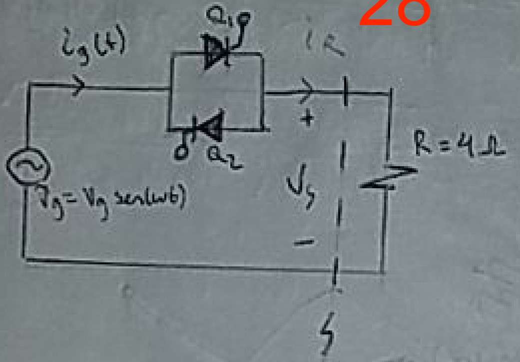
Examen Final

IE-0613

1-2020

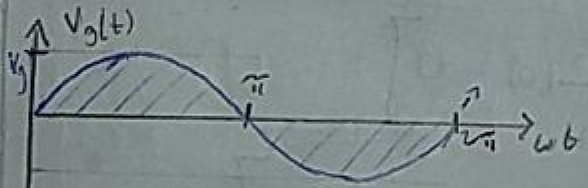
Problema 1: Controlador AC

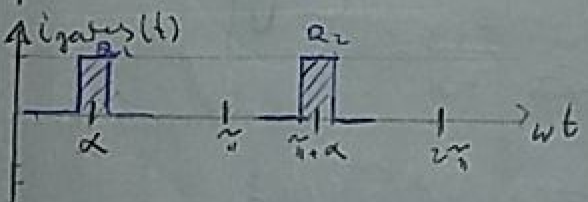


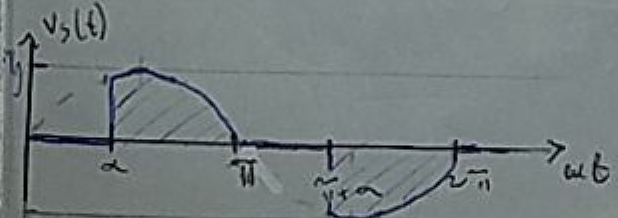
$V_g = 177\ \text{V}$ $\quad \omega = 2\pi \cdot 60\ \text{rad/s}$

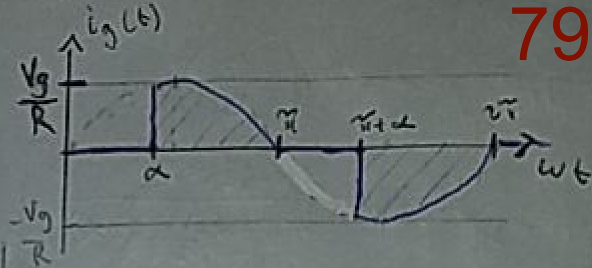
(a) $|I_{g1}|$ e $\measuredangle I_{g1}$

Asumiendo $i_g(t) = i_R = \frac{v_s}{R}$









Determinamos $I_{g1} = i_{R1} = \frac{V_{s1}}{R}$

$$a_1 = \frac{1}{\pi}\left[\int_\alpha^\pi \frac{V_g}{R}\,\text{sen}(\alpha)\cos(\alpha)\,d\alpha - \int_{\pi+\alpha}^{2\pi} \frac{V_g}{R}\,\text{sen}(\alpha)\cos(\alpha)\,d\alpha\right]$$

$$\Rightarrow a_1 = \frac{V_{g1}}{\pi R}\left[-\alpha + \sin(\alpha)\cos(\alpha) + \pi\right]$$

$$\Rightarrow \left[a_1 = \frac{-V_{g1}}{\pi R}\left[-\alpha + \sin(\alpha)\cos(\alpha) + \pi\right]\right] \quad (1)$$

$$b_1 = \frac{1}{\pi}\left[\int_\alpha^\pi \frac{V_g}{R}\,\text{sen}\,\alpha \cos\alpha\,d\alpha - \int_{\pi+\alpha}^{2\pi} \frac{V_g}{R}\,\text{sen}\,\alpha \cos\alpha\,d\alpha\right]$$

$$\Rightarrow \left[b_1 = \frac{V_{g1}}{\pi R}\left(-\text{sen}^2(\alpha)\right)\right] \quad (2)$$

$$C_1 = \sqrt{a_1^2 + b_1^2} = I_{g1} \quad (3)$$

(1), (2) en (3):

$$\boxed{I_{g1} = \frac{V_{g1}}{\pi R}\sqrt{\text{sen}^4(\alpha) + \left(\pi - \alpha - \sin(\alpha)\cos(\alpha)\right)^2}}$$

