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Estudio de Rectificadores Trifásicos

Ejercicio 3. Dos rectificadores controlados

Oskar Casquero, F. Javier Maseda, Jesús Romo & Itziar Martija

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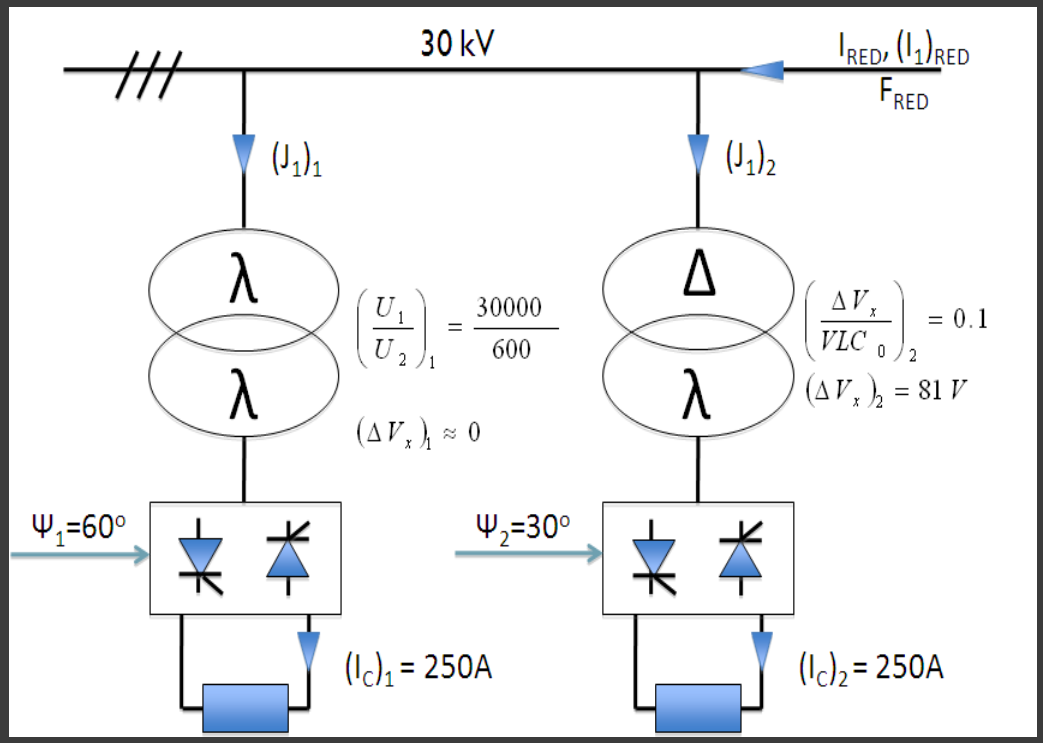

A. En el sistema rectificador de la figura, calcular:

1. Dibujar el diagrama vectorial de las tensiones $(V_{13})_1$ y $(V_{13})_2$.
2. Calcular $\left(\frac{n_2}{n_1}\right)_1$ y $\left(\frac{n_2}{n_1}\right)_2 = f\left(\frac{n_2}{n_1}\right)_1$
3. Dibujar $(J_1)_1$, $(J_1)_2$, e I_{RED}. Calcular sus valores eficaces.
4. Calcular la potencia de los transformadores y el factor de potencia de la red F_{RED}.
5. Calcular $(\varphi_1)_1$ y $(\varphi_1)_2$
6. Calcular $(I_1)_{RED}$ y τ_{RED}

B. Si se suponen los siguientes cambios en el sistema, $\psi_2 = 60^0$ $(VLC')_2 = 324V$ $\left(\frac{\Delta V_x}{V_{LC0}}\right)_1 = 0.1$ permaneciendo el resto de los datos invariables,

1. Calcular el valor eficaz de $(J_1)_1$, $(J_1)_2$.
2. Calcular I_{RED}.

C. Si dejasen de funcionar los siguientes tiristores: T1 en el rectificador 1, T1 y T1´en el rectificador 2, cual seria la forma de la tensión de en la carga. Considerar un $\psi = 0^0$ en ambos rectificadores.

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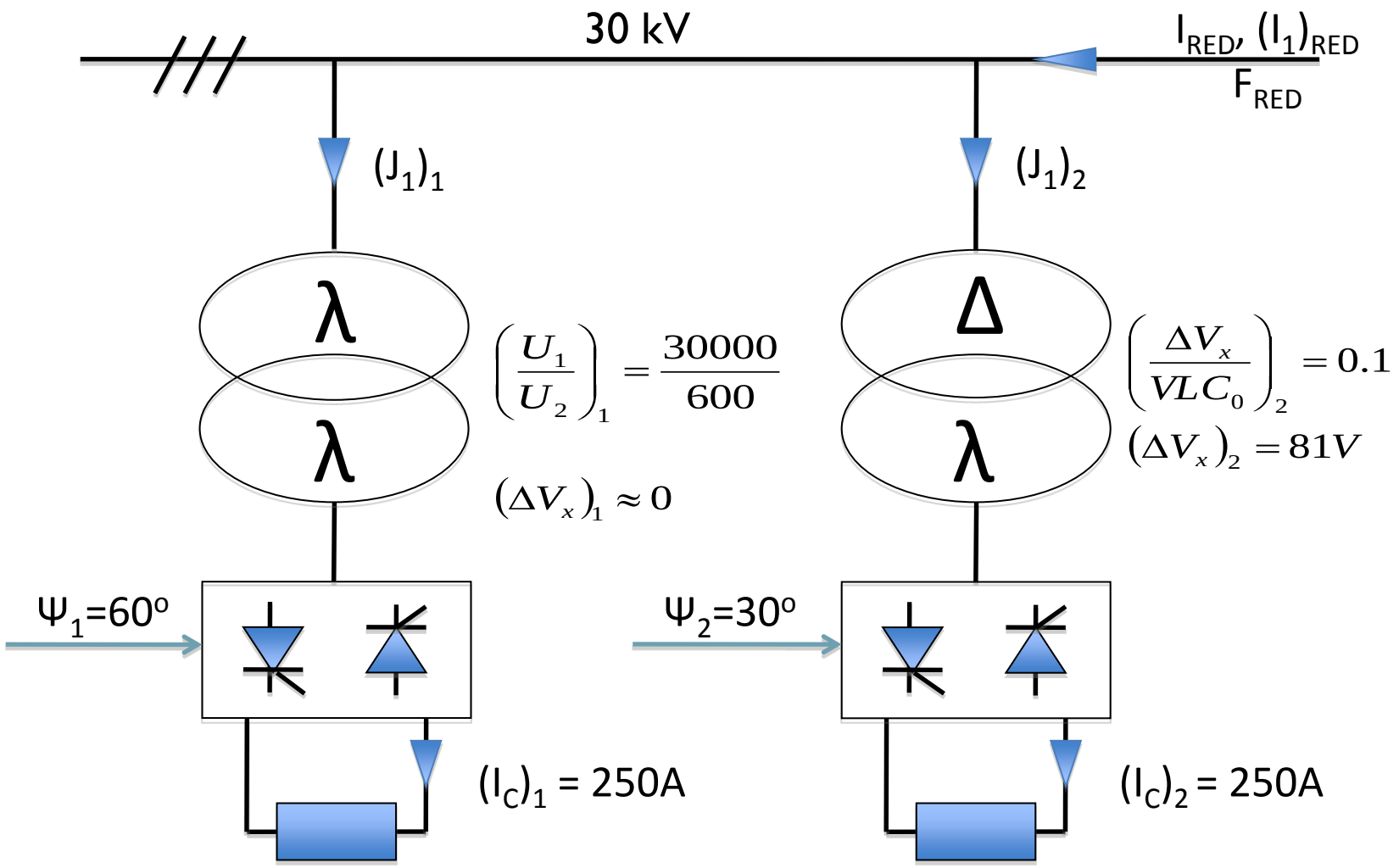
Circuito



