WPS-115-1 (presentation code)
Global technologies for substation applications
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Global technologies for substation applications

- Speaker name: Scott Andries, P.E.
- Speaker title: Business Development Mgr.
- Company name: ABB
- Location: Raleigh, NC, USA
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Convention Center exits in case of an emergency

Know your surroundings:
- Identify the meeting room your workshop is being held in
- Locate the nearest exit

YOU ARE HERE
Global technologies for substation applications
Research & History

Technology Research
- According to Stephen X. Hawkings* – “the laws of physics, and in particular of electricity, work the same in the US as it does in the rest of the world.”

* Stephen X. Hawkings is in no way related to Stephen W. Hawkings, the world renowned theoretical physicist; and is in reality a pen-name for Scott Andries
Definition of Dead Tank

- Interrupting enclosure (tank) is at ground potential
- Current enters/leaves tank via standard bushings

Applications (used preferentially in U.S.)

- Any
- Advantage: low-cost current transformers (CTs) on bushings
Global technologies for substation applications

Technology – Live Tank Breakers

Definition of Live Tank

- Interrupting enclosure (tank) is at line potential, supported by insulator columns

Applications (used preferentially in Europe+)

- Any
- Advantage: Smaller footprint & weight
Definition of Circuit Switcher

- Similar to Live Tank Breaker, except:
  - Duty Cycles: O or C-O
  - Operating Times: Slower

- Confusion – Live Tank Breakers

Typical Applications:
- Transformer Primary Protection
Global technologies for substation applications

Technology – Live Tank Breakers

Conventional Solution

- Dead Tank & Circuit Switchers

Innovation

- Large Transmission – Utilize both live & dead tank breakers
- Distribution Substations – replace older under-rated (kA) circuit switchers; new designs in lieu of circuit switchers
Global technologies for substation applications
Technology – Gas Insulated Switchgear
Global technologies for substation applications
Technology – Gas Insulated Switchgear

- Gas compartments
- Single line
- Plan view
- Section
- LCC
- CB
- CT
- VT
- Busbar w. DS/ES
- DS/ES
- HV-connection
- Fast acting earth. switch
Global technologies for substation applications
Technology – PASS (Plug and Switch Service)
Global technologies for substation applications
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Global technologies for substation applications

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Technology – PASS (Plug and Switch Service)

Conventional Solution
- Air Insulated & Gas Insulated Switchgear

Innovation
- PASS Switchgear
- 2-3 Terminal Applications (Taps)
- NERC Reliability Standards (breaker failure contingency)
- Mobile Transformers
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Technology – Disconnecting Circuit Breaker (DCB)

Conventional live tank breaker that has been modified to also serve as the disconnect switch

**Closed** (normal circuit breaker)

**Open** (normal circuit breaker)

**Disconnected** (mechanical lock-out and electrical interlocking)
Global technologies for substation applications
Technology – Disconnecting Circuit Breaker (DCB)

- DCB Mechanically locked in disconnected position
- Closed earthing switch assures primary de-energized instead of open DS as in traditional AIS
- Earthing switch motor-operated from remote

Un-blocked
Blocked
Global technologies for substation applications
Making substations smaller
Global technologies for substation applications
Making substations smaller
Global technologies for substation applications
Making substations smaller
Global technologies for substation applications
Making substations smaller
Global Technologies for Substations
Technology – Shunt Reactors

Conventional Solution
- 3 single-phase units

Innovation
- 1 three-phase unit; 5 leg/limb design for single pole reclosing or operation
  - 20% equipment cost savings
  - Additional EPC cost savings: foundations/installation
Global Technologies for Substations
Technology – Variable Shunt Reactor (VSR)

An Unconventional Reactor Built With Conventional Technology
Global Technologies for Substations Technology – Variable Shunt Reactor (VSR)

Conventional Solution
- 2 banks of 3 single-phase units (6) or 2 three-phase units (2)
- Improved reliability over high voltage air core reactors

Innovation
- 1 Variable Shunt Reactor
  - Eliminate frequent switching of reactors; reduce voltage step change
  - Lower price and losses than 2 unregulated units; smaller footprint
Global Technologies for Substations
Technology – IEC 61850

IEC and IEEE joined forces in 1999 and defined…

IEC 61850
“Communication Networks and Systems in Substations”

- IEC 61850 – first global standard in the Utility field
- Developed by 60 domain experts
- Supported by all major vendors
- Very fast acceptance by the market… except in the US, but picking up steam
Global Technologies for Substations
Technology – IEC 61850

