San Francisco IEEE PES Chapter
Evolution of the Digital Substation
The Digital Substation
Secondary system

- Reduce amount of cables by using fiber instead of copper
- Simplify P&C panels and increase safety by fully isolating from process
- Optimize drive and interface boxes with direct process bus connection
- Reduce maintenance through increased supervised area
# Substation Overview

<table>
<thead>
<tr>
<th>Network Level</th>
<th>Conventional</th>
<th>Modern (Retrofit)</th>
<th>Modern</th>
<th>Intelligent (Retrofit)</th>
<th>Intelligent</th>
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<tbody>
<tr>
<td>Station Level</td>
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<tr>
<td>Bay Level</td>
<td>Station Bus</td>
<td>Interbay Bus</td>
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<td>Station Bus</td>
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<tr>
<td>Process Level</td>
<td>Process Bus</td>
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</table>

- **Conventional**: Parallel, hardwired cabling
- **Modern (Retrofit)**: Station Bus, Interbay Bus
- **Modern**: Parallel, hardwired cabling
- **Intelligent (Retrofit)**: Station Bus, Interbay Bus, Process Bus
- **Intelligent**: Station Bus, Interbay Bus, Process Bus

- **Abb**
Evolution of designs
RTU / hardwired

- IEDs do not have communication capability
- Status monitoring and control via RTU hardwired connections
- Duplication of wiring, and associated testing, maintenance, and engineering
  - Process – Protection
  - Process – Control and monitoring
- Significant amount of connections, discrete relays (timing, bi-stable, etc), and switches driving the required panel space
Evolution of designs
DNP / Modbus

- Integration of status monitoring into IEDs
- Reduction of RTU cabinet
- Defined protocol stack
- Non standard modeling of substation equipment and functions
- Non standard data format
- Integration requires intimate knowledge of

While this architecture was a step forward in SA it resulted in the emergence of several proprietary protocols which locked users in – The emergence of DNP and Modbus addressed this, however, with a very shallow and non domain specific definition of the protocol this resulted in a high level of diversity in implementations which hindered interoperability.
Evolution of designs
IEC 61850 SA system

- Integration of status monitoring, protection, automation, and control into IEDs
- Digitization of copper wires
  - 61850-8-1
  - 61850-9-2
- Modeling of the substation, equipment and functions
- Protocol stack

IEC 61850 emerges has a holistic solution for communications inside utilities where domain specific modeling, protocol performance requirements, testing and validation, and life cycle of SA systems are addressed
Technology enabler
IEC 61850

- **Interoperability**
  - Exchange information between IEDs (Intelligent Electronic Devices) from several manufacturers
  - IEDs use this information for their own function

- **Free Configuration**
  - Free allocation of functions to devices
  - Support any philosophy of customer – centralized or decentralized systems

- **Long Term Stability**
  - Future proof
  - Follow progress in mainstream communication technology
  - Follow evolving system requirements needed by customers
DNP vs. 61850
Apples to oranges?

DNP 3.0 is a generic, non domain specific communications protocol – its limited to defining a set of rules that determine how data is transferred from one device to another.

IEC 61850 is a holistic standard for communications in electrical utilities where the modeling of data, system engineering, testing, and requirements on devices and performance of communication are defined.

In addition to this, multiple communication protocols enabling the exchange of information between devices are defined:

- Client server (MMS)
- GOOSE
- Sample measure values
- Etc...
DNP vs. 61850
Apples to oranges? - Engineering

- DNP
  - DNP only allows a bottom up engineering approach where each devices points list needs to be defined
  - Such point lists are then utilized to configure a master
  - The non domain specific nature of DNP requires system integrators to tie such points lists to actual substation data

- 61850
  - 61850 enables a top down engineering approach thanks to SCL
  - With SCL, each device has a file describing the data contained in it, the system can then be engineering in a system tool environment by dropping the devices files and configuring the desired reports
  - The result is a substation wide configuration file that describes the system can be reutilized in the future for quicker system deployment
DNP vs. 61850
Apples to oranges? – Real time communication

DNP

- No real time, peer to peer communication mechanism defined

61850

- GOOSE defined for real time peer to peer exchange of information (trip signals, blocking/unblocking, etc)
- SMV defined for real time distribution of current and voltage samples for the purposes of protection, metering, and monitoring
DNP vs. 61850
Apples to oranges? – Testing and validation

DNP

• No specific features enabling testing and commissioning

61850

• 61850 addresses testing of client server, GOOSE, and SMV by:
  ▪ Test mode which isolates devices being tested from the rest of the system reducing risk of misoperations
  ▪ Simulation mechanism enabling test sets to force the status of signals in an effort to validate a protection/automation scheme
  ▪ Substitution which suppresses changes of status during testing
IEC 61850
Basics: What is GOOSE messaging?

- GOOSE messages are based on change event
- GOOSE messages are managed by GCBs (GOOSE control block) inside IEDs
- GOOSE messages send “data sets” upon changes of state
- GOOSE messages include diagnostic functions (a “heart beat” to all devices subscribed is sent periodically)
IEC 61850: introduction to process bus

What is a sampled measured value?

