DC to AC converters

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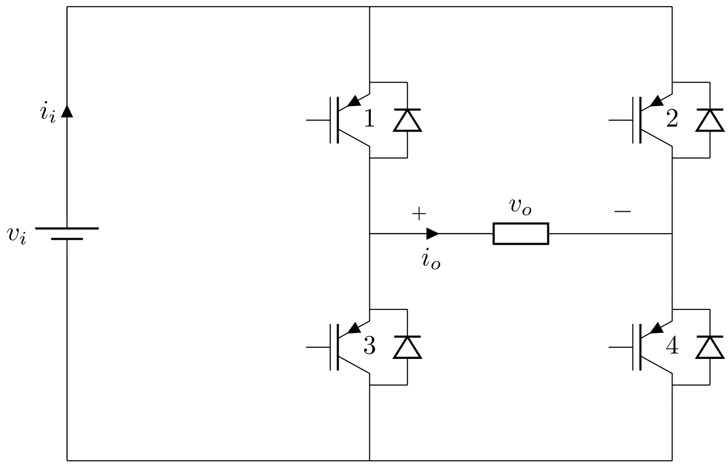
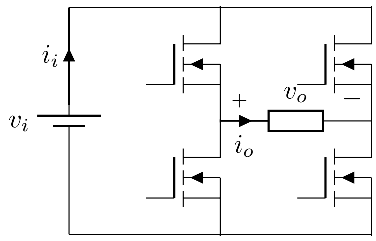
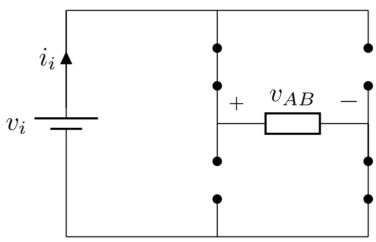
1 DC to AC converters

1.1 Full bridge circuit



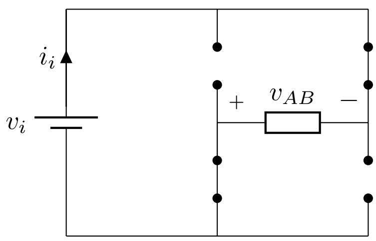


Direct polarization of the load. S1 and S4



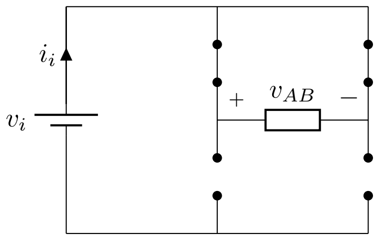
$$v_{AB} = V_i$$

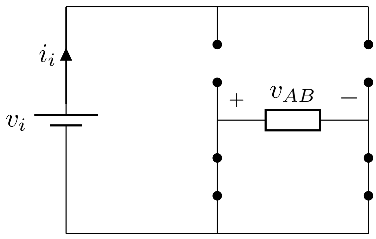
Inverse polarization of the load. S2 and S3



$$v_{AB} = -V_i$$

Grounding. S1 and S3 OR S2 and S4





$$v_{AB} = 0$$

Shorting the source. The two switches of a branch cannot be closed at the same time because it would short the source. That's the reason why same-branch switch control signals have to be complementary:

$$S1 = \bar{S}3$$
$$S2 = \bar{S}4$$

i_o and v_o phase shift If a phase shift φ exists between output voltage and current, the diodes in the bridge start conducting the current in some moments of the period.

RLC/RL Load If an RLC or RL load is connected to the inverter

- i_o can be considered perfectly sinusoidal as an analysis hypothesis.
- A phase-shift φ may appear and the diodes would conduct current.

2 Non modulated control

2.1 Square wave control

Control signals

Conducting devices When i_o is shifted φ from the voltage v_o:

- if v_o and i_o have the same sign, the IGBT are conducting the current.
- if v_o and i_o have the different sign, the diodes are conducting the current.

The 4 regions are

1. D4, D1

2. S1, S4
3. D1, D3
4. S1, S4

Output current

- when the IGBTs are conducting, current is leaving the source, $i_i > 0$.
- when the diodes are conducting, current is entering the source, $i_i < 0$.

The output current mean value can be calculated with the following integral:

$$
\begin{aligned}
\bar{i_i} &= \frac{1}{T} \int_{t}^{t+T} A \sin(\omega t)\, d\omega t \\
&= \frac{A}{\pi} \Big[-\cos(\omega t) \Big]_{\pi-\varphi}^{-\varphi} \\
&= \frac{A}{\pi} \Big[-\cos(\pi-\varphi) + \cos(-\varphi) \Big] \\
&= \frac{A}{\pi} \Big[-(\cos(\pi)\cos(\varphi) + \sin(\pi)\sin(\varphi)) + \cos(-\varphi) \Big] \\
&= \frac{A}{\pi} \Big[\cos(\varphi) + \cos(-\varphi) \Big] \\
&= \frac{2A}{\pi} \cos(\varphi)
\end{aligned}
$$

2.2 Phase shift control

Control signals

Conducting devices When i_o is shifted φ from the voltage v_o:

- if $v_o \neq 0$, v_o and i_o have the same sign, the IGBT are conducting the current.
- if $v_o \neq 0$, v_o and i_o have the different sign, the diodes are conducting the current.
- if $v_o = 0$, a pair diode-IGBT is conducting the current.

