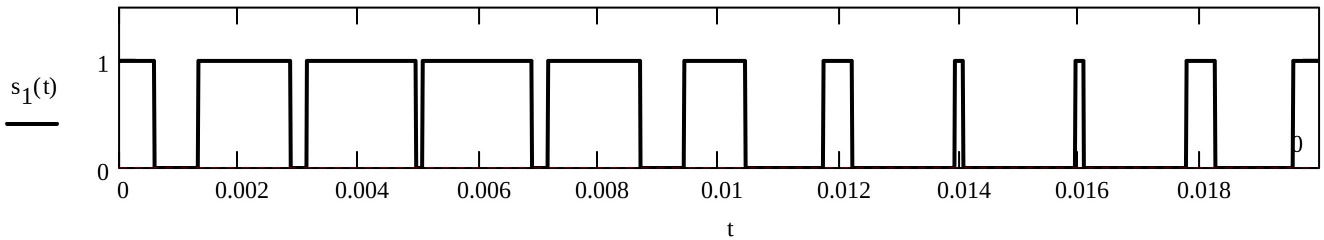
Primera pierna $s_1(t) := \text{if}\left(m_a(t) > \text{tri}(t), 1, 0\right)$ $s_3(t) := \text{if}\left(s_1(t) = 1, 0, 1\right)$

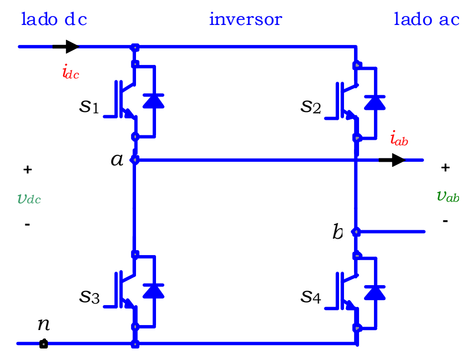
Segunda pierna $s_2(t) := \text{if}\left(m_a(t) > -\text{tri}(t), 0, 1\right)$ $s_4(t) := \text{if}\left(s_2(t) = 1, 0, 1\right)$

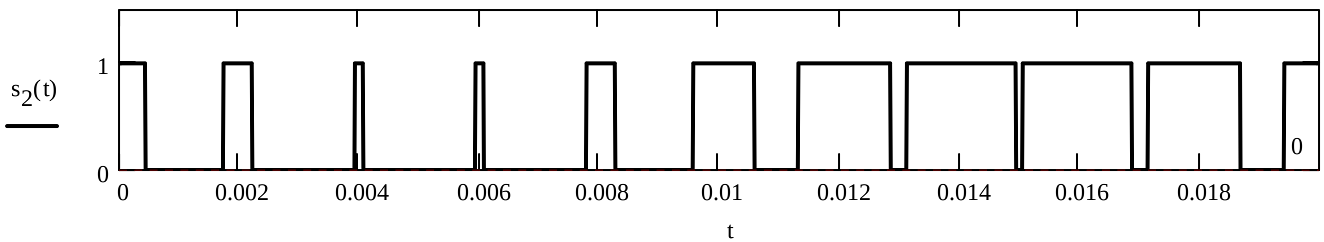


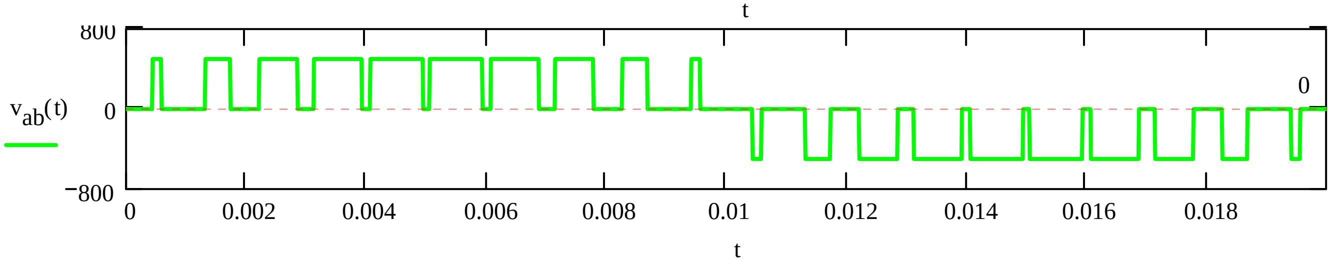
$s_{ab}(t) := s_1(t) - s_2(t)$

$v_{ab}(t) := s_{ab}(t) \cdot v_{dc}(t)$







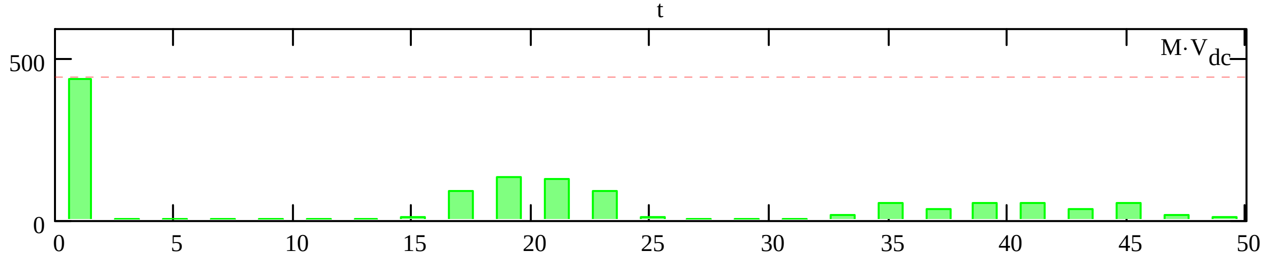


$N := 1024$ $m := 1..N$

$x_m := v_{ab}\left(\frac{m}{N} \cdot t_f\right)$ $xf := \text{FFT}(x)$

$xv(m) := \text{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

FFT de v_{ab}

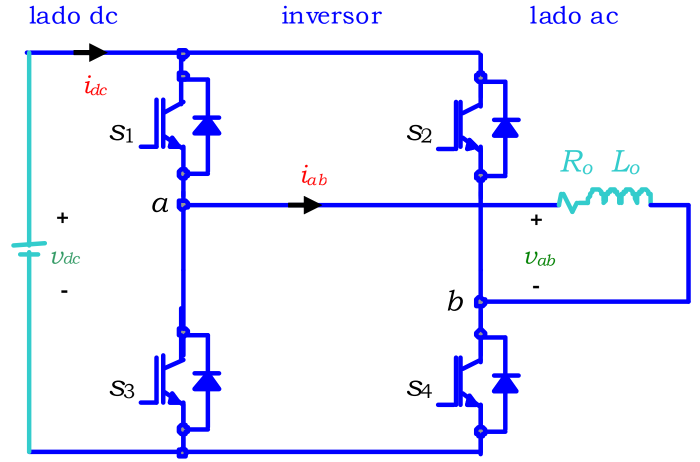


La fundamental del voltaje ac es igual a MV_{dc} y no hay componentes de frecuencia hasta f_{n_tr}.

$v_{ab1}(t) = V_{dc} \cdot m_a(t)$ $f \le f_{n\_tr}$

Modelo de Inversor de Voltaje Monofásico

Problema Estudiar el modelo del inversor de voltaje con Modulación SPWM.



$$v_{ab}(t) = R_o \cdot i_{ab}(t) + L_o \cdot di_{ab}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = v_{ab}(t) \cdot i_{ab}(t)$$

$$v_{ab}(t) = s_{ab}(t) \cdot v_{dc}(t)$$

$$s_{ab}(t) \cdot v_{dc}(t) = R_o \cdot i_{ab}(t) + L_o \cdot di_{ab}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = s_{ab}(t) \cdot v_{dc}(t) \cdot i_{ab}(t)$$

$$i_{dc}(t) = s_{ab}(t) \cdot i_{ab}(t)$$

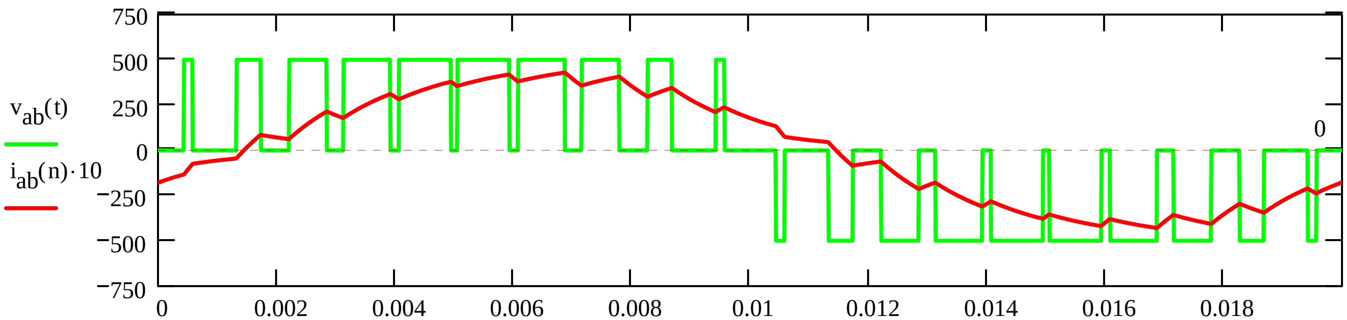
$$di_{ab}(t) = \frac{-R_o}{L_o} \cdot i_{ab}(t) + \frac{1}{L_o} \cdot s_{ab}(t) \cdot v_{dc}(t)$$

$$i_{dc}(t) = s_{ab}(t) \cdot i_{ab}(t)$$

Parámetros $L_o := 15 \cdot 10^{-3}$ $R_o := 10$

Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

$$D(t, x) := \frac{-R_o}{L_o} \cdot x_1 + \frac{1}{L_o} \cdot s_{ab}(t) \cdot v_{dc}(t) \qquad CI := 0 \qquad Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D) \qquad CI := Z_{n_f, 2} \qquad Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D) \qquad i_{ab}(n) := Z_{n, 2}$$



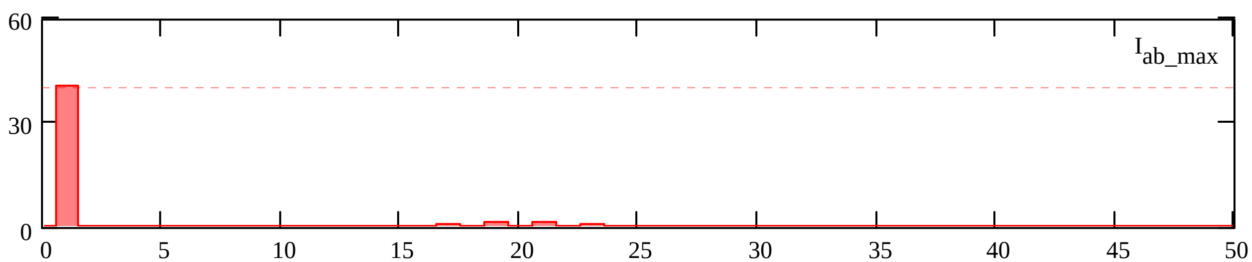
$N := 1024$ $m := 1 .. N$

$x_m := Z_{m \cdot \frac{n_f}{N}, 2}$ $xf := \mathrm{FFT}(x)$

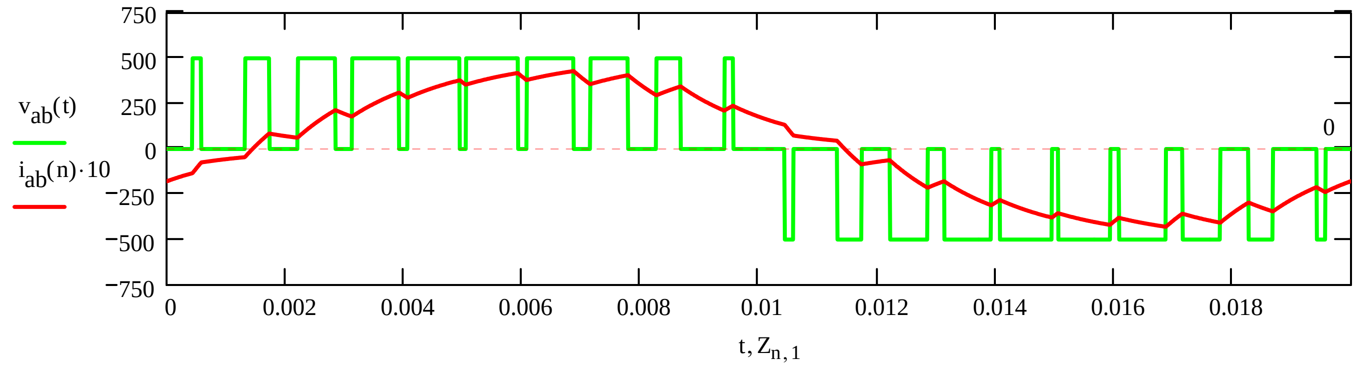
$xv(m) := \mathrm{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

$$I_{ab\_max} := \frac{M \cdot V_{dc}}{\sqrt{R_o^2 + (\omega_s \cdot L_o)^2}}$$

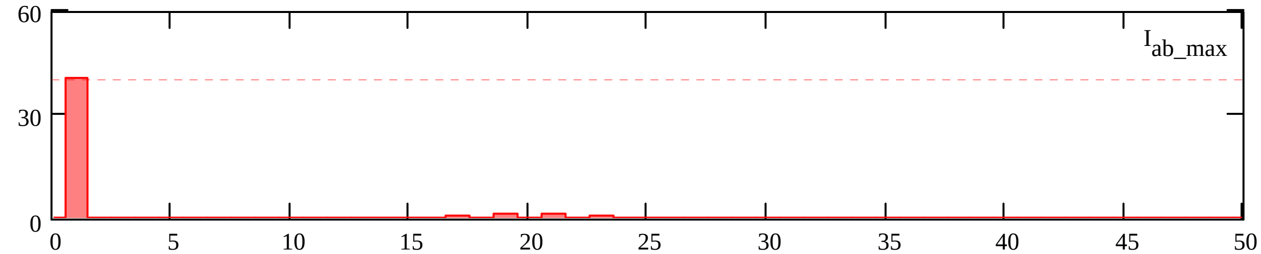
FFT de i_{ab}

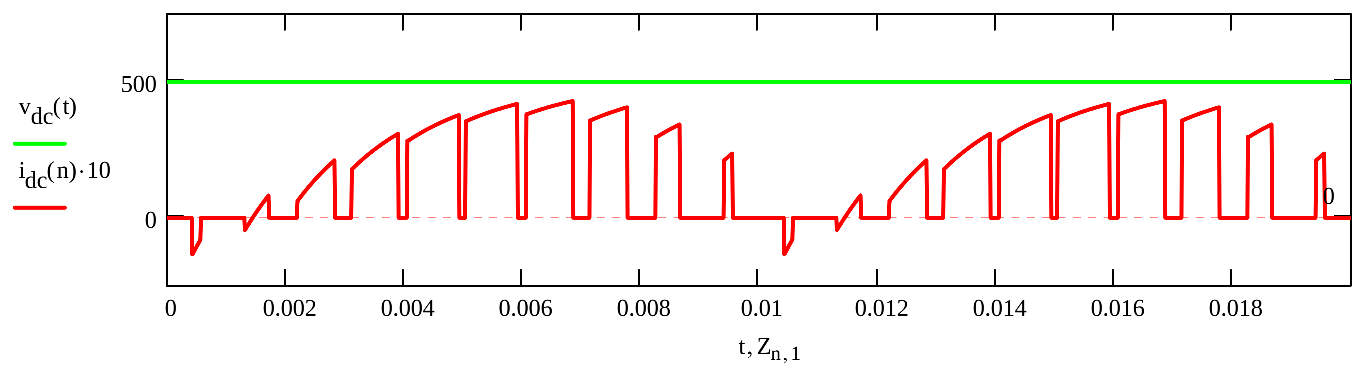


La carga natural es inductiva por la naturaleza del voltaje aplicado.

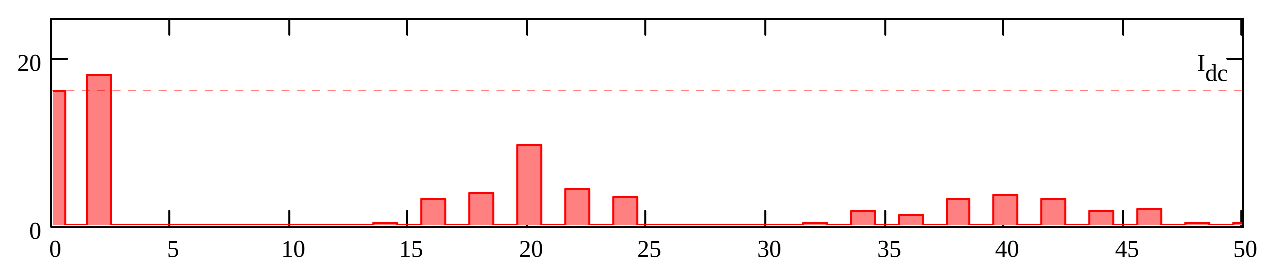


FFT de i_{ab}





FFT de i_{dc}



La corriente i_{dc} es,

$$\boxed{i_{dc}(t) = s_{ab}(t)\cdot i_{ab}(t)}$$

$$i_{dc}(n) := s_{ab}\left(n\cdot\frac{t_f}{n_f}\right)\cdot Z_{n,2}$$

$N := 1024$ $\qquad$ $m := 1..N$

$x_m := i_{dc}\left(m\cdot\frac{n_f}{N}\right)$ $\qquad$ $xf := FFT(x)$

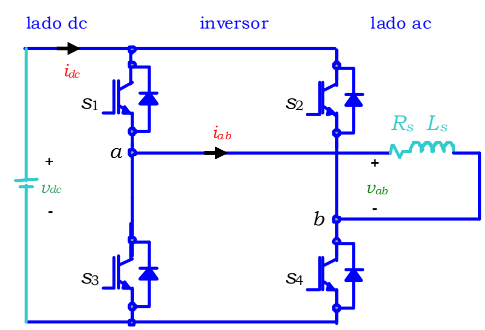
$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

El valor medio de la corriente i_{dc} es,

$$P := R_o\cdot\left(\frac{I_{ab\_max}}{\sqrt{2}}\right)^2 \qquad I_{dc} := \frac{P}{V_{dc}}$$

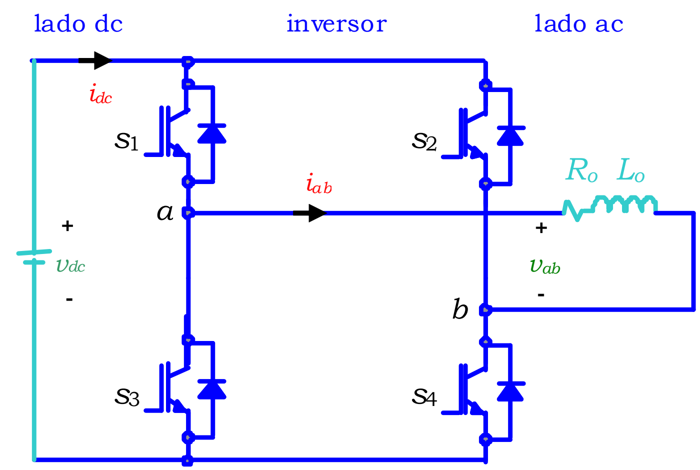
Notar que este último espectro se puede obtner mediante convolución,

$$i_{dc}(\omega) = s_{ab}(\omega) \oplus i_{ab}(\omega)$$



Modelo Promedio de Inversor de Voltaje Monofásico

Problema Estudiar el modelo promedio del inversor de voltaje.



$$v_{ab}(t) = R_o \cdot i_{ab}(t) + L_o \cdot di_{ab}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = v_{ab}(t) \cdot i_{ab}(t)$$

$$v_{ab}(t) = m_a(t) \cdot v_{dc}(t)$$

Se opta por trabajar con la fundamental.

$$m_a(t) \cdot v_{dc}(t) = R_o \cdot i_{ab}(t) + L_o \cdot di_{ab}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = m_a(t) \cdot v_{dc}(t) \cdot i_{ab}(t)$$

$$i_{dc}(t) = m_a(t) \cdot i_{ab}(t)$$

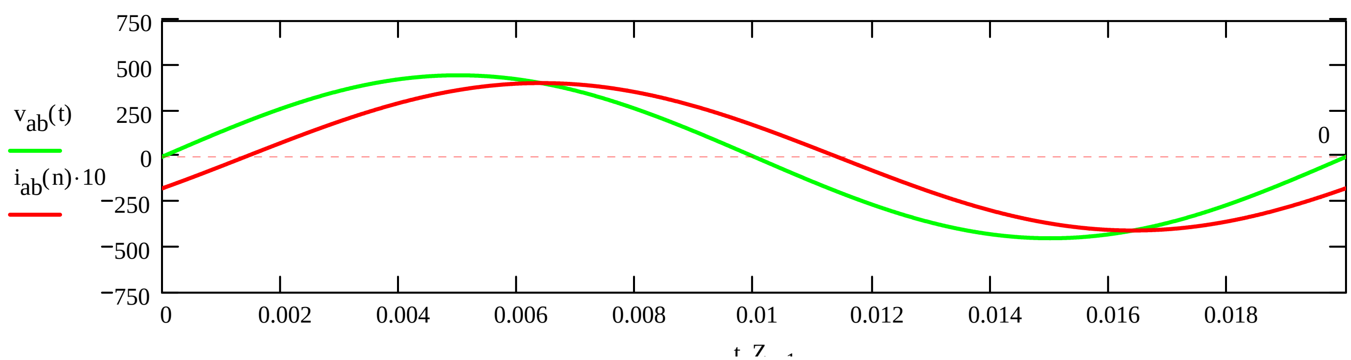
$$di_{ab}(t) = \frac{-R_o}{L_o} \cdot i_{ab}(t) + \frac{1}{L_o} \cdot m_a(t) \cdot v_{dc}(t)$$

$$i_{dc}(t) = m_a(t) \cdot i_{ab}(t)$$

Parámetros $L_o := 15 \cdot 10^{-3}$ $R_o := 10$

Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$ $v_{ab}(t) := m_a(t) \cdot v_{dc}(t)$

