Power Quality for **AC & DC Systems**

HVDC
with
VSC -
HVDC PLUS
Voltage sourced converter (VSC) topologies can be used for:

- HVDC Cable transmission systems (submarine and underground)
- Coupling of asynchronous AC networks as back to back solution
- FACTS, Active Filter
- Overhead line HVDC transmission

Fields of application of VSC technology:

- Energy transmission
- Energy distribution
- Power generation (wind parks)
- Oil and gas industry
- Power supply of mega cities
HVDC PLUS (Power Link Universal System)  
Shore to Off-Shore Supply

- HVDC Technologie based on Voltage Source Converters (VSC) up to 500MW and +/-300kV DC Voltage
- Use of Insulated Gate Bipolar Transistors (IGBTs) instead of GTOs or Thyristors
New additional Applications with HVDC PLUS (up to 1000 MW)

- Long-Distance Transmission
- System Interconnections
- Cable Interconnections
- Grid Access for Distributed Generation from regenerative Sources
- Extension of Overhead Lines
- Supply of Isolated Grids
- Grid Access for Offshore Wind Farms
- Supply of Facilities of Oil and Gas Industry

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HVDC PLUS –
The Power Link Universal System

 Compact Modular Design
 Less Space Requirements
 Advanced VSC Technology

Siemens uses MMC Technology (Modular Multilevel Converter)

Clean Energy to Platforms & Islands …
The Evolution of **HVDC PLUS and VSC Technology**

### Topologies:

- **Two-Level**
- **Three-Level**
- **Multilevel**

### Power Electronic Devices:

- **GTO / IGCT**
- **IGBT in PP**
- **IGBT Module**

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Power Transmission and Distribution
High harmonic Distortion

High Stresses resulting in HF Noise
The **Multilevel** Approach

Small Converter AC Voltage Steps

Small Rate of Rise of Voltage

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The Advanced Multilevel Approach: MMC – Modular Multilevel Converter

- Low Generation of Harmonics
- Low HF Noise
- Low Switching Losses
- No Snubbers required
### States and Current Paths of a Submodule in the MMC topology – an Advanced Solution

<table>
<thead>
<tr>
<th>State 1</th>
<th>State 2</th>
<th>State 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Off</strong> IGBT1  D1</td>
<td><strong>On</strong> IGBT1  D1</td>
<td><strong>Off</strong> IGBT1  D1</td>
</tr>
<tr>
<td><strong>Off</strong> IGBT2  D2</td>
<td><strong>Off</strong> IGBT2  D2</td>
<td><strong>On</strong> IGBT2  D2</td>
</tr>
<tr>
<td><strong>Off</strong> IGBT1  D1</td>
<td><strong>On</strong> IGBT1  D1</td>
<td><strong>Off</strong> IGBT1  D1</td>
</tr>
<tr>
<td><strong>Off</strong> IGBT2  D2</td>
<td><strong>Off</strong> IGBT2  D2</td>
<td><strong>On</strong> IGBT2  D2</td>
</tr>
</tbody>
</table>
Perfect Voltage Generation

Modular Multilevel Converter

AC and DC voltages controlled by converter leg voltages:

+U_d/2

U_ac

-U_d/2
MMC – AC & DC Converter Currents...

- Controlled by Voltage Sources

- $I_d - \frac{V_d}{2}$
- $+\frac{V_d}{2}$
- $\frac{I_{AC}}{2}$
- $\frac{I_{AC}}{2}$
- $\frac{I_{AC}}{2}$

- $I_d/3$

- $+V_d/2$
- $-V_d/2$

- Control

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Power Transmission and Distribution
MMC – Redundant Submodule Design

Phase Unit

High-Speed Bypass Switch

SM electronics

Submodule

PLUSCONTROL
Fully suitable for DC OHL Application:
Line-to-Line Fault – a crucial Issue
Line-to-Line DC Fault

Phase Unit

Submodule

SM electronics

IGBT1

D1

IGBT2

D2
Converter Reactors

Parallel connection of three voltage sources

Damp balancing currents between different phases

Limit current gradient during severe faults

Phase Unit
HVDC PLUS – The Advanced MMC Technology

Typical Converter Arrangement for 400 MW

Optional Seismic Reinforcements

Converter Module with more than 200 Submodules
30 MW Hardware Functional Performance Tests – The Converter (Top View and Side Views)
Main Tasks of PLUSCONTROL™

