Homework # 2 Solution

13.13 − 3

We have

$$v_{0s} = r_s \cdot i_{0s} + L_{ls} \cdot \frac{d}{dt} i_{0s}$$

Since i_{0s} is zero (by wye-connection) it follows that $v_{0s} = 0$

13.13-4

The negative voltage must occur when the lower diode is conducting, therefore the diode drop is 1 V
The small positive voltage must occur when the lower IGBT is conducting, therefore the switch drop is 1.5V

13.13-6

From Eqn (13.3-1), we have that

$$v_{abs} = \frac{2 \cdot \sqrt{3}}{\pi} \cdot v_{dc} \cdot \cos\left(\theta_c + \frac{\pi}{6}\right) + \frac{2 \cdot \sqrt{3}}{\pi} \cdot v_{dc} \cdot \sum_{j=1}^{\infty} \left[\frac{-1}{6 \cdot j - 1} \cdot \cos\left[(6 \cdot j - 1)\left(\theta_c + \frac{\pi}{6}\right)\right] + \frac{1}{6 \cdot j + 1} \cdot \mathrm{co}\right.$$

In the steady state, vbcs and vca are120 and 240 behind vabs. Thus we set

$$v_{bcs} = \frac{2 \cdot \sqrt{3}}{\pi} \cdot v_{dc} \cdot \cos\left(\theta_c - \frac{\pi}{2}\right) + \frac{2 \cdot \sqrt{3}}{\pi} \cdot v_{dc} \cdot \sum_{j=1}^{\infty} \left[\frac{-1}{6 \cdot j - 1} \cdot \cos\left[(6 \cdot j - 1)\left(\theta_c - \frac{\pi}{2}\right)\right] + \frac{1}{6 \cdot j + 1} \cdot \mathrm{c}\right.$$

$$v_{cas} = \frac{2 \cdot \sqrt{3}}{\pi} \cdot v_{dc} \cdot \cos\left(\theta_c + \frac{5 \cdot \pi}{6}\right) + \frac{2 \cdot \sqrt{3}}{\pi} \cdot v_{dc} \cdot \sum_{j=1}^{\infty} \left[\frac{-1}{6 \cdot j - 1} \cdot \cos\left[(6 \cdot j - 1)\left(\theta_c + \frac{5 \cdot \pi}{6}\right)\right] + \frac{1}{6 \cdot j -}\right.$$

13.13 − 9

we have:

$$-v_{ag} + v_{as} + v_{ng} = 0 \qquad (1)$$

$$-v_{bg} + v_{bs} + v_{ng} = 0 \qquad (2)$$

$$-v_{cg} + v_{cs} + v_{ng} = 0 \qquad (3)$$

$$\frac{v_{as}}{R_a} + \frac{v_{bs}}{R_b} + \frac{v_{cs}}{R_c} + 0 \qquad (4)$$

Combining (1-4)

$$\frac{v_{ag} - v_{ng}}{R_a} + \frac{v_{bg} - v_{ng}}{R_b} + \frac{v_{cg} - v_{ng}}{R_c} = 0 \qquad (5)$$

Solving (5) for the line-to-neutral voltage

$$v_{ng} = \frac{\left(v_{ag} \cdot R_b \cdot R_c + v_{bg} \cdot R_a \cdot R_c + v_{cg} \cdot R_a \cdot R_b\right)}{\left(R_b \cdot R_c + R_a \cdot R_c + R_a \cdot R_b\right)} \qquad (6)$$

Substituion of (6) into (1) and solving

$$v_{as} = R_a \cdot \frac{\left(v_{ag} \cdot R_c + v_{ag} \cdot R_b - v_{bg} \cdot R_c - v_{cg} \cdot R_b\right)}{\left(R_b \cdot R_c + R_a \cdot R_c + R_a \cdot R_b\right)} \qquad (7)$$

