Exploring Substations of the Future

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Product or function – Individually specified equipment working to a similar objective

It's a complex system whose performance is measured individually and as availability

Equipment purchased and evaluated individually
WHAT CAN SUBSTATIONS BE...

- Lean Substation
- Digital Substation
- Mobile Substation

How do specifications of each equipment within substations link together?

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QUESTIONS FOR SUBSTATIONS

How can I increase the *availability of my substations*?

How can I *reduce space and cost* in existing and new installations?

How can I *optimize the utilization of my assets, reducing maintenance efforts*?
TYPICAL CHALLENGES

- Unexpected service events
- Efficient design & operation
- Space limitations in urban areas
- More extensive use of assets required
- Handle asset data and retrieve information
- Cyber Security threats

How Resilient?
Are they Resilient?

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EXAMPLE - AIS/MTS/GIS - WHAT TO CHOOSE?

Grade of encapsulation

Air-Insulated Substations (AIS)

- (+) efficient in investment cost
- (+) easy to maintain and repair
- (-) space consuming
- (-) exposure to harsh environment
  - preference for rural areas

Mixed-Technology Substations (MTS*)

- (+) pre-assembled, pre-tested components ease refurbishment and minimize outage time

Gas-Insulated Substations (GIS)

- (+) compact, space saving design
- (+) integration into surrounding environment
- (-) higher investment cost compared to AIS, MTS
- (-) dependence on OEM for spares and in case of damage
  - preference for urban areas

Function integration

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* MTS – Mixed Technology Switchgear (IEC 62271 – 205)
AIS/GIS/MTS EXAMPLES

- 145m² versus 6000m²
- GIS = 2.5 - 3.5 X AIS price
- GIS = 1.5 - 2.2 X MTS Price
- Land/space savings ~ R920/m²
AIS/MTS/GIS BAY EXAMPLE

- 11m² versus 76m² (MTS vs AIS)
- 3m² versus 11m² (GIS vs MTS)
### QUESTIONS TO BE ASKED

<table>
<thead>
<tr>
<th></th>
<th>AIS</th>
<th>MTS</th>
<th>GIS</th>
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<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Low</td>
<td>Moderate</td>
<td>Higher</td>
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<tr>
<td><strong>Space required</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
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<tr>
<td><strong>Flexibility</strong></td>
<td>Low</td>
<td>Low</td>
<td>High</td>
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<tr>
<td><strong>Modular</strong></td>
<td>Low</td>
<td>High</td>
<td>High</td>
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<tr>
<td><strong>Maintenance</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Civil works</strong></td>
<td>High</td>
<td>Low</td>
<td>Low</td>
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</tbody>
</table>

- Mobile application
- Space versus cost
- CAPEX and OPEX long term planning
- Ease of maintenance
- Future planning of additional bays
NEW TECHNOLOGIES OR EVOLUTION?

Vacuum circuit breaker, 72.5 kV, 2010

GIS, 72.5 kV, 2016

- One gas compartment for circuit breaker, disconnector and earthing switches
- Worldwide leading F-gas free environmental friendly technology

GIS, 145kV, first in the world, Air insulated

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Non-conventional instrument transformers (NCITs) are current and/or voltage measurement devices with no significant output power: According IEC 61869-6 (2016), their output power is “typically lower or equal to 1 VA”
CT/VT EXAMPLES…

- No iron core necessary due to optical measurement principle
  - No saturation effects
  - Very good transient performance
  - Reduced weight

- Reduced insulation effort compared to conventional ITs

- Very small and lightweight

- Easy interconnection to digital station bus complying to IEC 61850

- Cost saving potential due to reduced cabling effort – only optical fiber(s) needed instead of large copper cross-sections

*Complete electrical insulation between primary and secondary equipment due to optical fibers*

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DECENTRALIZED RECTIFICATION

HVDC - Diode Rectifier Unit DRU

HVAC - Transformer for Offshore Transmission Module

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TRANSFORMERS FOR BUILDINGS

Environmental friendly, safe & reliable in operation, highly economical

London, inner City: Ester fluid filled unit with ester, water coolers, heat reclaim and heat exchangers

Esters have a higher fire safety factor
- Higher flash and fire point
- Fire point over 300°C
  - K class rating (IEC 61100 / 61039)
- Lower gas conversion factor
  - Tank rupture prevention improvement

Esters are environmentally friendly
- Readily biodegradable
  - In accordance with OECD 301
- Fully biodegradable
  - In accordance with IEC 61039
- Classified as non-hazardous to water

Esters can extend the lifetime of the transformer
- Slower decrease in the degree of polymerization
- Dielectric strength unaffected by water
- Higher temperature limits

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DIGITAL VULNERABILITY… IS IT REALLY?

Specific requirements
- 24/7 operation
- Interfaces to unsecure networks
- Components from different vendors
- Standard OS components
- Proprietary technology

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CONVENTIONAL OR NEW

a. Optimization in layout and design
b. using state-of-the-art technology
c. using new (non-disruptive) technology

- Lean Substation (2.0)
- Digital Substation

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QUESTIONS TO BE ASKED

✓ Specifications and regulations, do they allow new Technologies?
✓ Do current Cost Capitalization (OPEX or CAPEX driven) models realize new Technology benefit?
✓ How can we integrate equipment more efficiently and effectively?

Demand creates innovation

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