- Introduction and overview
- Glossary
- General requirements
- System and Project management
- Communication requirements
- Communication model (Data model and Services)
- Substation Configuration Language (SCL)
- Conformance testing

Part 1: General requirements
Part 2: Glossary
Part 3: System and Project management
Part 4: Communication requirements
Part 5: Communication model (Data model and Services)
Part 6: Substation Configuration Language (SCL)
Part 7-1 to 7-4: Communication model (Data model and Services)
Part 8: Conformance testing
Part 9: Station Bus
Part 10: Sampled Values (Process Bus)

- Part 8-1: Mapping for MMS-TCP/IP-Ethernet
- Part 8-x: for Future Use
- Part 9-1: serial unidirectional point-to-point
- Part 9-2: Mapping on IEEE 802.3(Ethernet)
Global Technologies for Substations
Technology – IEC 61850

Network Level

Station Level

Bay Level

Process Level

IEC 61850
Global Technologies for Substations
Technology – IEC 61850

TERNA SICAS Program for 360/220/150kV S&Ss, Italy
- Large-scale standardization of IEC 61850-compliant solutions
- Creation, homologation and supply of:
  - 40 types-tested bay control and protection solutions
  - High-quality user interface standard and sequencer
  - Incorporation of 3rd party IEDs and units with IEC 61850 communication interfaces
- Efficient project implementation

EOL 380 kV Laufenburg Substation, Switzerland
- The world’s first HV substation with IEC 61850-compliant IED
- Stepwise retrofit of seven out of 17 bays:
  - New control and redundant protection
  - Gateway to existing station HMI
  - Integration of 3rd party Main 2 IEDs with IEC 61850 communication interfaces
  - Sustainable concept for easy migration of remaining bays/station HMI

DEWA Frame contract, Dubai
- Supply of 20 IEC 61850-based SA systems
- State-of-the-art systems for new 132/11 kV S&Ss:
  - Short lead times realised by highly qualified project team
  - Redundancy concept, independent key components and physically separated communication networks
  - Proven technology and functionality
- Safeguarded investment into interoperable systems for any make of switchgear.

CANADA
- Teck Cominco, Waneta S/S 230/63kV
- EPCOR East Industrial S/S 240/25kV
- Manitoba Hydro S/S 230 kV

USA
- TVA Bradley S/S 500/161kV
- Formosa Plastics S/S 138/13.8 kV

NEK refurbishes its HV S/Ss Delbrügge & Verma, Bulgaria
- The first 400/220 kV 33/38 kV to be refurbished obtain IEC 61850-compliant SA
  - Different configurations: double busbar, 1½ cub, ring
  - Redundant station servers and operator workstations in hot standby mode
  - Integration of some 70 new RE660 IEDs and four RE650 numerical busbar protection systems
  - Integration of 110 kV stations via RTU as well as existing RE621 line protection
- Optimal life cycle management through future-proof retrofit concept

ENELVE’s and ENELCO’s Solar & Modanes S/S, Venezuela
- IEC 61850 is key to the utility’s strategy for SA throughout its grids
  - Uniform system structure with redundant station level for high scalability
  - Redundant Ethernet ring with switches for direct connection of all control & protection IEDs with IEC 61850 communication interface
  - High-quality operator interface with proven applications for control and monitoring of the entire 132/24 kV & 157/33 kV S&S
- Enhanced efficiency with harmonized SA systems for new and retrofit substations

MEW’s Financial Harbour, Sitra & Bughwein S/S, Bahrain
- The three 220/11 kV GIS substations will strengthen the grid and increase the reliability of the power supply
  - Redundant Station HMI with redundant, independent gateways
  - One product family, RE670, for Control and Protection
  - Bar/Section control unit RE670 for all three voltage levels
  - RE650 busbar and breaker fusions protection
  - EOL 110 kV Substation in Bahrain

Six new HV substations for PGCIL, India
- 400/220 kV GIS S/S at Mahabaleshwar, 400/220 kV AIS S/S at Bhatapara, Ratibad, Raigarh and Raigarh, 400 kV AIS S/S at Bira

PGCIL’s new substations will be controlled and monitored by IEC 61850-based SA systems featuring:
  - Redundant Station HMI using Main/SCADA Pro
  - One product family, RE670, for Control and Protection
  - RE670 bar control unit for all voltage levels
  - RE650 busbar protection system with IEC 61850 communication interface
  - Integration of 3rd party Main 2 IEDs on IEC 61850 platform

220/110/33kV for Sohar Industrial Area, Oman
- Automation with verified IEC 61850 implementation for raw GIS substations
  - Redundant Station HMI
  - Scalable bay control unit RE670 for all three voltage levels
  - Enhanced operational efficiency and safety through optimized solution

Overall ABB involved in > 300 IEC 61850 projects
Global Technologies for Substations
Technology – IEC 61850

Back in the Day
Standard cabling

Mimic board
Fault recorder
Protection
Parallel wiring
Bay

Conventional
Point-to-point connections since 1980’s..

