Direct AC/AC Matrix Converters

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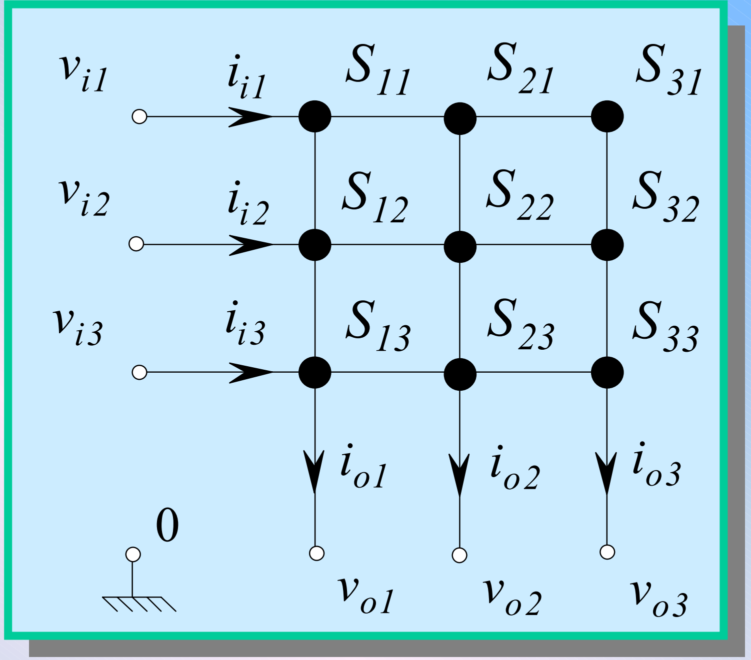
Matrix Converters

- ***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**



Basic scheme of matrix converters.