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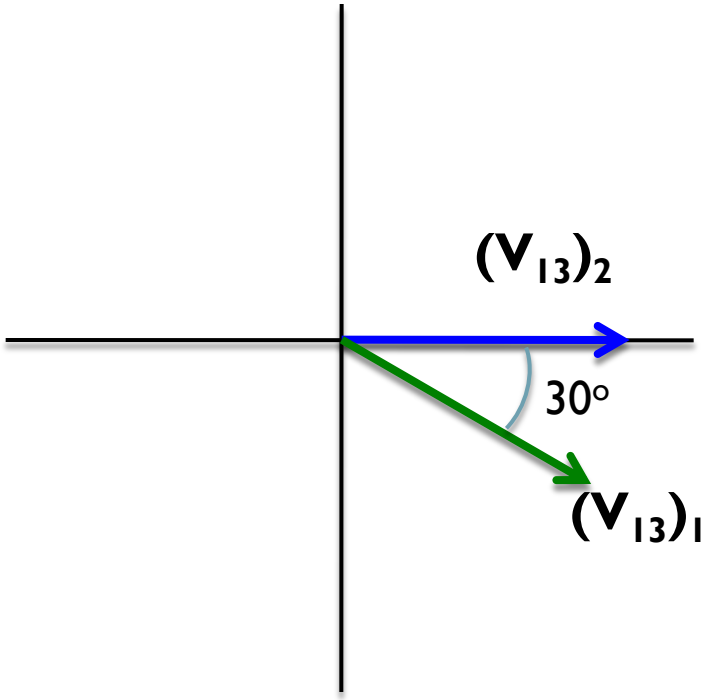
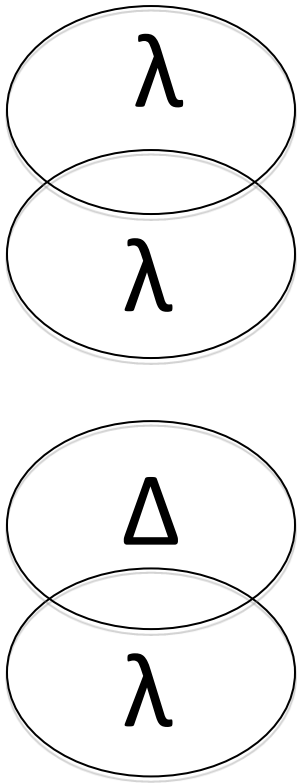
Resolución



Resolución apartado A



$$\frac{\Delta V_x}{VLC_0} = 0.1;\ \Delta V_x = 81V \Rightarrow VLC_0 = 810\,V$$

$$VLC_0 = \frac{3\sqrt{3}V_0}{\pi} \Rightarrow V_0 = \frac{810\,\pi}{3\sqrt{3}} = 490\,V;$$

$$(U_2)_2 = \frac{\sqrt{3}\,V_0}{\sqrt{2}} = \frac{\sqrt{3}\ 490}{\sqrt{2}} = 600\,V$$

$$\left(\frac{U_1}{U_2}\right)_1 = \frac{30000}{600} \Rightarrow \left(\frac{n_1}{n_2}\right)_1 = \frac{U_1/\sqrt{3}}{U_2/\sqrt{3}} = \frac{30000/\sqrt{3}}{600/\sqrt{3}} = 50$$

$$\left(\frac{U_1}{U_2}\right)_2 = \frac{30000}{600} \Rightarrow \left(\frac{n_1}{n_2}\right)_2 = \frac{U_1}{U_2/\sqrt{3}} = \frac{30000}{600/\sqrt{3}} = 50\sqrt{3}$$

$$\Rightarrow \left(\frac{n_2}{n_1}\right)_2 = \frac{1}{\sqrt{3}} \cdot \left(\frac{n_2}{n_1}\right)_1$$