$D(t,x) := \frac{-R_o}{L_o} \cdot x_1 + \frac{1}{L_o} \cdot m_a(t) \cdot v_{dc}(t)$ $CI := 0$ $Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D)$ $CI := Z_{n_f, 2}$ $Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D)$ $i_{ab}(n) := Z_{n,2}$



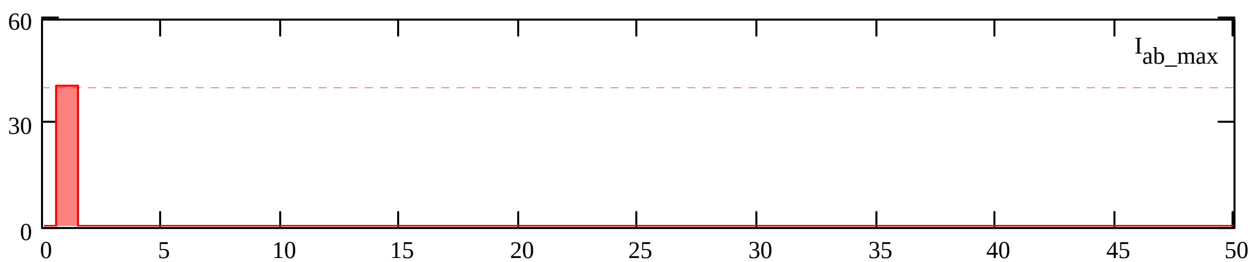
$N := 1024$ $m := 1 .. N$

$x_m := Z_{m \cdot \frac{n_f}{N}, 2}$ $xf := \mathrm{FFT}(x)$

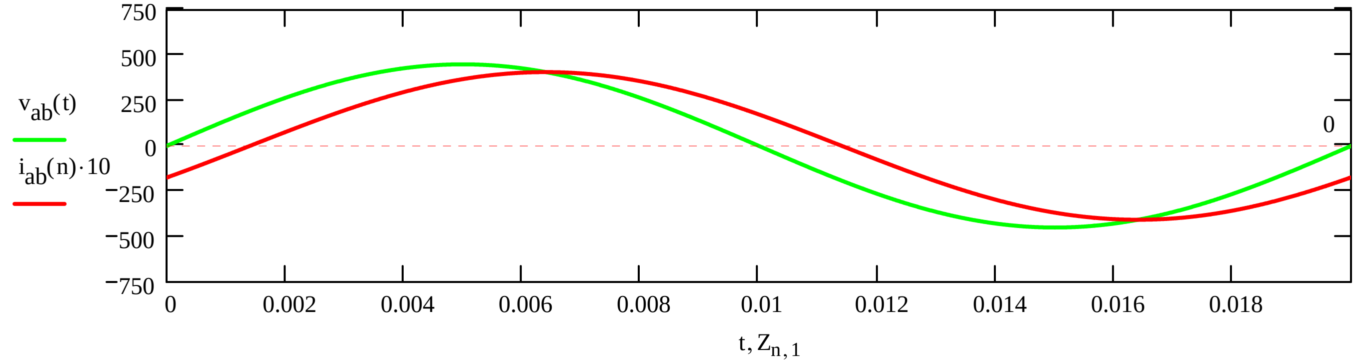
$xv(m) := \mathrm{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

$$I_{ab\_max} := \frac{M \cdot V_{dc}}{\sqrt{R_o^2 + (\omega_s \cdot L_o)^2}}$$

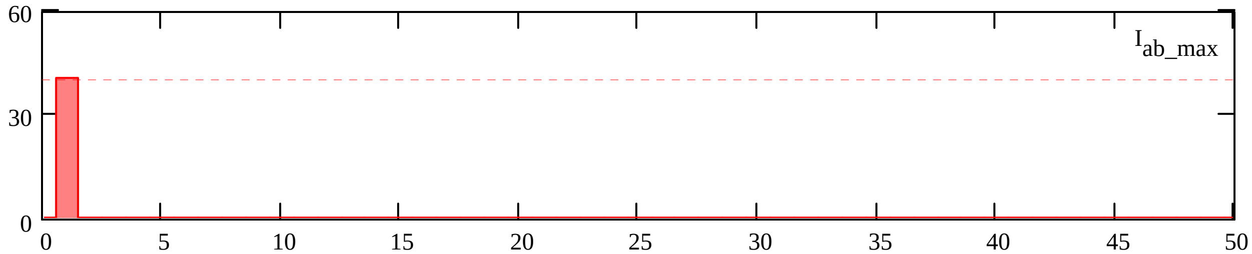
FFT de i_{ab}

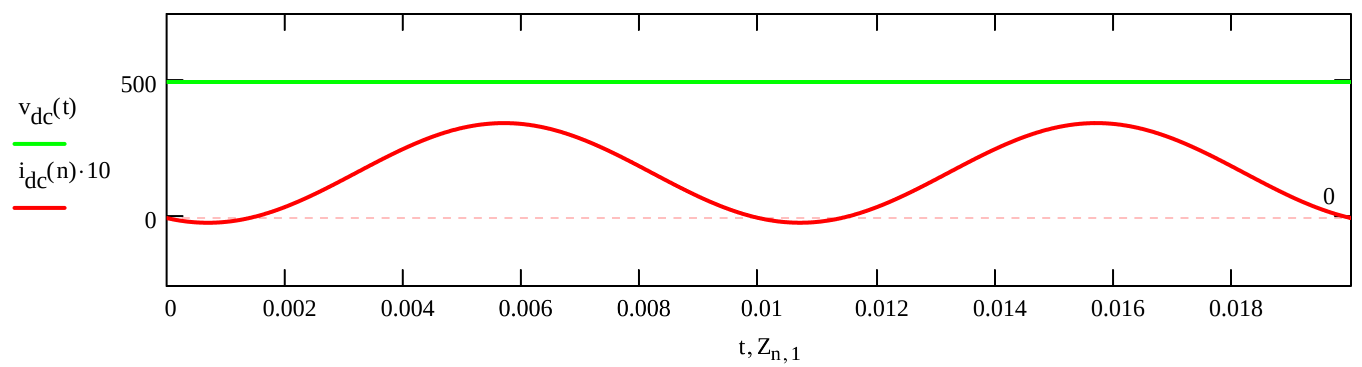


Notar que desaparece sólo la información relacionada con la conmutación.

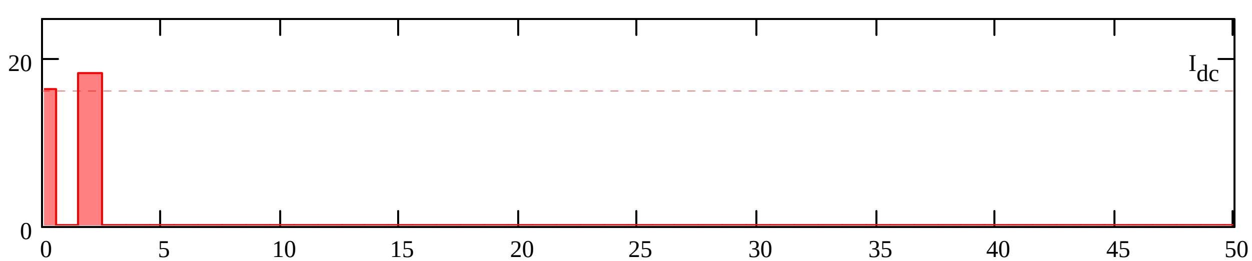


FFT de i_{ab}





FFT de i_{dc}



La corriente i_{dc} es,

$$\boxed{i_{dc}(t) = m_a(t)\cdot i_{ab}(t)}$$

$$i_{dc}(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot Z_{n,2}$$

$$N := 1024 \qquad m := 1..N$$

$$x_m := i_{dc}\left(m\cdot\frac{n_f}{N}\right) \qquad xf := FFT(x)$$

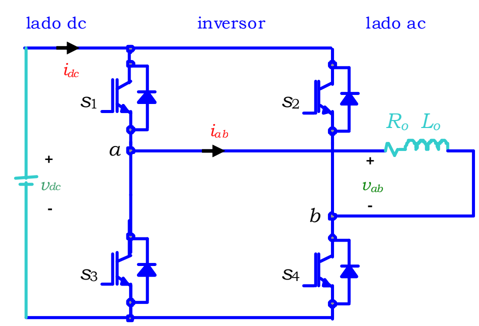
$$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$$

El valor medio de la corriente i_{dc} es,

$$P := R_o\cdot\left(\frac{I_{ab\_max}}{\sqrt{2}}\right)^2 \qquad I_{dc} := \frac{P}{V_{dc}}$$

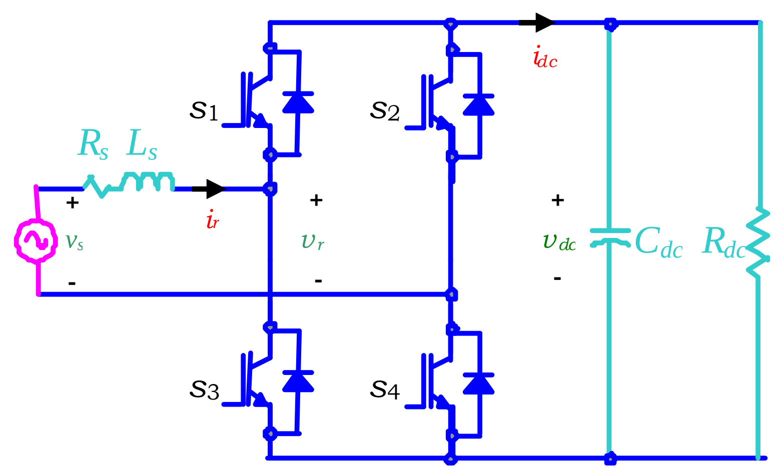
Notar que este último espectro se puede obtner mediante convolución,

$$i_{dc}(\omega) = m_a(\omega) \oplus i_{ab}(\omega)$$



Modelo de Rectificador de Voltaje Monofásico

Problema Estudiar el modelo del rectificador de voltaje con Modulación SPWM.



$$v_s(t) = R_s \cdot i_r(t) + L_s \cdot di_r(t) + v_r(t)$$

$$v_r(t) = s_{ab}(t) \cdot v_{dc}(t)$$

$$i_{dc}(t) = C_{dc} \cdot dv_{dc}(t) + \frac{v_{dc}(t)}{R_{dc}}$$

$$i_{dc}(t) = s_{ab}(t) \cdot i_r(t)$$

$$v_s(t) = R_s \cdot i_r(t) + L_s \cdot di_r(t) + s_{ab}(t) \cdot v_{dc}(t)$$

$$s_{ab}(t) \cdot i_r(t) = C_{dc} \cdot dv_{dc}(t) + \frac{v_{dc}(t)}{R_{dc}}$$

$$di_r(t) = \frac{v_s(t)}{L_s} - \frac{R_s}{L_s} \cdot i_r(t) - \frac{1}{L_s} \cdot s_{ab}(t) \cdot v_{dc}(t)$$

$$dv_{dc}(t) = \frac{1}{C_{dc}} \cdot s_{ab}(t) \cdot i_r(t) - \frac{1}{C_{dc} \cdot R_{dc}} \cdot v_{dc}(t)$$

Parámetros

$L_s := 30 \cdot 10^{-3}$ $R_s := 1$ $C_{dc} := 500 \cdot 10^{-6}$ $R_{dc} := 100$

La moduladora es, $M := 0.9$ $f_M := -10 \cdot \frac{\pi}{180}$

La tensión de red, $v_s(t) := \sqrt{2} \cdot 220 \cdot \sin(\omega_s \cdot t)$

$m_a(t) := M \cdot \sin(\omega_s \cdot t + f_M)$

Triangular, $tri(t) := \frac{2}{\pi} \cdot \mathrm{asin}\left(\sin\left(f_{n\_tr} \cdot \omega_s \cdot t + f_M \cdot f_{n\_tr} - \frac{\pi}{2}\right)\right)$

Primera pierna $s_1(t) := \mathrm{if}(m_a(t) > tri(t), 1, 0)$ $s_3(t) := \mathrm{if}(s_1(t) = 1, 0, 1)$

Segunda pierna $s_2(t) := \mathrm{if}(m_a(t) > -tri(t), 0, 1)$ $s_4(t) := \mathrm{if}(s_2(t) = 1, 0, 1)$

$s_{ab}(t) := s_1(t) - s_2(t)$

Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

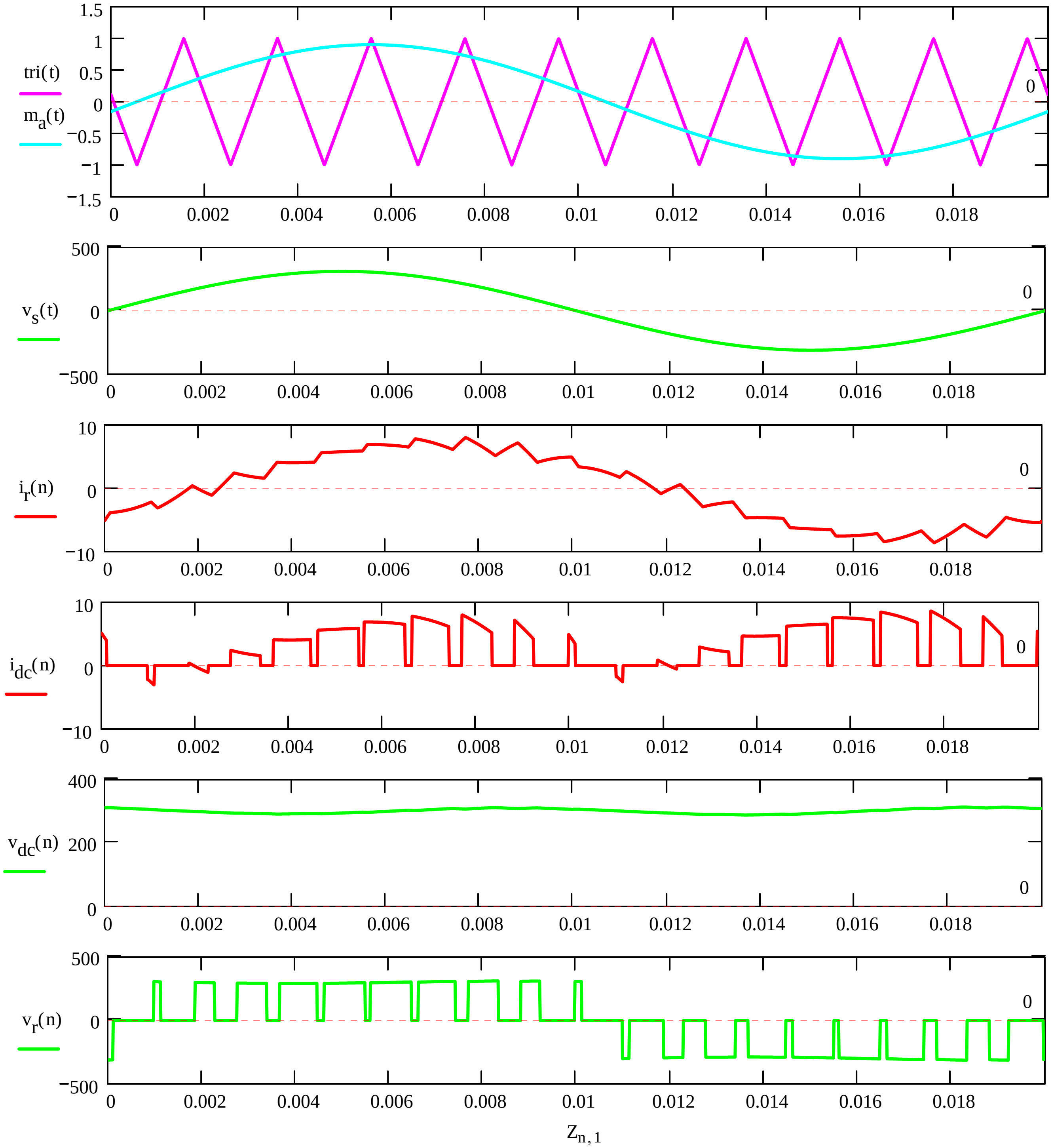
$$D(t,x) := \begin{pmatrix} \frac{-R_s}{L_s} \cdot x_1 - \frac{1}{L_s} \cdot s_{ab}(t) \cdot x_2 + \frac{v_s(t)}{L_s} \\ \frac{1}{C_{dc}} \cdot s_{ab}(t) \cdot x_1 - \frac{1}{C_{dc} \cdot R_{dc}} \cdot x_2 \end{pmatrix}$$

$CI := \begin{pmatrix} -5 \\ 315 \end{pmatrix}$ $Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D)$

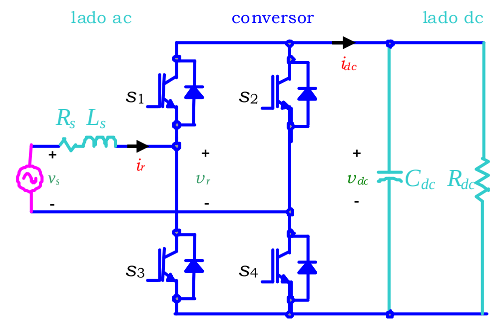
$CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \end{pmatrix}$ $Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D)$

$i_r(n) := Z_{n,2}$ $i_{dc}(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot i_r(n)$

$v_{dc}(n) := Z_{n,3}$ $v_r(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot v_{dc}(n)$

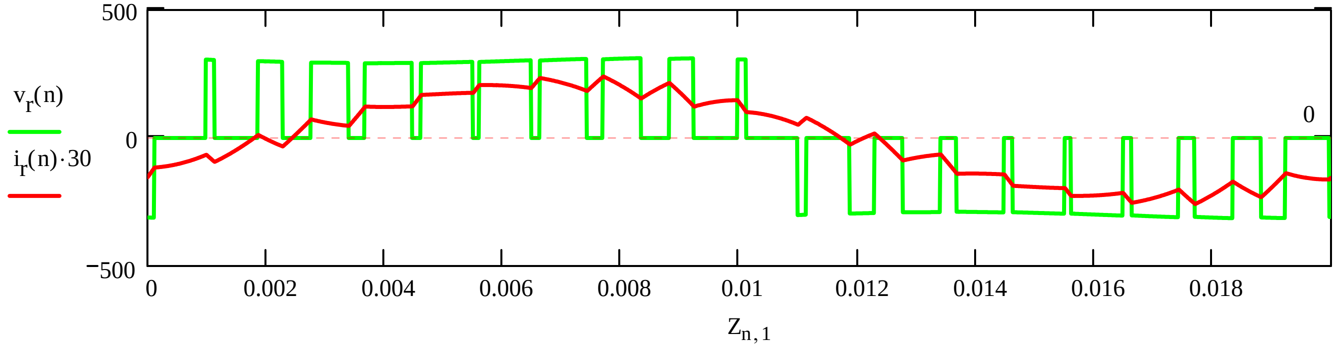


La triangular ha sido modificada en fase para minimizar la distorsión en la señal PWM.



El tamaño del condensador define el ripple u oscilación resultante. Hay un segundo armónico de voltaje que lo define un segundo armónico de corriente.

Debiera verse una distorsión adicional por efecto de la tensión DC no constante.

