Development trends in Substation Design

on behalf of SC B3

Hans-Erik Olovsson
Convenor Activity Area 1 (AA1)
« Substation concepts and development »
Agenda

- Evolution of primary equipment and design
- Trends for substations in urban areas
- UHV see a renaissance
- IEC 61850 for secondary systems
- Future developments “around the corner”
Primary design principles

- Historically AIS S/S were designed for CB maintenance, since circuit breakers needed maintenance very frequently
- Single line configuration where accordingly built up with CB’s “surrounded” by DS
Modern CB´s require maintenance 15 years+, however open air DS´s unchanged.
Primary design principles cont.

- Disconnecting function today more needed for maintenance of OH-lines, Power Transformers, Reactors etc.
- New designs with disconnecting function “together” with CB, instead of separate, has evolved
  - Hybrid
  - Disconnecting CB
  - Rotating CB
  - Withdrawable CB

Main Stream
(SF6 encl. contacts)

Niche products

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Rotating CB  Withdrawable CB

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Primary design principles

- Installing the disconnecting function together with CB
  - Reduce footprint
  - Extends maintenance intervals, for the solutions having all primary contacts in SF6
  - Resulting in an overall higher availability
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Utility challenges

**Environment**
- Reduce outlet of (CO2, …)
- Sound, visual impact, ….
- Interior (Personell safety)
- Exterior (Third party safety)

**Electrical dependence**
- Increased customer services
- Reliability
- Political pressure
- Investment decision

**Profitability**
- Reduce maintenance costs
- Reduce outages
- Minimize penalties
- Image

**Legislation**
- Report inventory of SF6
- SF6 leakage limited by law (California)

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Problem with Urban substations

- Originally outskirt of city, now surrounded by residential buildings, offices, shopping centers, hotels etc.
- Usually open air substation, with not so nice aesthetic, society want power without seeing it
- Third party safety has become an issue
- Evolution driven by permitting and siting issues that have become the “long lead time” item, external (visual) view very important
- Making substation ”invisible” makes it easier to get acceptance by the society
Urban substations visual view

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Pros with “invisible” solutions

- No substation fence and yard, building itself give the “shell” protection and third party safety
- Station modularized and as much as possible pre-manufactured
- Can be located close to the consumers, virtually ”invisible” in building or truly invisible underground
- Site work as little and short as possible, saves cost, shorten overall delivery time and minimize disturbance to neighbors during site activities
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Existing and planned US 765 kV

Composite Wind Resource Map

Wind Power Classification

- **Resource Potential**: Marginal, Fair, Good, Excellent, Outstanding, Superb
- **Wind Power Density at 50 m**: 200 - 300, 300 - 400, 400 - 500, 500 - 600, 600 - 800, 800 - 1000 W/m²
- **Wind Speed at 50 m**: 5.6 - 6.4, 6.4 - 7.0, 7.0 - 7.5, 7.5 - 8.0, 8.0 - 8.8, 8.8 - 11.1 m/s
- **Wind Speed at 50 m in mph**: 12.5 - 14.3, 14.3 - 15.7, 15.7 - 18.8, 16.8 - 17.9, 17.9 - 19.7, 18.7 - 24.6

Wind speeds are based on a Weibull k value of 2.0

Source: U.S. Department of Energy, National Renewable Energy Laboratory

Transmission Lines Voltage (kV):
- 345 - 499
- 500 - 699
- 700 - 799
- 1000 (DC)

Source: POWERmap, powermap.platts.com, 20007 Platts, a division of the McGraw-Hill Companies

The remaining states use data from the 1987 "Wind Energy Atlas of the United States".
AEP’s Vision Of An Interstate Transmission Grid

- President Eisenhower envisioned a modern interstate highway system for the US economy and national security in 1956
  - Imagine our economy today without the interstate highway system
- Similarly, AEP envisions an interstate electric transmission grid for the US economy and national security
- AEP collaborated with the American Wind Energy Association to create a interstate electric transmission grid to enable 350 GW of wind capacity

The AEP Advantage: 100 years of transmission leadership experience in the United States
India 800/1200 kV AC-system

- Started to build a 800 kV network, first S/S in 2004, as a backbone for their system
- Planning for a 1200 kV system as a backbone to the backbone. (2016)
China 1100 kV AC-system

- South-North connection, in service January 2009
  Transmission capacity 2800 MW
- Number of large DC-connections West-East
  up to +/- 800 kV, 6400 MW
China 1100 kV AC-system

- Hybrid or GIS solutions
Japan 1100 kV AC-system

- Has been discussed since the 90-ies
- Upgrading existing 500 kV to 1100 kV
- Some lines already prepared for 1100 kV
- First stations about to be energized
CIGRE UHV-activities

- WG A3.22 Technical requirements for substation equipment exceeding 800 kV, TB 362 Dec. 2008
- WG B3.22 Technical requirements for substations exceeding 800 kV, TB 362 Dec. 2009
- WG A3.28 Switching phenomena and testing req. for UHV & EHV equipment, May 2010
- WGB3.29 Field tests technology on UHV substation during constr. and operation, May 2010
- Common CIGRE/IEC Colloquia
  - Beijing, July 2007
  - New Delhi, Jan 2009
  - ...
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Station bus IEC 61850-8-1

- Almost all customers use IEC 61850-8-1 protocol today, very fast transition from proprietary protocols
- Make it possible to use Intelligent Electronic devices (IEDs) from different manufacturers connected to the same station bus
- IEC 61850-8-1 also enable splitting between function and physical location
Station bus changes

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Process bus IEC 61850-9-2

- This is next step and a more revolutionary change, going from 1A/110 V -> fiber optic
- Will make it possible to exchange all copper cable, except for power feeding, to fiber optics
- Many pilots installed around the world
- First commercial delivery under way (Australia)
- Enabler for introduction of Non Conventional Instrument Transformers (NCIT)
Process bus introduction
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Non conventional instr. Transf.

- Process bus, IEC 61850-9-2
  - Will enable introduction of NCIT using fiber optics sensors
  - Environmental friendly no copper, steel, iron, concrete, insulation material, etc.
  - NCIT will be possible to integrate in other high voltage apparatus and further reduce the footprint of substation
  - Merging units on NCIT transfer sensor signals to 9-2 protocol
Future Substation

- IEC 61850-9-2 implemented
- Non conventional sensors for current and voltage
- Fiber optic cables throughout, except power feeding
Summary

- “Switching machines” with reduced maintenance (all primary contacts in SF6)
  - maintenance focus -> fault tolerant focus, 1 ½-CB, 2-CB
- Invisible substations for urban areas
  - Virtual invisible in buildings similar to surrounding
  - Truly invisible underground for city centers.
- UHV solutions renaissance in many countries
- IEC 61850 moving very fast
  - 8-1 station bus is already the preferred standard
  - 9-2 process bus in the doorstep
- NCITs around the corner, linked to 9-2 introduction
Thank you for your attention!