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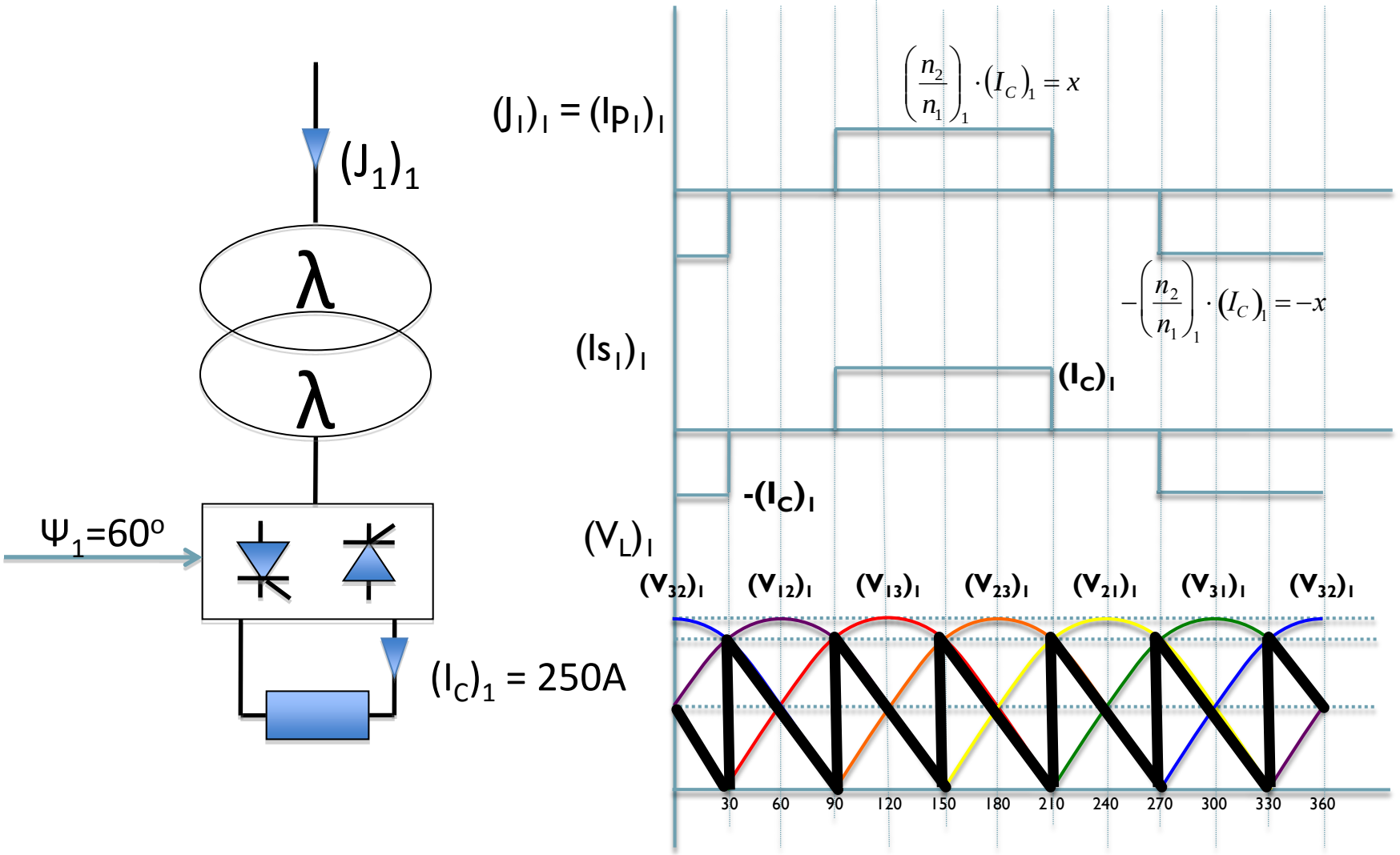
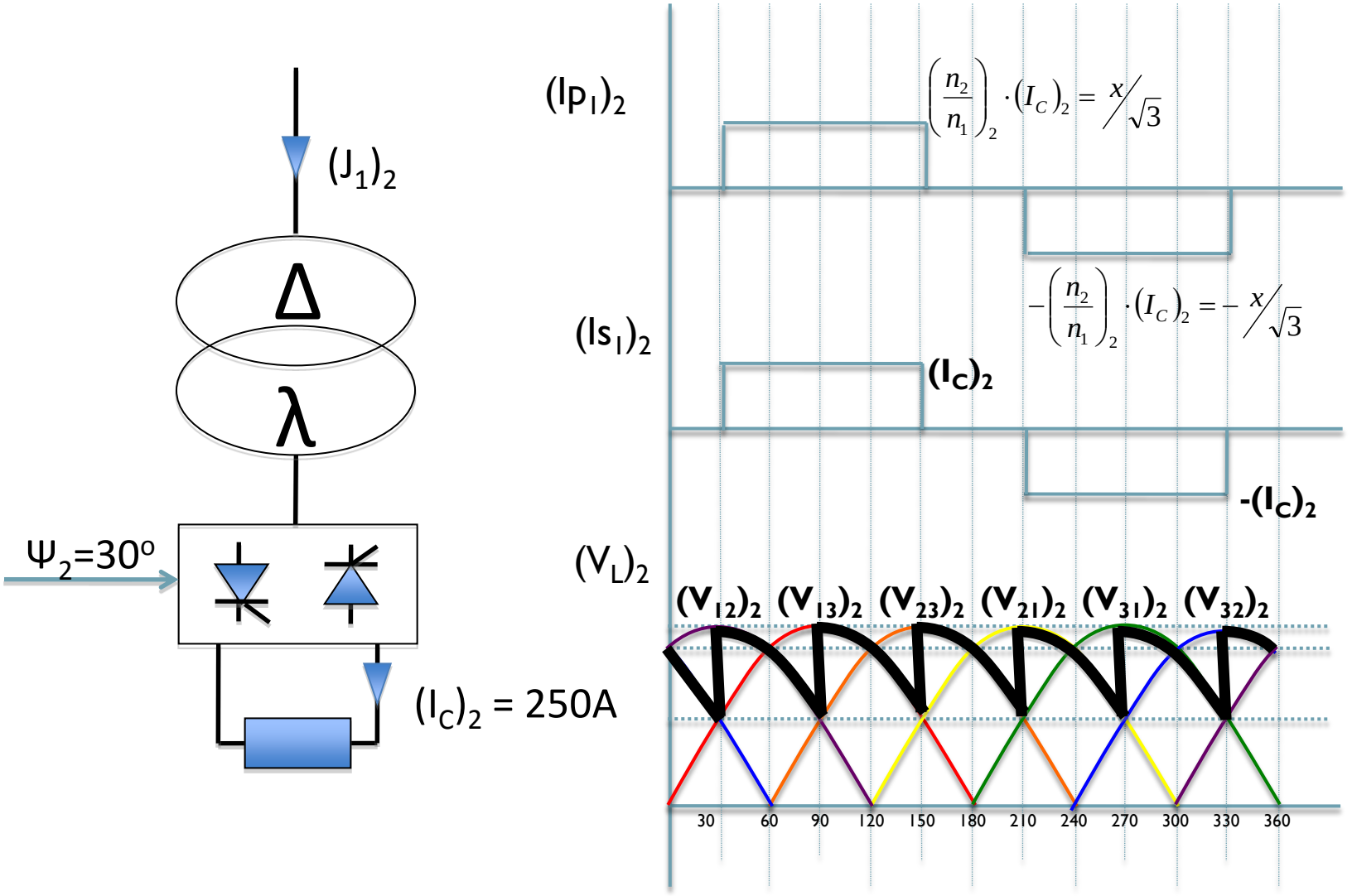
Resolución apartado A