$\measuredangle I_{g_1} = \arctan\left(\frac{-a_1}{b_1}\right)$

$$\Rightarrow \left[\measuredangle I_{g_1} = \arctan\left(\frac{\operatorname{sen}^2\alpha}{\pi - \alpha - \frac{1}{2}\operatorname{sen}(2\alpha)}\right) \right]$$

(b) I_{g_3} y Gráfica I_{g_3}/I_{g_1}

$$a_3 = \frac{1}{\pi}\left[\int_{\alpha}^{\pi} \frac{V_g}{R}\operatorname{sen}(a)\operatorname{sen}(3a)\,da + \cdots \int_{\alpha+\pi}^{2\pi} \frac{V_g}{R}\operatorname{sen}(a)\operatorname{sen}(3a)\,da \right]$$

$$\Rightarrow \left[a_3 = \frac{-V_g}{2\pi R}\sin^3(\alpha)\cos(\alpha) \right] (4)$$

-2, error

$$b_3 = \frac{1}{\pi}\left[\int_{\alpha}^{\pi} \frac{V_g}{R}\sin(a)\cos(3a)\,da + \cdots \int_{\alpha+\pi}^{2\pi} \frac{V_g}{R}\sin a\cos(3a)\,da \right]$$

$$\Rightarrow \left[b_3 = \frac{-2V_g}{\pi R}\sin^2\alpha\left(\cos(2\alpha)\right) \right] (5)$$

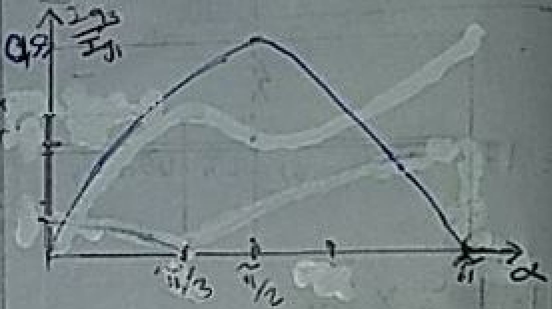
$$c_3 = \sqrt{a_3^2 + b_3^2} = I_{g_3} \; (6)$$

(4), (5) en (6):

$$\left[I_{g_3} = \frac{V_g}{\pi R}\sqrt{4\operatorname{sen}^6(\alpha)\cos^2(\alpha) + \operatorname{sen}^4(\alpha)\cos^2(2\alpha)} \right]$$

$$\frac{I_{g_3}}{I_{g_1}} = \sqrt{\frac{4\operatorname{sen}^6(\alpha)\cos^2(\alpha) + \operatorname{sen}^4(\alpha)\cos^2(\alpha)}{\operatorname{sen}^4(\alpha) + (-\alpha - \operatorname{sen}(\alpha)\cos(\alpha) + \cdots}}$$

$$\Rightarrow \left[\frac{I_{g_3}}{I_{g_1}} = \frac{|\operatorname{sen}(\alpha)|}{2} \right] ✓$$



Pto crítico den $\alpha = \pi/2$

$$\left[\alpha = \frac{\pi}{2} \Rightarrow \frac{I_{g_3}}{I_{g_1}} = 0{,}3 \right]$$

$$\left[\frac{I_{g_3}}{I_{g_1}}(0) = 0 \right]$$

$$\left[\lim_{\alpha \to \pi} \frac{I_{g_3}}{I_{g_1}}(\alpha) = 0 \right]$$

(c) $\alpha = 30°$

$$|I_{g_1}| = 31,0 \text{ vs } 42$$

$$|I_{g_3}| = 3,52 \text{ vs } 4,11$$

$$\measuredangle I_{g_1} \cong \pi + 0,114 \cong 186,5° \text{ vs. } 183,5°$$

$$\frac{I_{g_3}}{I_{g_1}}(\alpha) \cong 0,114 \text{ vs } 0,098$$

(d) $I_{g_1}(\pi/2)$, $I_{g_3}(\pi/2)$, $\theta_1(\pi/2)$

$$I_{g_1}(\pi/2) \cong 26,23\text{ A} \quad \text{v: } 24,1\text{A}$$

$$I_{g_3}(\pi/2) \cong 14,08\text{ A} \quad \text{v: } 13,43\text{A}$$

$$\theta_1 \cong \pi + 0,37 \cong 3,71 \quad = 212° \quad \text{v: } 213°$$

$$\Rightarrow \frac{I_{g_3}}{I_{g_1}} \cong 1,82 \quad \text{vs } 1,77$$

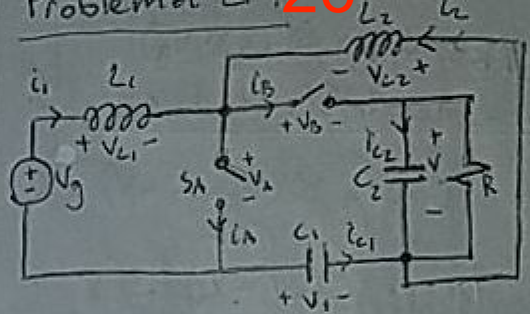
(e)

