HVDC Solutions for System Interconnection and Advanced Grid Access

Joerg Dom, Dietmar Retzmann, Cristen Schimpf, Dag Soerangr
Global Trends on Power Markets

- CO₂ Reduction – Green Energy
- Megacities – Security of Supply
Conclusions of IPCC: CO₂ Increase due to human Influence is much higher than natural Fluctuation

Carbon Dioxide Variations in the Air

The Industrial Revolution has caused a dramatic Rise in CO₂

A crucial Global Issue: to achieve CO₂ Reduction

### Sources:
Siemens PTD TI, Wikipedia, 2006
Task 1 of Security of Power Supply
If Power Flow exceeds the Design Criteria: **Blackout**

*System Enhancement necessary!* 


*Source: ITC 8/2003 – “Blackout”*

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**Problems only in the synchronous interconnected Systems**

**The US Blackout 2003: Congestion, Overloads and Loop Flows**

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**PTDF (Power Transfer Distribution Factor)**

- **Max % PTDF**: 
  - 25.00% 
  - 5.00% 
  - 2.00%
Task 2
Sustainability of Power Supply
Development of Power Systems

- Extensions of Interconnected Systems
- Increased Power Exchange among the Interconnected Systems
- Transmission of large Power Blocks over long Distances (Hydro, Wind*, and Solar Energy)
- Renewable Energy Resources at favorable Locations*

* A big Issue for the Grid Developments - in all Countries
Today’s Challenges for a Solution Provider

- Low Investments!
- Transmission Efficiency!
- Power Quality!
- Long Lifetime!
- Low CO₂ Emissions!
- System Stability!

The Solution is:
Power Electronics

SIEMENS
The Global Potential in CO\textsubscript{2} Reduction and Security Enhancement is huge

Use of Advanced Solutions for Power Transmission
Use of Power Electronics for HVDC & FACTS

Transient Performance and Losses

More Dynamics for better Power Quality:
- Use of Power Electronic Circuits for Controlling P, V & Q
- Parallel and/or Series Connection of Converters
- Fast AC/DC and DC/AC Conversion

- Transition from “slow” to “fast”

Switching Frequency

On-Off Transition 20 - 80 ms

50/60 Hz

<500 Hz

The Solution for Bulk Power Transmission

Depending on Solution

2-4 %

Losses

Thyristor
1-2 %

GTO

IGBT / IGCT

> 1000 Hz

Power Transmission and Distribution
High Voltage Direct Current

HVDC

High Power DC Transmission Systems
**Advanced Power Transmission Systems**

**HVDC - High Voltage DC Transmission: It makes P flow**

- **HVDC “Classic”** with LT Thyristors* (Line-commutated Converter)
- **HVDC “Bulk”** with 800 kV – for 5,000 MW to > 7,000 MW
- **HVDC PLUS** (Voltage-Sourced Converter – VSC)
- **HVDC can be combined with FACTS**
- **V-Control included**

**HVDC-LDT - Long Distance Transmission**

**B2B - The Short Link**

- Back-to-Back Station
- Submarine Cable Transmission
- Long Distance OHL Transmission

* LTT = Light-Triggered Thyristor with integrated Break-over Protection

800 kV for minimal Line Transmission Losses
Options of HVDC Interconnections

a) Back-to-Back Solution
b) HVDC Long Distance Transmission
c) Integration of HVDC into the AC System

Can be connected to long AC Lines
Hydro Plants for:
- Base Load and
- Energy Storage

Benefits of HVDC:
- Clean Energy
- CO₂ Reduction

“flexible”

Plus Wind Power

“fuzzy”

Covering Base and Peak-Load Demands

Basslink HVDC: remote Infeed of Green Energy

SIEMENS

2005

-no additional Thermal Plants
-Cost Reduction

Transmission and Distribution
Ed Stern, President of Neptune RTS: “High Voltage Direct Current Transmission will play an increasingly important Role, especially as it becomes necessary to tap Energy Reserves whose Sources are far away from the Point of Consumption.”

Safe and reliable Power Supply for the Megacities – “Blackout Prevention”

Customer: Neptune RTS
End User: Long Island Power Authority (LIPA)
Location: New Jersey: Sayreville
          Long Island: Duffy Avenue
Project
Development: NTP-Date: 07/2005
             PAC: 07/2007
Supplier: Consortium
          Siemens / Prysmian
Transmission: Sea Cable – 500 kV
Power Rating: 600/660 MW monopolar
Transmission Dist.: 82 km DC Sea Cable
                 23 km Land Cable
Neptune HVDC: 660 MW Full Power Delivery in Trial Operation – 2 Weeks ahead of Schedule

Blackout in New York City – June 27, 2007

Neptune HVDC successfully supported Long Island’s Power Supply - 700,000 Households could be saved

385,000 People without Electricity in Manhattan and Bronx: Subway broke down, Traffic Lights out of Operation – up to 1 hour Power Outage
Europe – The HVDC Portfolio is growing

**Storebælt**

- **Customer:** Energinet.dk
- **System Data:**
  - Rating: 600 MW
  - Voltage: 400 kV DC
  - Thyristor: 8 kV LTT
  - Cable Length: 56 km