Resolución apartado A



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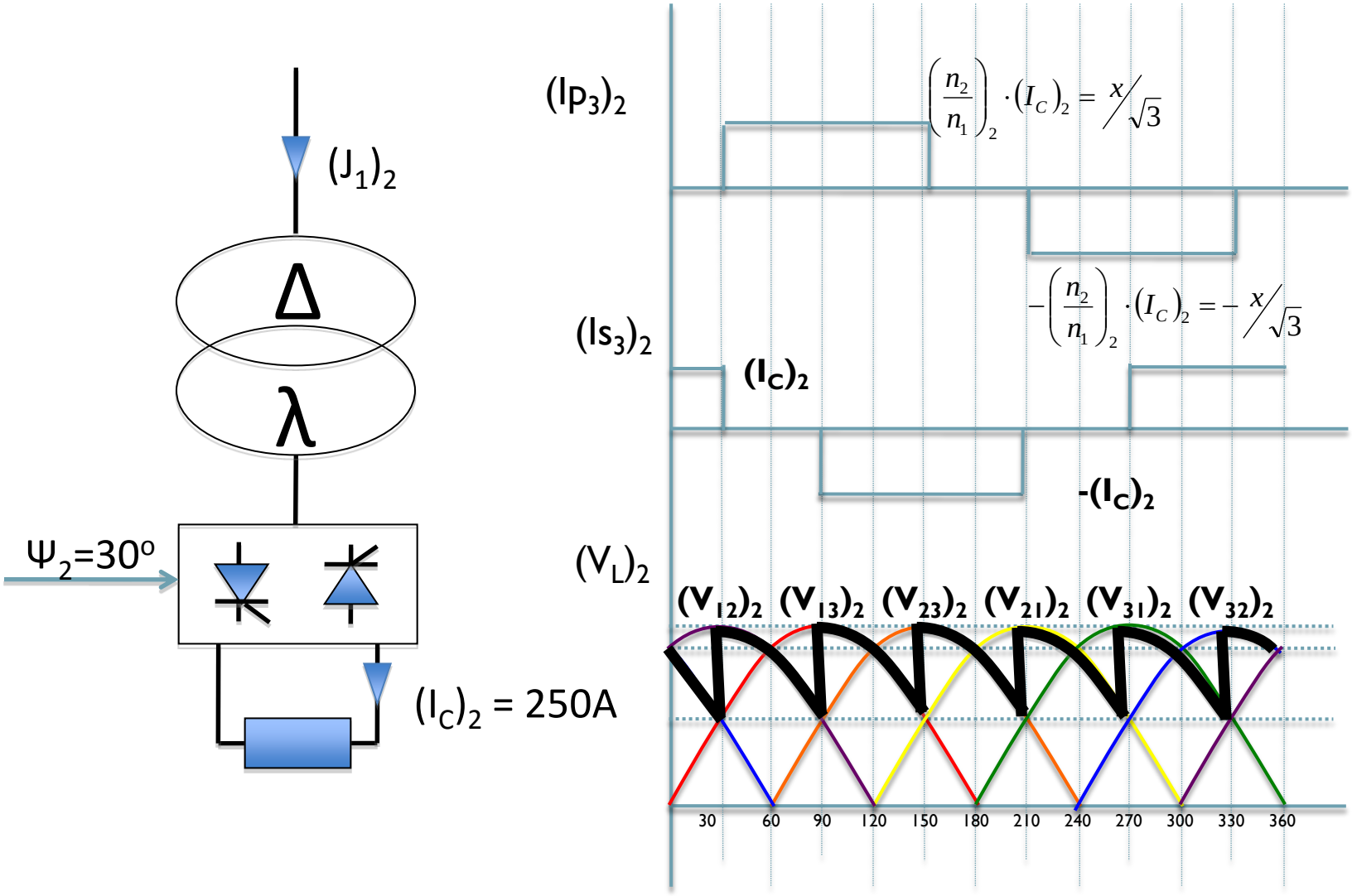
Resolución apartado A