SCADA/EMS
HMI
RTU
Serial connection
Bay

"Smart"
Open communication

SCADA/EMS
HMI
RTU / Gateway

IEC61850-8
61850-9-2
Global Technologies for Substations
Power supply for urban environments

- Inner-city substation concepts
- Smoothly integrated into urban surroundings – invisible and safe for the public
- Enables high voltage levels near to load centers for high quality power supply

**Indoor Substations**
- Integration into buildings
- Architectural incorporation into existing or new developed urban areas

**Underground Substations**
- Whole substation underground
Global Technologies for Substations Technology – Invisible Substations (Indoor)

- High availability
- Low cost for preparation of land
- Pre-fabricated
- Short erection time at site

- Low maintenance cost
- Can easily be moved
- Environmental friendly
- Personnel safe
Global Technologies for Substations
Technology – Invisible Substations (Indoor)
Global Technologies for Substations

Technology – Invisible Substations (Indoor)

- Modularized solution
- Voltage range 34.5 – 161kV
- Withdrawable Circuit Breakers
Global Technologies for Substations
Technology – Invisible Substations (Indoor)
Global Technologies for Substations
Technology – Invisible Substations (Indoor)
Global Technologies for Substations
Technology – Invisible Substations (Indoor)
Global Technologies for Substations
Technology – Invisible Substation (Underground)

- Below a building or building complex
- Underneath parks or green space
- In a parking deck
- At traffic circles or under road crossings
- Into other public places (airports, sports complexes etc.)

The ABB underground concept is free to be integrated into any urban complex
Global Technologies for Substations
Technology – Invisible Substation (Underground)

Design of underground substations

- Civil design and civil works
- Fulfill requirements according to soil conditions
- Water-proofing and dewatering
- Integration in the surrounding structures
- Optimized physical arrangement
- Limited space availability
- Flexible cable access
- Equipment Accessibility

- Highest safety requirements due to proximity to the public
- Fire Protection and Emergency Exits
- No public hazards and maximum protection
- Control noise and vibration emissions
- Air supply and equipment cooling
- Easy transportation and logistic access of all equipment
- Transport and access
- Minimize maintenance requirements

Environmental influence
Cooling and ventilation

Optimum technical solution and overall cost
Beauregard, Switzerland

Customer need
- Replacement of 50 year old Substation
- Increased availability of local network

ABB’s response
- Construction, installation and commissioning of new underground Substation consisting of
  - 72.5 (60) kV GIS Switchgear
  - 12 (8) kV AIS Switchgear (18 Duplex feeders)
  - 2 Power Transformers 20 MVA, 60/8 kV
  - 1 Petersen coil
  - Control and protection, metering system
  - Complete auxiliary systems

Customer benefits
- Optimization of network
- Aesthetic integration of the substation building in the urban environment
- Additional use as parking space
Lusail – Boulevard I and Boulevard II, Qatar

Customer need
- HV power supply as pre-requisite for new infrastructure development in Lusail
- Substations could not impact local residential and commercial area

ABB’s response
- Two 66/11 kV underground substations 13 m below ground level
- 2 x 12 bays 66kV GIS, 2 x 40 bays 11kV AIS
- 2 x 3 transformers 40 MVA
- Advanced transformer design
- Optimized ventilation and cooling based on heat dissipation studies
- Optimization of design based on ABB experience
- Substation automation and auxiliary systems

Customer benefits
- Critical on-time delivery met developer needs
- Zero influence on public surroundings
Lusail – Boulevard I and Boulevard II
Gouttes d‘Or, Switzerland

Customer need
- Reliable power distribution for the urban area of Neuchatel
- Replacement of the former station

ABB‘s response
- New underground substation
- 60 kV HV-GIS
- 8 kV MV-AIS
- Two transformers 20 MVA
- Selection of most compact ABB equipment enabling space optimized layout
- Space optimized access and escape routes

