Siemens VSC Technology
Voltage Source Converter
Two Level VSC (Phase Module)
Voltage Source Converter
Three Level VSC (Phase Module)

Power Transmission and Distribution
Voltage Source Converter
Two Level VSC (Phase Module)

Power Transmission and Distribution
Voltage Source Converter
Three Level VSC (Phase Module)

\[
\begin{align*}
V_{d/2} & \quad M \\
\frac{V_{d}}{2} & \quad -
\end{align*}
\]

\[
V_{ac}
\]

\[
V_{ac} \quad \frac{V_{d}}{2}
\]

\[
- \frac{V_{d}}{2}
\]
# Valve Technology

## 2-Level versus 3-Level Converter (I)

### Converter AC Voltage

<table>
<thead>
<tr>
<th></th>
<th>2-Level</th>
<th>3-Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmonics (THD)</td>
<td>100 %</td>
<td>approx. 50 %</td>
</tr>
<tr>
<td>du/dt</td>
<td>100 %</td>
<td>50 %</td>
</tr>
</tbody>
</table>

### Design

<table>
<thead>
<tr>
<th></th>
<th>2-Level</th>
<th>3-Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve Modules</td>
<td>1 type</td>
<td>3 different types</td>
</tr>
<tr>
<td>Construction</td>
<td>compact</td>
<td>less compact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(mid-point clamping)</td>
</tr>
</tbody>
</table>

### Control

<table>
<thead>
<tr>
<th></th>
<th>2-Level</th>
<th>3-Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VSC standard</td>
<td>special control algorithms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(mid-point potential)</td>
</tr>
<tr>
<td></td>
<td>2-Level</td>
<td>3-Level</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td><strong>Footprint</strong></td>
<td>smaller</td>
<td>larger</td>
</tr>
<tr>
<td><strong>Losses</strong></td>
<td>100%</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Investment Costs</strong></td>
<td>smaller</td>
<td>larger</td>
</tr>
</tbody>
</table>
Siemens Valve Technology
IGBT Converter - Protection

DC Voltage Limitation
- Special control algorithms
- DC Chopper
- Discharging device and converter trip

Converter Current Limitation
- Special control algorithms
- Peak current control using high transient switching frequency (>1 kHz)
- Converter trip
Siemens VSC Technology
HD GTO Converter Protection

DC Voltage Limitation
- Special control algorithms
- DC Chopper
- Discharging device and converter trip

Converter Current Limitation
- Special control algorithms
- Peak current control using high transient switching frequency (1 kHz)
- Converter trip
Siemens VSC Technology
HD GTO

HD-GTO

Nominal Data

\[ V_{DRM} \quad 4500 \, V \quad I_{TQRM} \quad 4000 \, A \]

Characteristic data for continuous operation

\[
\begin{align*}
V_{\text{max}} & \quad 2800 \, V_{\text{ripple}} (*) & I_{\text{max}} & \quad 3000 \, A_{\text{peak}} \\
V_{\text{max}} & \quad 2500 \, V_{\text{average}} (*) & I_{\text{max(ph)}} & \quad 2000 \, A_{\text{RMS}} **) \\
\end{align*}
\]

*) depends on number of series connected GTOs
**) depends on switching frequency
Press-Pack IGBT (PPI)

Nominal Data

\[ V_{\text{DRM}} = 4500 \, \text{V} \quad (6500 \, \text{V}) \]

\[ I_{\text{TQRM}} \approx 3000 \, \text{A} \]

Characteristic data for continuous operation

\[ V_{\text{max}} = 2800 \, V_{\text{ripple}} \quad (3360 \, V_{\text{ripple}}) \]

\[ i_{\text{max}} \quad \text{n.a.} \]

\[ V_{\text{max}} = 2500 \, V_{\text{average}} \quad (3000 \, V_{\text{average}}) \]

\[ I_{\text{max(ph)}} = 800 \, A_{\text{RMS}} \]

