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ABB Power Systems
HVDC
Ludvika, Sweden

HVDC Equipment for 800 kV HVDC
Brazil-China-India Summit Meeting on HVDC & Hybrid Systems
Rio de Janeiro
July 16-18 2006

abb.com/hvdc
Converter options

- Single twelve pulse group per pole: 3000-4500 MW
- Series connected twelve pulse groups in each pole: 4500-6400 MW
- Parallel twelve pulse groups per pole: 6000-9000 MW
UHVDC - one pole

Exposed to 800 kV dc
Development areas

- External insulation:
  - Transmission lines (Converter stations)
- Converter transformers, barrier system, cleats and leads
- Wall bushing, mechanical
- Transformer bushings, thermal, electrical
- Seismic/mechanical questions (very high structures in the DC-yard)
- Reliability
## Insulation coordination

### Transformer references

<table>
<thead>
<tr>
<th>Project</th>
<th>Nominal dc level</th>
<th>LIWL</th>
<th>SIWL</th>
<th>DC 2h</th>
<th>Polarity reversal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Itaipu</td>
<td>600</td>
<td>1800</td>
<td>1500</td>
<td>965</td>
<td>690</td>
</tr>
<tr>
<td>HQ/NEH</td>
<td>500</td>
<td>1425</td>
<td>1300</td>
<td>762</td>
<td>486</td>
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<tr>
<td>Rihand-Delhi</td>
<td>500</td>
<td>1550</td>
<td>1290</td>
<td>800</td>
<td>568</td>
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<tr>
<td>3GC</td>
<td>500</td>
<td>1675</td>
<td>1425</td>
<td>810</td>
<td>597</td>
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</tbody>
</table>

### Transformer - 800 kV

<table>
<thead>
<tr>
<th>Design base</th>
<th>Nominal dc level</th>
<th>LIWL</th>
<th>SIWL</th>
<th>DC 2h</th>
<th>Polarity reversal</th>
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</thead>
<tbody>
<tr>
<td>Itaipu</td>
<td>800</td>
<td>2400</td>
<td>2000</td>
<td>1287</td>
<td>920</td>
</tr>
<tr>
<td>HQ/NEH</td>
<td>800</td>
<td>2280</td>
<td>2080</td>
<td>1219</td>
<td>778</td>
</tr>
<tr>
<td>Rihand-Delhi</td>
<td>800</td>
<td>2480</td>
<td>2064</td>
<td>1280</td>
<td>909</td>
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<tr>
<td>3GC</td>
<td>800</td>
<td>2680</td>
<td>2280</td>
<td>1296</td>
<td>955</td>
</tr>
</tbody>
</table>
800 kV transformer

Transformer data upper group

Transformer type: Two-winding converter transformer

Rated power: 248 MVA

Rated voltages: 525/168,4 kV

No-load loss: 170 kW

Load loss (50 Hz): 600 kW

<table>
<thead>
<tr>
<th>Height</th>
<th>4850 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>3500 mm</td>
</tr>
<tr>
<td>Length</td>
<td>10850 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>260 tons</td>
</tr>
</tbody>
</table>
Converter transformer

• Prototype manufactured
• First round of testing completed:
  • AC 800 kV 60 min
  • AC 900 kV 5 min
  • DC 1100 kV 60 min
  • DC 1250 kV 6 h
800 kV HVDC converter transformer and transformer bushings

© ABB Power Technologies
Power Systems DC - 8 -
800 kVdc transformer bushing

- Based on proven design used in 3G projects in China
- Hollow core composite insulator
- Silicon rubber sheds with proven profile
- $\text{SF}_6$ enhanced insulation
- "Explosion safe" – no porcelain

Insulation length (indoor) 7.6m
800 kV DC wall bushing

- Insulation length outdoor 9m
- Insulation length indoor 6.7m

- Enlarged 3G-concept
- SF₆ filled bushing
- "Explosion safe" – no porcelain
- Positioning ~10 degrees to horizon beneficial for electrical performance
- Silicon rubber sheds with proven profile
Thyristor Valve Layout

- Saturable Reactor Module
- Thyristor Module
- TCU Derivative Feeding Capacitor
- DC Grading Resistor
- Thyristor
- Thyristor Control Unit
- Damping Resistors
- Damping Capacitors
- TCU Derivative Feeding Resistor
Thyristors

- The valve voltage is not decisive for the thyristor. Will be handled by sufficient number of thyristor positions in series. Due to the well defined voltage grading each individual thyristor position has the same electrical stress in an 800 kV valve as in a 500 kV valve!

- The critical parameter for the thyristors is the short circuit current. This is given by the ratio between rated DC current and transformer reactance.
## Experience of 14000 5” thyristors

<table>
<thead>
<tr>
<th>Project</th>
<th>Power Transmitted, MW</th>
<th>Number of thyristors</th>
<th>Commissioned year</th>
<th>Nominal Current, A</th>
<th>Overload Current, A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garabi 1 Brazil</td>
<td>1100</td>
<td>1728</td>
<td>2000</td>
<td>4020</td>
<td>-</td>
</tr>
<tr>
<td>Garabi 2 Brazil</td>
<td>1100</td>
<td>1728</td>
<td>2002</td>
<td>4020</td>
<td>-</td>
</tr>
<tr>
<td>Three Gorges-Changzhou, China</td>
<td>3000</td>
<td>4176</td>
<td>2003</td>
<td>3000</td>
<td>3555 @20°C</td>
</tr>
<tr>
<td>Rapid City USA</td>
<td>2x100</td>
<td>336</td>
<td>2003</td>
<td>3920</td>
<td>-</td>
</tr>
<tr>
<td>Three Gorges-Guandong, China</td>
<td>3000</td>
<td>4176</td>
<td>2004</td>
<td>3000</td>
<td>3555 @20°C</td>
</tr>
<tr>
<td>Sylmar Replacement Project Project USA</td>
<td>3100</td>
<td>2016</td>
<td>2004</td>
<td>3100</td>
<td>3650 @20°C</td>
</tr>
</tbody>
</table>

