Recent Developments and new Trends
GIS – MTS – AIS  Substation Technology

Presentation on behalf of  CIGRE SC B3
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High Voltage Substations, SF₆

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Achievement and Application of Modern Power Grid Switchgear Technology

- Introduction
- New Trends
  - in Power Systems
  - in Power Transmission and Distribution
- Drivers
- Examples of Advanced Equipment
  - AIS/GIS Switchgear
  - Mixed Technologies Switchgear
  - Substation Layout Improvements
  - Gas Insulated Lines
  - Underground Substations
- Conclusions
Messages

Things that Industry has been saying . . .
... especially after the numerous congestions

New technologies exist to relieve congestion on the grid

New control & communications technologies need to be applied

We need greater reliability standards for power transmission

The regulatory environment isn’t sufficient for today’s investment
Globalisation/Liberalisation

Deregulation - Privatisation: Opening of the markets, Independent Transmission Companies (ITCs), Regional Transmission Organisations (RTOs)

Bottlenecks in Transmission

Problem of uncontrolled Loop-Flows

Overloading & Excess of SCC Levels

System Instabilities / Outages

Investments in Power Systems

System Enhancement & Interconnections:

- Higher Voltage Levels
- New Transmission Technologies
- Renewable Energies
Developments of Power Markets

Power Market Drivers
- Increasing Power Demand
- Dezentralized Generation/Smart Grids
- Environmental Constraints
- New Market Conditions

Strong Competition leads to
- Use of Power Electronics
- New Technologies
- Advanced Solutions, not only products, are required
Development of Power Consumption

- Isolated Small Grids
- Higher Voltage Levels
- High Investments
- Long Distance Transmission
- Transmission Bottlenecks
- Demand for Clean Power & High Quality
- Least Cost Planning
- New Technologies
- Energy Imports

- Least Cost Planning

Developing Countries
Emerging Countries
Industrialised Countries

Power Consumption per Capita

Wolfgang Degen ©
Senior Technical Consultant
AC-Voltage Levels
Milestones and Limitations

1 110 kV Lauchhammer – Riesa / Germany (1911)
2 220 kV Brauweiler – Hoheneck / Germany (1929)
3 287 kV Boulder Dam – Los Angeles / USA (1932)
4 380 kV Harspranget – Halsberg / Sweden (1952)
5 735 kV Montreal – Manicouagan / Canada (1965)
6 1200 kV Ekibastuz – Kokchetav / USSR (1985)
7 1100 kV China / 1200 kV India

Source: Siemens
PTD SE NC - 2010
Trends in Power Transmission and Distribution

**Deregulation/Privatisation**
Opening of the markets, Independent Transmission Companies ITCs, Regional Transmission Organisations RTOs

**Bottlenecks in Transmission**
Ageing of Equipment, Integration of Renewables, Environmental and social restraints for new installations, Cost of Outages

**Investments in Power Transmission and Distribution**
Higher Voltage and Current Levels, Optimizing Substation Configuration, Life Cycle Cost (Investment, Operation & Maintenance, Outages, Disposal)
Basic design of transmission systems optimized to best technical performance and lowest investment
### Impact of Utility Privatisation

<table>
<thead>
<tr>
<th>IMPACT OF PRIVATISATION</th>
<th>OPPORTUNITY OR IMPACT ON EQUIPMENT</th>
<th>CUSTOMER BENEFIT</th>
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</thead>
</table>
| Move towards functional specifications | - More scope for standardization  
- More scope for innovative designs | - Reduced lead times  
- Improved quality  
- Better product/better service |
| Rapid response required to system needs | - Pre engineered, modular solutions | - Improved risk management  
- Ability to take on bigger responsibilities |
| Increased competition and opportunities | - Driver of innovation  
- Alternative solutions | - Better value  
- Flexibility |
| Organisational Changes | - Less reliance on customers expertise  
- Information not data needed | - Improved services from suppliers |
| Focus on capital spend more linked to end customer requirements | - Greater emphasis on factors other than just capital cost | - Reduced life cycle costs  
- New approaches to asset management |
Changes in Power Transmission and Distribution - New Hybride Switchgear Solutions