**BritNed**

- **Customer:** BritNed Development Ltd.
- **System Data:**
  - Rating: 1000 MW
  - Voltage: 400 kV DC
  - Thyristor: 8 kV LTT
  - Cable Length: 200 km

**2010**

- **Energy Exchange by Sea Cable**
- **Sharing of Reserve Capacity**
- **No Increase in Short-Circuit Power**
Siemens received the Order for the World’s first 800 kV HVDC in China Southern Power Grid

Siemens – the Leader in Bulk Power DC Transmission Technology

Commercial Operation:
- 2009 – Pole 1
- 2010 – Pole 2

5,000 MW
1,418 Km
+/- 800 kV DC

Reduction in CO₂ versus local Power Supply with Energy-Mix

32.9 m tons p.a. - by using Hydro Energy and HVDC for Transmission
Jinping ± 800 kV HVDC Transmission Project

For Comparison: Germany

Planned for 2012

6,400 MW
+/− 800 kV DC

2,237 Km

Source: “Brazil-India-China Summit Meeting on HVDC & Hybrid Systems – Planning and Engineering Issues”, July 2006, Rio de Janeiro, Brazil
Grid Extension in India - Hybrid AC plus DC

Prospects in China and India:
“Smart” and Strong Grids

Similar Prospects ... as in China

Source: “Brazil-India-China Summit Meeting on HVDC & Hybrid Systems - Planning and Engineering Issues”, July 2006, Rio de Janeiro, Brazil

Power Transmission and Distribution
Technology Issues for
for UHV DC Transmission

More Power out of the Grid …

plus CO₂ Reduction
Air-Core, Air-cooled **Smoothing Reactor** and **Converter Transformer** – The Dimensions are “huge”

**500 kV DC** in the Pictures – are now being extended to **800 kV DC**

Mostly an **Issue of Mechanics** – but **not only** ...
UHV DC Reactor – in Test Field

800 kV DC
3,125 A
75 mH
28 tons!
800 kV HVDC Transformer under Construction

320 MVA Single-Phase* Transformer

48** Transformers – for the Yunnan-Guangdong UHV DC Project

Core Design: 3 Limbs & 2 Return Limbs
L x W x H: 26 x 6.4 x 15.2 m
Total Weight: 512 tons

* for Transportation Reasons
** plus 8 Spare Units

Test Voltages

AC (1 min) 1,020 kV
SI 1,790 kV
LI (FW/CW) 2,080/2,320 kV
DC (2 hrs) 1,175 kV
PR (90/90/45 min) 935 kV
Valve Hall Configuration – for UHV DC

Each Valve Group can be bypassed ... n-1 Criteria

"Ready for Transmission"
N-1 Criteria: fully redundant HVDC Scheme – with two 12-Pulse Converters per Pole

Transformer Bushings

400 kV DC

Each Pole can be operated with 400 kV DC

800 kV DC

400 kV-Valve Group

800 kV-Valve Group

N-1 Criteria: Redundancy through Bypass-Breakers

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“Snapshots” from DC Valve Tower Testing

Dielectric Testing of Valve-Support Structure
Finally ...

... it will look like this:
Power Quality for AC & DC Systems

HVDC
with VSC
HVDC PLUS
HVDC PLUS – The Power Link Universal System

- Low Switching Frequency
- Reduction in Losses
- Less Stresses

In Comparison with 2 and 3-Level Converter Technologies

... with 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 (PTD)
The Multilevel Approach

Small Converter AC Voltage Steps

Small Rate of Rise of Voltage
The **Advanced Multilevel** Approach: **MMC – Modular Multilevel Converter**

- Low Generation of Harmonics
- Low HF Noise
- Low Switching Losses
HVDC PLUS with MMC – Basic Scheme

Submodule (SM)

Phase Module

Vd
The Result: **MMC – a perfect Voltage Generation**

AC and DC Voltages controlled by Converter Leg Voltages:

\[ V_{AC} \]

\[ +V_d/2 \]

\[ V_{Conv.} \]

\[ 0 \]

\[ -V_d/2 \]
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
HVDC PLUS – The Advanced MMC Technology

Typical Converter Arrangement for 400 MW

Optional Seismic Reinforcements

Converter Leg with more than 200 Submodules
Benefits of HVDC PLUS

Example 400 MW

HVDC "Classic"

Space Saving
Conclusions

Transmission needs ...

Elimination of Bottlenecks and Congestion by use of Advanced Technologies
Power System Expansion ...

... with Advanced Transmission Solutions

From Congestion, Bottlenecks and Blackout towards a “Smart Grid”
The Future ? - Global Link for Green Energy
with HVDC and FACTS
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

World's longest HVDC Cable in Operation

World's 1st HVDC with Transmission Voltage of 800 kV!
Intelligent Solutions for Power Transmission

with HVDC & FACTS from Siemens

Now available – with VSC PLUS Technology

HVDC PLUS and SVC PLUS

... and the Lights will keep shining!
Thank You for your Attention!