Problem parameters

$$v_{dc} := 100$$

$$R_a := 2 \qquad R_b := 4 \qquad R_c := 4$$

Now lets make a function of it

$$v_{ag}(\theta_c) := \text{if}\left(\cos(\theta_c) > 0, v_{dc}, 0\right)$$

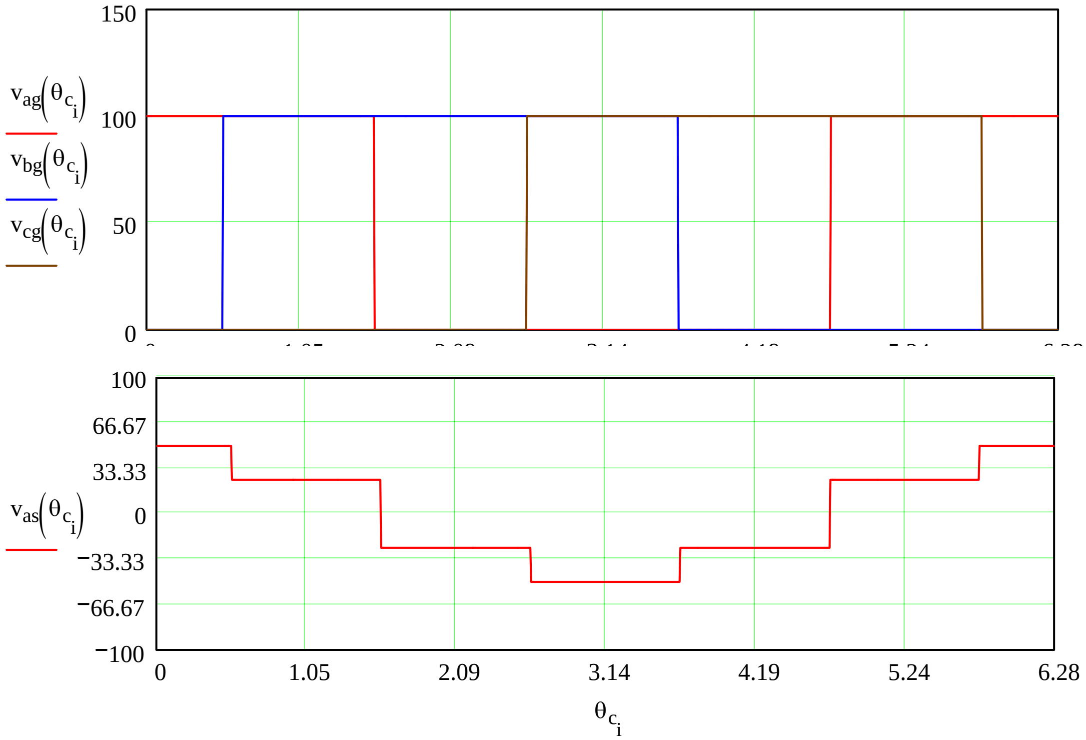
$$v_{bg}(\theta_c) := \text{if}\left(\cos\left(\theta_c - \frac{2 \cdot \pi}{3}\right) > 0, v_{dc}, 0.0\right)$$

$$v_{cg}(\theta_c) := \text{if}\left(\cos\left(\theta_c + \frac{2 \cdot \pi}{3}\right) > 0, v_{dc}, 0.0\right)$$

$$v_{as}(\theta_c) := R_a \cdot \frac{\left(v_{ag}(\theta_c) \cdot R_c + v_{ag}(\theta_c) \cdot R_b - v_{bg}(\theta_c) \cdot R_c - v_{cg}(\theta_c) \cdot R_b\right)}{\left(R_b \cdot R_c + R_a \cdot R_c + R_a \cdot R_b\right)}$$

$$N := 1000 \qquad i := 0 .. N - 1$$

$$\theta_{c_i} := \frac{i}{N - 1} \cdot 2 \cdot \pi$$



150
100
50
0
$v_{ag}(\theta_{c_i})$
$v_{bg}(\theta_{c_i})$
$v_{cg}(\theta_{c_i})$
100
66.67
33.33
0
−33.33
−66.67
−100
$v_{as}(\theta_{c_i})$
0
1.05
2.09
3.14
4.19
5.24
6.28
θ_{c_i}

13.3 − 10

$v_{ttl} := 5.0$

$v_{thresh} := 3.4$

$R := 1000$

$t_{delay} := 1.5 \cdot 10^{-6}$

Following a turn on, the voltage at the input node of the and gate will be described by

$$v = v_{ttl}\left(1 - e^{\frac{-t}{R \cdot C}}\right)$$

$$v_{thresh} = v_{ttl}\left(1 - e^{\frac{-t_{delay}}{R \cdot C}}\right)$$

$$\ln\left(1 - \frac{v_{thresh}}{v_{ttl}}\right) = \frac{-t_{delay}}{R \cdot C}$$

$$C := \frac{-t_{delay}}{\left[\ln\left[\frac{(v_{ttl} - v_{thresh})}{v_{ttl}}\right] \cdot R\right]}$$

$C = 1.316 \times 10^{-9}$

13.13 − 14

We have

$$v_{dc} := 100$$

We want

$$v_{qsr} := 50$$

$$v_{dsr} := 10$$

Now, in the converter reference frame we have that

$$v_{qsc} = \frac{1}{2} d \cdot v_{dc}$$

$$v_{dsc} = 0$$

From the frame to frame transformation

$$\begin{pmatrix} v_{qsr} \\ v_{dsr} \end{pmatrix} = \begin{pmatrix} \cos(\theta_{rc}) & -\sin(\theta_{rc}) \\ \sin(\theta_{rc}) & \cos(\theta_{rc}) \end{pmatrix} \cdot \begin{pmatrix} \frac{1}{2} d \cdot v_{dsc} \\ 0 \end{pmatrix}$$

Thus

$$v_{qsr} + j \cdot v_{dsr} = \frac{1}{2} \cdot d \cdot v_{dc} \cdot e^{j\theta_{rc}}$$

So

$$d := \frac{2}{v_{dc}} \cdot \sqrt{{v_{qsr}}^2 + {v_{dsr}}^2} \qquad d = 1.02$$

$$\theta_{rc} := \arg\left(v_{qsr} + j \cdot v_{dsr}\right) \qquad \theta_{rc} = 0.197$$

$$\theta_r = \theta_c - \theta_{rc}$$