The 6 regions are

1. diodes
2. igbts
3. S1 and D2
4. diodes

5. igbts
6. D4 and S3

Output current

- when the IGBTs are conducting, current is leaving the source, $i_i > 0$.
- when the diodes are conducting, current is entering the source, $i_i < 0$.
- when a IGBT-diode pair is conducting, no current leaves or enter the source, $i_i = 0$.

3 PWM control

Modulation parameters:

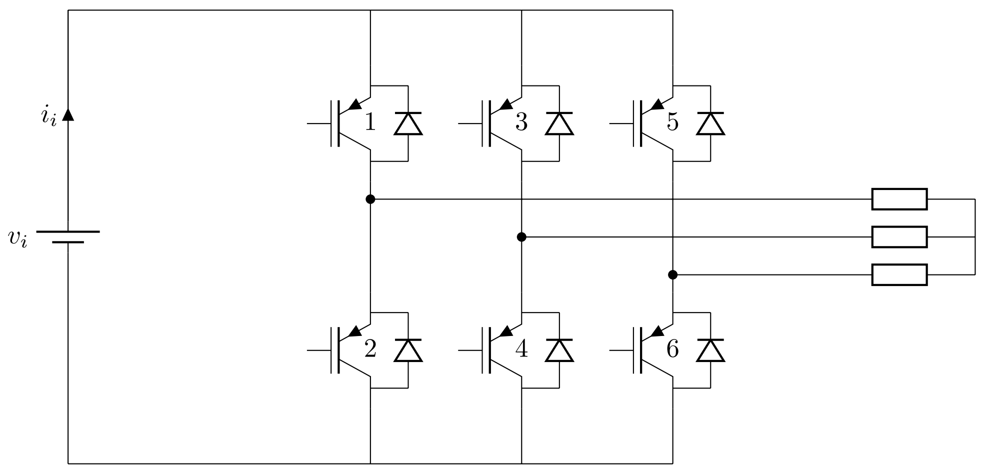
$$m_a = \frac{V_{sin}}{V_{tri}} < 1$$

$$m_f = \frac{T_{sin}}{T_{tri}} = \frac{f_{tri}}{f_{sin}} > 1$$

3.1 Unipolar PWM

3.2 Bipolar PWM

4 Triphasic inverters



4.1 Non modulated control

Control

- Same-branch switches are complementary.
- Each switch conducts for 180 degrees and then opens for other 180 degrees.
- Branches are phase-shifted 120 degrees between them.

4.2 PWM control

Control

5 Inverter amplitudes tables

PWM Sinusoidal Unipolar. Normalized amplitudes, V_n/V_{DC}

m_a	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
$n = 1$	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
$n = 2mf + -1$	0.10	0.19	0.27	0.33	0.36	0.37	0.35	0.31	0.25	0.18
n= 2mf+-3	0.00	0.00	0.01	0.02	0.04	0.07	0.10	0.14	0.18	0.21

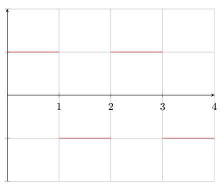
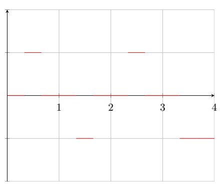
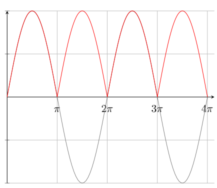
PWM Sinusoidal Bipolar. Normalized amplitudes, V_n/V_{max}

m_a	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
$n = 1$	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
$n = mf$	1.27	1.24	1.20	1.15	1.08	1.01	0.92	0.82	0.71	0.60
$n = mf + -2$	0.00	0.02	0.03	0.06	0.09	0.13	0.17	0.22	0.27	0.32

PWM Sinusoidal Triphasic. Normalized amplitudes, V_n/V_{DC} (line tension)

m_a	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
$n = 1$	0.087	0.173	0.260	0.346	0.433	0.520	0.606	0.693	0.779	0.866
$n = mf + -2$	0.003	0.013	0.030	0.053	0.801	0.114	0.150	0.190	0.232	0.275
$n = 2mf + -1$	0.086	0.165	0.232	0.282	0.313	0.321	0.307	0.272	0.221	0.157

Fourier series table

Function	Fourier Series
	$\frac{4}{\pi}\left(\frac{\sin(t)}{1}+\frac{\sin(3t)}{3}+\frac{\sin(5t)}{5}+...\right)$
	$\frac{4}{\pi}\left(\frac{\sin(t)\cos(\beta)}{1}+\frac{\sin(3t)\cos(3\beta)}{3}+\frac{\sin(5t)\cos(5\beta)}{5}+...\right)$
	$\frac{2}{\pi}-\frac{4}{\pi}\left(\frac{\sin(t)}{1\cdot 3}+\frac{\sin(2t)}{3\cdot 5}+\frac{\sin(3t)}{5\cdot 7}+...\right)$