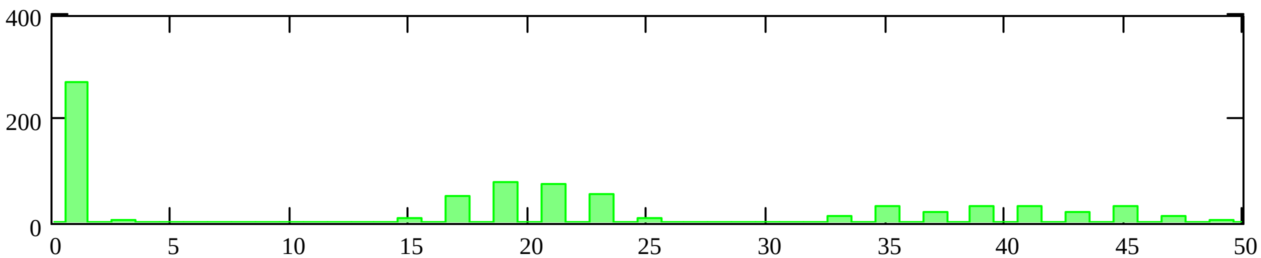


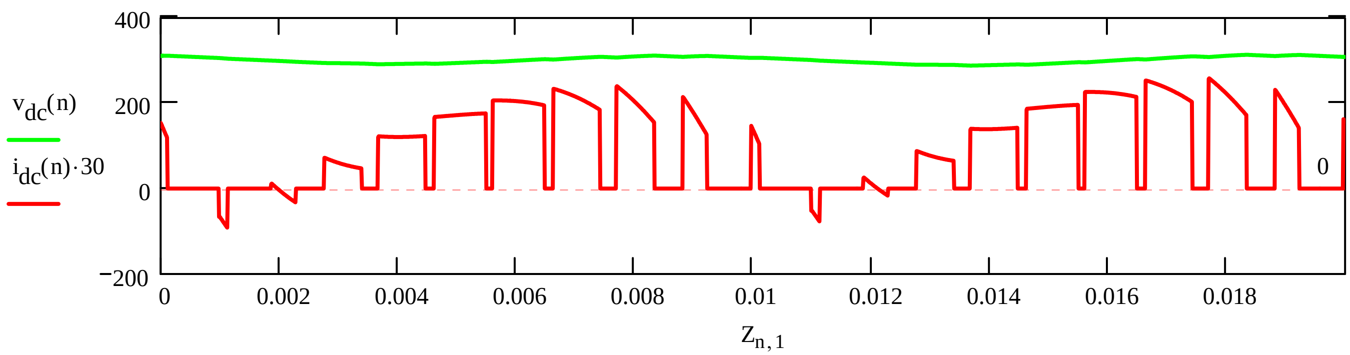
$N := 1024$ $\quad m := 1..N$

$x_m := v_r\left(m\cdot\frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

FFT de v_r



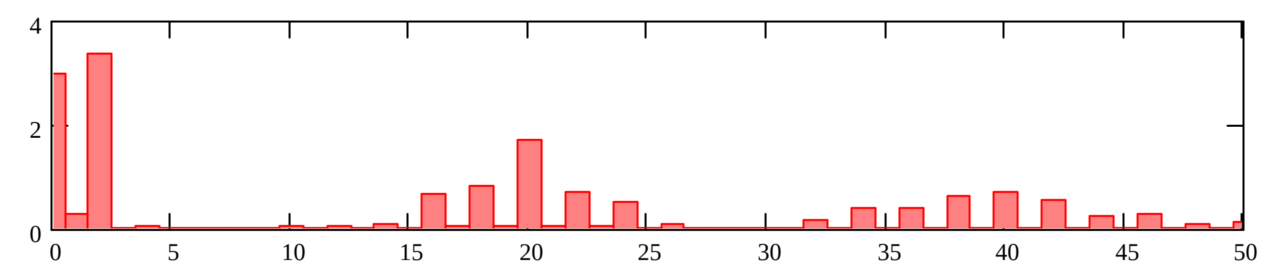


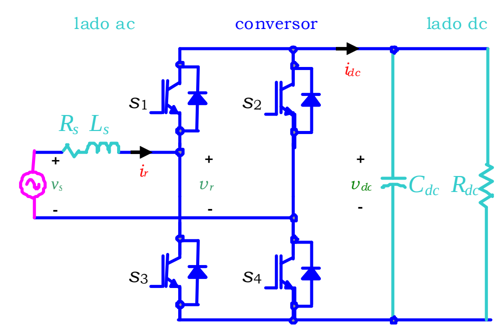
$N := 1024$ $\quad m := 1..N$

$x_m := i_{dc}\left(m\cdot\frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

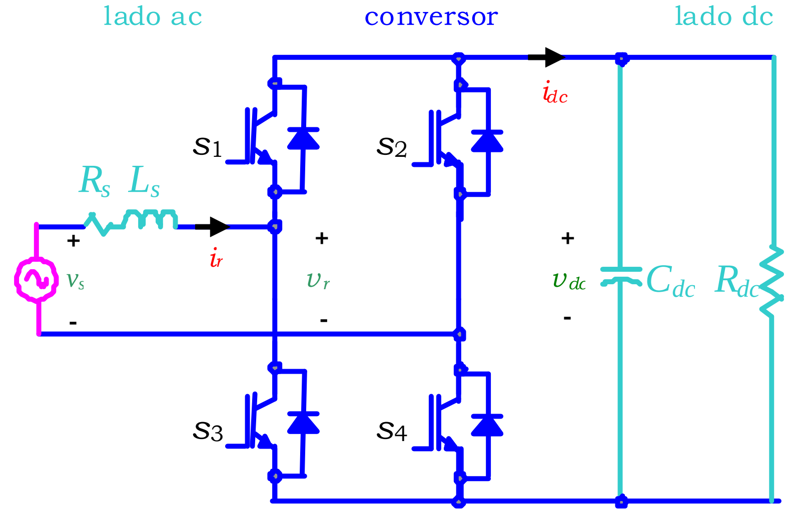
FFT de i_{dc}





Modelo Promedio de Rectificador de Voltaje Monofásico

Problema Estudiar el modelo promedio del rectificador de voltaje.



$$di_r(t) = \frac{v_s(t)}{L_s} - \frac{R_s}{L_s}\cdot i_r(t) - \frac{1}{L_s}\cdot s_{ab}(t)\cdot v_{dc}(t)$$

$$dv_{dc}(t) = \frac{1}{C_{dc}}\cdot s_{ab}(t)\cdot i_r(t) - \frac{1}{C_{dc}\cdot R_{dc}}\cdot v_{dc}(t)$$

Se utiliza la moduladora

$$di_r(t) = \frac{v_s(t)}{L_s} - \frac{R_s}{L_s}\cdot i_r(t) - \frac{1}{L_s}\cdot m_a(t)\cdot v_{dc}(t)$$

$$dv_{dc}(t) = \frac{1}{C_{dc}}\cdot m_a(t)\cdot i_r(t) - \frac{1}{C_{dc}\cdot R_{dc}}\cdot v_{dc}(t)$$

Parámetros

$L_s := 30\cdot 10^{-3}$ $\quad R_s := 1$ $\quad C_{dc} := 500\cdot 10^{-6}$ $\quad R_{dc} := 100$

La moduladora es, $M := 0.9$ $\quad f_M := -10\cdot\frac{\pi}{180}$

La tensión de red, $v_s(t) := \sqrt{2}\cdot 220\cdot \sin(\omega_s\cdot t)$

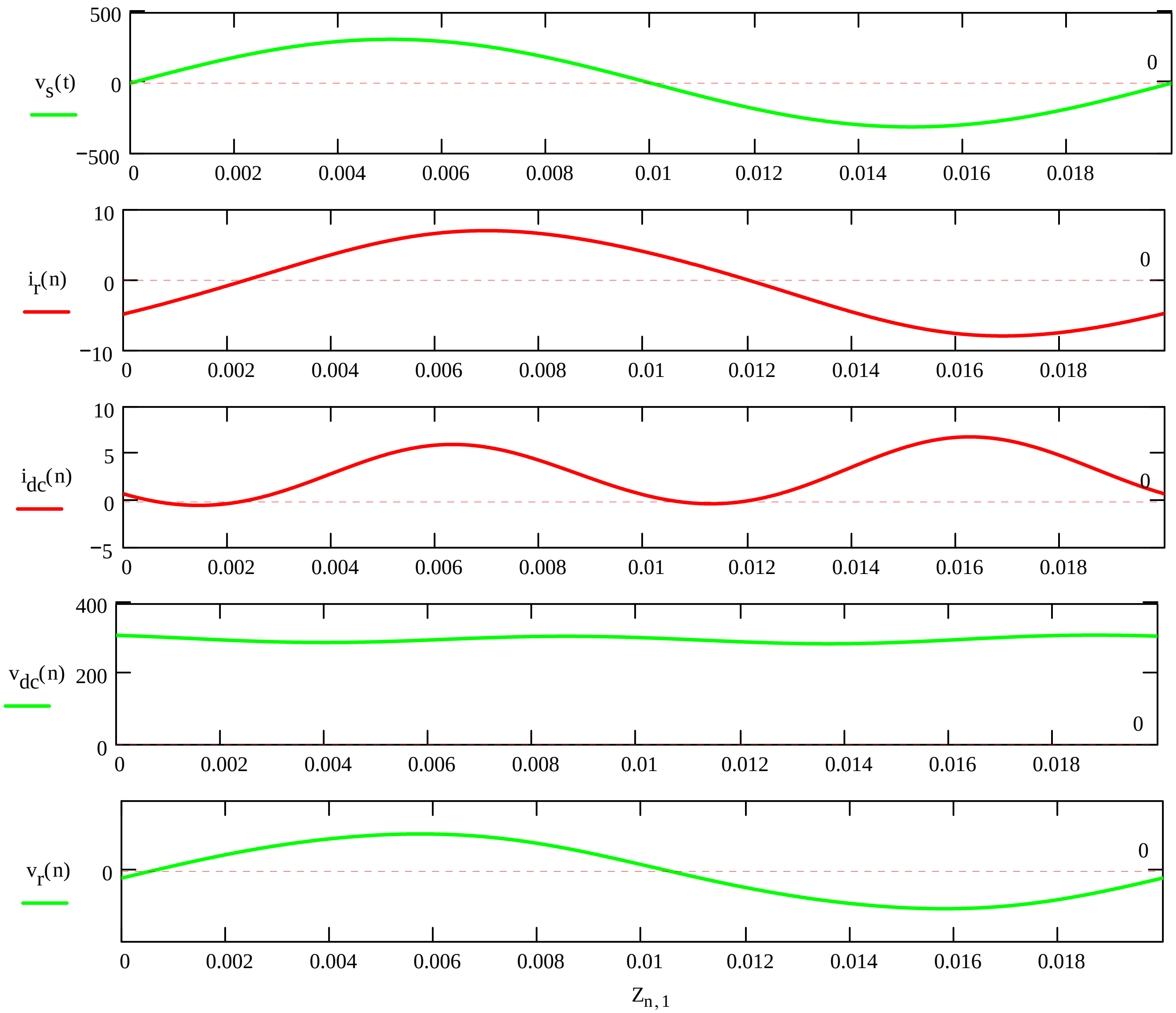
$m_a(t) := M\cdot \sin(\omega_s\cdot t + f_M)$

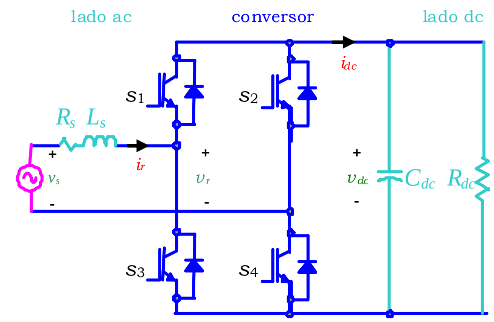
Simulación $\quad t_f := 0.02 \quad n_f := 2048 \quad n := 1 .. n_f \quad t := 0, \frac{t_f}{n_f} .. t_f$

$$D(t,x) := \begin{pmatrix} \frac{-R_s}{L_s}\cdot x_1 - \frac{1}{L_s}\cdot m_a(t)\cdot x_2 + \frac{v_s(t)}{L_s} \\ \frac{1}{C_{dc}}\cdot m_a(t)\cdot x_1 - \frac{1}{C_{dc}\cdot R_{dc}}\cdot x_2 \end{pmatrix}$$

$CI := \begin{pmatrix} -5 \\ 315 \end{pmatrix}$ $\quad Z := \text{rkfixed}(CI, 0, t_f, n_f, D)$ $\qquad CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \end{pmatrix}$ $\quad Z := \text{rkfixed}(CI, 0, t_f, n_f, D)$

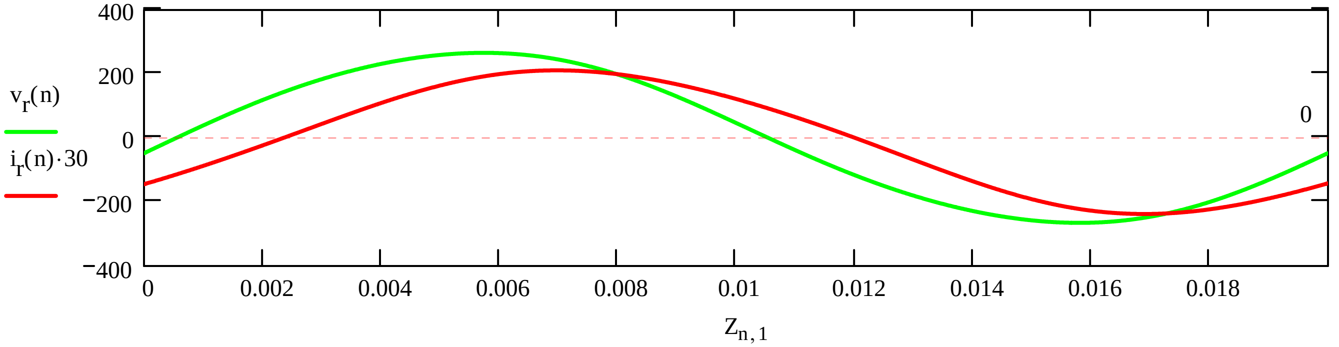
$i_r(n) := Z_{n,2}$ $\quad i_{dc}(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot i_r(n)$ $\quad v_{dc}(n) := Z_{n,3}$ $\quad v_r(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot v_{dc}(n)$





El tamaño del condensador define el ripple u oscilación resultante.

Debiera verse una distorsión adicional por efecto de la tensión DC no constante.

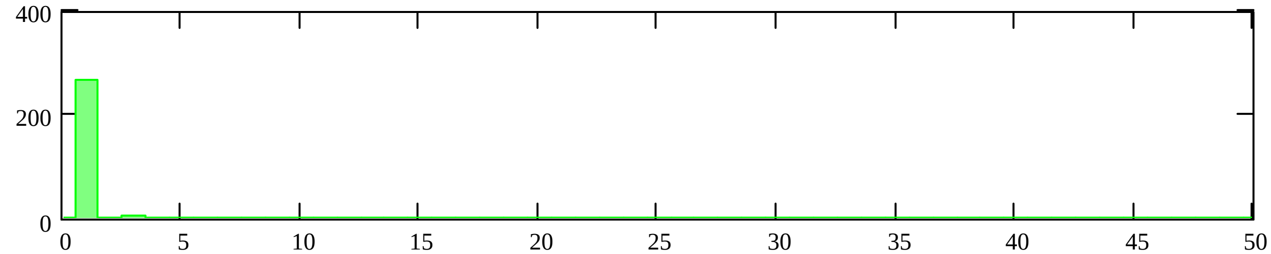


$N := 1024$ $\quad m := 1 .. N$

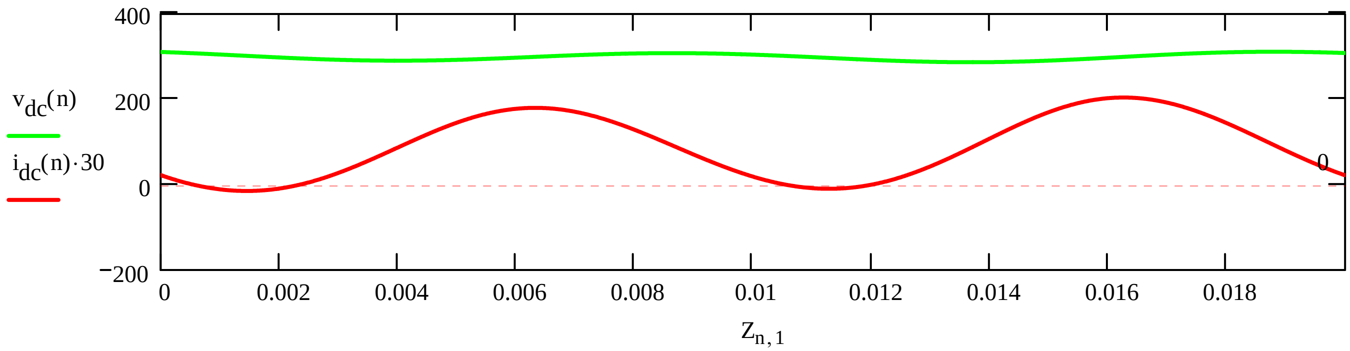
$x_m := v_r\left(m \cdot \frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := \text{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

FFT de v_r



Las CI no son las más apropiadas, pues el sistema todavía no está en estado estacionario.

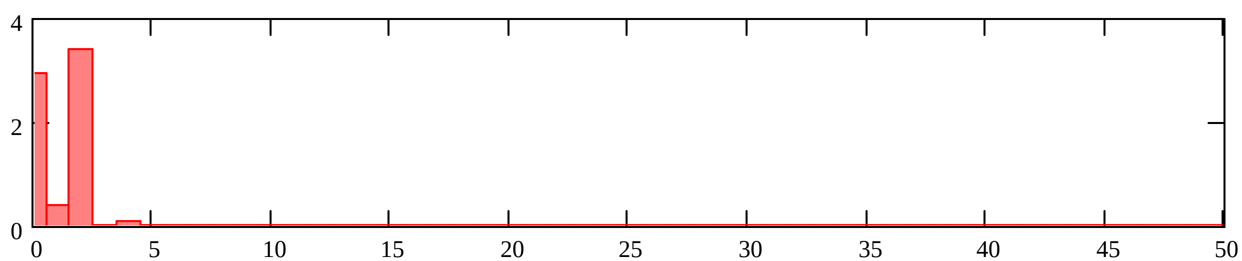


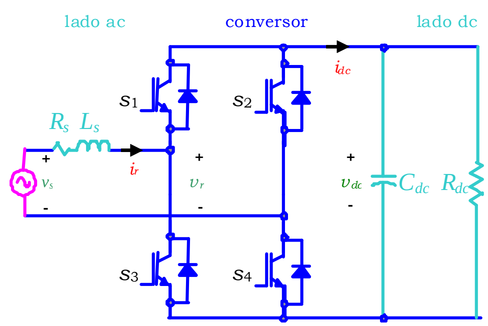
$N := 1024$ $\quad m := 1 .. N$

$x_m := i_{dc}\left(m \cdot \frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := \text{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

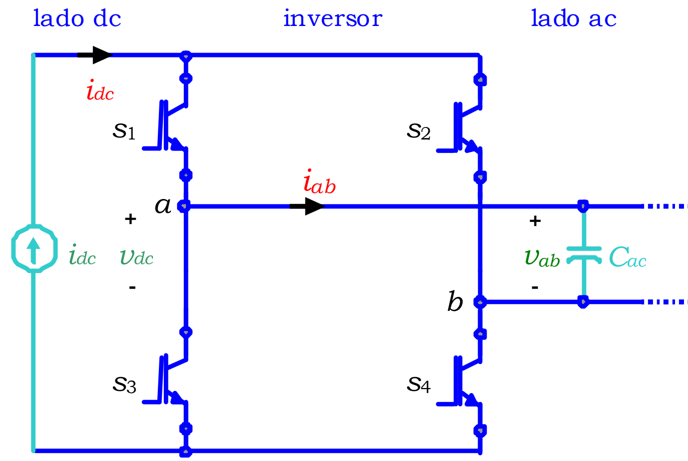
FFT de i_{dc}





Inversor de Corriente Monofásico

Problema Estudiar el inversor de corriente con Modulación SPWM.



La moduladora es, $M := 0.9$ $\quad f_M := 0$ $\quad m_a(t) := M \cdot \sin(\omega_s \cdot t + f_M)$

La triangular es, $f_{n\_tr} := 6$ $\quad per := 1$

$$tri(t) := \frac{2}{\pi} \cdot asin\left(\sin\left(f_{n\_tr} \cdot \omega_s \cdot t + f_M \cdot f_{n\_tr} - \frac{\pi}{2}\right)\right)$$

Primera pierna $s_1(t) := if(m_a(t) > tri(t), 1, 0)$ $\quad s_3(t) := if(s_1(t) = 1, 0, 1)$

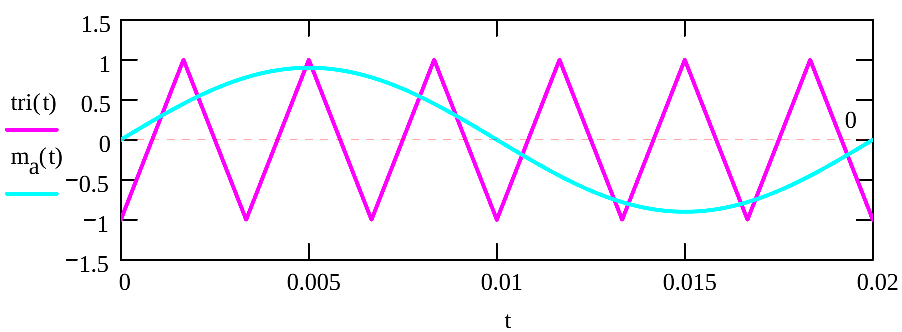
Segunda pierna $s_2(t) := if(m_a(t) > -tri(t), 0, 1)$ $\quad s_4(t) := if(s_2(t) = 1, 0, 1)$

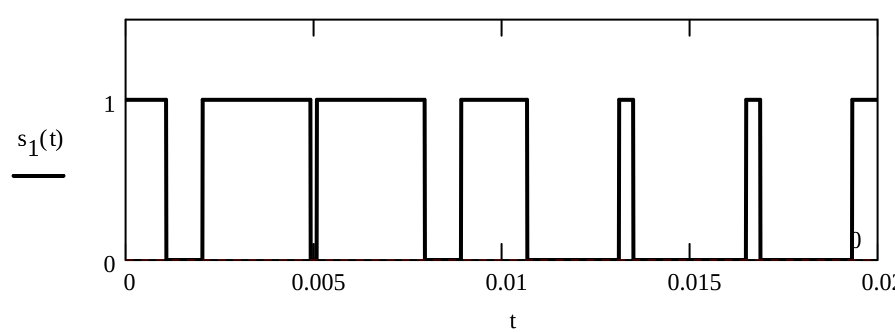
La función de switcheo es, $s_{ab}(t) := s_1(t) - s_2(t)$

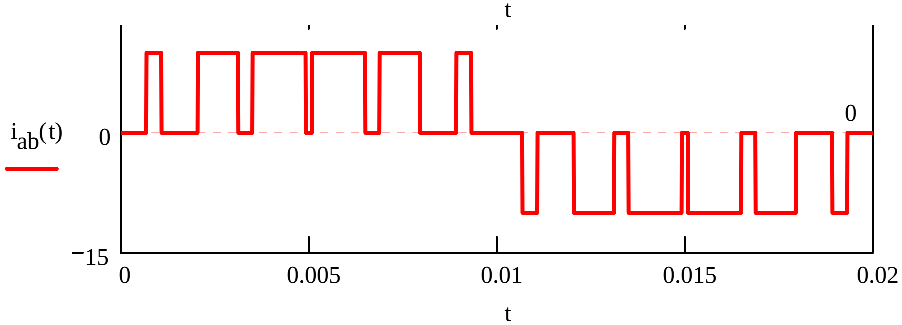
Las corrientes son, $i_{dc}(t) := 10$ $\quad i_{ab}(t) := s_{ab}(t) \cdot i_{dc}(t)$

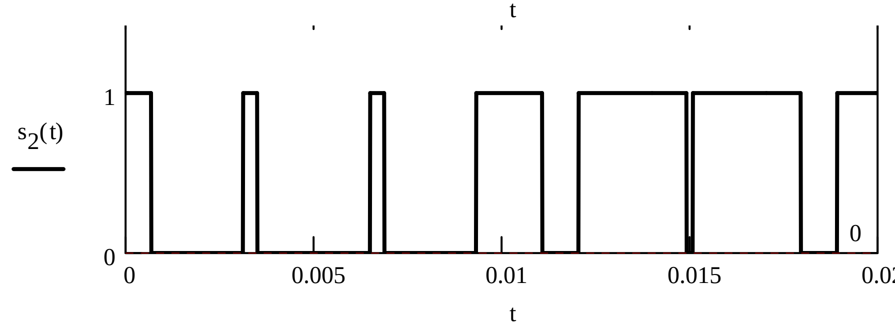
$v_{dc}(t) := s_{ab}(t) \cdot v_{ab}(t)$

Las funciones $s_1(t)$, $s_2(t)$, $s_3(t)$ y $s_4(t)$ no corresponden al encendido y apagado de los switches para lograr la corriente $i_{ab}(t)$ en el circuito.