1960
Indoor-AIS (conventionel)

1980
GIS Dead Tank AIS Live Tank

2000
GIS PASS Ft-Compact AIS

2020
GIS HIS PASS Ft-Compact AIS

100% market
High-Voltage Substations – Solutions

Gas-Insulated Substations

Air-Insulated Substations

Highly-Integrated Substations
Results:
progress of circuit-breaker technology, reduced number of interrupter units with increasing breaking capability
progress of casting and machining technology of aluminum casted parts
use of computerized production and testing, design of integrated components
use of intelligent monitoring and diagnostic tools to prolongate maintenance activities compact integrated substations with the following features
up to 98% of space reduction in comparison to AIS
up to 75% reduction of SF6 volume
delivery of completely sealed and tested bay units up to 245 kV
leakage rates down to less 0.5% p. compartment and year
The life cycle cost can only be evaluated if the cost breakdown structure has been worked properly. IEC 60300-3-3 [1] is proposing a general cost breakdown structure for high voltage applications which shall be applied here.

\[ LCC = Cost_{acquis.} + Cost_{ownership} + Cost_{disposal} \]

Cost of acquisition: cost of the equipment (system cost) and the cost of installation

Cost of ownership: operation cost

- maintenance cost (planned preventive maintenance cost + planned corrective maintenance cost)
- cost of unplanned unavailability

Cost of disposal: all cost of decommissioning and disposal after use
Substation arrangement with 420kV disconnecting circuit breaker
New equipment allows simplified arrangements

Example: Traditional double busbar layout may be replaced by sectionalized single busbar. Used together, LTB Compact and LTB Combined give the optimal solution. Compact switching module LTB compact. Disconnecting circuit-breaker LTB Combined.
420/550 kV
Comparison of AIS with MTS Solutions

Conventional AIS

MTS with air insulated Busbar

MTS with encapsulated Busbar

200 m

20 m

60 m

0 10% 30% 100%
Mixed Technologies Switchgear build of Switchgear Assemblies

Switchgear Assemblies
Component – Bay - Switchgear

- Insulation Considerations
- Installation & Functionality Considerations

- AIS
- Conventional

- GIS
- Compact

- Hybrid IS
- Combined

Definition in Accordance with IEC 62271-205
IEC 62271-205 Compact switchgear assemblies for rated voltages above 52 kV

1.1 Scope

...compact switchgear assemblies consisting of at least one switching device directly connected to ... one or more other devices... . Such assemblies are made up of devices ... and are designed, tested and supplied for the use as a single unit.

Annex A
Compact switchgear assemblies consist ... of a combination of air-insulated switchgear (AIS) and gas-insulated switchgear (GIS), so called mixed technology switchgear (MTS).
Comparision of cost structure of LCC of GIS, MTS, AIS Switchgear

sample substation
a typical H-
arrangement in
145kV with 4
circuit breakers

Disposal Cost
Failure Cost
Maintenance Cost
Operating Cost
Installation Cost
System Cost
Gas-Insulated Switchgear 145 kV
Switchgear Bay

1 Circuit-breaker interrupter unit
2 Spring-stored-energy operating mechanism with circuit-breaker control unit
3 Busbar I with disconnector and earthing switch
4 Busbar II with disconnector and earthing switch
5 Outgoing module with disconnector and earthing switch
6 Make-proof earthing switch (high speed)
7 Current transformer
8 Voltage transformer
9 Cable sealing end
10 Integrated local control cubicle
MTS - Highly Integrated Switchgear
GIS Type

1 Circuit-breaker interrupter unit
2 Spring-stored-energy operating mechanism with circuit-breaker control unit
3 Outgoing module with disconnector and earthing switch
4 Splitting module
5 Current transformer
6 Voltage transformer
7 High-speed earthing switch (make-proof)
8 Cable sealing end
9 Outdoor bushing
10 Rack

Gas-tight bushings possible
MTS Solution - GIS Type 4-CB H-Arrangement
Gas Insulated Equipment
Modular Structure
MTS type gas-insulated modules
Dead Tank CB – 145 kV
Technical Details

- Bushing DT
- Clearance 1250 mm
- Current transformer
- DC/ES control cubicle
- CT control cubicle
- CB control cubical
- Disconnector / earthing switch
- Circuit breaker
- Base frame
- Spring drive mechanism
Compact MTS module by adding AIS disconnectors / earthing switches on both sides of a dead tank circuit breaker

Hybrid composed of a dead tank breaker accompanied by AIS disconnectors / earthing switches
MTS Substation Garraf 145 kV
Barcelona, Spain
## Comparison MTSS vs. AIS of Powerlink / Australia