- Arrancador de estado sólido:

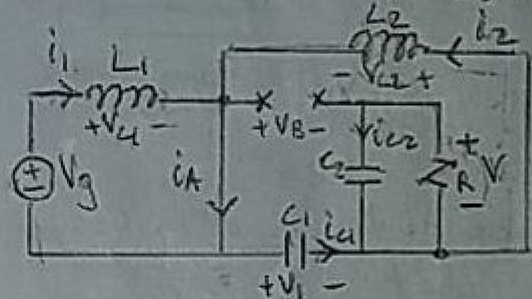
Un dispositivo de potencia eléctrica que permite controlar el arranque y apagado de motores de inducción.

Controla las corrientes y el par de arranque, para regular la tensión desde valores bajos a la tensión nominal.

Problema 2: 26



Intervalo I: $0 < t \le DT_s \Rightarrow S_A \Rightarrow ON$, $S_B \Rightarrow OFF$

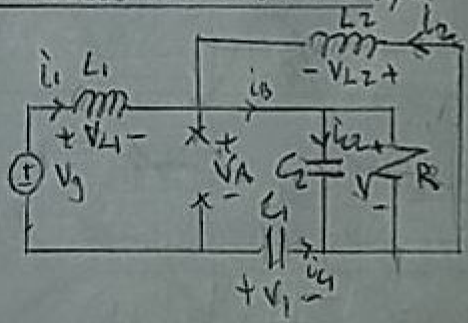


$$v_{L_1} \cong V_g \qquad I_{C_1} \cong I_2$$

$$v_{L_2} \cong -V_1 \qquad I_{C_2} \cong -V/R$$

$$V_B \cong V_1 - V \qquad I_A = I_1 + I_2$$

Intervalo II: $DT_s < t < T_s \Rightarrow S_A \Rightarrow OFF$



$V_{L_1} \cong V_g + V_1 - V \qquad I_{C_1} \cong -I_1$

$V_{L_2} \cong -V \qquad I_{C_2} \cong I_1 + I_2 - \frac{V}{R}$

$V_A \cong V \qquad I_B \cong I_1 + I_2$

-2, error

a. • $V(D, D', V_g)$, $V_1(D, D', V_g)$

Balance de Volt/s en L_1, L_2:

$\langle V_{L_1} \rangle = D V_g + D'(V_g + V_1 - V) = 0$

$\Rightarrow \boxed{V_g = D'(V - V_1)}$ (1)

-2, error

$\langle V_{L_2} \rangle = -D V_1 - D V = 0$

$\boxed{V = -V_1}$ (2)

Balance de Amp/s en C_1, C_2:

$\langle i_{C_1} \rangle = D I_2 - D' I_1 = 0$

$\Rightarrow \boxed{I_2 = \frac{D'}{D} I_1}$ (3)

$\langle i_{C_2} \rangle = D(-V/R) + D'(I_1 + I_2 - V/R) = 0$

$\Rightarrow \boxed{V/R = I_1 + I_2}$ (4)

(2) en (1):

$\frac{V_g}{D'} = -2V_1$

$\Rightarrow \boxed{V_1 = \frac{-1}{2D'} \cdot V_g}$ (5)

$\boxed{V = -V_1 = \frac{1}{2D'} \cdot V_g}$ (6)

• $I_1(D, D', V_g, R)$, $I_2(D, D', V_g, R)$

(3) en (4):

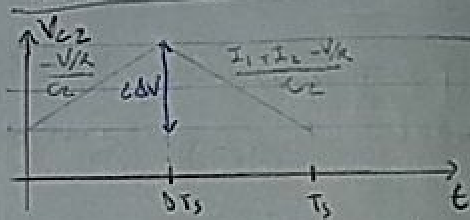
$I_1 \left(\cancel{1 + \frac{D'}{D}}^{\frac{1}{D}}\right) = V/R$

