UHV 1200 kV AC Transmission

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Power Transmission and Distribution

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Technical Alternatives for Bulk Power Transmission

HVAC Systems

- 500 kV conventional as also series compensated
- 750 kV conventional as also series compensated
- 1200 kV conventional as also series compensated

HVDC Systems

- ± 500 kV bipole
- ± 550 kV bipole
- ± 600 kV bipole
- ± 800 kV bipole
Development of Voltages Levels for AC Power Transmission

Voltage

Year


110 kV Lauchhammer – Riesa / Germany (1911)
220 kV Brauweiler – Hoheneck / Germany (1929)
287 kV Boulder Dam – Los Angeles / USA (1932)
380 kV Harspranget – Halsberg / Sweden (1952)
735 kV Montreal – Manicouagan / Canada (1965)
1200 kV Ekibastuz – Kokchetav / USSR (1985)
EHV and UHV AC Systems – at Present

- Voltage Levels of **735 kV** to **765 kV AC** have been introduced in the following Countries:
  - Canada, Brazil, Russia (USSR), South Africa, South Korea, U.S.A. and Venezuela

- **UHV Transmission Lines (1000 kV and above)** have been built in Russia and Japan
  - Ekibastuz – Kokchetav (500 km)
  - Kokchetav – Kustanay (400 km)
  - Minami – Niigata / Nishi – Gunma (200 km)
  - Kita – Tochigi / Minami – Iwaki (250 km)

- However, **today** these **UHV Transmission Lines** are operated at **500 kV**
Product-Portfolio Non-Switching HV-Products

- Coil Products
- Bushings
- Line Traps
- Current and Voltage Transformer
- Arrester
The existing C.B. product range is covering 800 kV. Scaling up to 1000 kV is possible.
High-Voltage Circuit-Breaker 3AT4/ 5 EI up to 1000 kV

- EHVAC C.B. is using proven design and can be scaled up from existing 550/800 kV type to 1000 kV
- R&D program may be decided for 1000kV according to specification
- Requirements for short circuit current and higher altitudes above sea-level have to be specified
- Ambient and environmental conditions have to be considered
1000 kV EHVAC Double Break Disconnectors

from existing range of 800kV.....

**Technical Data**

- Rated voltage: 800 kV
- Rated lightning impulse
  - Withstand voltage (1,2/50 µs): 2100 kV
  - Across the isolating distance: 2235 kV
- Rated switching impulse
  - Withstand voltage: 1300 kV
  - Across the isolating distance: 1725 kV
- Rated current: 4000 A
- Rated short-time current: 63 kA

...to 1000kV design:
Up-scaling will cover the requirements on creepage distance & mechanical strength of porcelain
1200 kV Power Transformer Prototype tested in 1972

- EHVAAC Transformer using proven design can be scaled up from existing 800 kV type
- R&D program may be decided for 1000kV according to specification
- Dielectric specification and transport dimensions determine R&D cost and time
- Test facilities are an open issue
Recent Activities for UHV

Transformer & Reactor Bushings:

Type OTA; Trench UK *, Oil-Paper Technology
Production: Hebburn/UK, MWB Shanghai/China
Design for 1200 kV Transformer is available
Reference: Henjiang / China

* now Siemens
Development of UVH AC Transmission

Rated Voltage: 1000 kV
Maximum Operation Voltage: 1100 kV

Bundle of 8 Conductors

1000 kV Test Line in China

Source: State Grid Corporation of China
Road Map for UVH AC Transmission in China

**1000 kV Pilot Project**

Project Highlights:
- Totally 650km Length
- Including two UHV-AC Substations and one Switchgear Station

Source: [State Grid](https://www.sgcc.com.cn)
Specific Issues – for UHV AC

The AC Measurements for UHV

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

SF₆ 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
Tower Configurations

<table>
<thead>
<tr>
<th>Line conductors</th>
<th>Kita – Iwaki</th>
<th>Ekibastuz – Kokchetav</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air gap clearance phase-earth [m]</td>
<td>8 x 31.5 mm ACSR</td>
<td>8 x 24.1 mm AS-330</td>
</tr>
<tr>
<td>6.5</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>
Bundle Design and Tower Configuration

Voltage: 1000 kV
Phase conductor wire: 8 x 403/52 ACSR
Outer diameter: 27.7 mm
Sub conductor spacing: 400 mm

Ø = 1.07 m
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Resistance</td>
<td>0.0107 Ω/km</td>
</tr>
<tr>
<td>Reactance</td>
<td>0.267 Ω/km</td>
</tr>
<tr>
<td>Capacitance</td>
<td>14.15 nF/km</td>
</tr>
<tr>
<td>Surge impedance</td>
<td>245 Ω</td>
</tr>
<tr>
<td>Surge impedance load</td>
<td>4080 MW</td>
</tr>
<tr>
<td>Charging power</td>
<td>4.45 MVAR/km</td>
</tr>
<tr>
<td>Maximum surface gradient</td>
<td>14.7 kV/cm</td>
</tr>
</tbody>
</table>
Sectional view of the transmission line vertical to the line axis
Reactive Power Demand of Overhead Lines
as a Function of Load

Reactive Power
[MVAr/100 km]
1000 kV AC Transmission Line
No-Load Operation

Need of shunt compensation

<table>
<thead>
<tr>
<th>L (km)</th>
<th>Q_c (Mvar)</th>
<th>V_2/V_1</th>
</tr>
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<tbody>
<tr>
<td>250</td>
<td>1,133</td>
<td>1.04</td>
</tr>
<tr>
<td>500</td>
<td>2,417</td>
<td>1.17</td>
</tr>
<tr>
<td>750</td>
<td>4,169</td>
<td>1.50</td>
</tr>
<tr>
<td>1000</td>
<td>7,670</td>
<td>2.45</td>
</tr>
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</table>
Transmission System with Shunt and Series Compensation

Load capability of transmission system referred to the surge impedance load

Transmission angle as a function of degree of compensation

- \( K_p = 0 \)
- \( K_p (\text{ind}) = 0.5 \)
- \( K_s = \text{Degree of series comp.} \)

\( K_p = \text{Degree of shunt comp.} \)
Load Capability of Transmission System
Referred to Surge Impedance Load (SIL)

\[ K_p = \text{Degree of shunt compensation} \]

\[ \frac{P}{SIL} \]

Graph showing the relationship between \( K_p \) (cap.) and \( K_p \) (ind.) with \( P/SIL \) as the dependent variable.
Power Frequency Overvoltage During 1-phase Auto-reclosing

Power frequency overvoltage of disconnected phase during 1-phase auto-reclosing for different $Z_0/Z_1$ ratios of shunt reactor.
Ultra HVAC System > 1000 kV

- Early research works on feasibility of 1100 kV system by AEP, Furnas and some manufacturers.

- Further research works on 1000 kV by ENEL-CESI in Italy

- 1100 kV TEPCO line in Japan (140 km)

- 1100 kV line in Russia operated at 500 kV as reported

- 1000 kV demonstration line with 3 substations are currently under development in China

- Conclusion: UHVAC technology is technically feasible. R&D works are needed on the equipment side