Customer benefits
- New space for park, recreation and parking areas
- Smooth architectural integration into the urban landscape surrounding the site
Gouttes d’Or, Switzerland
Heidelberg UW Altstadt, Germany

**Customer need**
- Advanced power supply and distribution in an area within Heidelberg historic district

**ABB’s response**
- Integration of all substation equipment into a historic building
- 110kV GIS
- Flood protected installation

**Customer benefits**
- Station invisible to the public and compliant with historic district requirements
Global Technologies for Substations
Technology - Economic Evaluation of Designs

Parts of an Economic Evaluation of Substations

- Reliability Analysis
- Predict the Total Project Cost
  - Initial Costs
  - Operation & Maintenance Costs
  - Cost of Power Interruption
- Optimize Reliability vs. Cost
- Factor in Intangibles (safety, aesthetics)

Analytical Software Tools

- SubRel™
- SubRank™
- ETAP
Global Technologies for Substations
Technology - Economic Evaluation of Designs
# Global Technologies for Substations

## Technology - Economic Evaluation of Designs

### Table 1. Transmission Line Reliability

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Stochastic</th>
<th>Determined</th>
<th>Total</th>
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<tr>
<td>AIS Collector Bus</td>
<td>0.2115</td>
<td>0.8</td>
<td>1.0115</td>
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<tr>
<td>OD</td>
<td>0.7479</td>
<td>6.4</td>
<td>7.1479</td>
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<td>AIS Ring Bus</td>
<td>0.1176</td>
<td>0.4</td>
<td>0.5176</td>
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<td>OD</td>
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<td>OD</td>
<td>0.1039</td>
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</table>

Maintenance | Failure
Global Technologies for Substations
Technology - Economic Evaluation of Designs

\[ LCC = IC + [FC + VC] \times \left[ \frac{(1+p)^n - 1}{p \times (1+p)^n} \right] \]

where:

- \( LCC \) = Life Cycle Cost
- \( IC \) = Investment Cost
- \( FC \) = O&M Cost, i.e., fixed annual cost
- \( VC \) = Interruption Cost, i.e., variable cost
- \( n \) = substation planned life time
- \( p \) = Interest rate

SubRel™

- Interruption Cost
  - Cost of Interrupted Energy $/kWh – Duration
  - Cost of Interrupted Power $/kW – Frequency
Global Technologies for Substations
Technology - Economic Evaluation of Designs

Life Cycle Cost

- Failure LCC
- O&M LCC
- Investment Cost

A  B  C

0  5,000,000  10,000,000  15,000,000  20,000,000
Global Technologies for Substations

Summary

- Footprint – space savings – making substations smaller
- Reliability, Availability, & Maintainability
  - Indoor vs. Outdoor (shell protection)
  - Less Equipment
- Safety and Security
- Environmental & Permitting (aesthetics, sound)
- Closer to the Load Centers
- Complements Underground Cables
- Life Cycle Cost Effectiveness
### Customer Training at the Marriott World Center

#### Power Systems Substations

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Code</th>
<th>Location</th>
<th>Title</th>
<th>Presenter</th>
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<td>EPS-124-1A</td>
<td>Technology &amp; Solution Center (Theater #1)</td>
<td>Logistics planning for large substation projects</td>
<td>Scott Andries</td>
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<td>Denver Conference Room</td>
<td>Substation alliance concepts: Case Study</td>
<td>Bob Reymers</td>
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<td>Substation design fundamentals: How substations are designed and deployed in the market place</td>
<td>Tracey Evers</td>
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<td>Rigid bus design for AC substations: Electromechanical considerations for substation design</td>
<td>Paason Rojanatavorn</td>
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<td>Grand Ballroom 13</td>
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<td>Melvin Brown</td>
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Substations Sales & Marketing Team

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Meeting Rooms at the Marriott World Center
Reserved for Power Systems Substations

Monday, April 18th 4:30 pm – 5:30 pm
(Marco Island Meeting Room)

Tuesday, April 19th 4:30 pm – 5:30 pm
(Marco Island Meeting Room)

Wednesday, April 20th 5:30 pm – 6:30 pm
(Marco Island Meeting Room)
Reminders
Automation & Power World 2011

- Please be sure to complete the workshop evaluation

- Professional Development Hours (PDHs) and Continuing Education Credits (CEUs):
  - You will receive a link via e-mail to print certificates for all the workshops you have attended during Automation & Power World 2011.
  - BE SURE YOU HAVE YOUR BADGE SCANNED for each workshop you attend. If you do not have your badge scanned you will not be able to obtain PDHs or CEUs.
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