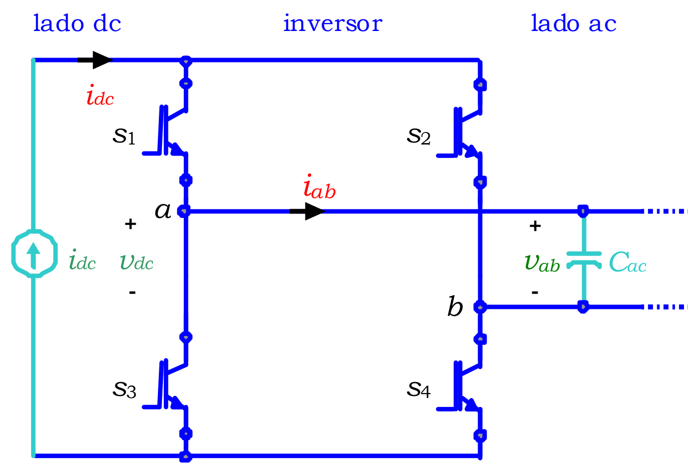






Inversor de Corriente Monofásico

Problema Estudiar el inversor de corriente con Modulación SPWM.



Auxiliar 1 $s_a(t) := \text{if}\left(m_a(t) > tri(t), 1, 0\right)$ $s_c(t) := \text{if}\left(s_a(t) = 1, 0, 1\right)$

Auxiliar 2 $s_b(t) := \text{if}\left(m_a(t) > -tri(t), 0, 1\right)$ $s_d(t) := \text{if}\left(s_b(t) = 1, 0, 1\right)$

Primera pierna $s_1(t) := s_a(t) \cdot s_d(t)$ $s_3(t) := s_b(t) \cdot s_c(t)$

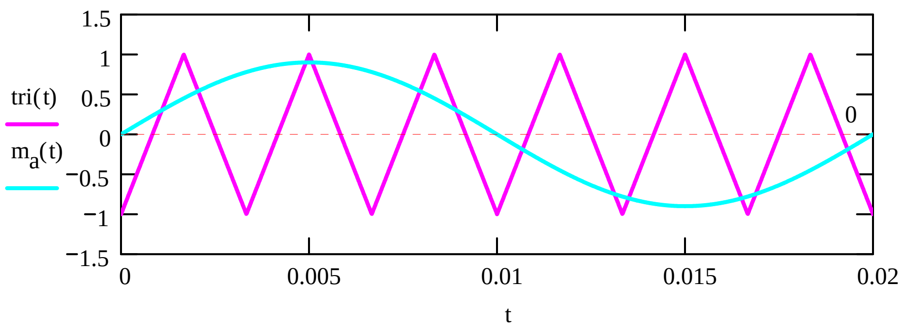
Segunda pierna $s_4(t) := s_1(t)$ $s_2(t) := s_3(t)$

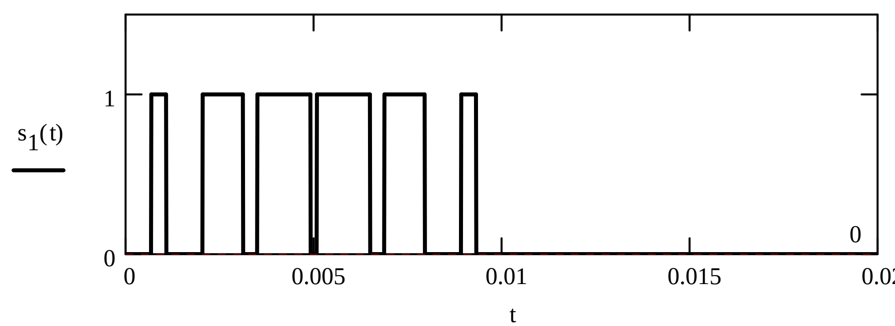
La función de switcheo es, $s_{ab}(t) := s_1(t) - s_2(t)$

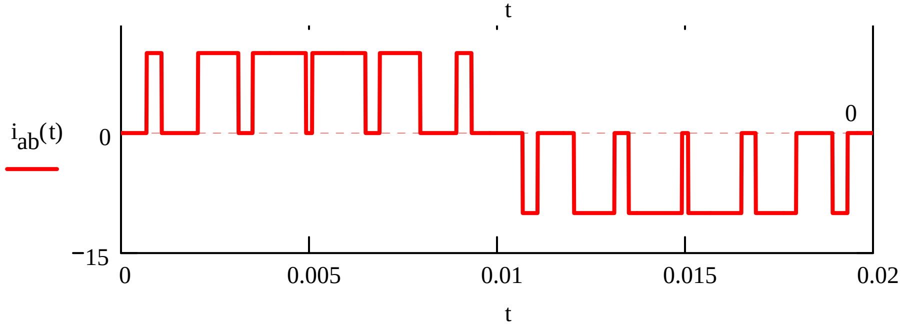
Las corrientes son, $i_{dc}(t) := 10$ $i_{ab}(t) := s_{ab}(t) \cdot i_{dc}(t)$

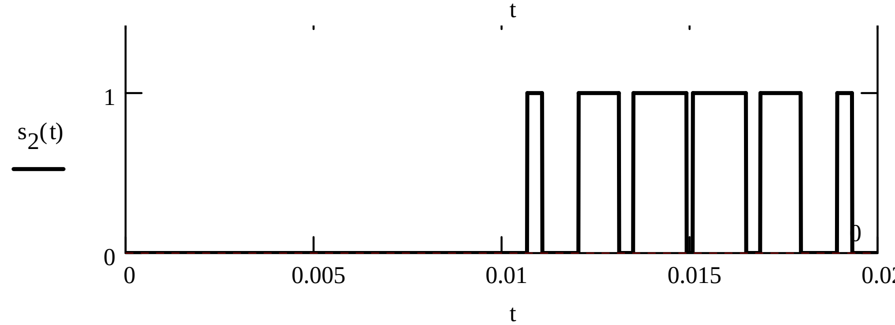
$v_{dc}(t) := s_{ab}(t) \cdot v_{ab}(t)$

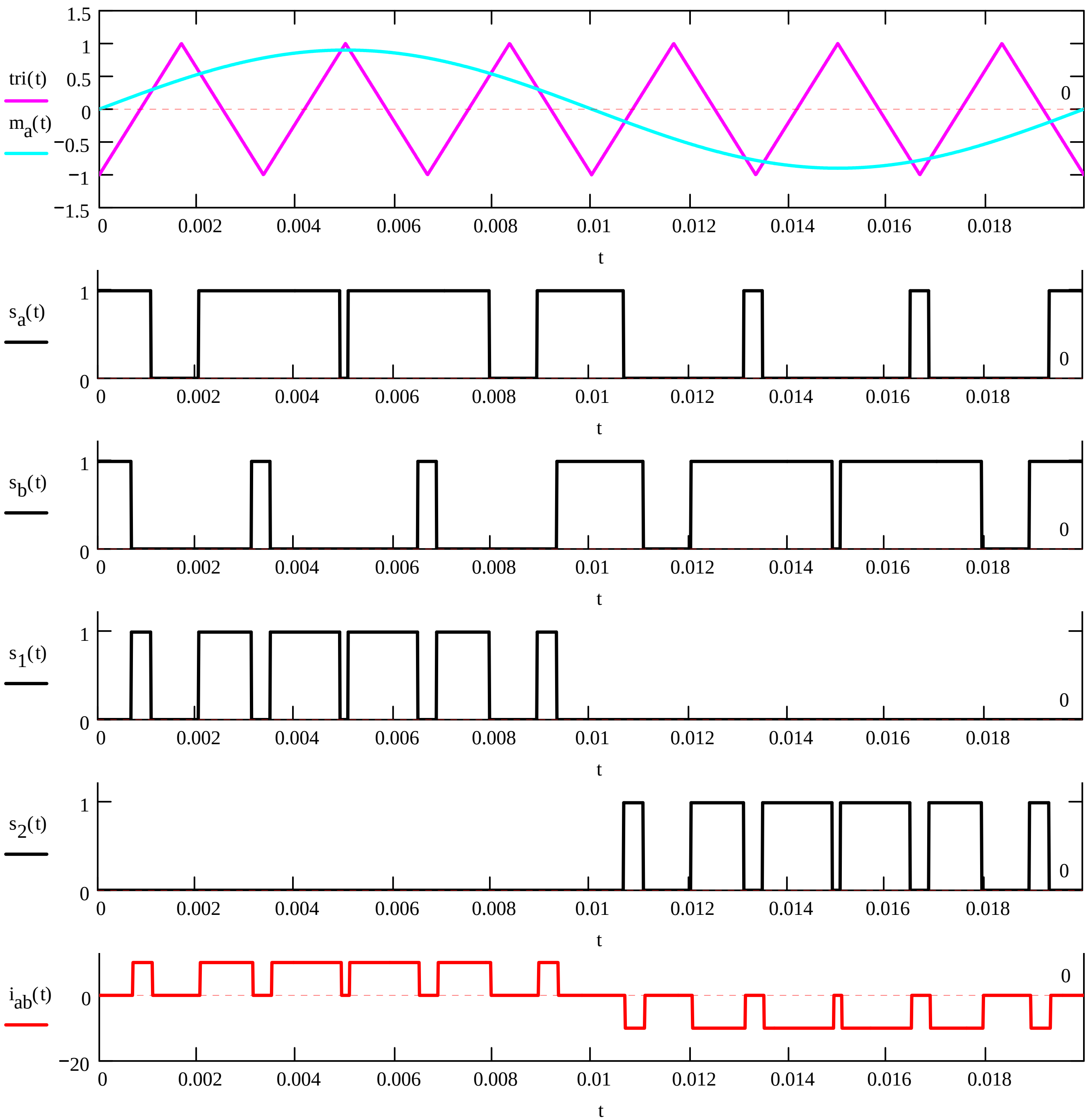
Las funciones $s_1(t)$, $s_2(t)$, $s_3(t)$ y $s_4(t)$ ahora si corresponden al encendido y apagado de los switches para lograr la corriente $i_{ab}(t)$ en el circuito.

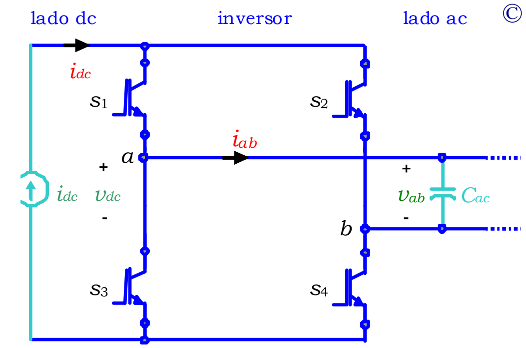












$s_a(t) := \text{if}\left(m_a(t) > \text{tri}(t), 1, 0\right)$

$s_b(t) := \text{if}\left(m_a(t) > -\text{tri}(t), 0, 1\right)$

$s_c(t) := \text{if}\left(s_a(t) = 1, 0, 1\right)$

$s_d(t) := \text{if}\left(s_b(t) = 1, 0, 1\right)$

$s_1(t) := s_a(t) \cdot s_d(t)$

$s_3(t) := s_b(t) \cdot s_c(t)$

$s_4(t) := s_1(t)$

$s_2(t) := s_3(t)$

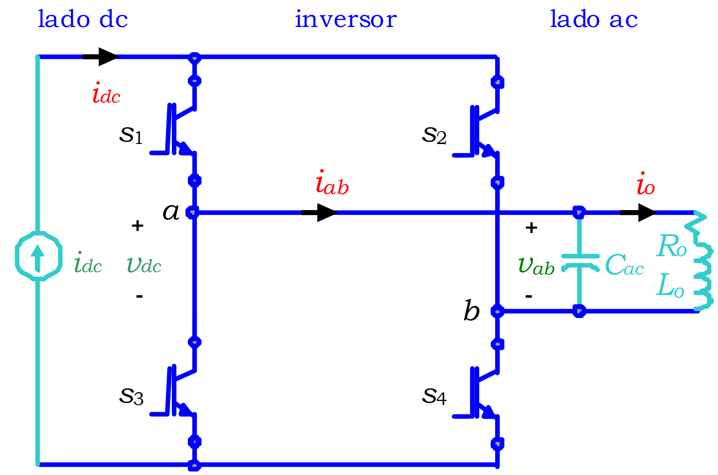
$s_{ab}(t) := s_1(t) - s_2(t)$

$i_{ab}(t) := s_{ab}(t) \cdot i_{dc}(t)$ $\quad$ $v_{dc}(t) := s_{ab}(t) \cdot v_{ab}(t)$

La tarea de generaación de pulsos de disparo la puede realizar un circuito lógico binario en línea. Falta la distribución del estado nulo.

Modelo de Inversor de Corriente Monofásico

Problema Estudiar el modelo del inversor de corriente con Modulación SPWM.



$$v_{ab}(t) = R_o \cdot i_o(t) + L_o \cdot di_o(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = v_{ab}(t) \cdot i_{ab}(t)$$

$$i_{ab}(t) = C_{ac} \cdot dv_{ab}(t) + i_o(t)$$

$$i_{ab}(t) = s_{ab}(t) \cdot i_{dc}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = v_{ab}(t) \cdot s_{ab}(t) \cdot i_{dc}(t)$$

$$v_{ab}(t) = R_o \cdot i_o(t) + L_o \cdot di_o(t)$$

$$v_{dc}(t) = s_{ab}(t) \cdot v_{ab}(t)$$

$$s_{ab}(t) \cdot i_{dc}(t) = C_{ac} \cdot dv_{ab}(t) + i_o(t)$$

$$di_o(t) = \frac{-R_o}{L_o} \cdot i_o(t) + \frac{1}{L_o} \cdot v_{ab}(t)$$

$$dv_{ab}(t) = \frac{-1}{C_{ac}} \cdot i_o(t) + \frac{1}{C_{ac}} \cdot s_{ab}(t) \cdot i_{dc}(t)$$

Parámetros

$L_o := 30 \cdot 10^{-3}$ $R_o := 10$ $C_{ac} := 100 \cdot 10^{-6}$ $i_{dc}(t) := 10$

La triangular es, $f_{n\_tr} := 10$ $per := 1$ $tri(t) := \frac{2}{\pi} \cdot asin\left(sin\left(f_{n\_tr} \cdot \omega_s \cdot t + f_M \cdot f_{n\_tr} - \frac{\pi}{2}\right)\right)$

Auxiliar 1 $s_a(t) := if(m_a(t) > tri(t), 1, 0)$ $s_c(t) := if(s_a(t) = 1, 0, 1)$

Auxiliar 2 $s_b(t) := if(m_a(t) > -tri(t), 0, 1)$ $s_d(t) := if(s_b(t) = 1, 0, 1)$

Primera pierna $s_1(t) := s_a(t) \cdot s_d(t)$ $s_3(t) := s_b(t) \cdot s_c(t)$

Segunda pierna $s_4(t) := s_1(t)$ $s_2(t) := s_3(t)$

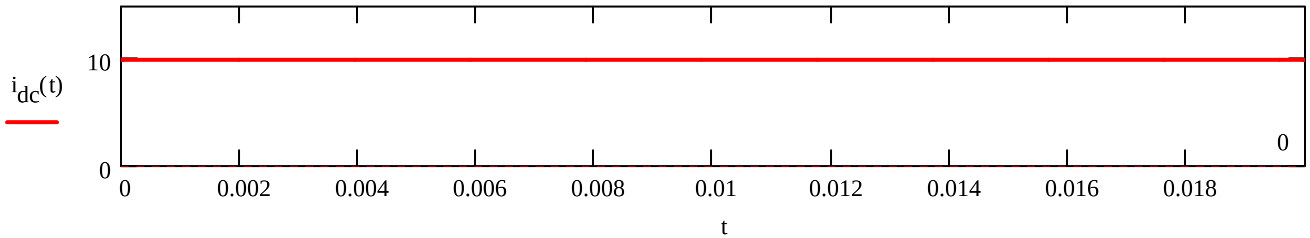
Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

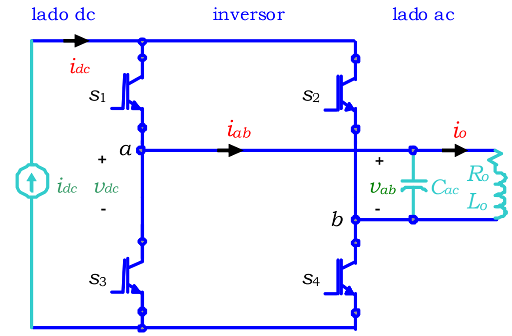
La función de switcheo es, $s_{ab}(t) := s_1(t) - s_2(t)$

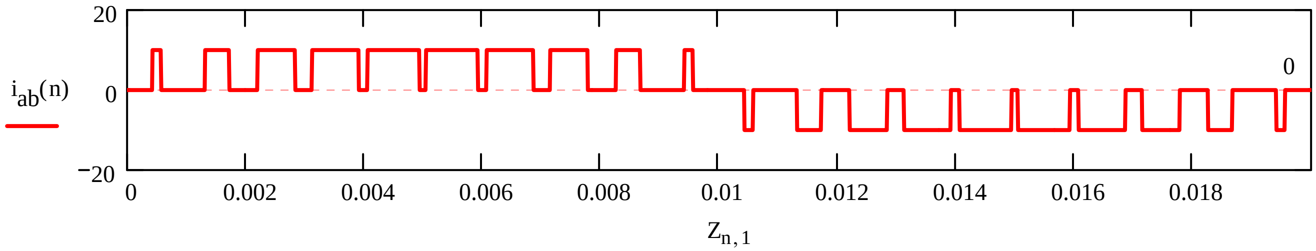
$$D(t,x) := \begin{pmatrix} \frac{-R_o}{L_o} \cdot x_1 + \frac{1}{L_o} \cdot x_2 \\ \frac{-1}{C_{ac}} \cdot x_1 + \frac{1}{C_{ac}} \cdot s_{ab}(t) \cdot i_{dc}(t) \end{pmatrix}$$

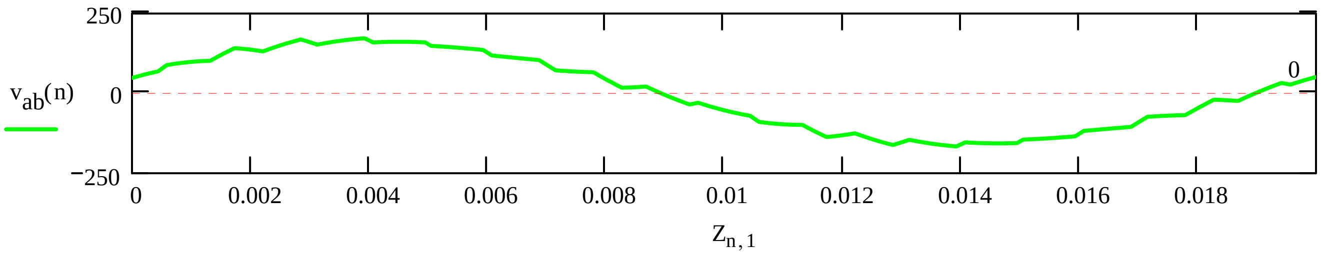
$CI := \begin{pmatrix} -5 \\ 315 \end{pmatrix}$ $Z := rkfixed(CI, 0, t_f, n_f, D)$ $CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \end{pmatrix}$ $Z := rkfixed(CI, 0, t_f, n_f, D)$

