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).

The switching frequency of 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 \( \alpha - \beta \) 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 \( v_{\text{ref}} \).

**Solution:**

a. The \( \alpha - \beta \) components of the three-phase reference voltages;

\[
\begin{bmatrix}
  v_{\alpha} \\
  v_{\beta}
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
  1 & -1/2 & -1/2 \\
  0 & \sqrt{3}/2 & -\sqrt{3}/2 \\
\end{bmatrix} \begin{bmatrix}
  v_{a} \\
  v_{b} \\
  v_{c}
\end{bmatrix} = \frac{2}{3} \begin{bmatrix}
  1 & -1/2 & -1/2 \\
  0 & \sqrt{3}/2 & -\sqrt{3}/2 \\
\end{bmatrix} \begin{bmatrix}
  398.37 \\
  145.81 \\
  -544.18
\end{bmatrix} = \begin{bmatrix}
  398.37 \\
  145.81 \\
  -544.18
\end{bmatrix}
\]

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

\[
\theta = \tan^{-1} \frac{v_{\beta}}{v_{\alpha}} = \tan^{-1} \frac{398.37}{398.37} = 45^\circ
\]

It will be in sector I

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

The switching sequence is:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Switching Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>000 100 111 110 111 111</td>
</tr>
<tr>
<td>II</td>
<td>000 010 111 111 011 011</td>
</tr>
<tr>
<td>III</td>
<td>000 110 111 111 111 011</td>
</tr>
<tr>
<td>IV</td>
<td>000 010 111 111 011 011</td>
</tr>
<tr>
<td>V</td>
<td>000 001 111 111 011 011</td>
</tr>
<tr>
<td>VI</td>
<td>000 001 011 111 011 011</td>
</tr>
</tbody>
</table>

The table above provides the switching sequences for each sector.
\[ v_{ref} = \sqrt{v_x^2 + v_y^2} = \sqrt{398.37^2 + 398.37^2} = 563.38 \]

\[ m_a = \frac{\sqrt{3}v_{ref}}{V_{DC}} = \frac{\sqrt{3} \times 563.38}{1220} = 0.8 \]

d. The dwell times;
Note that with sampling frequency = 720Hz, \( T_s = 1/720 = 0.0014 \text{sec} \)
\[ T_a = \frac{\sqrt{3}v_{ref}T_s}{V_{DC}} \sin \left( \frac{\pi}{3} - \theta \right) = \frac{\sqrt{3} \times 563.38 \times 0.0014}{1220} \sin \left( \frac{\pi}{3} - \frac{\pi}{4} \right) = 0.0011 \times 0.2588 = 0.00028468 \]
\[ T_b = \frac{\sqrt{3}v_{ref}T_s}{V_{DC}} \sin \theta = \frac{\sqrt{3} \times 563.38 \times 0.0014}{1220} (0.707) = 0.0007854 \]
\[ T_0 = T_s - T_a - T_b = 1/720 - 0.00028468 - 0.0007854 = 0.00031881 \]

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
\[ V_1 = \frac{2}{3} V_{DC} \angle 0^\circ = \frac{2}{3} 1220 \angle 0^\circ = 813.33 \angle 0^\circ \]
\[ V_2 = \frac{2}{3} V_{DC} \angle 60^\circ = \frac{2}{3} 1220 \angle 60^\circ = 813.33 \angle 60^\circ \]
\[ V_0 = 0 \]