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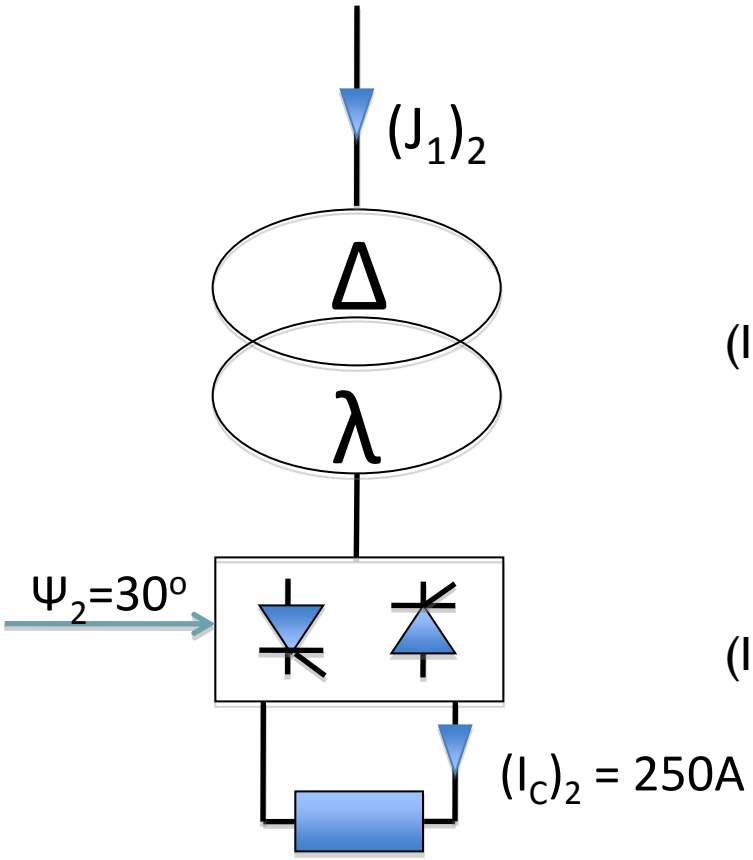
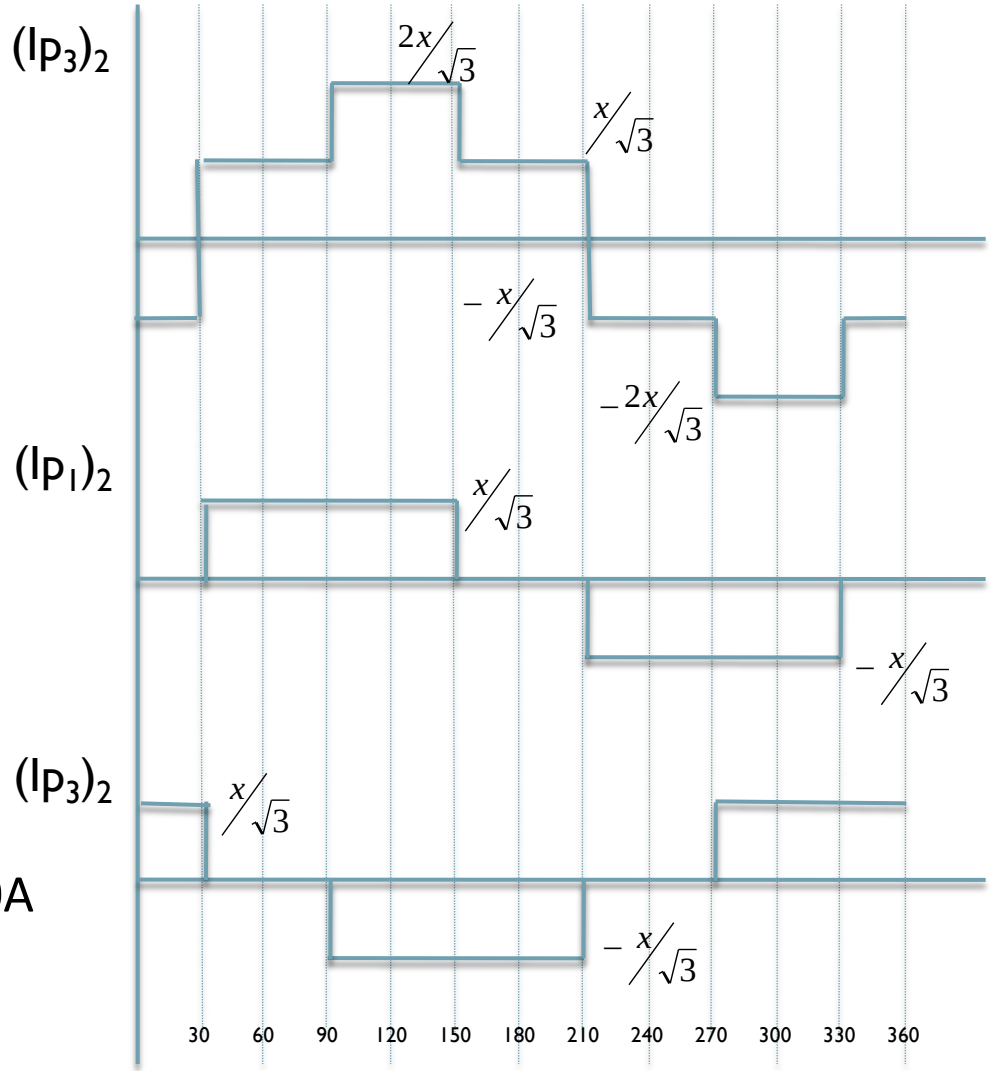
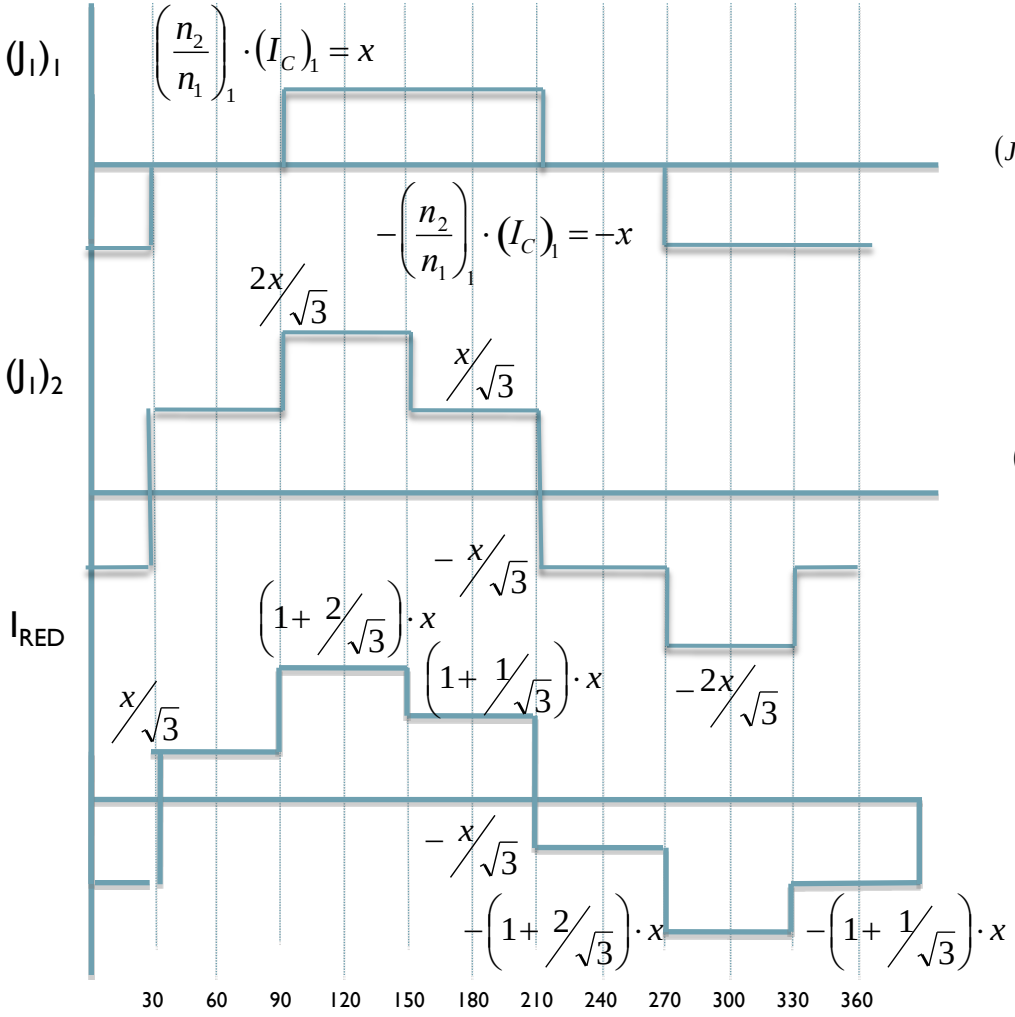
Resolución apartado A

$(J_1)_2 = (Ip_1)_2 - (Ip_3)_2$





Resolución apartado A



$$(J_1)_1 = \sqrt{\frac{1}{2\pi}\left[2\frac{2\pi}{3}x^2\right]} = x\sqrt{\frac{2}{3}} = \sqrt{\frac{2}{3}}\frac{1}{50}250 = 4.08\ A$$

$$(J_1)_2 = \sqrt{\frac{1}{2\pi}\left[2\frac{\pi}{3}\left(\frac{2}{\sqrt{3}}x\right)^2 + 4\frac{\pi}{3}\left(\frac{1}{\sqrt{3}}x\right)^2\right]} =$$

$$= x\sqrt{\frac{1}{3}\frac{4}{3} + \frac{2}{3}\frac{1}{3}} = x\sqrt{\frac{2}{3}} = 4.08\ A$$

$$I_{RED} = \sqrt{\frac{1}{2\pi}\left[2\frac{\pi}{3}\left(\frac{1}{\sqrt{3}}x\right)^2 + 2\frac{\pi}{3}\left(\left(1+\frac{1}{\sqrt{3}}\right)x\right)^2 + 2\frac{\pi}{3}\left(\left(1+\frac{2}{\sqrt{3}}\right)x\right)^2\right]} =$$

$$= x\sqrt{\frac{1}{3}\frac{1}{3} + \frac{1}{3}\left(1+\frac{2}{\sqrt{3}}+\frac{1}{3}\right) + \frac{1}{3}\left(1+\frac{4}{\sqrt{3}}+\frac{4}{3}\right)} = x\sqrt{\frac{12}{9}+\frac{2}{\sqrt{3}}} =$$

$$= x\sqrt{2.488} = 1.5774 \cdot \frac{1}{50} \cdot 250 = 7.88\ A$$

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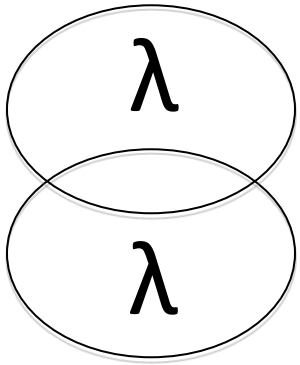
Resolución apartado A

