More Power out of the Grid …

plus CO₂ Reduction

Use of Advanced Solutions for UHV Transmission
HVDC - High Voltage DC Transmission:

- HVDC "Classic" with LT Thyristors* (Line-commutated Converter)
- HVDC "Bulk" with 800 kV – for 5,000 MW to > 6,400 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

* LTT = Light-Triggered Thyristor with integrated Break-over Protection
Benefits of HVDC: it makes Power flow

Fault-Current Blocking

G~

V1

\[ P \]

V2

\[ G~ \]

I1

I2

Q1

\[ \alpha \text{ and } \gamma \]

Q2

L and C

Slow Functions

Fast Functions

Benefits of HVDC in a synchronous AC System

The Firewall for Blackout Prevention

Power & Voltage Control
Fault-Current Blocking
Some Countries will need Bulk Power Transmission Corridors …

Solutions:
- DC: 4-6 GW
- AC: 6-10 GW

Prospects of UHV DC & UHV AC

... Increase in Transmission Distance – and Reduction in Losses
Example China: **Long Distances between Generation and Load Centers (500 ~ 2,000 km)**

Source: State Grid of China - 2005
The Solution: **AC & DC Power Transmission from West to East – Three Bulk Power Transmission Corridors**

**North Corridor**: 
- Transmission Capacity of each Corridor will be 20 GW by 2020 …
- … the installed Generation Capacity will be 900 GW
- 800 kV DC & 1,000 kV AC

**Central Corridor**: 
- 3 x 20 GW

**South Corridor**: 
- Sources: [State Grid](http://www.stategrid.com) [CEPRI](http://www.cepri.com)
China will use UVH AC Transmission ...

Rated Voltage: 1,000 kV
Maximum Operation Voltage: 1,100 kV

... and possibly India will follow!

Source: State Grid
UVH DC Test Line put into Service on June 28, 2007 in Changping District, Beijing, China.

Rated Voltage: \( \pm 800 \text{kV} \)

Maximum Source Voltage: \( \pm 1,200 \text{kV} / 0.5 \text{A} \)

Sources:

Total Length of Test Line: 1,084 m

Span of middle Section: 300 m

Power Transmission and Distribution
China Southern Power Grid - Prospects of Grid Developments

CSG:

Five Provinces

1 million km²

220 million People

- By 2010, West-East Power Transfer will increase from 11.5 GW to 13.5 GW
- By 2010, the Transmission Capacity from West to East will increase to 22.4 - 24.4 GW

- By 2009, the first ±800kV DC Transmission Project in the World will be launched by China Southern Power Grid
- By 2010, a large Corridor with 5 DC Lines and 8 AC Lines will be formed

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

Yunnan-Guangdong

5,000 MW
+/- 800 kV DC

1,418 Km

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

Reduction in CO2 versus local Power Supply with Energy-Mix

32.9 m tons p.a. - by using Hydro Energy and HVDC for Transmission

Power Transmission and Distribution
Jinping ± 800 kV HVDC Transmission Project

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

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

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

Similar Prospects ... as in China

+/- 800 kV HVDC!
Benefits of Hybrid AC/DC Solutions for Bulk Power Transmission in restricted Right-of-Way Areas

**DEVELOPMENT OF CHICKEN NECK AREA**

**50 GW Hybrid:**
≈ 10 GW AC
≈ 40 GW DC

Source: “Brazil-India-China Summit Meeting on HVDC & Hybrid Systems – Planning and Engineering Issues”, July 2006, Rio de Janeiro, Brazil
More Power out of the Grid …

- for generated 2860 MW → AC-bus of rectifier station 2814 MW

plus CO$_2$ Reduction

Technology Issues for
for UHV DC Transmission
The Solution – for UHV AC

Example AC Test Transformer 1,200 kV

Transformer Bushings:

Type OTA; Trench UK *, Oil-Paper Technology
Production: Hebburn/UK, MWB Shanghai/China
Transformer Design for 1,200 kV is available
Reference: Henjiang / China

* now Siemens
Specific Issues – for UHV AC

The AC Measurements for UHV

Essential to UHV System Control and Energy Management, e.g. with FACTS

Capacitive Voltage Divider
Type TEHMF Trench Canada *
Production: Toronto und Shanghai
In Service up to 800 kV
Scaling-up for 1100 kV is no Problem

* now Siemens

$\text{SF}_6$ insulated CT and PT – Design is well proven
Type SAS, SVS; Trench Germany *
Production: Bamberg and Shanghai
In Service up to 800 kV
Scaling-up for 1100 kV is no Problem

* now Siemens
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 Measurements

800 kV DC Application:
Design and Manufacturing based on existing Technology

Voltage Divider 500 kV DC East-South Interconnector, India

Easy to “extend” on UHV DC

- All Measuring Components are at high Potential
- Signal Transmission via optical Fibers inside the Composite Housing

500 kV DC Current Transducer in Zhaoqing, China
UHV DC Reactor – in Test Field

800 kV DC
3,125 A
75 mH
28 tons!
UHV DC Bushing at Test Lab TU Graz – Austria

800 kV DC Bushing in Test Field

Power Transmission and Distribution
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
Solutions for **UHV DC Thyristor Valves**

- UHV DC Valves with proven **modular Design** based on existing Technology and Know-How for **DC Voltage 800 kV**
- Valve Tower Configuration: Double or Quadruple Valve
- Proven existing **LT Technology**
HVDC Thyristor Valves – Principle Circuit of a 12-Pulse Group

Valve Tower Arrangement

Multiple Valve Unit (Quadruple Valve)

Valve Branch

to DC Line: + or -

Example 500 kV

SIEMENS
800 kV – HVDC with 2 Converters per Pole

To AC Bus & Filters

DC Line

Neutral

800 kV
N-1 Criteria: fully redundant HVDC Scheme – with two 12-Pulse Converters per Pole

Transformer Bushings

400 kV DC

800 kV DC

Each Pole can be operated with 400 kV DC

N-1 Criteria: Redundancy through Bypass-Breakers
Valve Hall Configuration – for UHV DC

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

"Ready for Transmission"
Thorough Testing is essential …

Verification of Mechanical Performance
Cantilever Bending Test for DC Insulators

Verification of Clearance Distances for UHV DC Equipment
Testing of DC Bypass-Breakers

800 kV DC

400 kV DC
“Snapshots” from DC Valve Tower Testing

Dielectric Testing of Valve-Support Structure
Finally …

… it will look like this:
Siemens is successful in the HVDC Business – for more than 30 Years

World’s 1st HVDC with LTT and integrated BOD

World’s 1st HVDC with Transmission Voltage above 500 kV

World’s 1st HVDC with 8 kV Thyristors

World’s longest HVDC Cable in Operation

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

Advanced HVDC Technologies

Thank You for your Attention!