- Calculation of required Converter Module Voltages
- Selection of Submodules to be switched
- Control of Active and Reactive Power
- Submodule Voltage Balancing Control

SIMATIC TDC Measuring System
SIMATIC TDC C&P System
© Siemens AG

Power Transmission and Distribution
Main Features of PLUSCONTROL™

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard 19 inch racks</td>
<td></td>
</tr>
<tr>
<td>Highest degree of modularity</td>
<td></td>
</tr>
<tr>
<td>Advanced redundancy concept</td>
<td></td>
</tr>
<tr>
<td>Hot plug capability of PCBs and fans</td>
<td></td>
</tr>
<tr>
<td>High submodule interfacing capability</td>
<td></td>
</tr>
<tr>
<td>High numerical and logical performance</td>
<td></td>
</tr>
<tr>
<td>Integration into proven SIMATIC TDC systems</td>
<td></td>
</tr>
</tbody>
</table>

Highly flexible and highly reliable control system
Options for Transmission Redundancy

a) Solution with 4 Cables
- Use of Standard AC Transformers
- Symmetrical Monopole

b) Solution with 3 Cables
- HVDC Transformers required
- Bipole

© Siemens AG
Power Transmission and Distribution
# Features and Benefits of MMC Topology

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Low Converter Losses *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Switching Frequency of Semiconductors</td>
<td>Only small or even no Filters required</td>
</tr>
<tr>
<td>Low Generation of Harmonics</td>
<td>High Flexibility, economical from low to high Power Ratings</td>
</tr>
<tr>
<td>High Modularity in Hardware and Software</td>
<td>High Availability of State-of-the-Art Components</td>
</tr>
<tr>
<td>Use of well-proven Standard Components</td>
<td>Use of standard AC Transformers</td>
</tr>
<tr>
<td>Sinus shaped AC Voltage Waveforms</td>
<td>Low Engineering Efforts, Power Range up to 1000 MW</td>
</tr>
<tr>
<td>Easy Scalability</td>
<td>High Reliability, low Maintenance Requirements</td>
</tr>
<tr>
<td>Reduced Number of Primary Components</td>
<td>Robust System</td>
</tr>
<tr>
<td>Low Rate of Rise of Currents even during Faults</td>
<td></td>
</tr>
</tbody>
</table>

* 2.8 % – both Stations
Benefits of HVDC PLUS

Space Saving

Example 400 MW

© Siemens AG
Example of HVDC PLUS Station: 2 x 100 MW

Options:

- a) DC Cables
- b) DC B2B

Dimensions:
- 85 m
- 96 m
HVDC PLUS Station – Option for 100 MW B2B SIEMENS

Half the Width by vertical Arrangement: 2 Reactors and 2 Converter Modules on Top of each other
Results of Computer Simulation: 400 MW with 200 Submodules per Converter Module

AC Converter Voltages

Currents in the AC Terminals

Six Converter Module Currents

Obviously, no AC Filters required
Dynamic Response to an AC Line-to-Ground Busbar Fault – Inv. Side (Computer Simulation)

- AC Busbar Voltages
- AC Converter Voltages
- DC Converter Current
- Fault Ride-Through Capability
Dynamic Response to an AC Line-to-Ground Remote Fault – Inv. Side (Computer Simulation)

AC Busbar Voltages

\( V_{\text{DC}} + 200 \text{ kV} \)

AC Converter Voltages

\( V_{\text{DC}} - 200 \text{ kV} \)

DC Converter Current

Fault Ride-Through Capability
### General Features of VSC Technology

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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</thead>
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<tr>
<td>Grid Access of weak AC Networks</td>
<td></td>
</tr>
<tr>
<td>Independent Control of Active and Reactive Power</td>
<td></td>
</tr>
<tr>
<td>Supply of passive Networks and Black-Start Capability</td>
<td></td>
</tr>
<tr>
<td>High dynamic performance</td>
<td></td>
</tr>
<tr>
<td>Low Space Requirements</td>
<td></td>
</tr>
</tbody>
</table>

### Additional Features and Benefits of HVDC PLUS
Trans Bay Cable Project, USA
World’s 1st VSC HVDC with MMC-Technology

Energy Exchange by Sea Cable
No Increase in Short-Circuit Power

P = 400 MW, ± 200 kV DC Cable

Q = +/- 170-300 MVAr

Dynamic Voltage Support

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Power Transmission and Distribution
Trans Bay Cable Project, USA