$\Rightarrow \boxed{I_1 = D \cdot V/R}$ (7)

(7) en (3):

$\boxed{I_2 = D' \cdot V/R}$ (8)

• Rizado de $\Delta V(n, D, D', V_g, f_s, L_1, L_2, R)$



$2\Delta V = DT_s \left(\frac{V}{RC_2}\right)$ (9)

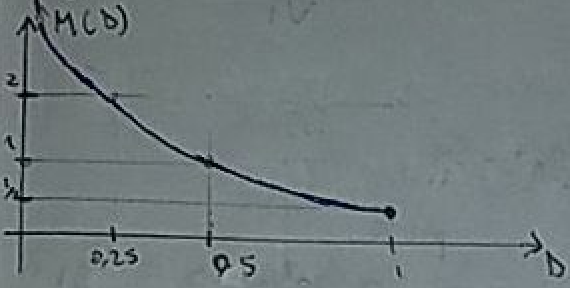
(6) en (9)

$\Delta V = \frac{1}{2} \cdot \frac{\cancel{D}}{f_s} \cdot \frac{1}{2\cancel{D'}} \cdot \frac{V_g}{RC_2}$

$\Rightarrow \boxed{\Delta V = \frac{V_g}{4 f_s R C_2}}$ (10)

b. M(D)

$$\frac{V}{V_g} = \frac{1}{2D} = M(D)$$



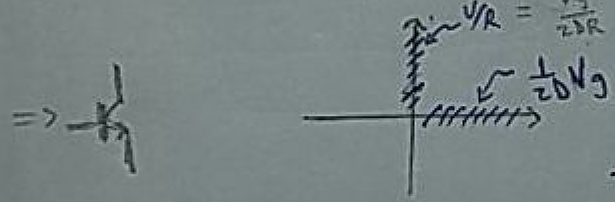
- Su comportamiento es propio de un buck-boost, al permitir en V una tensión mayor o menor a V_g, al variar D.
- Nótese que V puede ser desde infinitas veces más grande (en teoría) a 1/2 del valor de V_g.

c. S_A y S_B

Switch A:

ON: $I_A \cong I_1 + I_2 = \frac{V_g}{2DR}$ (+)

OFF: $V_A \cong V = \frac{1}{2D} \cdot V_g$ (+)

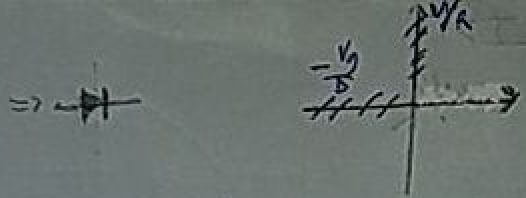


Switch B:

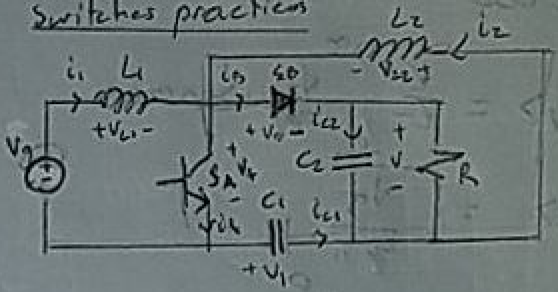
ON: $I_B \cong I_1 + I_2 = \frac{V_g}{2DR}$ (+)

OFF: $V_B \cong V_1 - V = 2V_1 -$

$\Rightarrow V_B \cong -\frac{1}{D} \cdot V_g$ (−)