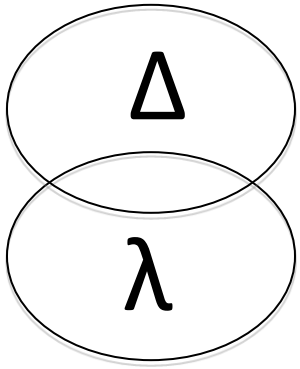
$$\left(V_{LC}{}'\right)_1 = \left(V_{LC0}{}'\right)_1 - \left(\Delta V_X\right)_1 = 810 \cdot \cos 60^0 = 405V$$



$$\left(V_{LC0}{}'\right)_1 = \left(V_{LC0}\right)_1 = V_{LC0}\big|_{PD3} = \frac{3\sqrt{3}V_O\big|_{PD3}}{\pi} = \frac{3\sqrt{3}\left(600\sqrt{\frac{2}{3}}\right)}{\pi} = 810v$$

$$V_O\big|_{PD3} = \sqrt{2} \cdot \left(U_2 \big/ \sqrt{3}\right) = 600\sqrt{\frac{2}{3}}$$

$$\left(V_{LC}{}'\right)_2 = \left(V_{LC0}{}'\right)_2 - \left(\Delta V_X\right)_2 = 701.5 - 81 = 620.5V$$



$$\left(V_{LC0}{}'\right)_2 = \left(V_{LC0}\right)_2 \cdot \cos\psi_2 = 810 \cdot \cos 30^o = 701.5V$$

$$\left(V_{LC0}\right)_2 = V_{LC0}\big|_{PD3} = \frac{3\sqrt{3}V_O\big|_{PD3}}{\pi} = \frac{3 \cdot \sqrt{3} \cdot \left(600\sqrt{\frac{2}{3}}\right)}{\pi} = 810v$$

$$V_O\big|_{PD3} = \sqrt{2} \cdot \left(U_2 \big/ \sqrt{3}\right) = 600\sqrt{\frac{2}{3}}$$

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Resolución apartado A

$$F_{RED} = \frac{(P_{LC})_1 + (P_{LC})_2}{\sqrt{3}\cdot U_1 \cdot I_{RED}} = \frac{\left[(V_{LC}')_1 \cdot (I_C)_1\right] + \left[(V_{LC}')_2 \cdot (I_C)_2\right]}{\sqrt{3}\cdot U_1 \cdot I_{RED}} = \frac{[405\cdot 250] + [620\cdot 250]}{\sqrt{3}\cdot 30000 \cdot 7.88} = 0.625$$

$$P_{T1} = P_{T2} = \sqrt{3}\cdot 30000 \cdot 4.08 = 212003\,VA = 212\,kVA$$

$$\cos(\varphi_1)_1 = \cos(\psi_1) - \left(\frac{\Delta V_X}{V_{LC0}}\right)_1$$

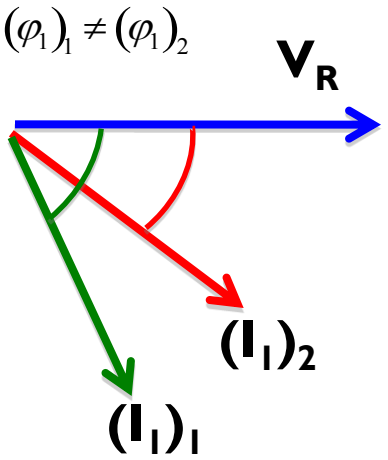
$$\cos(\varphi_1)_1 = \cos(\psi_1)$$

$$(\varphi_1)_1 = 60^0$$

$$\cos(\varphi_1)_2 = \cos\psi_2 - \left(\frac{\Delta V_X}{V_{LC0}}\right)_2$$

$$\cos(\varphi_1)_2 = \cos 30^o - 0.1 = 0.766$$

$$(\varphi_1)_2 = \arccos(0.766) = 40^o$$



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Resolución apartado A

$$(I_1)_1 = \frac{(V_{LC0})_1 \cdot (I_C)_1}{\sqrt{3} \cdot U_1} = \frac{810 \cdot 250}{\sqrt{3} \cdot 30000} = 3.9A$$

$$(I_1)_2 = \frac{(V_{LC0})_2 \cdot (I_C)_2}{\sqrt{3} \cdot U_1} = \frac{810 \cdot 250}{\sqrt{3} \cdot 30000} = 3.9A$$

$$(I_1)_{RED} = \sqrt{(I_1)^2_{RED,X} + (I_1)^2_{RED,Y}} = \sqrt{4.93^2 + 5.88^2} = 7.67A$$

$$(I_1)_{RED,X} = (I_1)_{1,X} + (I_1)_{2,X} = 1.95 + 2.98 = 4.93A$$

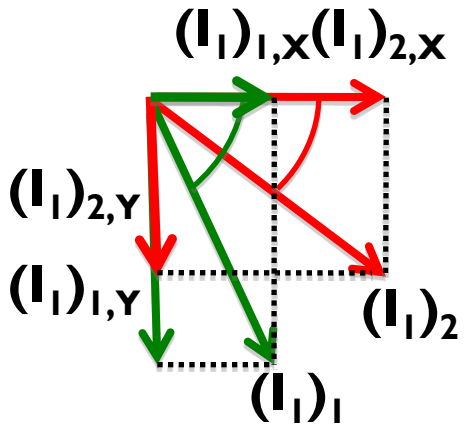
$$(I_1)_{1,X} = (I_1)_1 \cdot \cos(\varphi_1)_1 = 3.9 \cdot \cos 60 = 1.95A$$

$$(I_1)_{2,X} = (I_1)_2 \cdot \cos(\varphi_1)_2 = 3.9 \cdot \cos 40 = 2.98A$$

$$(I_1)_{RED,Y} = (I_1)_{1,Y} + (I_1)_{2,Y} = 3.38 + 2.5 = 5.88A$$

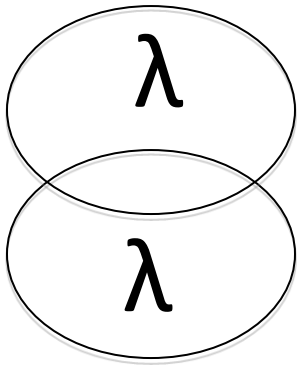
$$(I_1)_{1,Y} = (I_1)_1 \cdot \sin(\varphi_1)_1 = 3.9 \cdot \sin 60 = 3.38A$$

$$(I_1)_{2,Y} = (I_1)_2 \cdot \sin(\varphi_1)_2 = 3.9 \cdot \sin 40 = 2.5A$$

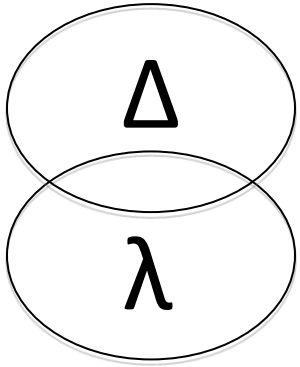


$$\tau_{RED} = \frac{(I_{\approx})_{RED}}{(I_1)_{RED}} = \frac{\sqrt{I^2_{RED} - (I_1)^2_{RED}}}{(I_1)_{RED}} = \sqrt{\left(\frac{I_{RED}}{(I_1)_{RED}}\right)^2 - 1} = \sqrt{\left(\frac{7.88}{7.67}\right)^2 - 1} = 0.23$$