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

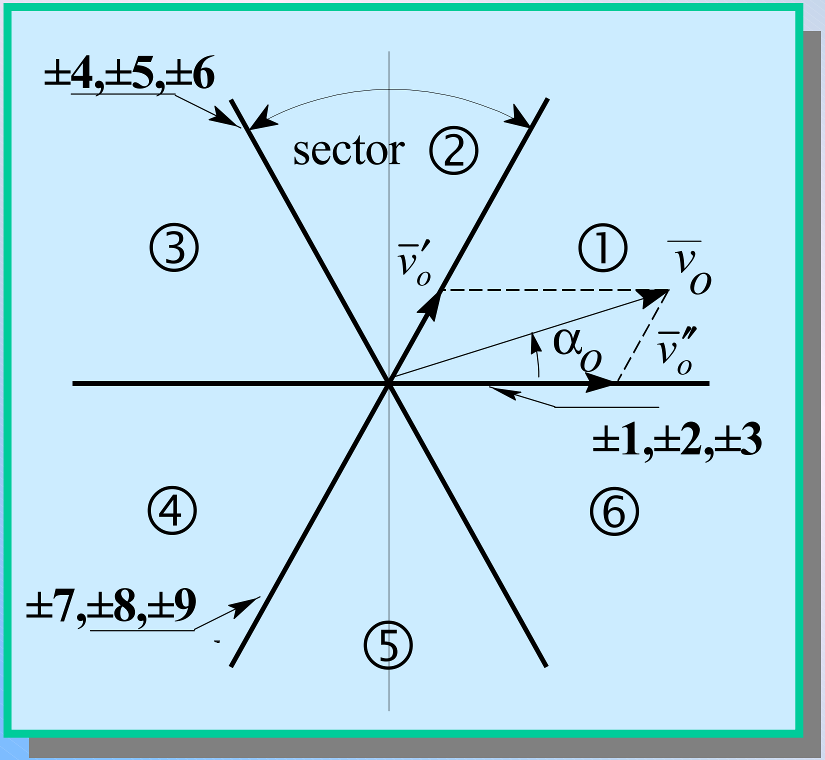
Switching Configurations Employed

Switching configuration list	Switches On			v_o	α_o	i_i	β_i
+1	S_{11}	S_{22}	S_{32}	$2/3\ v_{12i}$	0	$2/\sqrt{3}\ i_{o1}$	$-\pi/6$
–1	S_{12}	S_{21}	S_{31}	$-2/3\ v_{12i}$	0	$-2/\sqrt{3}\ i_{o1}$	$-\pi/6$
+2	S_{12}	S_{23}	S_{33}	$2/3\ v_{23i}$	0	$2/\sqrt{3}\ i_{o1}$	$\pi/2$
–2	S_{13}	S_{22}	S_{32}	$-2/3\ v_{23i}$	0	$-2/\sqrt{3}\ i_{o1}$	$\pi/2$
+3	S_{13}	S_{21}	S_{31}	$2/3\ v_{31i}$	0	$2/\sqrt{3}\ i_{o1}$	$7\pi/6$
–3	S_{11}	S_{23}	S_{33}	$-2/3\ v_{31i}$	0	$-2/\sqrt{3}\ i_{o1}$	$7\pi/6$
+4	S_{12}	S_{21}	S_{32}	$2/3\ v_{12i}$	$2\pi/3$	$2/\sqrt{3}\ i_{o2}$	$-\pi/6$
–4	S_{11}	S_{22}	S_{31}	$-2/3\ v_{12i}$	$2\pi/3$	$-2/\sqrt{3}\ i_{o2}$	$-\pi/6$
+5	S_{13}	S_{22}	S_{33}	[illegible]	[illegible]	[illegible]	[illegible]
–5	S_{12}	S_{23}	S_{32}	[illegible]	[illegible]	[illegible]	[illegible]
+6	S_{11}	S_{23}	S_{31}	$2/3\ v_{31i}$	$2\pi/3$	$2/\sqrt{3}\ i_{o2}$	$7\pi/6$
–6	S_{13}	S_{21}	S_{33}	$-2/3\ v_{31i}$	$2\pi/3$	$-2/\sqrt{3}\ i_{o2}$	$7\pi/6$
+7	S_{12}	S_{22}	S_{31}	$2/3\ v_{12i}$	$4\pi/3$	$2/\sqrt{3}\ i_{o3}$	$-\pi/6$
–7	S_{11}	S_{21}	S_{32}	$-2/3\ v_{12i}$	$4\pi/3$	$-2/\sqrt{3}\ i_{o3}$	$-\pi/6$
+8	S_{13}	S_{23}	S_{32}	$2/3\ v_{23i}$	$4\pi/3$	$2/\sqrt{3}\ i_{o3}$	$\pi/2$
–8	S_{12}	S_{22}	S_{33}	$-2/3\ v_{23i}$	$4\pi/3$	$-2/\sqrt{3}\ i_{o3}$	$\pi/2$
+9	S_{11}	S_{21}	S_{33}	$2/3\ v_{31i}$	$4\pi/3$	$2/\sqrt{3}\ i_{o3}$	$7\pi/6$
–9	S_{13}	S_{23}	S_{31}	$-2/3\ v_{31i}$	$4\pi/3$	$-2/\sqrt{3}\ i_{o3}$	$7\pi/6$
0_1	S_{11}	S_{21}	S_{31}	[illegible]	[illegible]	[illegible]	[illegible]
0_2	S_{12}	S_{22}	S_{32}	[illegible]	[illegible]	[illegible]	[illegible]
0_3	S_{13}	S_{23}	S_{33}	[illegible]	[illegible]	[illegible]	[illegible]