*) switching frequency 750 Hz (1000 Hz)
Siemens VSC Technology
HD GTO Module

HD-GTO Module

Modules for the 200 MW Example

Main Data

- No of GTOs
- Voltage
- Current
- Switching frequency

\[ n_{\text{GTO}} = 14 + 2 \]

\[ V_{\text{valve}} = 35 \text{ kV average} \]

\[ I_{\text{ph}} = 1800 \text{ A}_{\text{RMS}} \]

\[ f_s = 300 \text{ Hz cont.} \]

\[ f_s = 1000 \text{ Hz 1s} \]
## Siemens VSC Technology PPI Module

### PPI Module

#### Example

<table>
<thead>
<tr>
<th>Main Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of IGBTs</td>
<td>( n_{\text{IGBT}} \leq 25 \ (3\text{level}) \leq 50 \ (2\text{level}) )</td>
</tr>
<tr>
<td>Voltage</td>
<td>70 kV average</td>
</tr>
<tr>
<td></td>
<td>140 kV average</td>
</tr>
<tr>
<td>Current</td>
<td>800 A_{\text{RMS}}</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>600 Hz  cont.</td>
</tr>
<tr>
<td></td>
<td>1000 Hz  1s</td>
</tr>
</tbody>
</table>

### HVDC PLUS

Power Link Universal Systems
Siemens VSC Technology
HD GTO Converter

Three-Level HD-GTO Converter
- \( V_{d\ av} \) 50 kV
- \( a_{\ max} \) \( \geq 0.95 \) Conv. Voltage Ratio
- \( I_{ac}^{(1)} \) 2000 A
- \( S_{\ conv} \) 100 MVA
- \( C \) 2 mF
- \( f_{\ PWM} \) 300 Hz

Conv. Voltage Ratio

Power Transmission and Distribution
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IGBT Element 4.5 kV, 750 A DC
Valve Technology
IGBT Element 4.5 kV, 750 A DC
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IGBT Element 4.5 kV, 750 A DC
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Turn-on waveform of Series Connected IGBTs

Series-connection of HV IGBT's

- Voltage $V_{ce}$ of upper IGBT
- Voltage $V_{ce}$ of lower IGBT
- Current $I_c$ of both IGBT's

Voltage ($V$), Current ($A$) vs. Time ($\mu s$)
Valve Technology
Turn-off waveform of Series Connected IGBTs

Series-connection of HV IGBT's

- Current Ic of both IGBT's
- Voltage Vce of upper IGBT
- Voltage Vce of lower IGBT

HVDC PLUS
Power Link Universal Systems

Power Transmission and Distribution
Valve Technology
Short-Circuit Behavior of IGBTs

Series-connection of HV IGBT's

- Short circuit current $I_{csc}$
- Voltage $V_{ce}$ of lower IGBT
- Voltage $V_{ce}$ of upper IGBT

Time (μs):

- Voltage ($V$, Current ($A$))
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Series Connection of IGBT

Fibre Optics Interface

Valve Control & Protection

Main Control

Power Transmission and Distribution
Valve Technology
Main Design Features of Converters (1)

- Capability of IGBTs to limit and turn-off Short Circuit Currents
  ➔ Protection of IGBTs
- External freewheeling Diodes with high $I^2t$-Value
  ➔ Protection of Diodes at external Failures
  ➔ no Break of Semiconductor Housings at worst case Failures
  ➔ superior Performance of fast Diodes compared to reverse conducting IGBT
- Advanced Gate Unit
  ➔ improved Switching Performance of IGBT
  ➔ Overvoltage Protection of IGBT
  ➔ Current Limiting Circuits
Valve Technology
Main Design Features of Converters (2)

• Selection of Components under Condition of minimal Losses
• Design for low Cosmic Ray Sensitivity
• Fast Detection of Failures
• Modular Structure of Converters
• redundant IGBT Levels in each Valve
• Efficient, reliable and corrosion-free Cooling
• System designed for little and easy Maintenance
• Use of well-proven Components and Materials of HVDC Valves
  ➞ high Fire Resistance, Reliability and Seismic Robustness