<table>
<thead>
<tr>
<th>Switchgear Solution</th>
<th>AIS</th>
<th>HIS</th>
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</thead>
<tbody>
<tr>
<td><strong>Value</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space</td>
<td>100%</td>
<td>30%</td>
</tr>
<tr>
<td>Visual impact</td>
<td>High</td>
<td>Low to Medium</td>
</tr>
<tr>
<td>Economical values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary equipment</td>
<td>100%</td>
<td>110%</td>
</tr>
<tr>
<td>Secondary equipment</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Earthwork, civil work, structures</td>
<td>100%</td>
<td>60%</td>
</tr>
<tr>
<td>Electrical assembly and erection</td>
<td>100%</td>
<td>70%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>100%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Life cycle costs after 10 years</strong></td>
<td>100%</td>
<td>Max. 70%</td>
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**Project:** HIS 8DN8-145kV “Upper Kedron”

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Wolfgang Degen ©
Senior Technical Consultant
HIS 145kV / 40kA
Project: Upper Kedron, Australia
Substation Layout Improvements

... if I had a dream ...

**Availability and Reliability**: highest values from equipment and redundancy by single line diagram

**Modular**: flexible and interchangeable depending on necessities

**Compact and Simplified**: not unnecessary elements as e.g. bus bars

**Uniform**: All substations with standardized solutions, so that material and people are exchangable

**Low maintenance**: Closest approach to zero maintenance, replacement instead of repair

**Environmentally integrable**

**Life cycle cost optimized**
Meshed Ring Single Line Layout

Meshed Ring Substation Design integrates all solutions

$1\frac{1}{2}$ Circuit-Breaker

1 Circuit-breaker

H-Arrangement

T-Arrangement
Example: Adaptation of a ring to 1 ½ Circuit-Breaker Single-Line Diagram

Source REE Red Electrica Spain
550kV Bay Module for 1½ CB-Arrangement With Vertical Bushings

- Bushing
- Disconnector / Earthing switch
- Current transformer
- Circuit breaker
- Control unit
550kV Bay Module for 1½ CB-Arrangement With Vertical Bushings

Requirement: Exchange of the CB within 6 Hours including gas works
Example: S/S Palos de la Frontera 400 kV

Ringarrangement
Physical Layout Double Busbar
Example of Mixed Technology Substation at 550kV
MTS 420kV Ostiglia, Italy
Applications of GIL: Laid in Tunnels or Directly Buried

- Small width of trench
- Min. interference with environment during installation
- High accessibility
- Cost advantage

Inside the GIL: 80% N₂ & 20% SF₆
1. 600 MVA Transformer
2. Encapsulated Surge Arrestors
3. Transfer Switching units
4. GIL Connection
5. Open Air Surge Arrestor
6. Overheadline

Physical Arrangement: Single Line, GIL laid in a tunnel through a mountain, connection of the Cavern Power Plant to the Overhead Line

Ratings:

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<tr>
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<tbody>
<tr>
<td>$U_r$</td>
<td>420 kV</td>
</tr>
<tr>
<td>$I_r$</td>
<td>2500 A</td>
</tr>
<tr>
<td>$U_{BIL}$</td>
<td>1640 kV</td>
</tr>
<tr>
<td>$I_s$</td>
<td>53 kA</td>
</tr>
</tbody>
</table>
Gas-Insulated Transmission Line (GIL)

View of the 275 kV Shinmeika-Tokai GIL
Gas-Insulated Transmission Line (GIL)

View of the 550 kV Sai Noi GIL
Substation design for the least environmental impact

Underground Substation in Front of Castle Main Gate in Nagoya, Japan
Underground GIS Substation to City of Anaheim for Disneyland

- HV GIS
- MV GIS
- Transformer
- Cap. Banks
Underground Substation Barbana Spain

The GIS and Transformers are located under an public park.
The substation supplies the inner city with energy.

artificial Waterfall avoids Transformer Noise
Haymarket Underground S/S
Sydney/Australia

The main substation features of the Haymarket Substation:
• 5 storey substation building, predominantly underground (3 floors)
• Single level, below ground, EHV plant floor with 28 bays of 330kV and 132kV GIS
• Unique integrated substation SF6 containment system
Haymarket Underground S/S
Sydney/Australia
132/330 kV GIS
Do you want more information??

CIGRE Brochure 380: The Impact of new functionalities on Substation Design

CIGRE Brochure 390: Evaluation of Different Switchgear Technologies (AIS, MTS, GIS) for Rated Voltages of 52 kV and above

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Thank you for your attention.
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