$i_o(n) := Z_{n,2}$ $v_{ab}(n) := Z_{n,3}$ $v_{dc}(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot v_{ab}(n)$ $i_{ab}(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot i_{dc}\left(n \cdot \frac{t_f}{n_f}\right)$

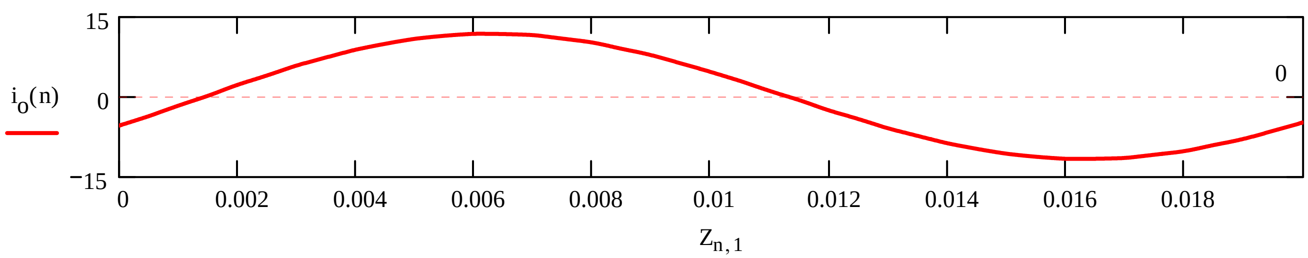




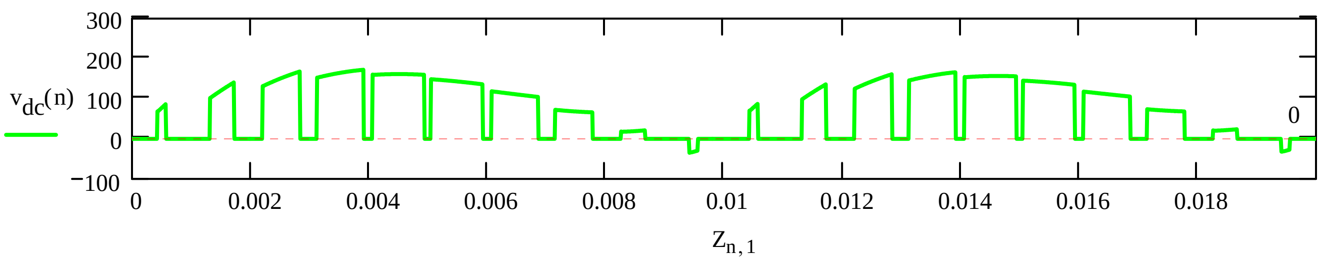




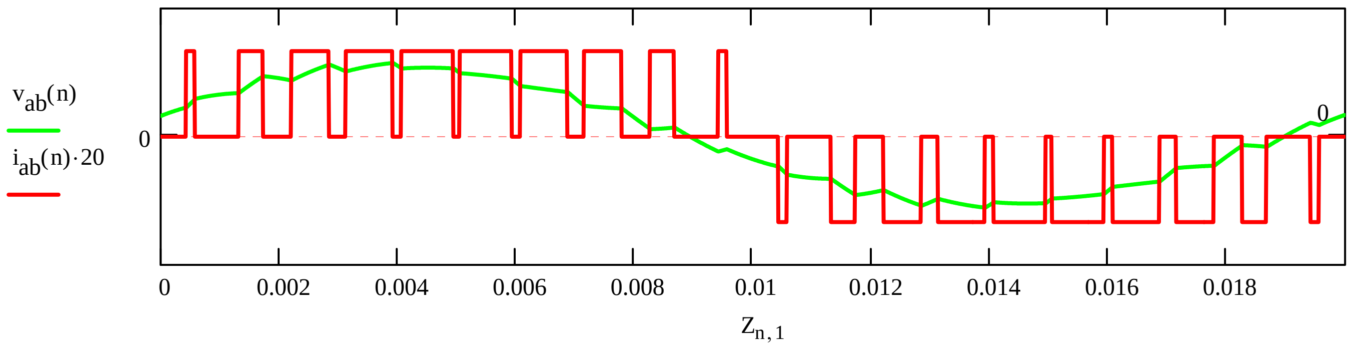
El tamaño del condensador define el ripple u oscilación resultante.



Se requiere un condensador en el lado ac por la naturaleza de la corriente i_{ab}.



La tensión en el enlace puede ser negativa lo que exige reverse blocking voltage capabilities a los switches.

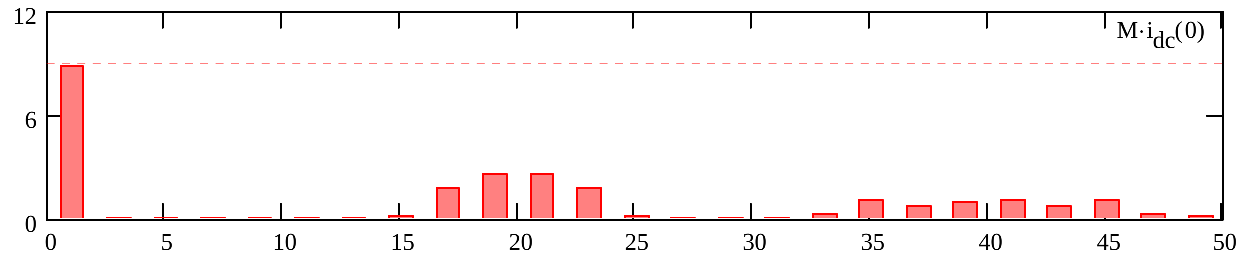


$N := 1024$ $m := 1..N$

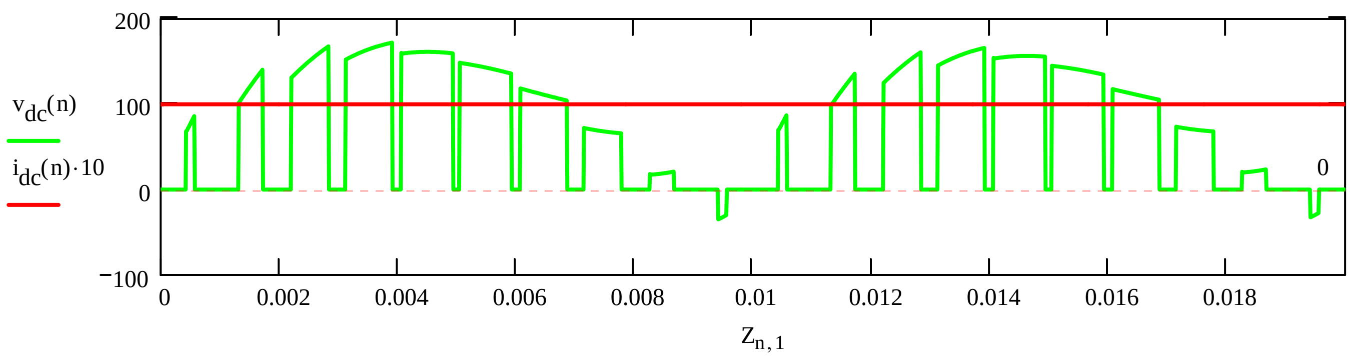
$x_m := i_{ab}\left(m\cdot\frac{n_f}{N}\right)$ $xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

FFT de i_{ab}



$M\cdot i_{dc}(0) = 9$



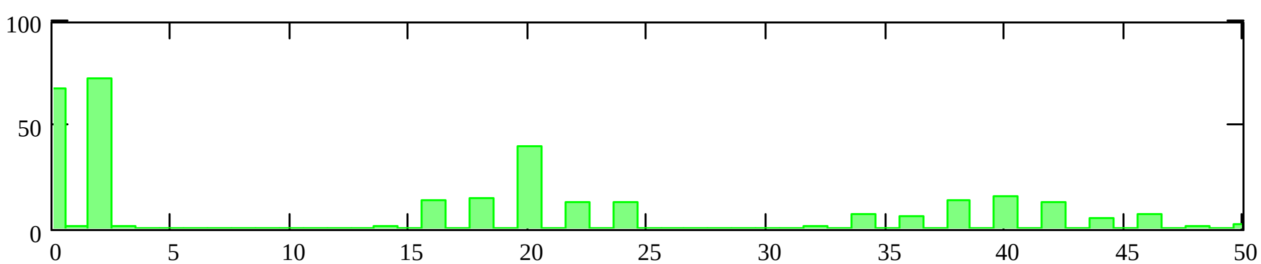
$N := 1024$ $m := 1..N$

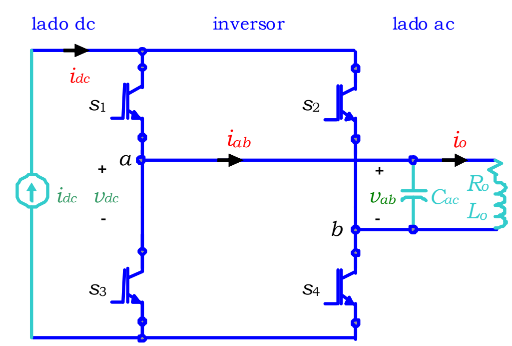
$x_m := v_{dc}\left(m\cdot\frac{n_f}{N}\right)$ $xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

$|xv(1)| = 67.51$ $|xv(3)| = 72.239$

FFT de v_{dc}





Modelo Promedio de Inversor de Corriente Monofásico

Problema Estudiar el modelo promedio del inversor de corriente.

$$di_o(t) = \frac{-R_o}{L_o}\cdot i_o(t) + \frac{1}{L_o}\cdot v_{ab}(t)$$

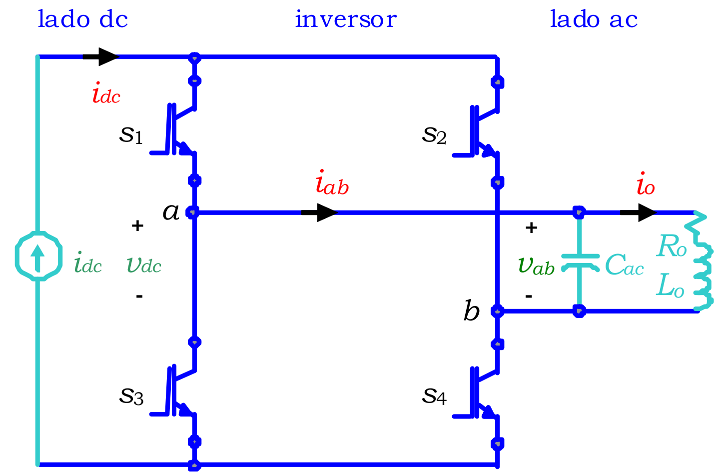
$$dv_{ab}(t) = \frac{-1}{C_{ac}}\cdot i_o(t) + \frac{1}{C_{ac}}\cdot s_{ab}(t)\cdot i_{dc}(t)$$

$$v_{dc}(t)\cdot i_{dc}(t) = v_{ab}(t)\cdot i_{ab}(t)$$

$$i_{ab}(t) = m_a(t)\cdot i_{dc}(t)$$

$$v_{dc}(t)\cdot i_{dc}(t) = v_{ab}(t)\cdot s_{ab}(t)\cdot i_{dc}(t)$$

$$v_{dc}(t) = m_a(t)\cdot v_{ab}(t)$$



$$di_o(t) = \frac{-R_o}{L_o}\cdot i_o(t) + \frac{1}{L_o}\cdot v_{ab}(t)$$

$$dv_{ab}(t) = \frac{-1}{C_{ac}}\cdot i_o(t) + \frac{1}{C_{ac}}\cdot m_a(t)\cdot i_{dc}(t)$$

Parámetros

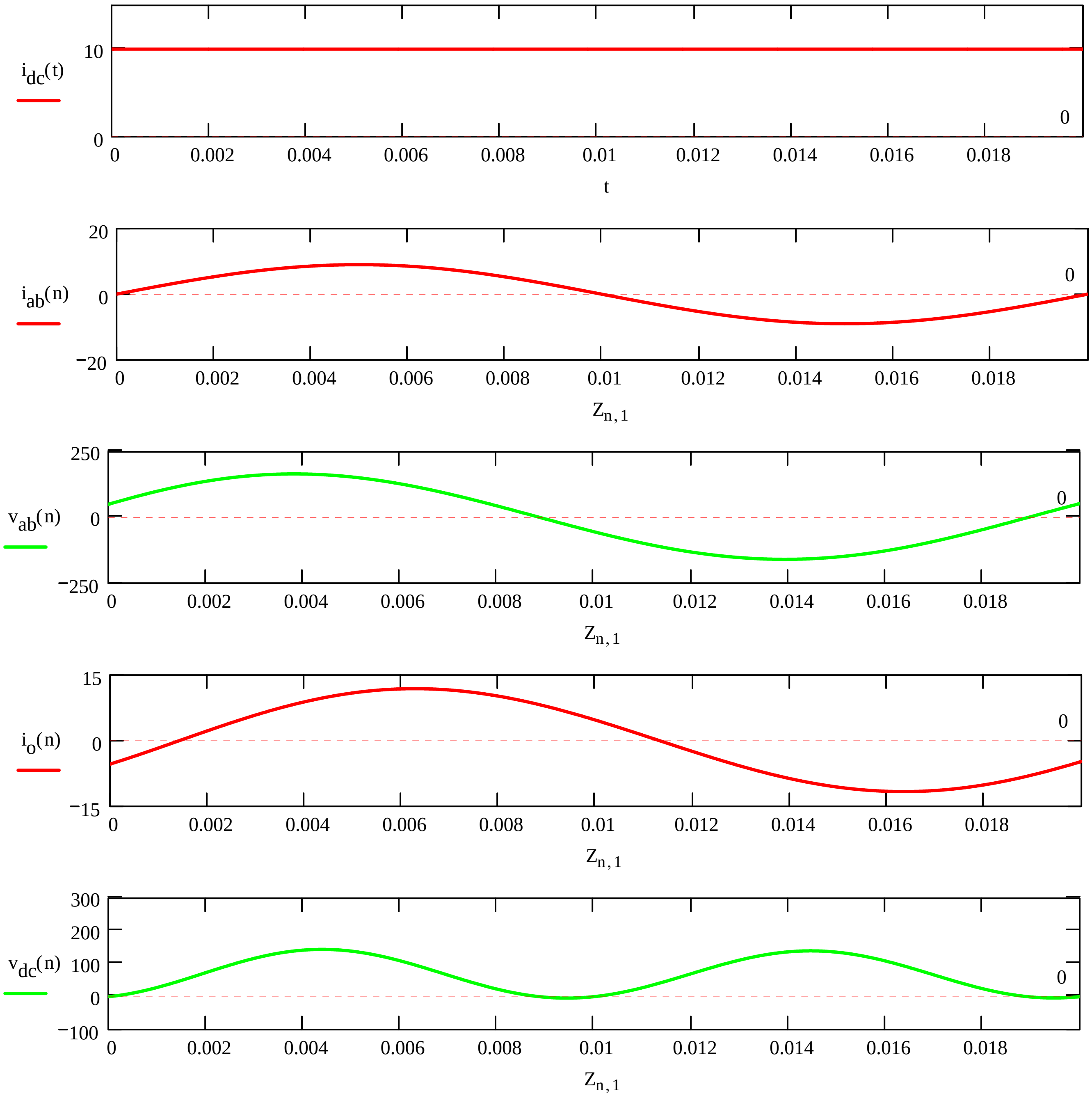
$L_o := 30\cdot 10^{-3}$ $R_o := 10$ $C_{ac} := 100\cdot 10^{-6}$ $i_{dc}(t) := 10$

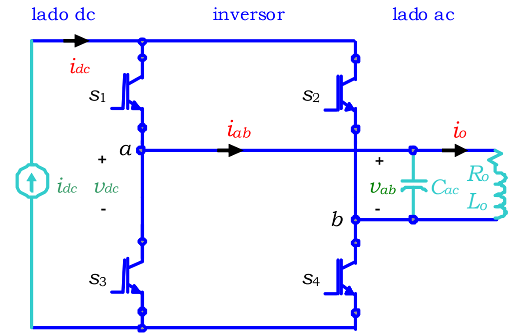
Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

$$D(t,x) := \begin{pmatrix} \frac{-R_o}{L_o}\cdot x_1 + \frac{1}{L_o}\cdot x_2 \\ \frac{-1}{C_{ac}}\cdot x_1 + \frac{1}{C_{ac}}\cdot m_a(t)\cdot i_{dc}(t) \end{pmatrix}$$

$CI := \begin{pmatrix} -5 \\ 315 \end{pmatrix}$ $Z := \text{rkfixed}(CI, 0, t_f, n_f, D)$ $CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \end{pmatrix}$ $Z := \text{rkfixed}(CI, 0, t_f, n_f, D)$

$i_o(n) := Z_{n,2}$ $v_{ab}(n) := Z_{n,3}$ $v_{dc}(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot v_{ab}(n)$ $i_{ab}(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot i_{dc}\left(n\cdot\frac{t_f}{n_f}\right)$

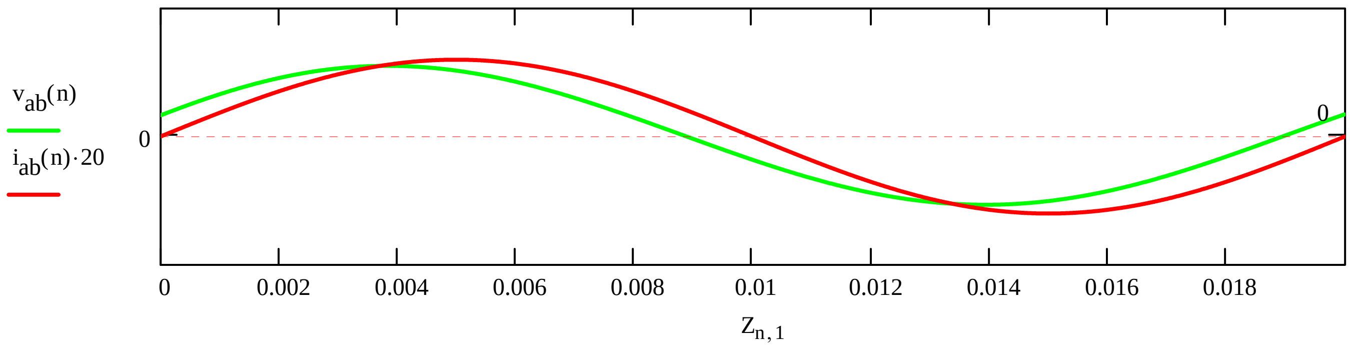




El tamaño del condensador define el ripple u oscilación resultante.

Se requiere un condensador en el lado ac por la naturaleza de la corriente i_{ab}.

La tensión en el enlace puede ser negativa lo que exige reverse blocking voltage capabilities a los switches.

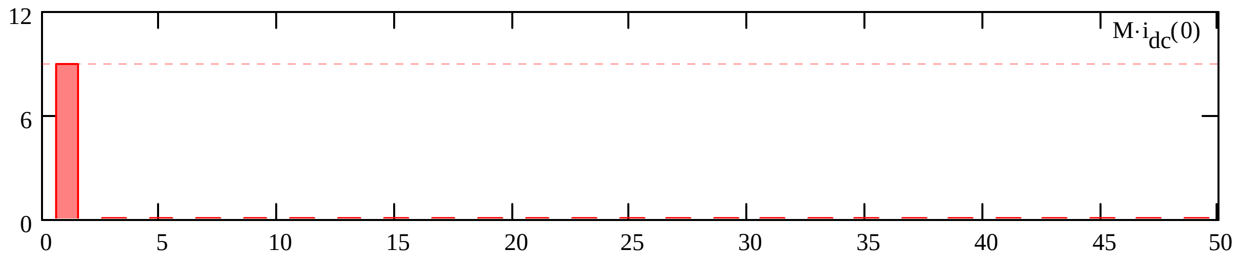


$N := 1024$ $\quad m := 1..N$

$x_m := i_{ab}\left(m\cdot\frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

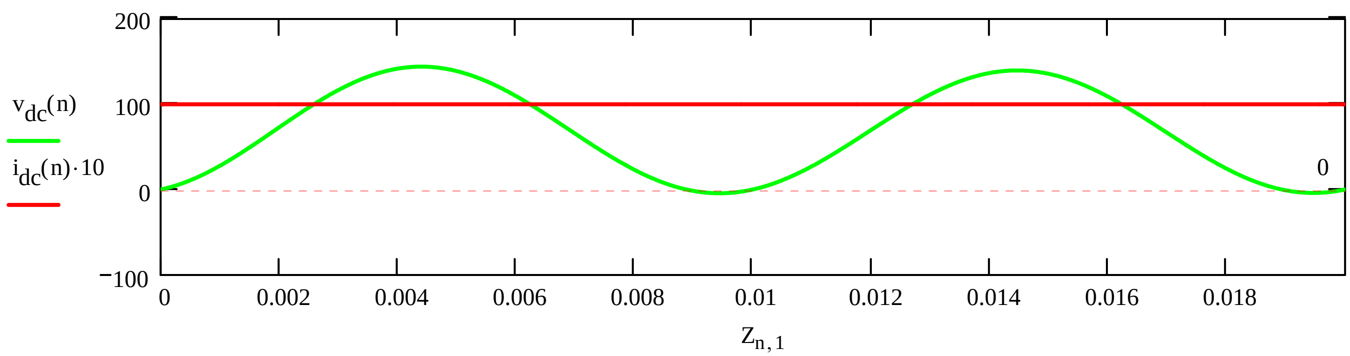
$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

FFT de i_{ab}



$M\cdot i_{dc}(0) = 9$

Se pierde la información de las armónicas de la conmutación. El modelo es válido hasta la frecuencia de la triangular.



