Direct AC/AC Matrix Converters

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Matrix Converters

- have received considerable attention in recent years
- may become a good alternative to PWM-VSI topology

- Bi-directional power flow
- Sinusoidal input/output waveforms
- Controllable input power factor
- Compact design, due to the lack of dc-link capacitors for energy storage

Topology complexity of the matrix converter makes study a hard task.
Space Vector Modulation (SVM) algorithm

SVM completely exploit the possibility of matrix converters to
• control the input power factor regardless the output power factor
• fully utilize the input voltages
• reduce the number of switch commutations in each cycle period.

SVM allows an immediate comprehension of the modulation process
• without the need for a fictitious DC link
• avoiding the addition of the third harmonic components.
Switching Configurations

$2^9 = 512$ Available

27 Possible

$21 = 18 + 3$ usefully employed

Active Configurations
Determine an output voltage vector $\bar{v}_o$, and an input current vector $\bar{i}_i$, having fixed directions

Zero Configurations
Determine zero input current and zero output voltage vectors
Switching Configurations Employed

<table>
<thead>
<tr>
<th>Switching configuration list</th>
<th>Switches On</th>
<th>(v_o)</th>
<th>(\alpha_o)</th>
<th>(i_i)</th>
<th>(\beta_i)</th>
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<td>(S_{11})  (S_{22}) (S_{32})</td>
<td>(2/3\ v_{12i})</td>
<td>0</td>
<td>(2/\sqrt{3}\ i_{o1})</td>
<td>(-\pi/6)</td>
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</tbody>
</table>

**Active configurations**

**Zero configurations**
Output Voltage and Input Current Space Vectors

Sectors and directions of the output line-to-neutral voltage vectors.

Sectors and directions of the input current vectors.
At any sampling instant
\( \overline{v}_o \) and \( \phi_i \) are known (reference quantities)

\( \overline{v}_i \) is imposed by the source (known by measurements)

**SVM Algorithm** is based on the selection of 4 active configurations that are applied for suitable time intervals within each cycle period \( T_c \).

The zero configurations are applied to complete \( T_c \).

The control of \( \phi_i \) can be achieved by controlling the phase angle \( \beta_i \) of the input current vector.
### SVM algorithm

Selection of the active switching configurations for each combination of
- **output voltage sector**
- **input current sector**
SVM Algorithm

Basic equations of the SVM algorithm

\[
\begin{align*}
\vec{v}_o' &= \vec{v}_o^I \delta^I + \vec{v}_o^I \delta^II = \frac{2}{\sqrt{3}} v_o \cos(\bar{\alpha}_o - \frac{\pi}{3}) e^{j[(K_v-1)\pi/3 + \pi/3]} \\
\vec{v}_o'' &= \vec{v}_o^III + \vec{v}_o^IV \delta^IV = \frac{2}{\sqrt{3}} v_o \cos(\bar{\alpha}_o + \frac{\pi}{3}) e^{j[(K_v-1)\pi/3]} \\
(\vec{i}_i^I \delta^I + \vec{i}_i^II \delta^II) \cdot j e^{j\beta_i} e^{j(K_i-1)\pi/3} &= 0 \\
(\vec{i}_i^III + \vec{i}_i^IV \delta^IV) \cdot j e^{j\beta_i} e^{j(K_i-1)\pi/3} &= 0
\end{align*}
\]

To satisfy to the requirements of the
- reference output voltage vector
- input current displacement angle.
SVM Algorithm

Solutions of the Basic Equations

\[
\delta^I = (-1)^{K_v+K_i} \frac{2}{\sqrt{3}} q \frac{\cos(\widetilde{\alpha}_o - \pi/3) \cos(\widetilde{\beta}_i - \pi/3)}{\cos \phi_i} \\
\delta^{II} = (-1)^{K_v+K_i+1} \frac{2}{\sqrt{3}} q \frac{\cos(\widetilde{\alpha}_o - \pi/3) \cos(\widetilde{\beta}_i + \pi/3)}{\cos \phi_i} \\
\delta^{III} = (-1)^{K_v+K_i+1} \frac{2}{\sqrt{3}} q \frac{\cos(\widetilde{\alpha}_o + \pi/3) \cos(\widetilde{\beta}_i - \pi/3)}{\cos \phi_i} \\
\delta^{IV} = (-1)^{K_v+K_i} \frac{2}{\sqrt{3}} q \frac{\cos(\widetilde{\alpha}_o + \pi/3) \cos(\widetilde{\beta}_i + \pi/3)}{\cos \phi_i}
\]

Applied for any combination of
- output voltage sector \(K_v\)
- input current sector \(K_i\)
SVM Algorithm

For the feasibility of the control strategy.

\[ |\delta^I| + |\delta^{II}| + |\delta^{III}| + |\delta^{IV}| \leq 1 \]

Otherwise: the instantaneous values of the input voltages do not allow to satisfy the requirements of output voltage and input power factor.