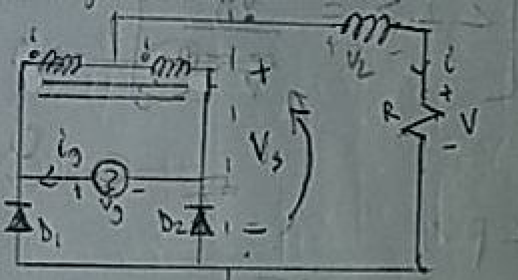


Switches prácticos

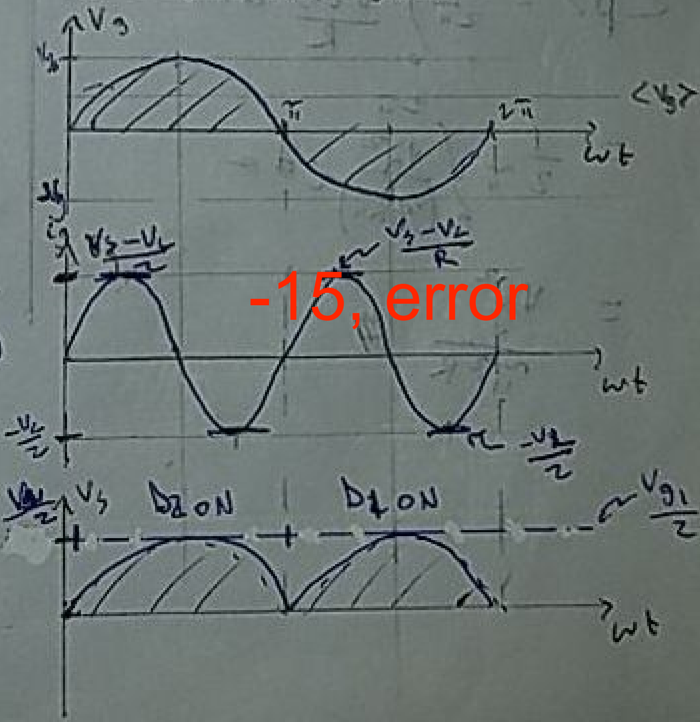


Problema 3: 25

- Elem ideales.
- L grande ⇒ DC choke



a) Dibujar v_g, i_g, v_s



-15, error

b. $\langle I\rangle$

$$\langle I\rangle = \frac{\langle V\rangle}{R}$$

$$\langle V_1\rangle = \frac{1}{2\pi}\int_0^{\pi} V_{g1}\cdot \operatorname{sen}\alpha\, d\alpha$$

$$\langle V_1\rangle = \frac{V_g}{\pi}$$

$$\langle V_3\rangle = \cancel{\langle V_2\rangle}^{0} + \langle V_1\rangle$$

$$\langle V\rangle = \frac{V_g}{\pi}$$

$$\Rightarrow \therefore \left[\langle I\rangle = \frac{V_g}{\pi R}\right]$$

c. $\langle p\rangle$

$$\langle p\rangle = \frac{1}{2\pi}\int_0^{2\pi} \frac{v^2(\alpha)}{R}\, d\alpha$$

$$= \frac{1}{2\pi}\int_0^{2\pi} \frac{V_g^2}{(\pi)^2}\, d\alpha$$

$$= \frac{V_g^2}{\pi^2 R}$$

d) THD

$$THD = \frac{\sqrt{\sum_{n=2} V_n^2}}{V_1}$$

$$V_{g1} = c_1$$

$$a_1 = \frac{1}{\pi}\int_0^{2\pi} V_{g1} \operatorname{sen}^2\alpha\, d\alpha = V_{g1}$$

$$b_1 = 0\,!$$

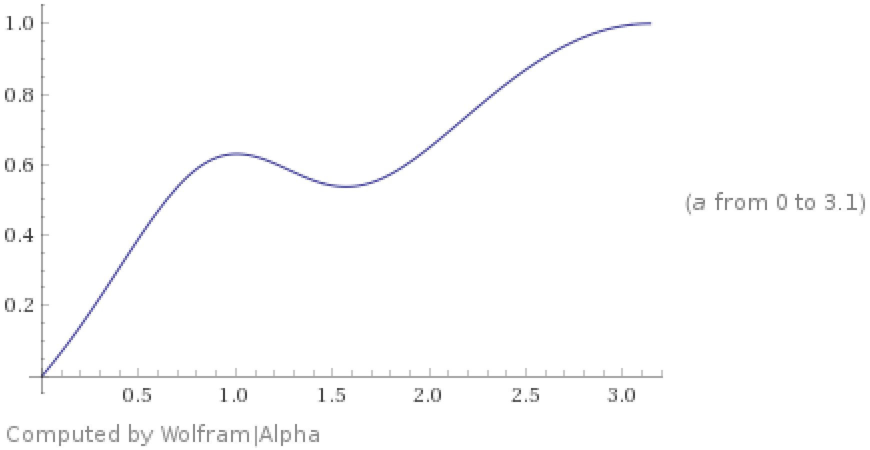
X

$$\left[c_1 = V_{g1}\cdot\right]$$

$$a_n = \frac{1}{\pi}\int_0^{2\pi} V_g \operatorname{sen}\alpha \operatorname{sen} n\alpha\, d\alpha = 0$$