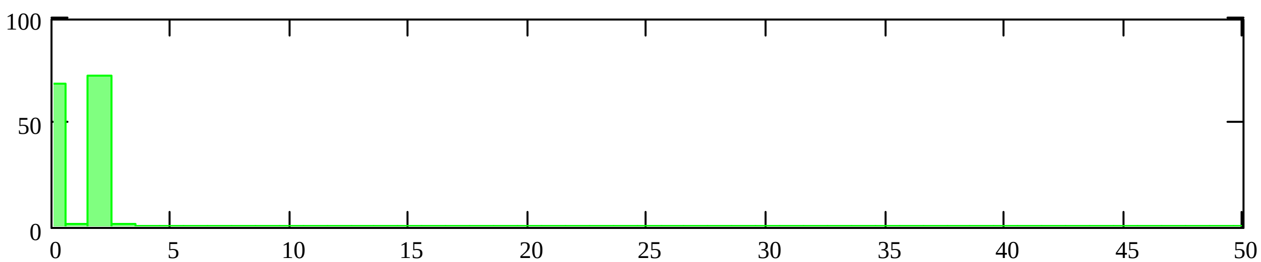
$N := 1024$ $\quad m := 1..N$

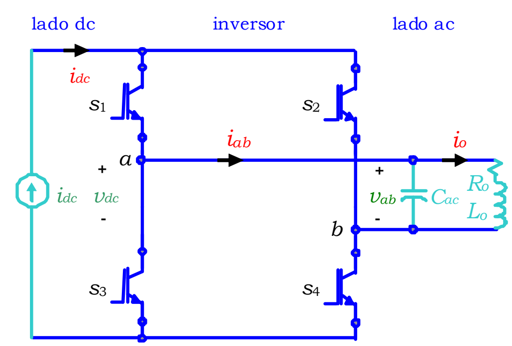
$x_m := v_{dc}\left(m\cdot\frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2)\cdot xf_{m\cdot per}$

$|xv(1)| = 68.73$ $\quad |xv(3)| = 73.029$

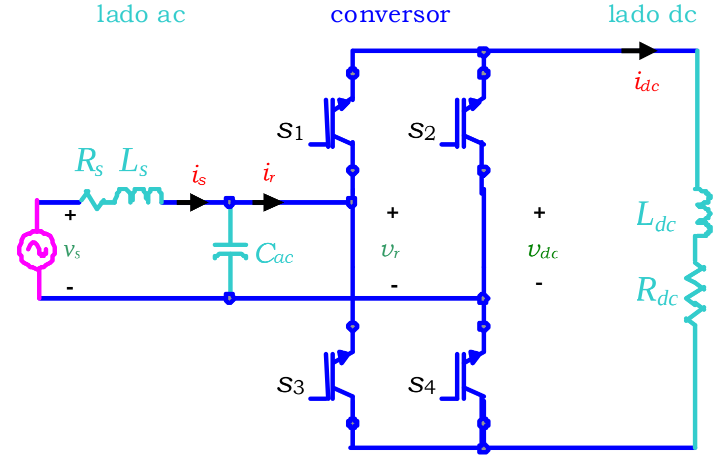
FFT de v_{dc}





Modelo de Rectificador de Corriente Monofásico

Problema Estudiar el modelo del rectificador de corriente con Modulación SPWM.



$$v_s(t) = R_s \cdot i_s(t) + L_s \cdot di_s(t) + v_r(t)$$

$$i_s(t) = C_{ac} \cdot dv_r(t) + s_{ab}(t) \cdot i_{dc}(t)$$

$$s_{ab}(t) \cdot v_r(t) = L_{dc} \cdot di_{dc}(t) + R_{dc}(t) \cdot i_{dc}(t)$$

$$i_r(t) = s_{ab}(t) \cdot i_{dc}(t)$$

$$v_{dc}(t) = s_{ab}(t) \cdot v_r(t)$$

$$di_s(t) = \frac{-R_s}{L_s} \cdot i_s(t) - \frac{1}{L_s} \cdot v_r(t) + \frac{1}{L_s} \cdot v_s(t)$$

$$dv_r(t) = \frac{1}{C_{ac}} \cdot i_s(t) - \frac{1}{C_{ac}} \cdot s_{ab}(t) \cdot i_{dc}(t)$$

$$di_{dc}(t) = \frac{-R_{dc}}{L_{dc}} \cdot i_{dc}(t) + \frac{1}{L_{dc}} \cdot s_{ab}(t) \cdot v_r(t)$$

Parámetros

$L_{dc} := 250 \cdot 10^{-3}$ $\quad R_{dc} := 10$

$C_{ac} := 25 \cdot 10^{-6}$ $\quad L_s := 5 \cdot 10^{-3}$

$R_s := 1$

La tensión de red, $v_s(t) := \sqrt{2} \cdot 220 \cdot \sin(\omega_s \cdot t)$

La moduladora es, $M := 0.9$ $\quad f_M := -10 \cdot \frac{\pi}{180}$ $\quad m_a(t) := M \cdot \sin(\omega_s \cdot t + f_M)$

Triangular, $tri(t) := \frac{2}{\pi} \cdot \operatorname{asin}\left(\sin\left(f_{n\_tr} \cdot \omega_s \cdot t + f_M \cdot f_{n\_tr} - \frac{\pi}{2}\right)\right)$

Auxiliar 1 $\quad s_a(t) := \text{if}(m_a(t) > tri(t), 1, 0)$ $\quad s_c(t) := \text{if}(s_a(t) = 1, 0, 1)$

Auxiliar 2 $\quad s_b(t) := \text{if}(m_a(t) > -tri(t), 0, 1)$ $\quad s_d(t) := \text{if}(s_b(t) = 1, 0, 1)$

Primera pierna $\quad s_1(t) := s_a(t) \cdot s_d(t)$ $\quad s_3(t) := s_b(t) \cdot s_c(t)$

Segunda pierna $\quad s_4(t) := s_1(t)$ $\quad s_2(t) := s_3(t)$

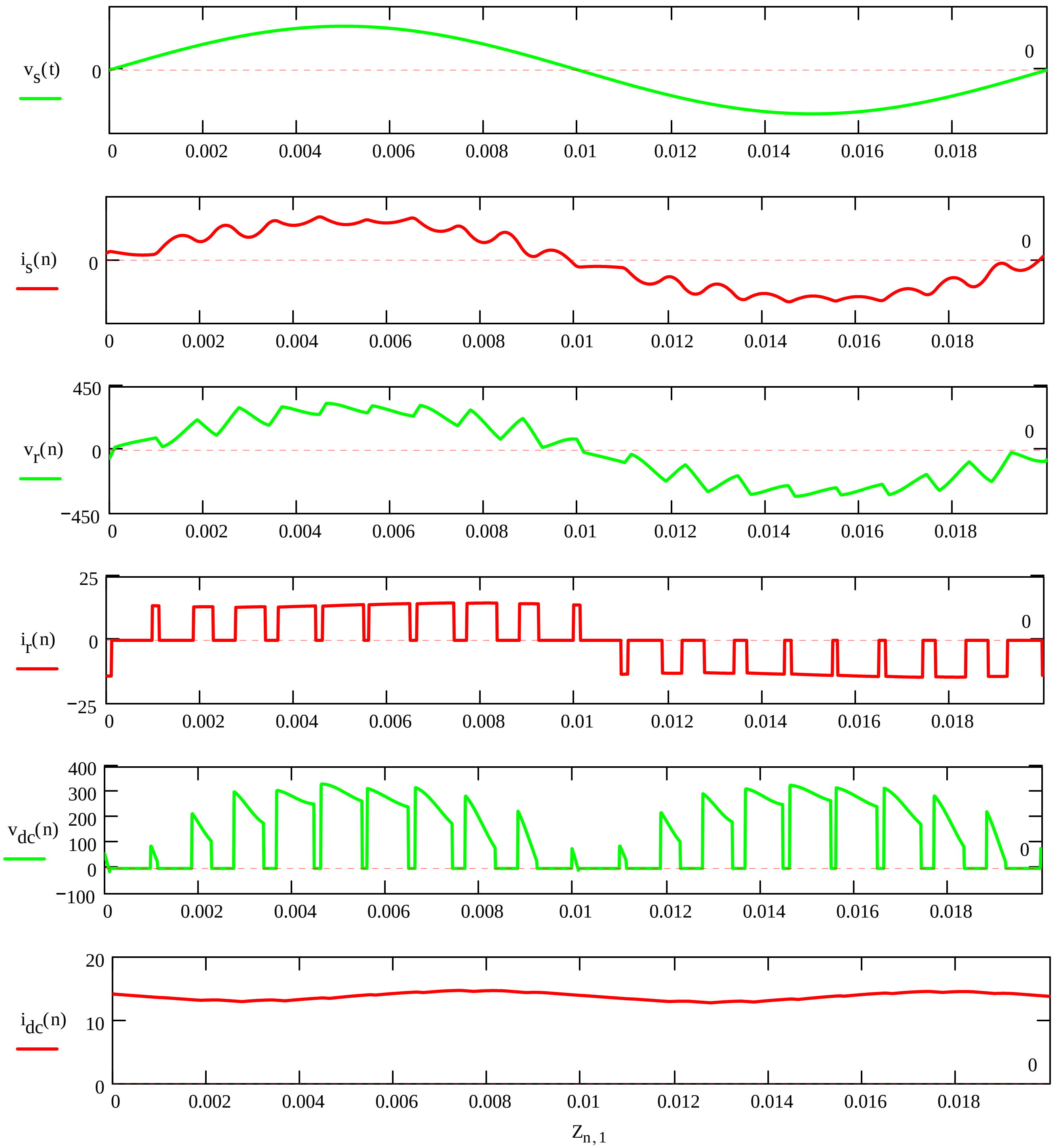
Simulación $\quad t_f := 0.02$ $\quad n_f := 2048$ $\quad n := 1 .. n_f$ $\quad t := 0, \frac{t_f}{n_f} .. t_f$

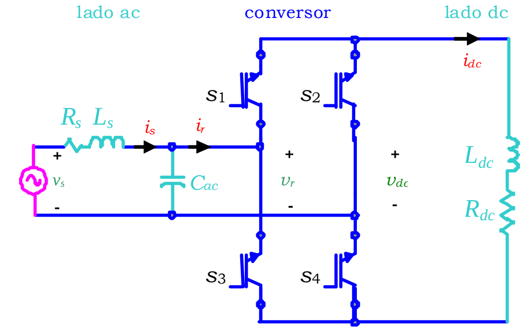
La función de switcheo es, $s_{ab}(t) := s_1(t) - s_2(t)$

$$D(t,x) := \begin{pmatrix} \frac{-R_s}{L_s} \cdot x_1 - \frac{1}{L_s} \cdot x_2 + \frac{1}{L_s} \cdot v_s(t) \\ \frac{1}{C_{ac}} \cdot x_1 - \frac{1}{C_{ac}} \cdot s_{ab}(t) \cdot x_3 \\ \frac{-R_{dc}}{L_{dc}} \cdot x_3 + \frac{1}{L_{dc}} \cdot s_{ab}(t) \cdot x_2 \end{pmatrix}$$

$$CI := \begin{pmatrix} 10 \\ 0 \\ 15 \end{pmatrix} \quad Z := rkfixed(CI, 0, t_f, n_f, D) \quad CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \\ Z_{n_f,4} \end{pmatrix} \quad Z := rkfixed(CI, 0, t_f, n_f, D)$$

$$i_s(n) := Z_{n,2} \quad v_r(n) := Z_{n,3} \quad i_{dc}(n) := Z_{n,4} \quad v_{dc}(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot v_r(n) \quad i_r(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot i_{dc}(n)$$



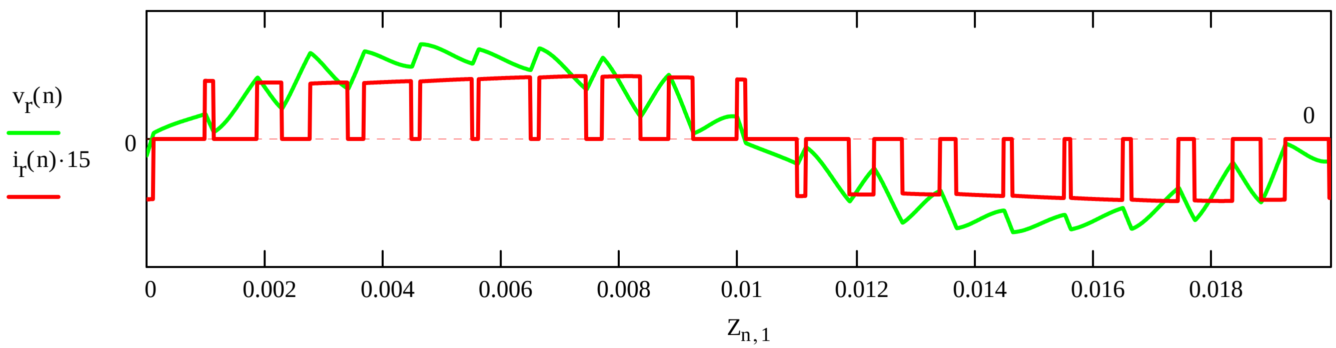


El tamaño del inductor L_s y condensador C_s define el ripple u oscilación resultante en la corriente i_s y voltaje v_r.

Se requiere un condensador en el lado ac por la naturaleza de la corriente i_r.

La tensión en el enlace puede ser negativa lo que exige reverse blocking voltage capabilities a los switches.

La corriente i_{dc} dista de ser constante, pero el tamaño de L_{dc} definde cuán oscilatoria es. En este caso se requiere de un gran L_{dc} por la segunda armónica de voltaje en v_{dc}.

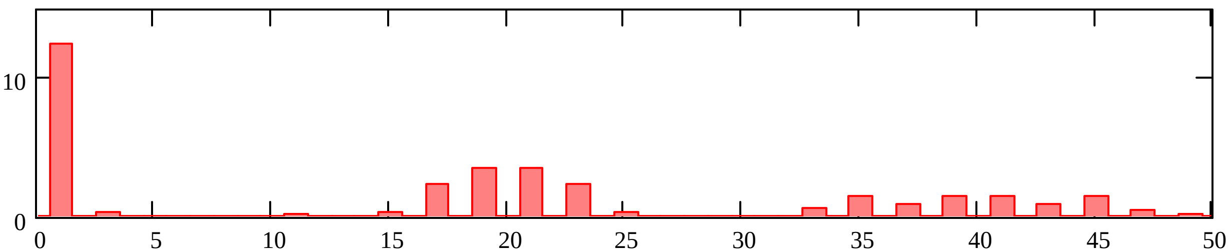


$N := 1024$ $\quad m := 1 .. N$

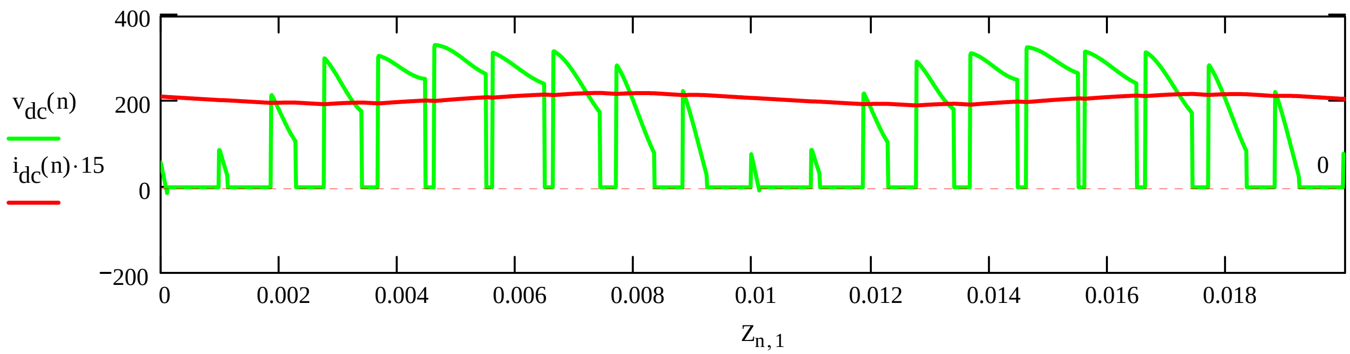
$x_m := i_r\left(m \cdot \frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := \text{if}\,(m = 1, 1, 2) \cdot xf_{m \cdot per}$

FFT de i_r



Aparecen armónicos no deseados de baja frecuencia que: (1) aumentan la distorsión, (2) exigen a los filtros en rms, (3) reducen el potencial ancho de banda de los controladores.



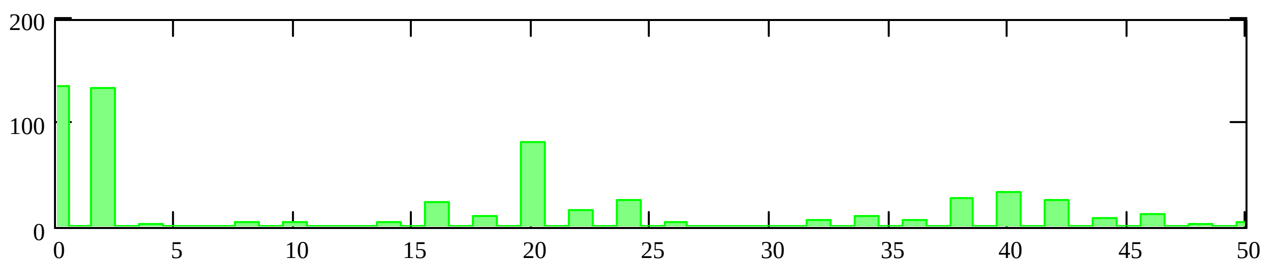
$N := 1024$ $\quad m := 1 .. N$

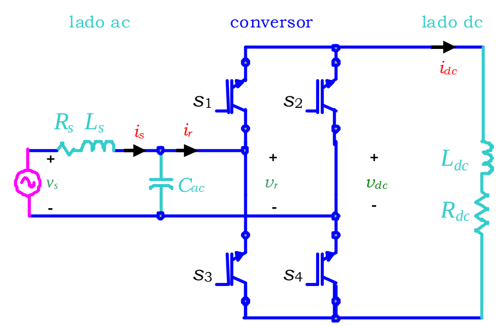
$x_m := v_{dc}\left(m \cdot \frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := \text{if}\,(m = 1, 1, 2) \cdot xf_{m \cdot per}$

$|xv(1)| = 135.245$ $\quad |xv(3)| = 132.929$

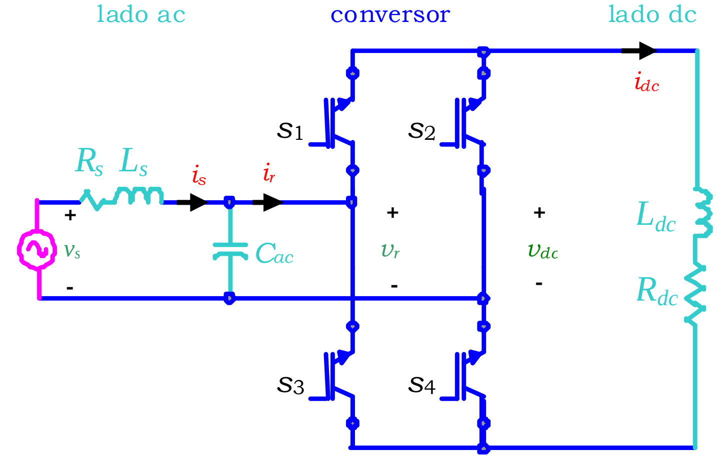
FFT de v_{dc}





Modelo Promedio de Rectificador de Corriente Monofásico

Problema Estudiar el modelo promedio del rectificador de corriente.



$$di_s(t) = \frac{-R_s}{L_s}\cdot i_s(t) - \frac{1}{L_s}\cdot v_r(t) + \frac{1}{L_s}\cdot v_s(t)$$

$$dv_r(t) = \frac{1}{C_{ac}}\cdot i_s(t) - \frac{1}{C_{ac}}\cdot s_{ab}(t)\cdot i_{dc}(t)$$

$$di_{dc}(t) = \frac{-R_{dc}}{L_{dc}}\cdot i_{dc}(t) + \frac{1}{L_{dc}}\cdot s_{ab}(t)\cdot v_r(t)$$

$$i_r(t) = m_a(t)\cdot i_{dc}(t)$$

$$v_{dc}(t) = m_a(t)\cdot v_r(t)$$

Parámetros

$L_{dc} := 250\cdot 10^{-3}$ $R_{dc} := 10$

$C_{ac} := 25\cdot 10^{-6}$ $L_s := 5\cdot 10^{-3}$

$R_s := 1$

$$di_s(t) = \frac{-R_s}{L_s}\cdot i_s(t) - \frac{1}{L_s}\cdot v_r(t) + \frac{1}{L_s}\cdot v_s(t)$$

$$dv_r(t) = \frac{1}{C_{ac}}\cdot i_s(t) - \frac{1}{C_{ac}}\cdot m_b(t)\cdot i_{dc}(t)$$

$$di_{dc}(t) = \frac{-R_{dc}}{L_{dc}}\cdot i_{dc}(t) + \frac{1}{L_{dc}}\cdot m_a(t)\cdot v_r(t)$$

Se utiliza la moduladora $m_a(t)$.