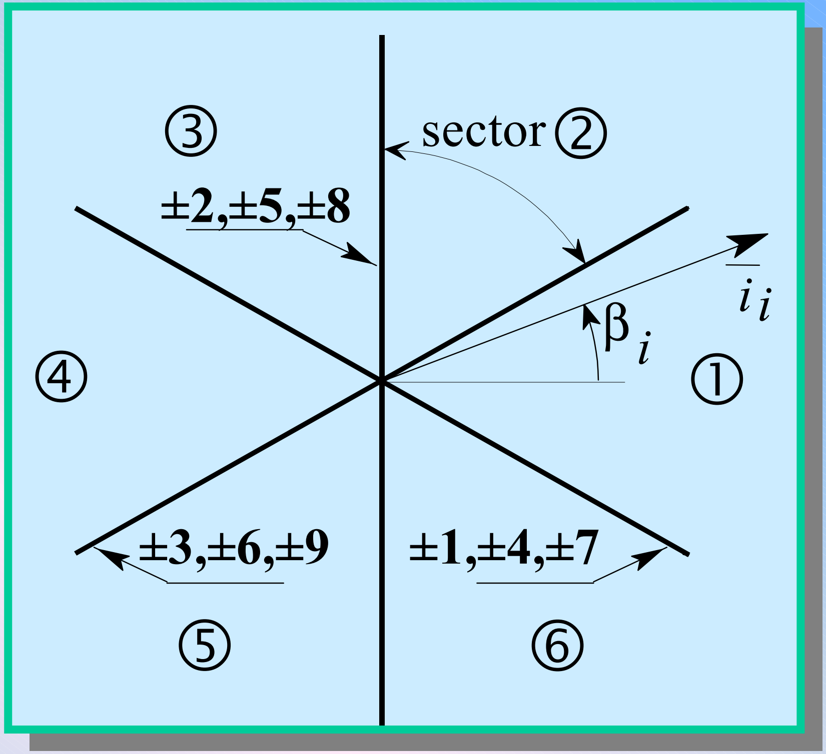
18 *Active configurations*

3 *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**.*

SVM Algorithm

At any sampling instant

$\bar{v}_o$ and φ_i are known (reference quantities)

$\bar{v}_i$ 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 φ_i *can be achieved by controlling the phase angle* β_i *of the input current vector.*

SVM algorithm

		Sector of the output voltage vector (K_v)											
		1 or 4				2 or 5				3 or 6			
Sector of the input current vector (K_i)	1 or 4	+9	+7	+3	+1	+6	+4	+9	+7	+3	+1	+6	+4
	2 or 5	+8	+9	+2	+3	+5	+6	+8	+9	+2	+3	+5	+6
	3 or 6	+7	+8	+1	+2	+4	+5	+7	+8	+1	+2	+4	+5
		I	II	III	IV	I	II	III	IV	I	II	III	IV

Selection of the active switching configurations for each combination of

- **output voltage sector**
- **input current sector**

Basic equations of the SVM algorithm

$$\bar{v}_o' = \bar{v}_o^I \delta^I + \bar{v}_o^{II} \delta^{II} = \frac{2}{\sqrt{3}} v_o \cos(\tilde{\alpha}_o - \frac{\pi}{3}) e^{j[(K_v - 1)\pi/3 + \pi/3]}$$

$$\bar{v}_o'' = \bar{v}_o^{III} \delta^{III} + \bar{v}_o^{IV} \delta^{IV} = \frac{2}{\sqrt{3}} v_o \cos(\tilde{\alpha}_o + \frac{\pi}{3}) e^{j[(K_v - 1)\pi/3]}$$

$$\left(\bar{i}_i^I \delta^I + \bar{i}_i^{II} \delta^{II}\right) \cdot j e^{j\tilde{\beta}_i} e^{j(K_i - 1)\pi/3} = 0$$

$$\left(\bar{i}_i^{III} \delta^{III} + \bar{i}_i^{IV} \delta^{IV}\right) \cdot j e^{j\tilde{\beta}_i} e^{j(K_i - 1)\pi/3} = 0$$

To satisfy to the requirements of the

- reference output voltage vector
- input current displacement angle.

SVM Algorithm

Solutions of the Basic Equations

$$\delta^{I} = (-1)^{K_v + K_i} \frac{2}{\sqrt{3}} q \frac{\cos(\tilde{\alpha}_o - \pi/3)\cos(\tilde{\beta}_i - \pi/3)}{\cos\varphi_i}$$

$$\delta^{II} = (-1)^{K_v + K_i + 1} \frac{2}{\sqrt{3}} q \frac{\cos(\tilde{\alpha}_o - \pi/3)\cos(\tilde{\beta}_i + \pi/3)}{\cos\varphi_i}$$

$$\delta^{III} = (-1)^{K_v + K_i + 1} \frac{2}{\sqrt{3}} q \frac{\cos(\tilde{\alpha}_o + \pi/3)\cos(\tilde{\beta}_i - \pi/3)}{\cos\varphi_i}$$

$$\delta^{IV} = (-1)^{K_v + K_i} \frac{2}{\sqrt{3}} q \frac{\cos(\tilde{\alpha}_o + \pi/3)\cos(\tilde{\beta}_i + \pi/3)}{\cos\varphi_i}$$

Applied for any combination of

- output voltage sector K_v
- input current sector K_i

SVM Algorithm

For the feasibility of the control strategy.

$$\left|\delta^{I}\right| + \left|\delta^{II}\right| + \left|\delta^{III}\right| + \left|\delta^{IV}\right| \leq 1$$

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