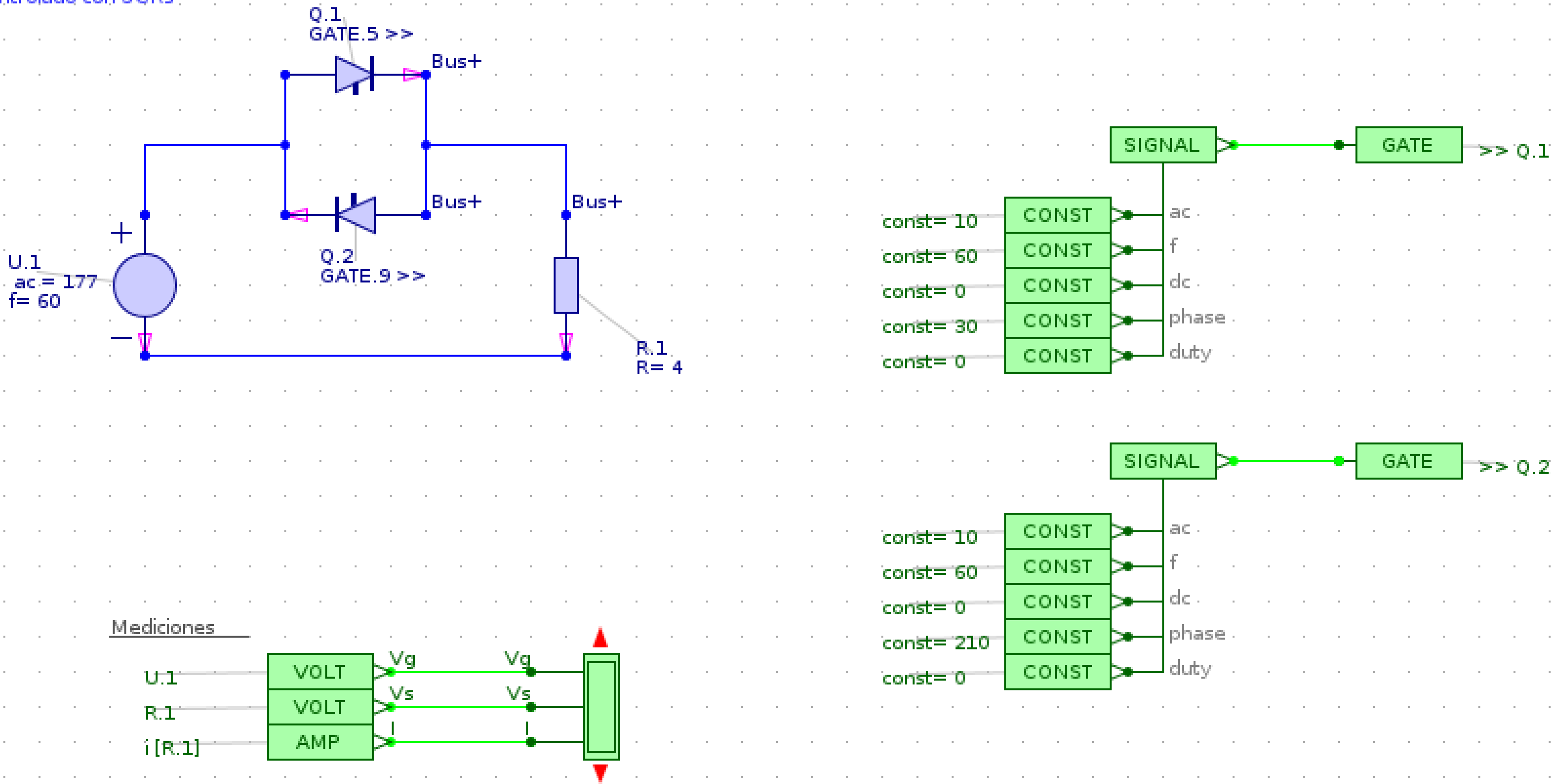
$$b_n = \frac{1}{\pi}\int_0^{2\pi} V_g \operatorname{sen} \cos(n\alpha)\, d\alpha =$$