One thyristor failed during commercial operation reported (Garabi 2002)
Valve

- New valve design to include 800 kV and 6” thyristors
- Conceptual design ready
- Modular prototype testing ready
Quadruple thyristor valve
Valve hall, quadruple 400 kV Valve

Dimensions valve halls, LxWxH:
High voltage group: 46.3x31.8x23.6 m, top of roof 27.3
Low voltage group: 35.4x26.6x16.6 m, top of roof 20.3

Height increase with 3 meter if single 12 pulse bridge for 800 kV
ABB Composite support insulator
Pole arrester
DC disconnector

SPOL 800 kV, picture of the tests at FGH lab, Mannheim
DC harmonic filter capacitor 800 kV

3GC 500 kVDC capacitor
DC-voltage divider
Platform for smoothing reactor
## Test voltages for equipment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>LI</th>
<th>SI</th>
<th>AC&lt;sub&gt;RMS&lt;/sub&gt;</th>
<th>DC</th>
<th>DC Polarity reversal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converter transformer, Valve side</td>
<td>1744</td>
<td>1518</td>
<td>900</td>
<td>1250</td>
<td>970</td>
</tr>
<tr>
<td>Transformer bushing, valve side</td>
<td>1744</td>
<td>1518</td>
<td>900</td>
<td>1250</td>
<td>970</td>
</tr>
<tr>
<td>Smoothing reactor, Across</td>
<td>2160/2</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
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<tr>
<td>Smoothing reactor, To ground</td>
<td>1950</td>
<td>1546</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
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<tr>
<td>Voltage divider</td>
<td>1950</td>
<td>1546</td>
<td>1000 (one minute)</td>
<td>N.A.</td>
<td>N.A.</td>
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<tr>
<td>Disconnecting switch</td>
<td>1950</td>
<td>1546</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
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<tr>
<td>PLC capacitor</td>
<td>1950</td>
<td>1546</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
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<tr>
<td>Wall bushing</td>
<td>1800</td>
<td>1518</td>
<td>1000 (one minute)</td>
<td>1235</td>
<td>1030</td>
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<tr>
<td>Thyristor multiple valve</td>
<td>1800</td>
<td>1518</td>
<td>N.A.</td>
<td>1040 (3 hrs)</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
Test facilities in ABB Sweden (Ludvika)

<table>
<thead>
<tr>
<th>Test</th>
<th>Required kV</th>
<th>Available STRI, kV</th>
<th>Available TRAFO, kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightning impulse</td>
<td>2000</td>
<td>3200</td>
<td>2800</td>
</tr>
<tr>
<td>Switching impulse</td>
<td>1550</td>
<td>1750</td>
<td>2000</td>
</tr>
<tr>
<td>AC</td>
<td>1000</td>
<td>1050</td>
<td>1000</td>
</tr>
<tr>
<td>DC</td>
<td>1250</td>
<td>1400</td>
<td>1075</td>
</tr>
</tbody>
</table>
External Insulation

- DC-LPE (Line Performance Estimator) work ongoing
- Expert team meetings to establish requirements on 800 kV insulators, ABB, NGK, CEPRI, Sediver, Xinghua University
  - Requirements for composite insulators agreed
  - Methods for high altitude correction agreed
- Pollution test station in operation in Yunnan
- Composite support insulator installed at TSQ site for verification
- All outdoor apparatus can be designed with composite insulators

Next:
- Evaluate test criteria for composite insulators
- Verification of DC-LPE based on experience from GeSha
- Tests on valve hall clearances in July
Reliability of converters

Large power blocks ask for extremely high reliability!

100% separation of poles, 3000MW each!

Far going separation of groups, 1500 MW each:

- Geographical
- Mechanical
- Electrical

Example:

- AC-yard
- Auxiliary power
- Control
- Cabling
- AC-filters
- Cooling, water supply
Test Circuit

- The long term being built at STRI, Ludvika
- In operation October 2006
±800 kV, 3000-4500 MW Converter Station
+/- 800 kV  6400 MW station
Indoor DC-yard
Brittle fractures can be found in crystalline rock. The length of the fracture can be supposed to relate to its depth extent, i.e. a 50 km long fracture zone might extend to the mantle. Such zones are usually water-bearing and low-resistive.
Development of 800 kV equipment and first project execution.

- Development 800 kV equipment
  - Bushing
  - Transformer model
  - Long term testing

- First commercial
  - +/-800 kV project
  - Feasibility study
  - Procurement

- System & detailed design
- Manufacture of equipment

- Erection pole 1
- Test & commissioning pole 1
- Commercial operation pole 1

- Erection pole 2
- Test & commissioning pole 2
- Commercial operation pole 2
Summary

- Project is on schedule
- Important knowledge obtained from service experience, calculations and pre-testing and integrated in 800kVdc design
- Design for transformer- and wall bushing prototypes ready and tests are ongoing
- Manufacturing of prototypes is on-going
- 800 kV test circuit- civil work ongoing
- Project is on track!