Insulation coordination for UHVDC 800 kV

abb.com/hvdc
Presentation items

- Operating experience
- Principles
- Smoothing reactor
- Insulation levels for different components
- Staging
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Insulation coordination. Experience from operation.

- Creepage flashovers -- Accurate creepage distance
  -- Accurate insulator design
- Flashover because of uneven wetting
  -- Attention to physical layout
- Overvoltages -- Excellent experience, no flashovers
  (Overdesign)
- Cost of withstand for Lightning Impulse and Switching
  Impulse is “small” (exception: Thyristor valve) at 500
  kv rating (creepage was dimensioning)
- At 800 kV the Lightning Impulse and Switching Impulse
  will influence size, weight and cost of equipment
Presentation items

- Operating experience
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Insulation coordination - principles

- Limitation of switching surges is essential
- Highly efficient arresters
- Installation of additional arresters on 800 kV dc bus and converter bus between transformer and valve
- Arresters installed very close to object (no distance effects)
- Subdivision of smoothing reactor – 50 % on 800 kV, 50 % on neutral bus
- Insulation margins

<table>
<thead>
<tr>
<th></th>
<th>Oil insulation</th>
<th>Air insulation</th>
<th>Single Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightning impulse</td>
<td>20 %</td>
<td>20 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Switching impulse</td>
<td>15 %</td>
<td>15 %</td>
<td>10 %</td>
</tr>
</tbody>
</table>

- Margin of insulation is sufficient – standard levels not applicable
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Air insulated smoothing reactor

350 mH

175 mH

175 mH

U1

U2

U3

U1

U2

U3
Air insulated smoothing reactor

Smoothing reactor is located on neutral bus at Skagerrak, CU and Inga-Shaba +/-500 kV project
## Air core smoothing reactors in ABB projects

<table>
<thead>
<tr>
<th>Location</th>
<th>kV</th>
<th>A</th>
<th>mH</th>
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</thead>
<tbody>
<tr>
<td>Rihand-Delhi</td>
<td>500</td>
<td>1500</td>
<td>180</td>
</tr>
<tr>
<td>HQ-NEH</td>
<td>500</td>
<td>2250</td>
<td>2x150</td>
</tr>
<tr>
<td>Sylmar</td>
<td>500</td>
<td>3100</td>
<td>2x150</td>
</tr>
<tr>
<td>Vizag</td>
<td>BtB</td>
<td>3900</td>
<td>2 x 30</td>
</tr>
<tr>
<td>UHVDC</td>
<td>800</td>
<td>3750</td>
<td>4x90</td>
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</table>

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Weight</th>
<th>Height</th>
<th>Diameter</th>
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</thead>
<tbody>
<tr>
<td>Sylmar</td>
<td>43</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td>UHVDC</td>
<td>40</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Platform for smoothing reactor and arrester
Presentation items

- Operating experience
- Principles
- Smoothing reactor
- Insulation levels for different components from a study using typical data
  NB! Only the upper 12-pulse converter is shown
- Staging
800 kV DC bus outside smoothing reactor

Switching overvoltages
- By-pass blocking w/o by-pass pair (1345 kV)
- Ground fault on line (1040 kV) 1)
- Disconnection of last ac line in inverter (1216 kV)

Lightning overvoltages
- Lightning surge (1625 kV)
- Shielding failure in dc switchyard
- OH line tower arcing horns

1) 1.7 p u at line midpoint

Two or three DC line arresters to cater for distance effects. All arresters are contributing to reduce switching surges
800 kV bus in valve hall

Switching overvoltages
- AC bus switching overvoltages (1128 kV)
- Inverter blocked w/o by-pass pair (1096 kV)
- Disconnection of last ac line in inverter (1320 kV)

Lightning overvoltages
- Lightning surge from line dc line
- Lightning surges from ac network

Arrester CBH may be necessary – To be finally decided at detailed study
Y/Y connected transformer

Switching overvoltages
- AC bus switching surges (1128 kV)
- Disconnection of last ac line in inverter (1312 kV)
- Inverter blocking w/o by-pass pair (1096 kV)

Lightning overvoltages
- Lightning surge from ac network
- Lightning surge from dc line

The arrester YG will be installed if necessary to reduce switching overvoltages. Otherwise arresters MH+V protect phase-to-ground insulation.
Thyristor valve insulation

Switching overvoltages
- AC network switching surge
- Earth fault between transformer and valve

Lightning overvoltages
- Lightning stroke from ac yard
- Lightning stroke from dc yard
Smoothing reactor on 800 kV pole bus

Switching overvoltages
NA

Lightning overvoltages
- Ground fault beside reactor
- Lightning surge from dc line

Each arrester has LIPL 900 kV
Smoothing reactor on neutral bus

Switching overvoltages
N A

Lightning overvoltages
• Ground fault beside reactor
• Lightning surge from dc line
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UHVDC, 2 x 12-pulse converters/pole

- 2 x 12 pulse groups/pole
- Max power 6200 MW at 800 kV DC
- Transformer data (6200 MW)
  - No: 24 units
  - 1Ø2W: 310 MVA
  - Weight: 310 tons
  - LxWxH: 8 x 4 x 5 meter
- Installed at Itaipu, in operation for 20 years
2 x 12 pulse groups/pole, switching arrangements

- Maximum flexibility & availability
- High speed by-pass switch
- Operational experience from Itaipu
- Operation at reduced voltage
  - 70 %
  - 35 %
UHVDC, stagewise extension

A

B

C

800 kV

600 kV

800 kV

600 kV

800 kV

600 kV

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## Converter configurations, 6000 MW, +/-800 kV, 3750 A

<table>
<thead>
<tr>
<th>First stage</th>
<th>Second stage</th>
<th>Transformer</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Connection</td>
<td>Voltage kV</td>
<td>Connection</td>
<td>Voltage kV</td>
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<tr>
<td>1x12pulse</td>
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<td>1x12pulse</td>
<td>800</td>
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<tr>
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<td>600</td>
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<td>800</td>
</tr>
<tr>
<td>1x12pulse</td>
<td>600</td>
<td>1x6pulse</td>
<td>800</td>
</tr>
<tr>
<td>3x6pulse</td>
<td>600</td>
<td>1x6pulse</td>
<td>800</td>
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</tbody>
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