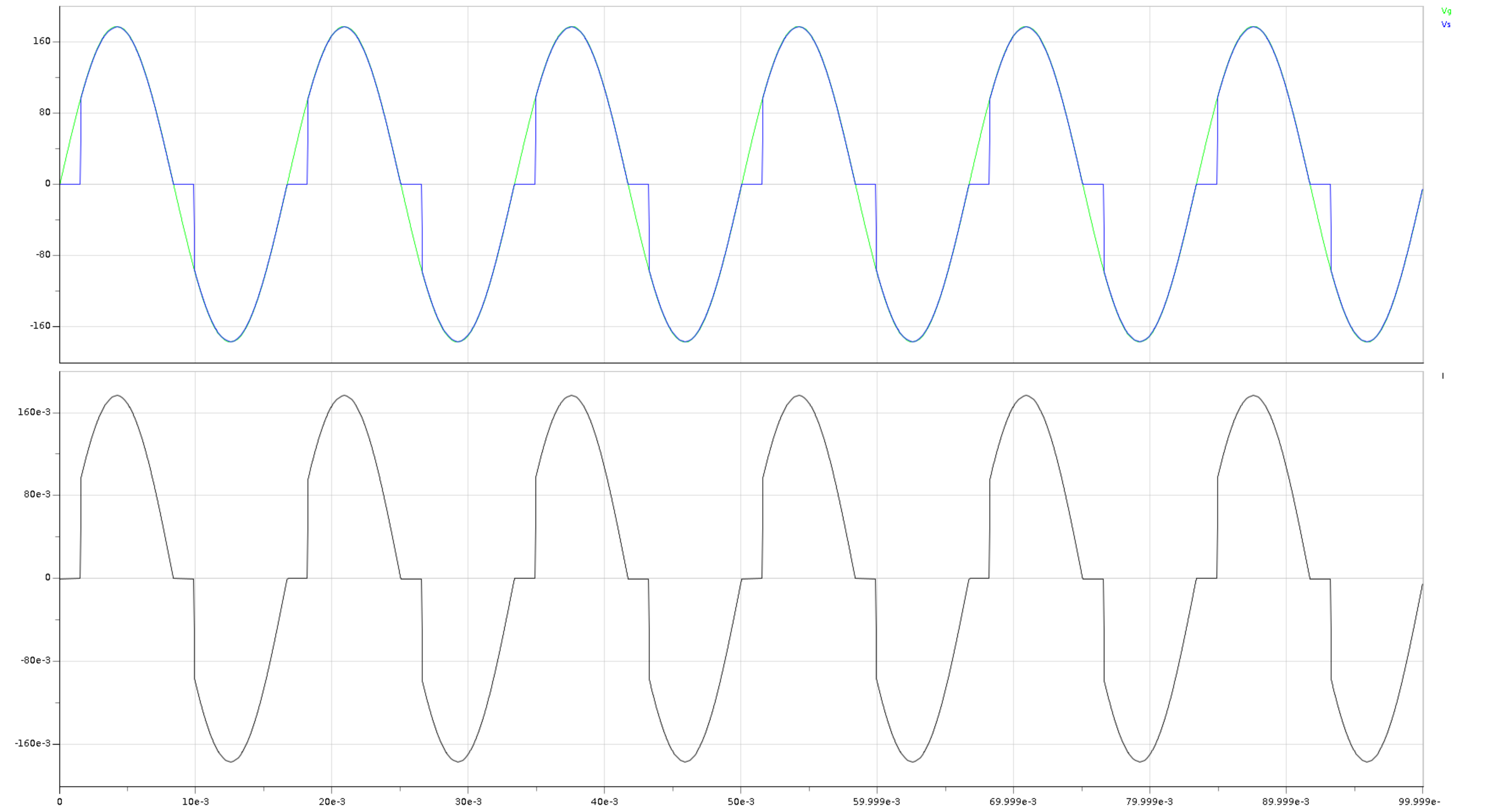
$$\therefore \left[THD = 0\right]$$


1.0
0.8
0.6
0.4
0.2
0.5
1.0
1.5
2.0
2.5
3.0
(a from 0 to 3.1)
Computed by Wolfram|Alpha

