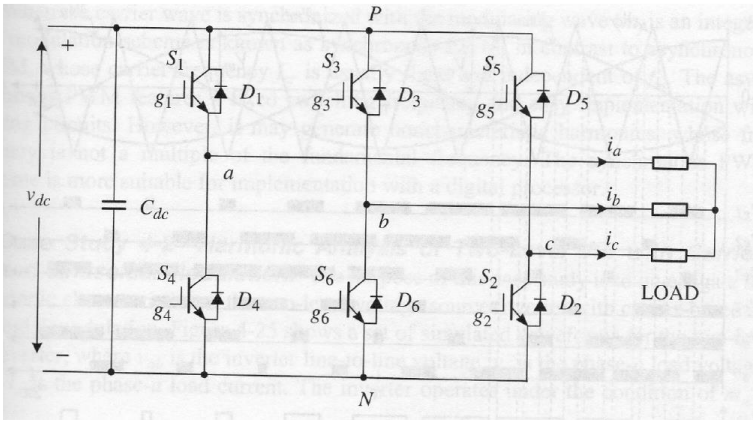
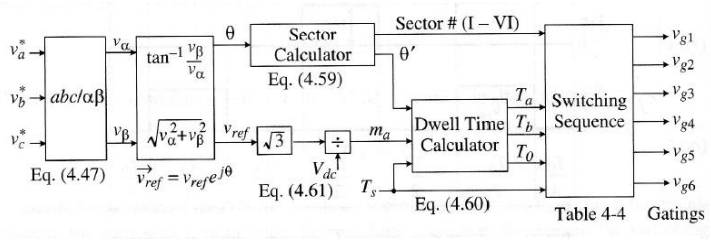
EE 459/559, Homework #5, Due Monday, March 24, 2014

Consider a two-level voltage source inverter shown below.



The inverter is connected to a three phase balanced RL load, and its DC voltage is 1220 volts. The inverter is modulated by space vector modulation and its simulation algorithm is given in the figure below ("Table 4-4" is the table to the right).



Sector	Switching Sequence						
I	$\vec{V}_0$	$\vec{V}_1$	$\vec{V}_2$	$\vec{V}_0$	$\vec{V}_2$	$\vec{V}_1$	$\vec{V}_0$
	000	100	110	111	110	100	000
II	$\vec{V}_0$	$\vec{V}_3$	$\vec{V}_2$	$\vec{V}_0$	$\vec{V}_2$	$\vec{V}_3$	$\vec{V}_0$
	000	010	110	111	110	010	000
III	$\vec{V}_0$	$\vec{V}_3$	$\vec{V}_4$	$\vec{V}_0$	$\vec{V}_4$	$\vec{V}_3$	$\vec{V}_0$
	000	010	011	111	011	010	000
IV	$\vec{V}_0$	$\vec{V}_5$	$\vec{V}_4$	$\vec{V}_0$	$\vec{V}_4$	$\vec{V}_5$	$\vec{V}_0$
	000	001	011	111	011	001	000
V	$\vec{V}_0$	$\vec{V}_5$	$\vec{V}_6$	$\vec{V}_0$	$\vec{V}_6$	$\vec{V}_5$	$\vec{V}_0$
	000	001	101	111	101	001	000
VI	$\vec{V}_0$	$\vec{V}_1$	$\vec{V}_6$	$\vec{V}_0$	$\vec{V}_6$	$\vec{V}_1$	$\vec{V}_0$
	000	100	101	111	101	100	000

The switching frequency f the converter is 720Hz. At a given instance of time, the three-phase reference voltages v_a*, v_b*, and v_c*, are found to be 398.37 volts, 145.81 volts, and -544.18 volts, respectively. Determine the following:

a. The α-β components of the three-phase reference voltages.
b. The angle of the reference voltage vector and sector number.
c. The reference voltage vector and modulation index.
d. The dwell times.
e. Three stationary space vectors that are used to synthesize the reference voltage vector v_{ref}.

Solution:

a. The α-β components of the three-phase reference voltages;

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} 398.37 \\ 145.81 \\ -544.18 \end{bmatrix} = \begin{bmatrix} 398.37 \\ 398.37 \end{bmatrix}$$

b. The angle of the reference voltage vector and its corresponding sector number;

$$\theta = \tan^{-1}\frac{v_\beta}{v_\alpha} = \tan^{-1}\frac{398.37}{398.37} = 45°$$

It will be in sector I

c. The reference voltage vector magnitude and the modulation index;

$$v_{ref} = \sqrt{v_\alpha^2 + v_\beta^2} = \sqrt{398.37^2 + 398.37^2} = 563.38$$

$$m_a = \frac{\sqrt{3} v_{ref}}{V_{DC}} = \frac{\sqrt{3}(563.38)}{1220} = 0.8$$

d. The dwell times;

Note that with sampling frequency = 720Hz, T_s=1/720=0.0014sec

$$T_a = \frac{\sqrt{3} v_{ref} T_S}{V_{DC}} \sin\left(\frac{\pi}{3} - \theta\right) = \frac{\sqrt{3} * 563.38 * 0.0014}{1220} \sin\left(\frac{\pi}{3} - \frac{\pi}{4}\right) = 0.0011 * .2588 = 0.00028468$$

$$T_b = \frac{\sqrt{3} v_{ref} T_S}{V_{DC}} \sin\theta = \frac{\sqrt{3} * 563.38 * 0.0014}{1220} (.707) = 0.0007854$$

$$T_0 = T_S - T_a - T_b = 1/720 - .00028468 - .0007854 = 0.00031881$$

e. The three stationary space vectors that are used to synthesize the reference voltage vector.

Since the reference vector is in sector I, it should be synthesized by V_1, V_2, and V_0, where

$$\underline{V}_1 = \frac{2}{3} V_{DC} \angle 0° = \frac{2}{3} 1220 \angle 0° = 813.33 \angle 0°$$

$$\underline{V}_2 = \frac{2}{3} V_{DC} \angle 60° = \frac{2}{3} 1220 \angle 60° = 813.33 \angle 60°$$

$$\underline{V}_0 = 0$$