La tensión de red, $v_s(t) := \sqrt{2}\cdot 220\cdot \sin(\omega_s\cdot t)$

La moduladora es,

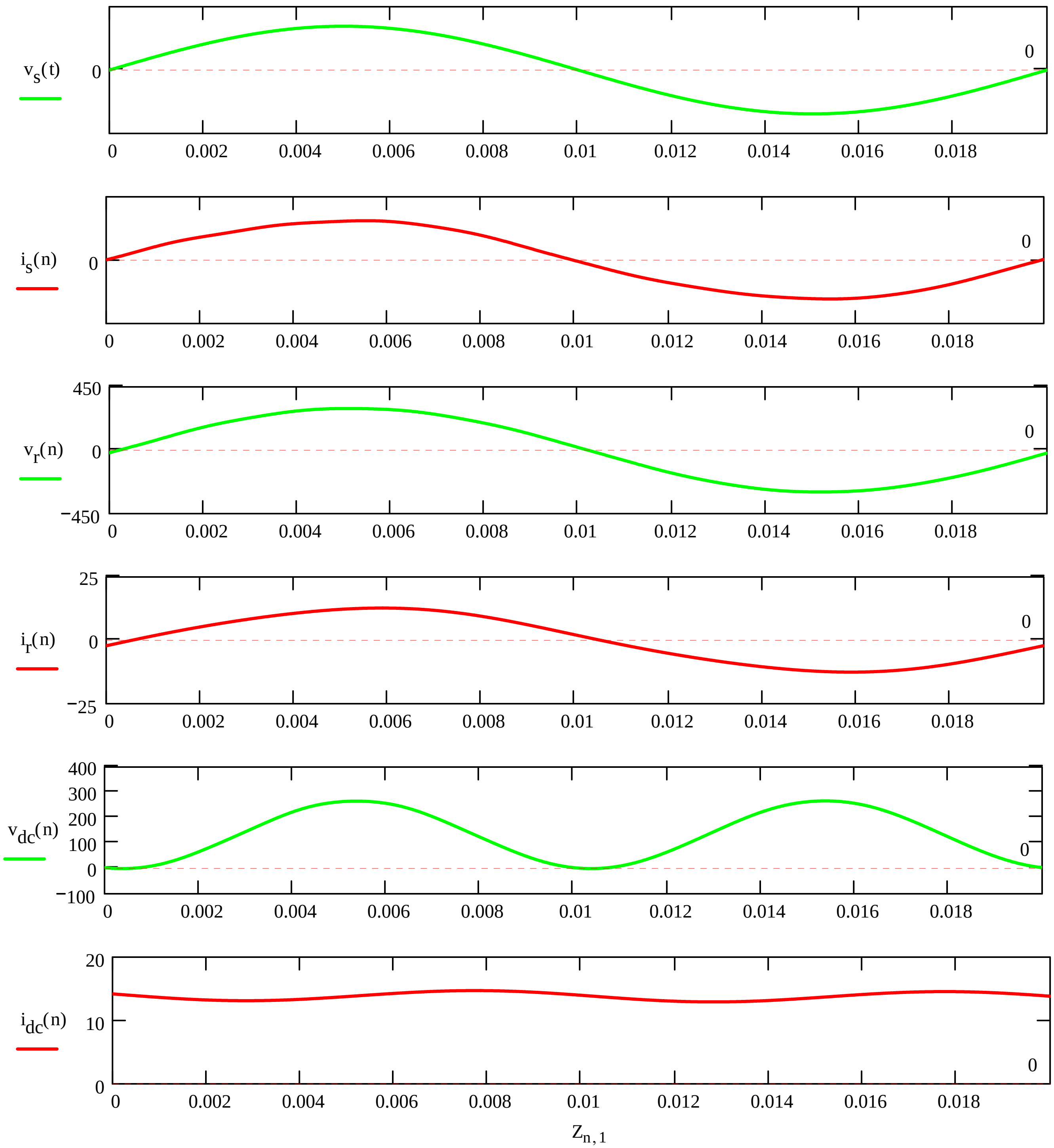
$M := 0.9$ $f_M := -10\cdot\frac{\pi}{180}$ $m_a(t) := M\cdot\sin(\omega_s\cdot t + f_M)$

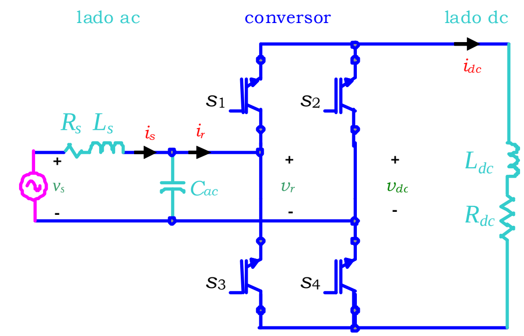
Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

$$D(t,x) := \begin{pmatrix} \frac{-R_s}{L_s}\cdot x_1 - \frac{1}{L_s}\cdot x_2 + \frac{1}{L_s}\cdot v_s(t) \\ \frac{1}{C_{ac}}\cdot x_1 - \frac{1}{C_{ac}}\cdot m_a(t)\cdot x_3 \\ \frac{-R_{dc}}{L_{dc}}\cdot x_3 + \frac{1}{L_{dc}}\cdot m_a(t)\cdot x_2 \end{pmatrix}$$

$CI := \begin{pmatrix} 0 \\ 0 \\ 15 \end{pmatrix}$ $Z := \text{rkfixed}(CI, 0, t_f, n_f, D)$ $CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \\ Z_{n_f,4} \end{pmatrix}$ $Z := \text{rkfixed}(CI, 0, t_f, n_f, D)$

$i_s(n) := Z_{n,2}$ $v_r(n) := Z_{n,3}$ $i_{dc}(n) := Z_{n,4}$ $v_{dc}(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot v_r(n)$ $i_r(n) := m_a\left(n\cdot\frac{t_f}{n_f}\right)\cdot i_{dc}(n)$

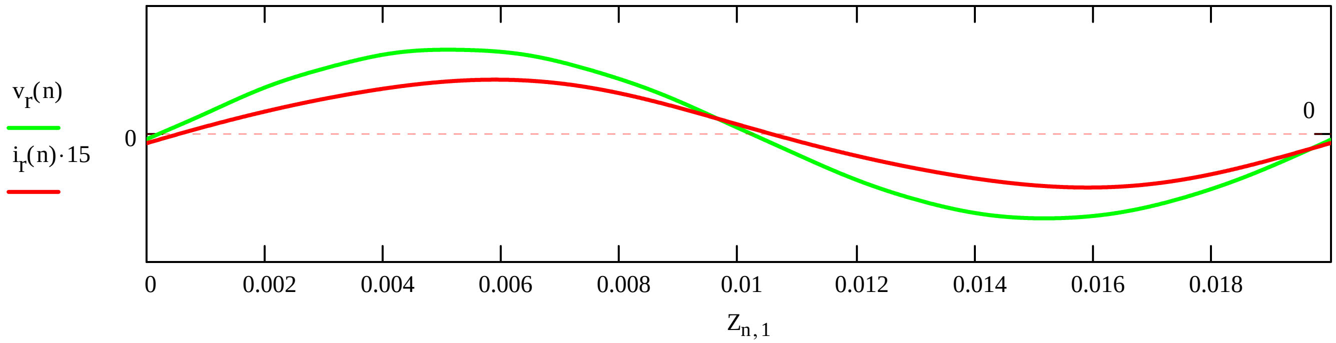




No hay ripple en la corriente i_s y voltaje v_r pues i_r es cuasi-sinusoidal.

No se puede hacer diseño de L_s y C_{ac} con este modelo.

La corriente i_{dc} dista de ser constante, pero el tamaño de L_{dc} definde cuán oscilatoria es. En este caso se requiere de un gran L_{dc} por la segunda armónica de voltaje en v_{dc}.

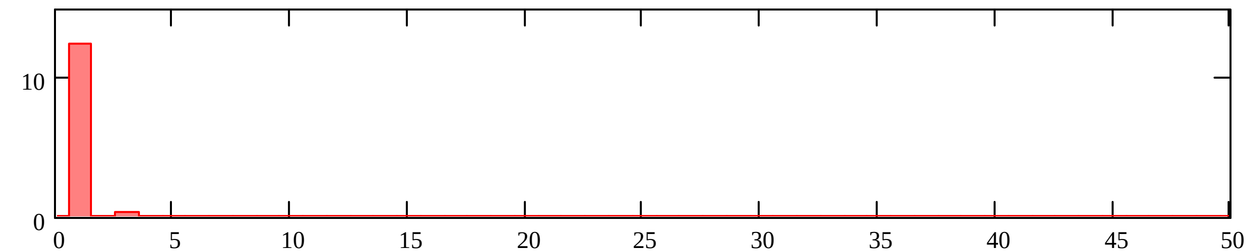


$N := 1024$ $\quad m := 1..N$

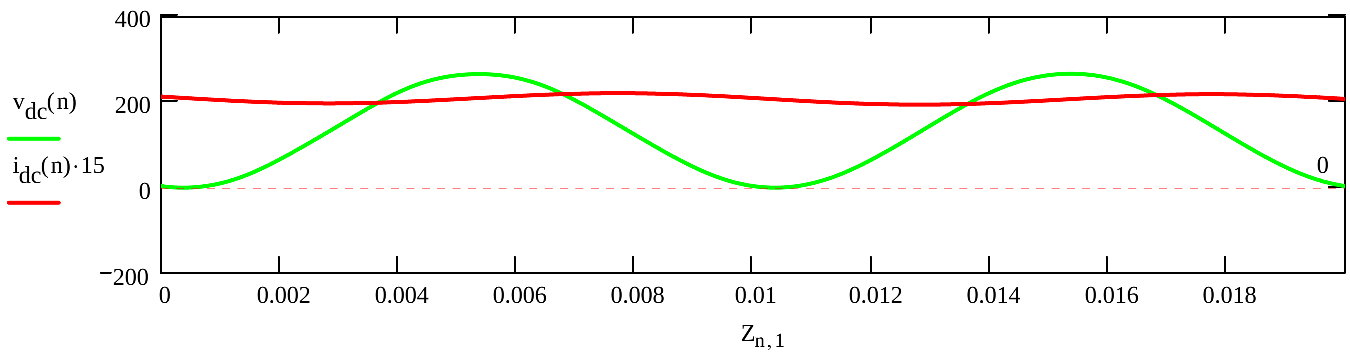
$x_m := i_r\left(m\cdot\frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := if(m = 1,1,2)\cdot xf_{m\cdot per}$

FFT de i_r



Aparecen armónicos no deseados de baja frecuencia que: (1) aumentan la distorsión, (2) exigen a los filtros en rms, (3) reducen el potencial ancho de banda de los controladores.



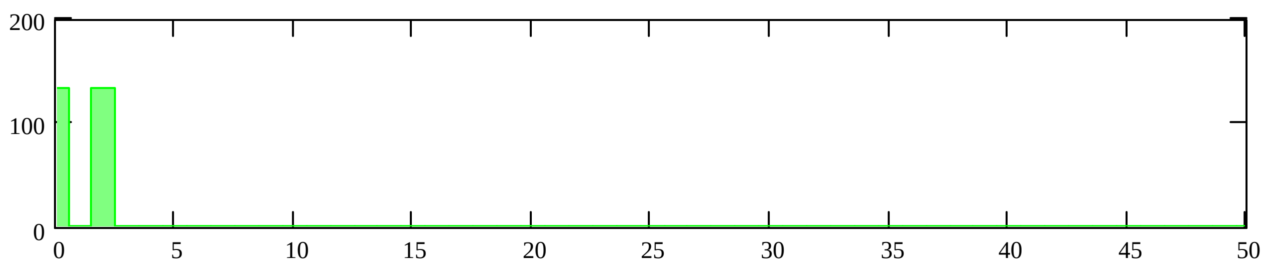
$N := 1024$ $\quad m := 1..N$

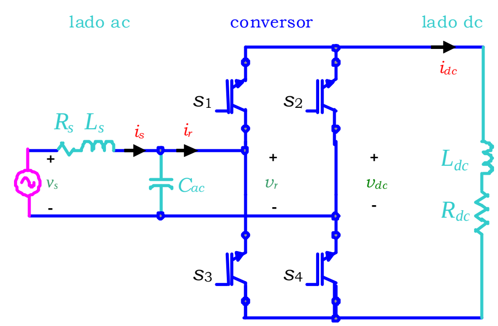
$x_m := v_{dc}\left(m\cdot\frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := if(m = 1,1,2)\cdot xf_{m\cdot per}$

$|xv(1)| = 133.818$ $\quad |xv(3)| = 133.698$

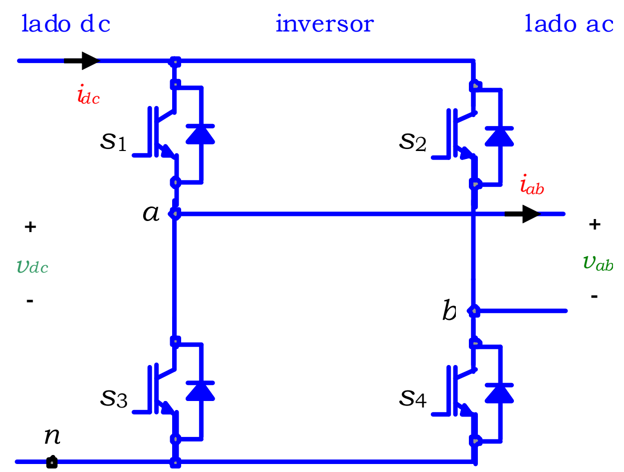
FFT de v_{dc}





Selective Harmonic Elimination en un Inversor de Voltaje Monofásico

Problema Estudiar la técnica SHE en un inversor de voltaje.



La señal de voltaje v_{an} se espera que tenga armónicas $v_{an,h}$ dadas por,

$$\frac{1}{2\cdot\pi}\cdot\left[1+2\cdot\sum_{k=1}^{N}(-1)^k\cdot\cos(n\cdot\alpha_k)\right]=M_n$$

para,

$$n = 1,3,5..2\cdot N-1$$

con N-1 par e igual al número armónicos a eliminar, α_k los ángulos a encontrar y M_n es la amplitud de la armónica n.

$N-1=2$ $\quad N:=3$ $\quad n=1,3,5$ $\quad M_1:=\frac{M}{2}$ $\quad M_3:=0$ $\quad M_5:=0$

$\alpha_1:=25\cdot\frac{\pi}{180}$ $\quad \alpha_2:=30\cdot\frac{\pi}{180}$ $\quad \alpha_3:=80\cdot\frac{\pi}{180}$

Given

$$\frac{2}{\pi}\cdot(1-2\cdot\cos(1\cdot\alpha_1)+2\cdot\cos(1\cdot\alpha_2)-2\cdot\cos(1\cdot\alpha_3))=M_1$$

$$\frac{2}{\pi}\cdot(1-2\cdot\cos(3\cdot\alpha_1)+2\cdot\cos(3\cdot\alpha_2)-2\cdot\cos(3\cdot\alpha_3))=M_3$$

$$\frac{2}{\pi}\cdot(1-2\cdot\cos(5\cdot\alpha_1)+2\cdot\cos(5\cdot\alpha_2)-2\cdot\cos(5\cdot\alpha_3))=M_5$$

$\alpha_1>0$ $\quad \alpha_2>\alpha_1$ $\quad \alpha_3>\alpha_2$ $\quad \alpha_3<\frac{\pi}{2}$

$Sol:=\text{Find}(\alpha_1,\alpha_2,\alpha_3)$ $\qquad Sol^T\cdot\frac{180}{\pi}=(26.286\ \ 38.174\ \ 87.93)$

$n_f:=f_{n\_tr}\cdot 4\cdot 50\cdot per$ $\quad n:=0..n_f$ $\quad t_f:=.02\cdot per$ $\quad t:=0,\frac{t_f}{n_f}..t_f$ $\quad HI:=0$ $\quad LO:=\text{if}(HI>0,0,1)$ $\quad \omega:=0,\frac{2\cdot\pi}{360}\cdot per..2\cdot\pi\cdot per$

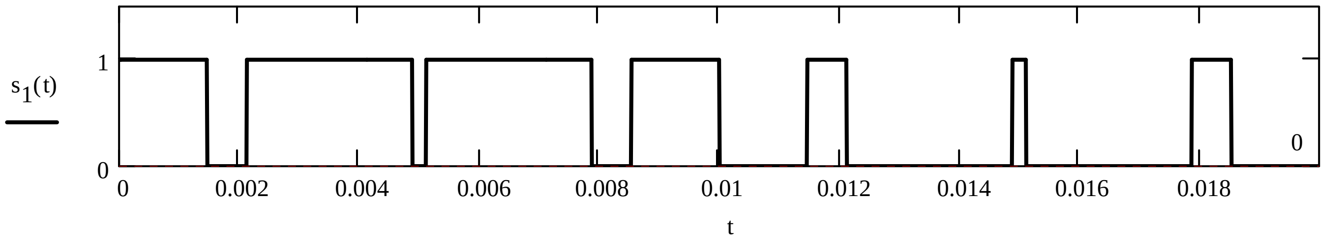
$g_a(\omega):=\text{if}(\omega>Sol_1,HI,LO)$ $\quad g_b(\omega):=\text{if}(\omega>Sol_2,LO,g_a(\omega))$ $\quad g_c(\omega):=\text{if}(\omega>Sol_3,HI,g_b(\omega))$

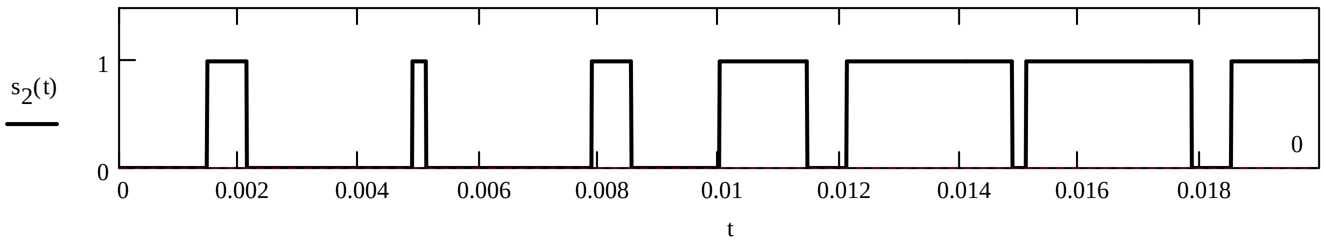
$g_x(\omega):=\text{if}\left(\omega>\frac{\pi}{2},g_c(\pi-\omega),g_c(\omega)\right)$ $\quad g_y(\omega):=\text{if}(\omega>\pi,1-g_x(2\cdot\pi-\omega),g_x(\omega))$

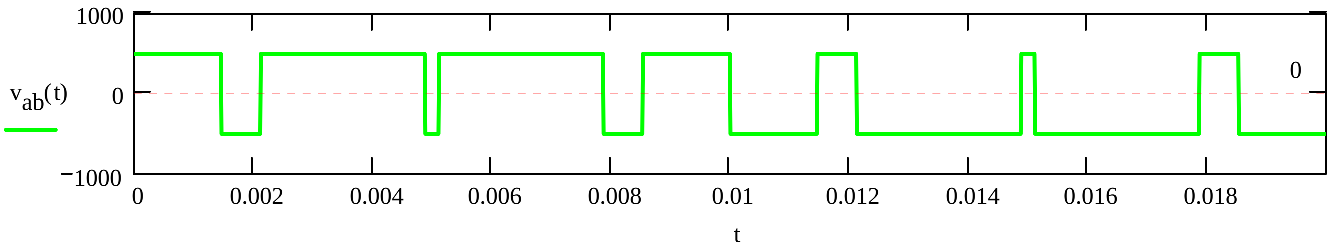
$s_1(t):=g_y\left(t\cdot\frac{2\cdot\pi}{t_f}\right)$ $\quad s_3(t):=\text{if}(s_1(t)=HI,LO,HI)$

$s_2(t):=s_3(t)$ $\quad s_4(t):=s_1(t)$

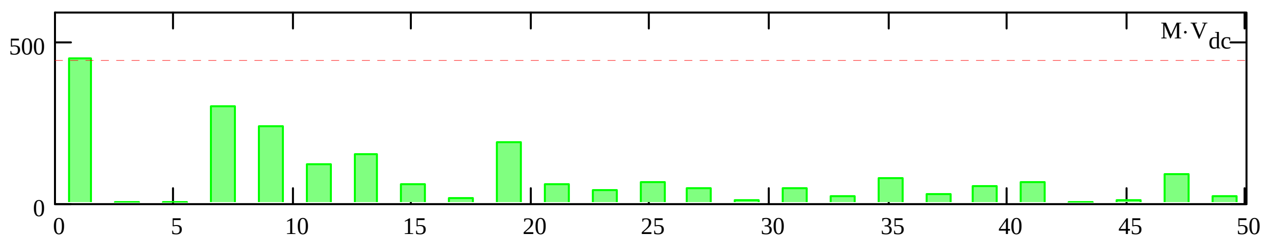
$s_{ab}(t):=s_1(t)-s_2(t)$

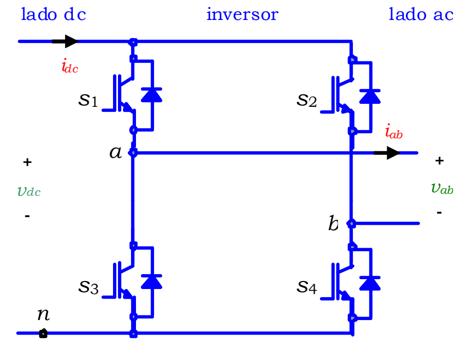






FFT de v_{ab}





$s_{ab}(t) := s_1(t) - s_2(t)$

$V_{dc} := 500$

$v_{dc}(t) := V_{dc}$

$v_{ab}(t) := s_{ab}(t) \cdot v_{dc}(t)$

$N := 1024$

$m := 1 .. N$

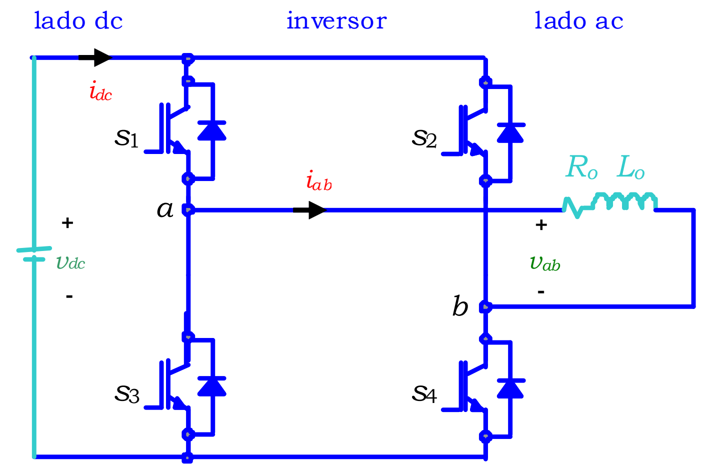
$x_m := v_{ab}\left(\frac{m}{N} \cdot t_f\right)$

$xf := FFT(x)$

$xv(m) := if(m = 1, 1, 2) \cdot xf_{m \cdot per}$

La fundamental del voltaje ac es igual a MV_{dc} y no hay componentes de frecuencia como diseñado.