Resolución apartado B



En el transformador 1 la relación de tensiones está dada y aunque se incrementan las pérdidas en el sistema la relación de transformación no se modifica



En el transformador 2 se mantienen las pérdidas

$$(V_{LC}')_2 = (V_{LC0}')_2 - (\Delta V_X)_2 = VLC_0 \cos\psi_2 - 81 = 324V$$

$$(V_{LC0}')_2 = (V_{LC0})_2 \cdot \cos\psi_2 = VLC_0 \cdot \cos 60^o = 405V$$

$$\frac{3\sqrt{3}V_0}{\pi}\cos 60^o = 405V$$

$$V_0 = \frac{405\pi}{3\sqrt{3}\cos 60^0} = 490V$$

En el transformador 2 tampoco cambia la relación de transformación

Resolución apartado B

Al no haber cambios en la corriente de carga y mantenerse la relación de transformación. Las corrientes no ve modificados sus valores eficaces.

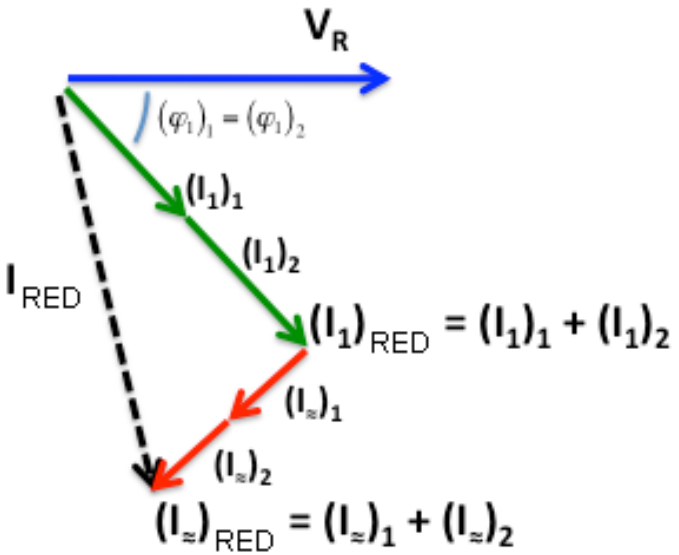
$$\cos(\varphi_1)_1 = \cos(\psi_1) - \left(\frac{\Delta V_X}{V_{LC0}}\right)_1 = \cos(60) - 0.10 = 0.4$$

$$(\varphi_1)_1 = 66.42^0$$

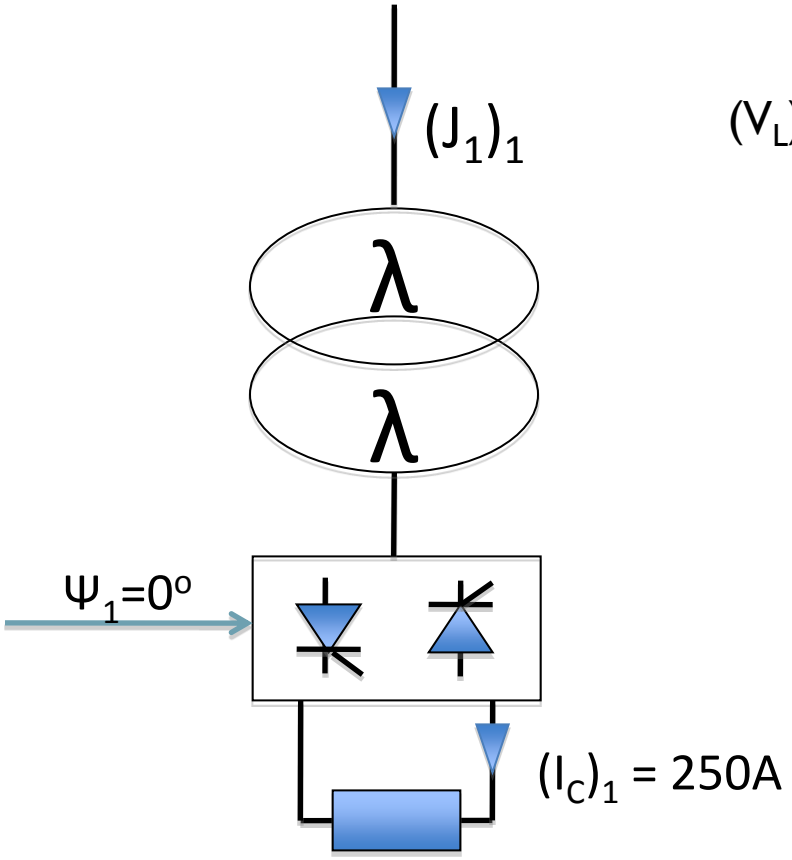
$$\cos(\varphi_1)_2 = \cos\psi_2 - \left(\frac{\Delta V_X}{V_{LC0}}\right)_2 = \cos(60) - 0.10 = 0.4$$