World’s 1st VSC HVDC with ±200 kV XLPE DC Cable

- Converter: Modular Multilevel HVDC PLUS Converter
- Rated Power: 400 MW @ AC Terminal receiving End
- DC Voltage: ±200 kV
- Submarine Cable: Extruded Insulation DC Cable
HVDC PLUS for Off shore application
AC versus DC

AC - System  Versus  DC - System

50 to 80 km  Max. cable length  No Limitations

Typical North Sea requirement  > 200 km
HVDC PLUS for Off shore application
Typical System Configuration

Platform A
Platform B
Platform C
Platform D

100-170 kV AC
60 Hz

DC Voltage

Platform for converter
Oil/Gas Field

HVDC transmission systems
HVAC transmission systems
Oil- and Gas production platforms
HVDC PLUS for Off shore application
Typical System Configuration

Cluster A
150 MW

Cluster B
200 MW

Cluster C
220 ... 660 MW

Cluster D
270 ... 620 MW

HVDC Transmission Systems:
HVDC PLUS for Off shore application
Off Shore converter station

Outline: 46 x 35 m²
Height: 20m

Offshore converter station
Platform mounted AC distribution switchgear
HVDC PLUS for Off shore application

Benefits

- Reduction of maintenance, no generation on the platform
- Decrease of energy costs, participation in deregulated market
- Reduction of emission

Vision
Unmanned Supply Platform
Siemens FACTS & HVDC - worldwide

Trans Bay Cable 2010
Lamar 2005
2, 2 El Dorado 2006
Devers 2006
Nine Mile 2005
Dayton 2006
Porter 2006
Paul Sweet 1998
2 Adelanto 1995
2 Midway 2004
3 Vincent 2000
Clapham 1995,
Refurbishment
Military Highway 2000
Eddy County 1992
La Pila 1999
2 Tecali 2002
Chinú 1998
Canô Limón 1970
Imperatriz 1999 B
5 North-South III, Lot B 2007
Sinop 2007
Serra de Mesa 1999 B
Samambaia 2002 B
Acaray 1981 B
Atacama 1999 B
2 Zem Zem 1983
Dúrmenr 1983
Duíma 1983
São Luís 2007
Fortaleza 1986
Milagres 1988
Campina Grande 2000
Funil 2001
P. Dutra 1997
Ibiuna 2002
Limpio 2003
Bom Jesus da Lapa 2002
2, 2 Tian Guang 2003
Kayenta 1992
K. Hede 1997
2 Laredo 2000
2 Benejama & Saladas 2006
Sullivan 1995
J. Jilone 2006
2 Hoy a Morena & J. Jilone 2004
Welsh 1995
2 Hoya Morena & J. Jilone 2004
Châteauguay 1984
2 Hoya Morena & J. Jilone 2004
2, 2 Thannet, 3 Greater Gabbard 2009-2011
2 Thannet, 3 Greater Gabbard 2009-2011
Roadsted 2006
Siems 2004
Etzenricht 1993
Wien Südost 1993
Ghusais, Hamria, Mankhool,
Satwa
2, 2 Gorakhpur
2, 2 Purnea
Kanjin (Korea) 2002
2 Fengjix 2006
2 Yangcheng 2000
2 Hechi 2003
2, 2 Tian Guan 2003
3 Puti 2005
2 Gooty 2003
2 Cuddapah 2003
2 Sabah 2006
Strathmore 2007
2 Kemps Creek 1999
1994-1995
1994-1995
2 Powerlink 2007,
Refurbishment2 Greenbank & Southpine
2008
3, 2 El Dorado 2006
2 Purnea 2006
2 Sabah 2006
2 th 1.7 GVar !

... and over 120 Industry SVCs all over the World
In total: over 180 SVCs
Status: 01-2008

Plus 23 Projects for HVDC Long-Distance Transmission ...
8 alone between 2000 & 2005 on 4 Continents

Power Transmission and Distribution © Siemens AG
Siemens is successful in the HVDC Business – for more than 30 Years

World’s 1st VSC HVDC with MMC-Technology

World’s 1st HVDC with 500 kV DC Cable

World’s 1st HVDC with 8 kV Thyristors

World’s 1st HVDC with Transmission Voltage above 500 kV Status: 01-2008

World’s longest HVDC Cable in Operation

World’s 1st HVDC with Transmission Voltage of 800 kV!
Thank You
for Your Attention!