Controlador AC Monofásico

Controlado con SCRs



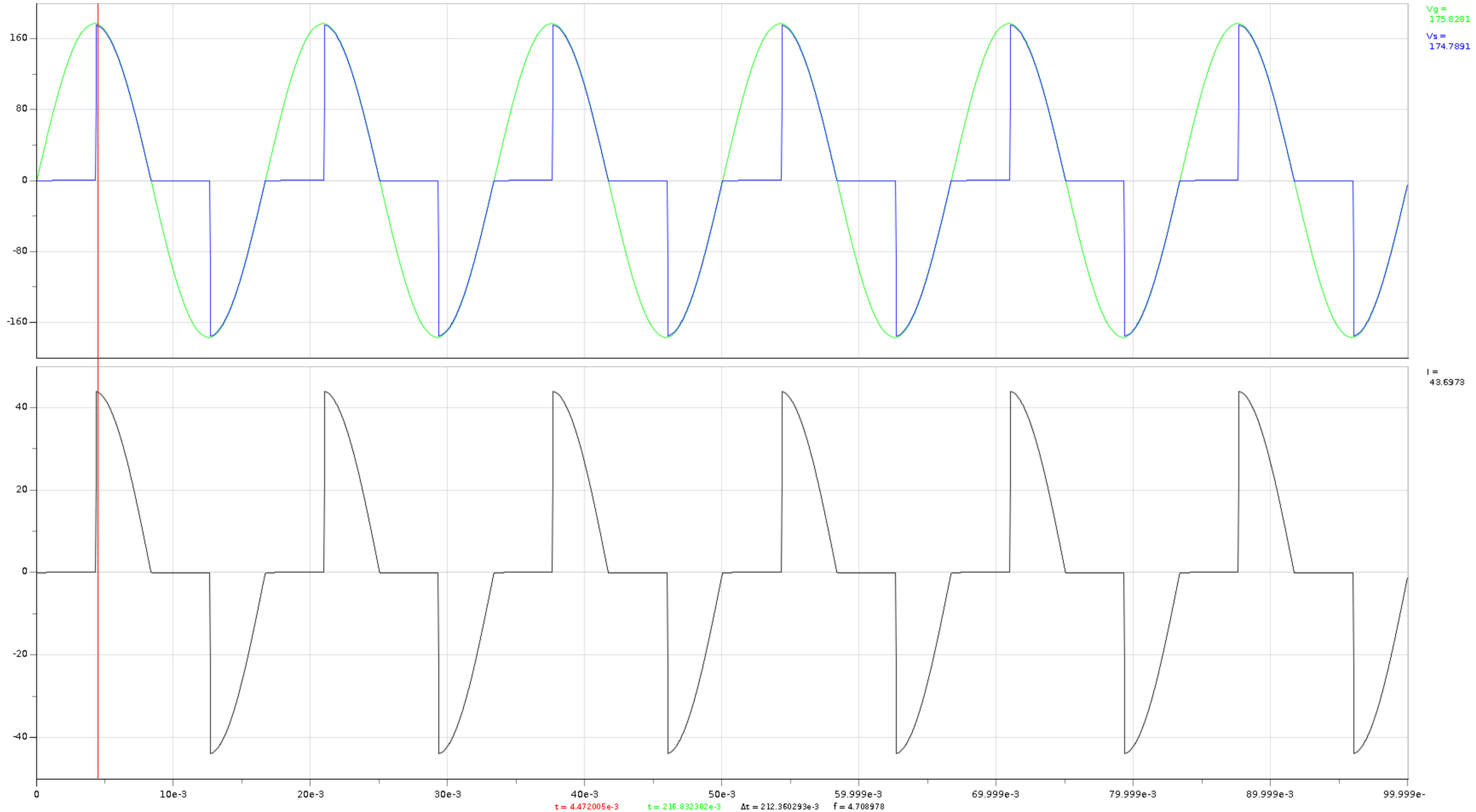

Vg
Vs
160
80
0
-80
-160
I
160e-3
80e-3
0
-80e-3
-160e-3
0
10e-3
20e-3
30e-3
40e-3
50e-3
59.999e-3
69.999e-3
79.999e-3
89.999e-3
99.999e-


50
40
30
20
10
0

I

Fourier Analysis | Worksheet Data | Reconstruction

n	c_n	phi_n [rad]
0	-23.209e-6	0
1	42.2442	-3.0773
2	681.8788e-3	73.4646e-3
3	4.4216	-445.5695e-3
4	326.2472e-3	673.3313e-3
5	3.6963	244.8418e-3



Vg =
175.8281
Vs =
174.7891
I =
43.6973
160
80
0
-80
-160
40
20
0
-20
-40
0
10e-3
20e-3
30e-3
40e-3
50e-3
59.999e-3
69.999e-3
79.999e-3
89.999e-3
99.999e-
t = 4.472005e-3
t = 216.832302e-3
Δt = 212.360293e-3
f = 4.708978

I

Fourier Analysis | Worksheet Data | Reconstruction

n	c_n	phi_n [rad]
0	-596.6338e-6	0
1	24.7778	-2.5712
2	154.0861e-3	1.1205
3	13.9907	1.5962
4	123.6874e-3	-1.2483
5	4.7099	-1.3776

I

Fourier Analysis | Worksheet Data | Reconstruction