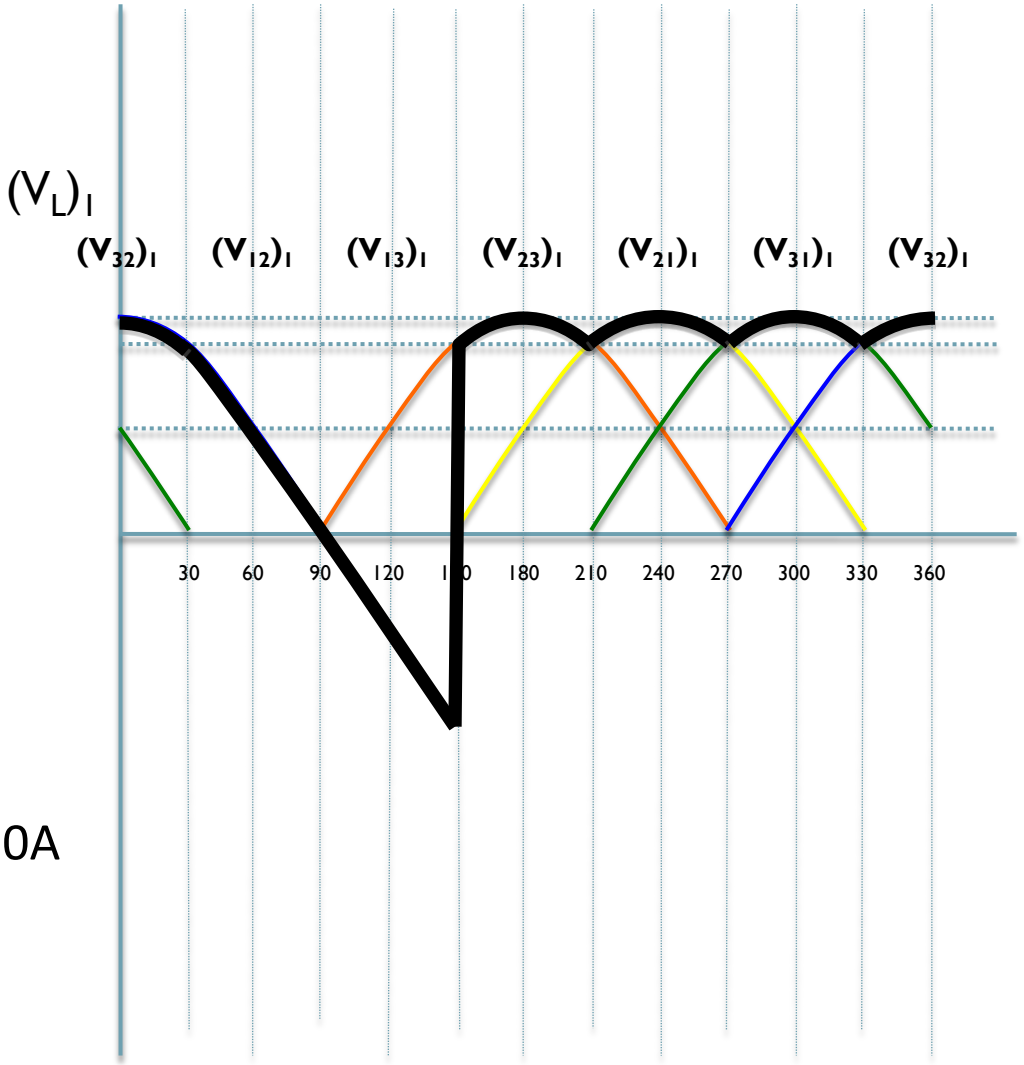
$$(\varphi_1)_1 = 66.42^0$$

$$I_{RED} = (J_1)_1 + (J_1)_2 = 2 \cdot 4.08 = 8.16A$$



Resolución apartado C





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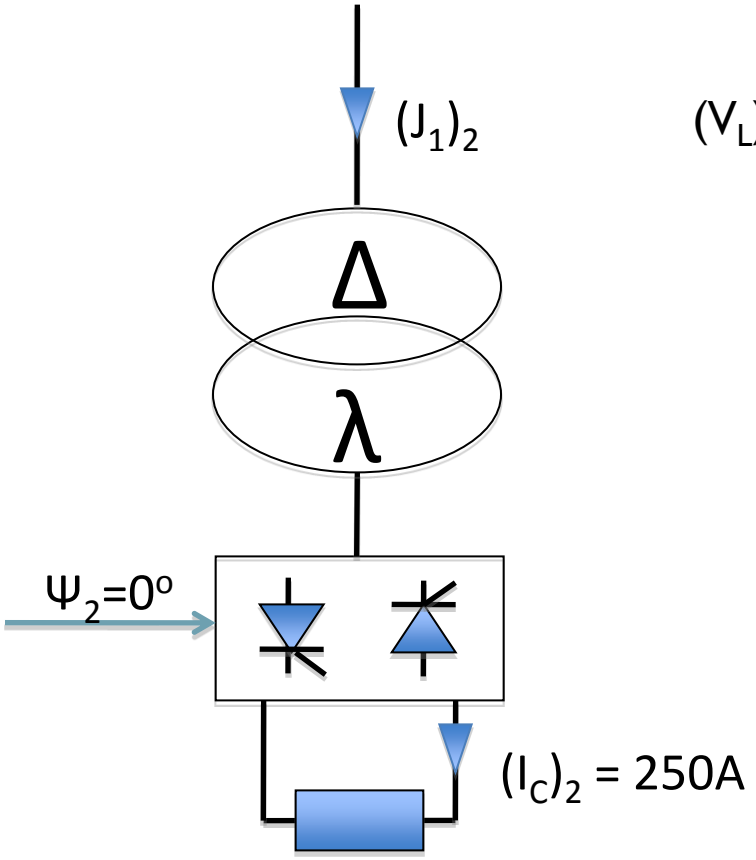
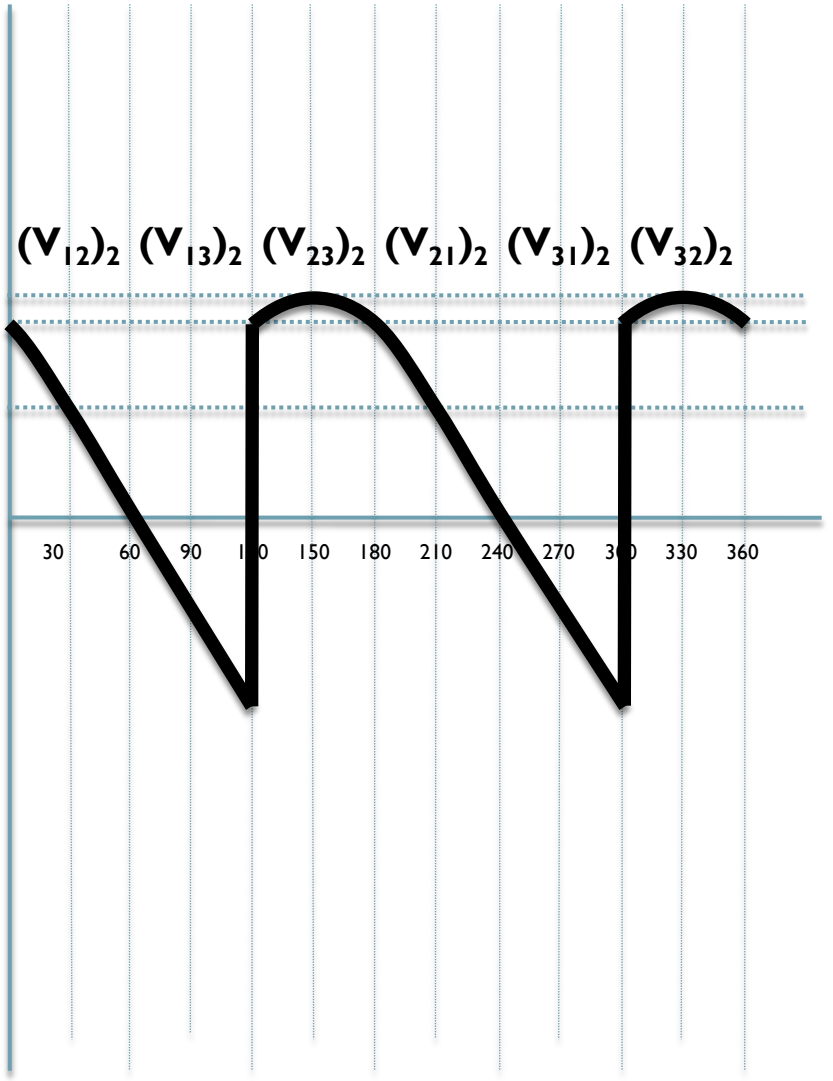
Resolución apartado C





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