Problema Estudiar la SHE en un inversor de voltaje.



$$v_{ab}(t) = R_o \cdot i_{ab}(t) + L_o \cdot di_{ab}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = v_{ab}(t) \cdot i_{ab}(t)$$

$$v_{ab}(t) = s_{ab}(t) \cdot v_{dc}(t)$$

$$s_{ab}(t) \cdot v_{dc}(t) = R_o \cdot i_{ab}(t) + L_o \cdot di_{ab}(t)$$

$$v_{dc}(t) \cdot i_{dc}(t) = s_{ab}(t) \cdot v_{dc}(t) \cdot i_{ab}(t)$$

$$i_{dc}(t) = s_{ab}(t) \cdot i_{ab}(t)$$

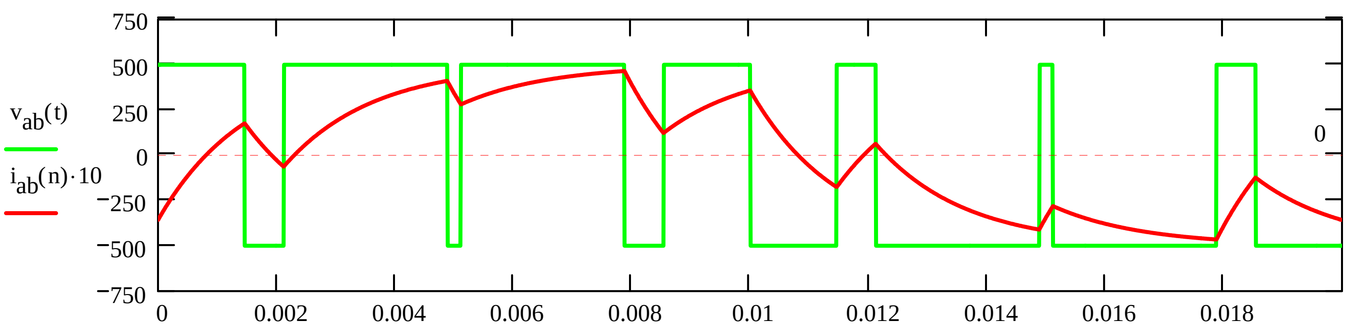
$$di_{ac}(t) = \frac{-R_o}{L_o} \cdot i_{ac}(t) + \frac{1}{L_o} \cdot s_{ab}(t) \cdot v_{dc}(t)$$

$$i_{dc}(t) = s_{ab}(t) \cdot i_{ab}(t)$$

Parámetros $L_o := 15 \cdot 10^{-3}$ $R_o := 10$

Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

$$D(t,x) := \frac{-R_o}{L_o} \cdot x_1 + \frac{1}{L_o} \cdot s_{ab}(t) \cdot v_{dc}(t) \qquad CI := 0 \qquad Z := \text{rkfixed}(CI, 0, t_f, n_f, D) \qquad CI := Z_{n_f, 2} \qquad Z := \text{rkfixed}(CI, 0, t_f, n_f, D) \qquad i_{ab}(n) := Z_{n,2}$$



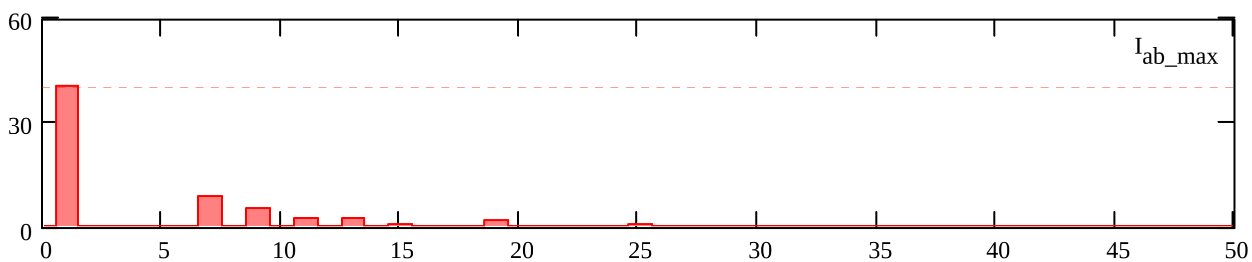
$N := 1024$ $m := 1 .. N$

$$x_m := Z_{m \cdot \frac{n_f}{N}, 2} \qquad xf := \text{FFT}(x)$$

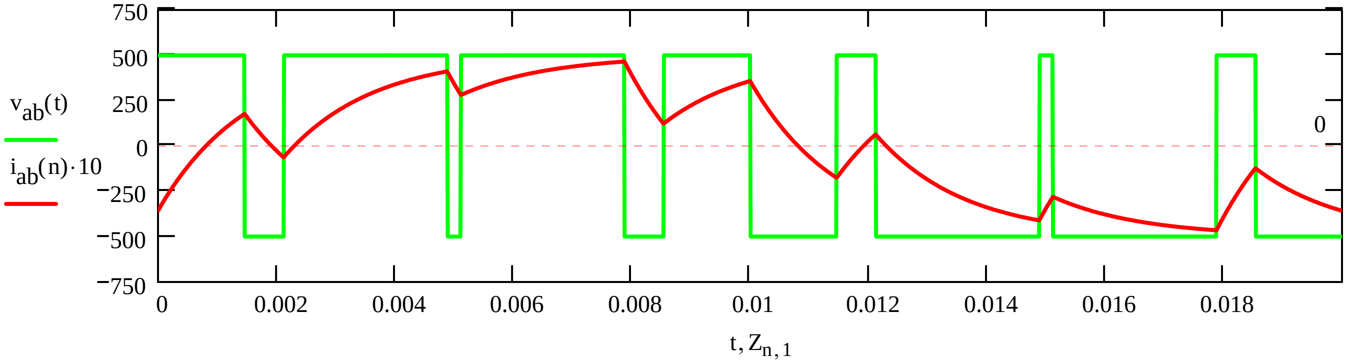
$$xv(m) := \text{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$$

$$I_{ab\_max} := \frac{M \cdot V_{dc}}{\sqrt{R_o^2 + (\omega_s \cdot L_o)^2}}$$

FFT de i_{ab}



La carga natural es inductiva por la naturaleza del voltaje aplicado.

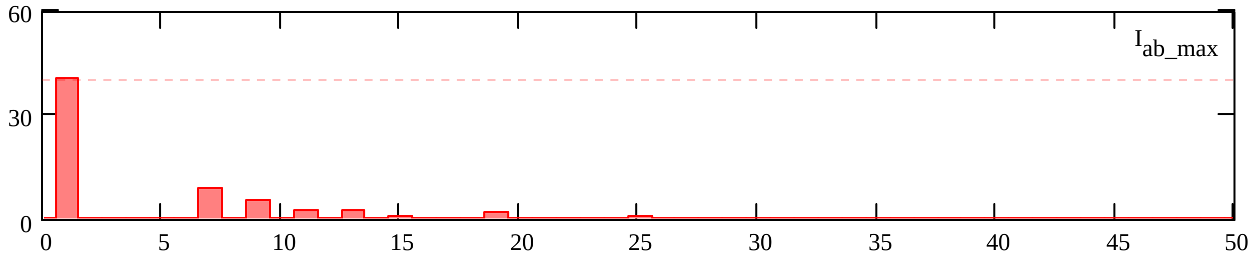


La corriente i_{dc} es,

$$\boxed{i_{dc}(t) = s_{ab}(t)\cdot i_{ab}(t)}$$

$$i_{dc}(n) := s_{ab}\left(n\cdot\frac{t_f}{n_f}\right)\cdot Z_{n,2}$$

FFT de i_{ab}



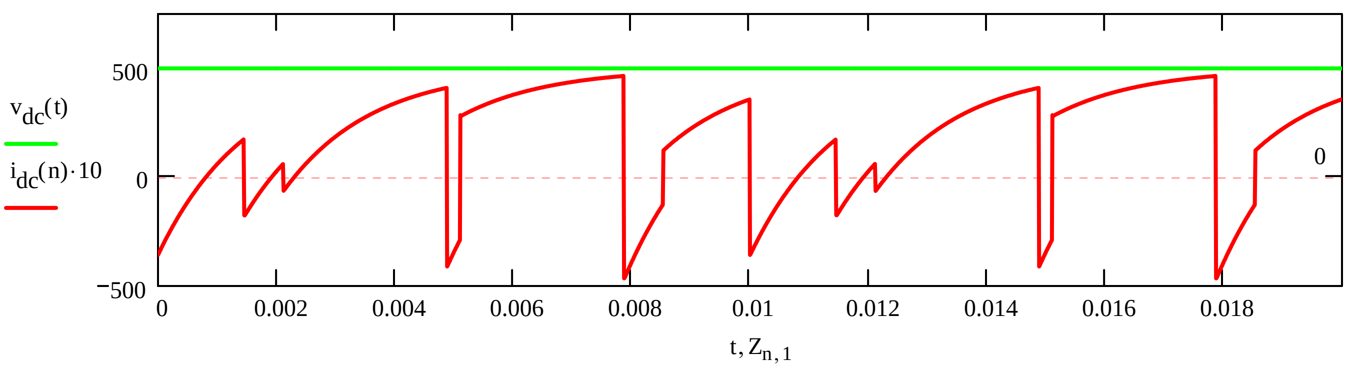
$N := 1024$ $\qquad$ $m := 1 .. N$

$x_m := i_{dc}\left(m\cdot\frac{n_f}{N}\right)$ $\qquad$ $xf := FFT(x)$

$xv(m) := \text{if}(m = 1, 1, 2)\cdot xf_{m\cdot per}$

El valor medio de la corriente i_{dc} es,

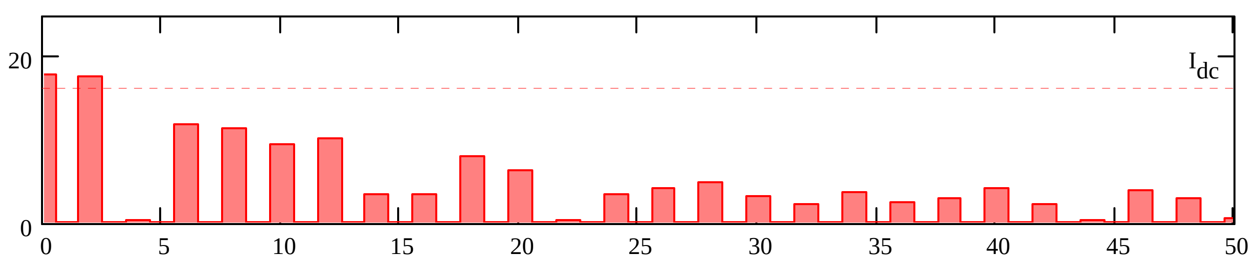
$$P := R_o\cdot\left(\frac{I_{ab\_max}}{\sqrt{2}}\right)^2 \qquad I_{dc} := \frac{P}{V_{dc}}$$

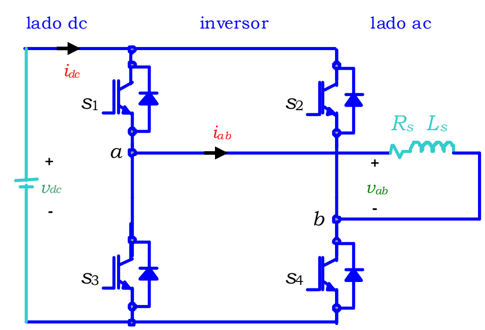


Notar que este último espectro se puede obtner mediante convolución,

$$i_{dc}(\omega) = s_{ab}(\omega) \oplus i_{ab}(\omega)$$

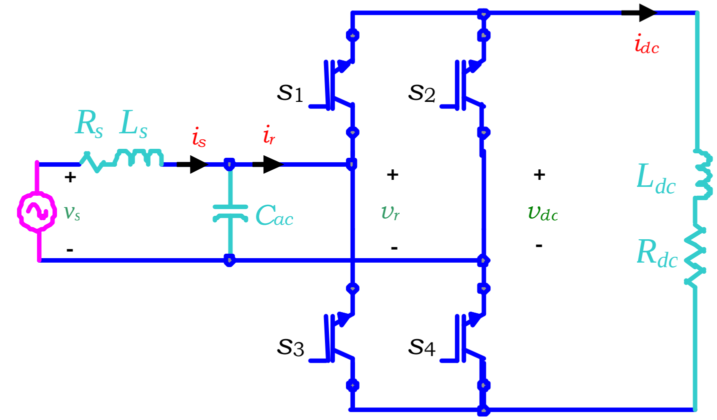
FFT de i_{dc}





SHE en un Rectificador de Corriente Monofásico

Problema Estudiar la SHE en un rectificador de corriente.



$$v_s(t) = R_s \cdot i_s(t) + L_s \cdot di_s(t) + v_r(t)$$

$$i_s(t) = C_{ac} \cdot dv_r(t) + s_{ab}(t) \cdot i_{dc}(t)$$

$$s_{ab}(t) \cdot v_r(t) = L_{dc} \cdot di_{dc}(t) + R_{dc}(t) \cdot i_{dc}(t)$$

$$i_r(t) = s_{ab}(t) \cdot i_{dc}(t)$$

$$v_{dc}(t) = s_{ab}(t) \cdot v_r(t)$$

$$di_s(t) = \frac{-R_s}{L_s} \cdot i_s(t) - \frac{1}{L_s} \cdot v_r(t) + \frac{1}{L_s} \cdot v_s(t)$$

$$dv_r(t) = \frac{1}{C_{ac}} \cdot i_s(t) - \frac{1}{C_{ac}} \cdot s_{ab}(t) \cdot i_{dc}(t)$$

$$di_{dc}(t) = \frac{-R_{dc}}{L_{dc}} \cdot i_{dc}(t) + \frac{1}{L_{dc}} \cdot s_{ab}(t) \cdot v_r(t)$$

Parámetros

$L_{dc} := 250 \cdot 10^{-3}$ $R_{dc} := 10$

$C_{ac} := 100 \cdot 10^{-6}$ $L_s := 5 \cdot 10^{-3}$

$R_s := 1$

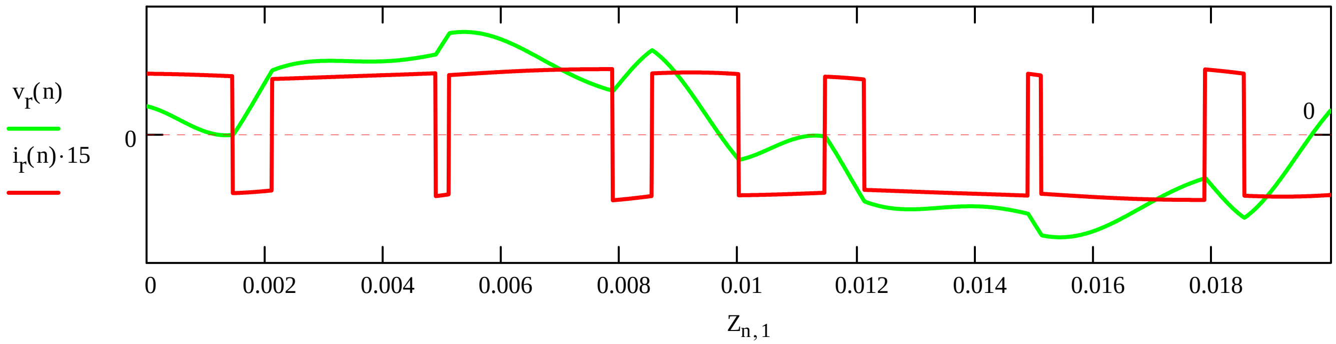
La tensión de red, $v_s(t) := \sqrt{2} \cdot 220 \cdot \sin(\omega_s \cdot t)$

Simulación $t_f := 0.02$ $n_f := 2048$ $n := 1 .. n_f$ $t := 0, \frac{t_f}{n_f} .. t_f$

$$D(t,x) := \begin{pmatrix} \frac{-R_s}{L_s} \cdot x_1 - \frac{1}{L_s} \cdot x_2 + \frac{1}{L_s} \cdot v_s(t) \\ \frac{1}{C_{ac}} \cdot x_1 - \frac{1}{C_{ac}} \cdot s_{ab}(t) \cdot x_3 \\ \frac{-R_{dc}}{L_{dc}} \cdot x_3 + \frac{1}{L_{dc}} \cdot s_{ab}(t) \cdot x_2 \end{pmatrix}$$

$CI := \begin{pmatrix} 10 \\ 0 \\ 15 \end{pmatrix}$ $Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D)$ $CI := \begin{pmatrix} Z_{n_f,2} \\ Z_{n_f,3} \\ Z_{n_f,4} \end{pmatrix}$ $Z := \mathrm{rkfixed}(CI, 0, t_f, n_f, D)$

$i_s(n) := Z_{n,2}$ $v_r(n) := Z_{n,3}$ $i_{dc}(n) := Z_{n,4}$ $v_{dc}(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot v_r(n)$ $i_r(n) := s_{ab}\left(n \cdot \frac{t_f}{n_f}\right) \cdot i_{dc}(n)$

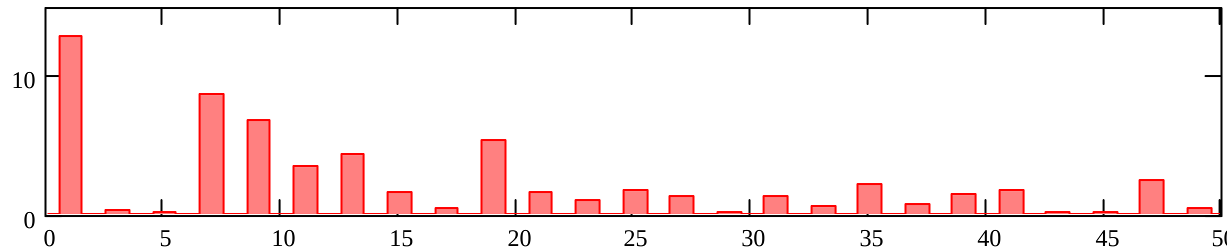


$N := 1024$ $\quad m := 1..N$

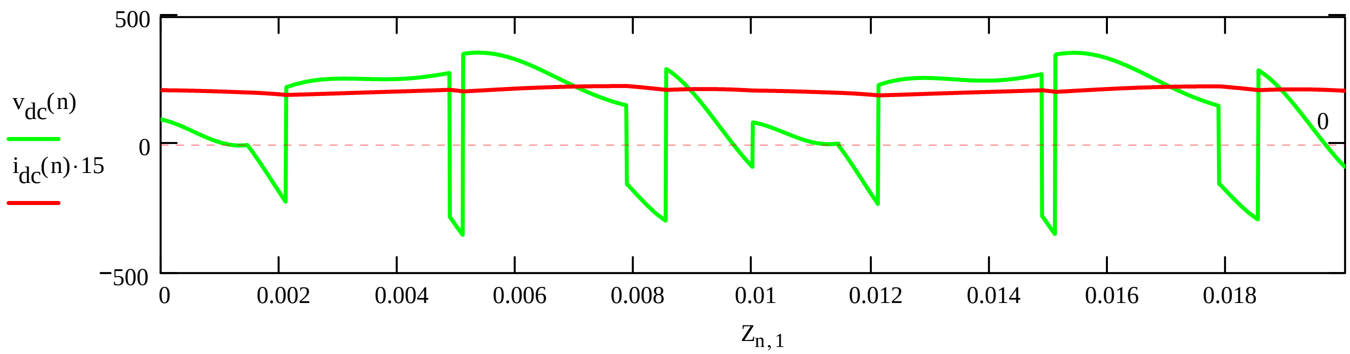
$x_m := i_r\left(m \cdot \frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := \text{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

FFT de i_r



Aparecen armónicos no deseados de baja frecuencia que: (1) aumentan la distorsión, (2) exigen a los filtros en rms, (3) reducen el potencial ancho de banda de los controladores.



$N := 1024$ $\quad m := 1..N$

$x_m := v_{dc}\left(m \cdot \frac{n_f}{N}\right)$ $\quad xf := FFT(x)$

$xv(m) := \text{if}(m = 1, 1, 2) \cdot xf_{m \cdot per}$

FFT de v_{dc}