- Merging and timely correlation current and voltage values from the three phases
- Sampling or re-sampling of current and voltage values
- Technology specific interface between NCIT/CIT and MU

Time synchronization

- Synchronize IEDs or other MUs when acting as time master, if required
- Receive time synchronization when acting as time slave, if required

Communication interface according to IEC 61850-9-2

IEC 61850-9-2
IEC 61850 enabler
Process bus interface

IEC 61850 Station Bus
Replace wiring and legacy protocols between bays by digital communication

IEC 61850 - 8-1
IEC 61850 - 8-1
IEC 61850 - 9-2
IEC 61850 Process Bus
Analog + Status + Commands
Acquire once, distribute digitally!
Transmission Switchgear with NCIT, Protection and Control

GIS with NCIT

Protection & Control

AIS with NCIT (FOCS)
Applications

Digital substation

Station Level
- Station automation
- Monitoring
- Fault evaluation
- Event and alarm viewing and acknowledgement
- Remote communication for telecontrol and supervision

Bay Level
- Protection
- Control
- Monitoring
- Interlocking
- Data acquisition

Process Level
- GIS or AIS switchgear
- Instrument transformers
- Power transformers
- Surge arresters
- Non-conventional transformers
Advanced protection, control and automation
The fundamentals behind the change

- Demand for real time process data has grown exponentially in the past decade
  - Reliability, grid resiliency, event analysis, contingency planning, proactive power system control
- Development of open standards encouraged by proven interoperable solutions paving the way
- Technology innovations with high performance microprocessors allow more functionality in a single device
- Pressure on reducing total cost of ownership and improving system performance and maintainability
  - While managing challenges of aging infrastructure and workforce reduction
  - While managing challenges of regulatory compliance (NERC/CIP & PRC)
- Need to address grid resiliency & system hardening
The digital substation
Solutions for utilities’ critical needs

Benefits of transformative digital solutions over traditional solutions

<table>
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<tr>
<th>Lower total cost of ownership</th>
<th>Enhanced safety</th>
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<tr>
<td></td>
<td>• Reduce risk of fire and safety hazards for your personnel</td>
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<th></th>
<th>Functional consolidation</th>
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<td></td>
<td>• New generation multi-function capabilities significantly reduces footprint</td>
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<thead>
<tr>
<th></th>
<th>Improved reliability and efficiency through simplicity</th>
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<tbody>
<tr>
<td></td>
<td>• Reduced complexity improves reliability and efficiency</td>
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</table>
Enhanced safety
Utilization of Sensor Technology

Non-conventional Instrument Transformers (NCIT)

- Reduce risk of injury from conventional Instrument Transformer failure or hazardous open CT circuit
- Elimination of CT circuit into the control house as

Redundant rogowski coil & capacitive voltage divider

Fiber optic current sensor

Process Bus

control house
Enhanced safety
Reducing the risks in the control house

Digital substation reduces wiring complexity and resulting risks for operations & maintenance personnel

Before

No cable tray

After

Single conduit to carry fibers
Analogy of functional consolidation
The evolution of technology

- Technology drives consolidation of functions in all industries
- Reduces amount of inventory
- Improves the work process
- Requires new skill sets investment
Proofs – Free allocation of function/logical nodes
Enables functional consolidation
Functional consolidation
Reduced footprint, hardware and infrastructure

• Reduced footprint/real estate
• Reduced inventory
• Reduced wiring/connections
• Reduced supporting infrastructure (cable trays, racks, etc.)

Conventional

Digital

14 protection & control devices
(Electro-Mechanical system could add 3 devices per function)

2 protection & control devices
including busbar protection/backup

Advanced protection solution
consolidate 3 panels to 1 panel

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Simplicity improves reliability
Reduces complexity and number of points of failure

Copper Wires

Conventional cabling
No of cables: 768
Conductors: 4500
Terminations: 9000

Test/Debug – Labor intensive
Maintenance – Drawings up to date?
Reliability – Many connections

Full Digital Communications

Full Communications
No. of Fibre optic cables: 4
Continuous self supervision

Test/Debug – Easier to test/debug using digital tools
Maintenance – Digital record of connections and network tools improves maintenance
Reliability – No conventional cables, self supervision of communications
Protection solutions (number of panels per application)

Trends on functional consolidation

- **Line**
  - 12 (1960)
  - 12 (1970)
  - 6 (1980)
  - 6 (1990)
  - 3 (2000)
  - 2 (2010)
  - 3 (2020?)

- **Transformer**
  - 4 (1960)
  - 4 (1970)
  - 4 (1980)
  - 3 (1990)
  - 2 (2000)
  - 1 (2010)
  - 4 (2020?)

- **Busbar**
  - 5 (1960)
  - 3 (1970)
  - 3 (1980)
  - 3 (1990)
  - 1 (2000)
  - 4 (2010)

- **Feeder**
  - 8 (1960)
  - 8 (1970)
  - 5 (1980)
  - 4 (1990)
  - 4 (2000)
  - 4 (2010)

- **Control**
  - 39 (1960)
  - 32 (1990)
  - 7 (2000)
  - 7 (2010)

More powerful devices. Functional integration on going

Centralized Protection and Control
Intelligent apparatus, software protection and control
Redundant or even triplication of hardware

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Cyber Security as an Enabler
Replace Fear with Knowledge – Defense in depth

Legend:
- Disabled ports / services
- Removable media access
- Individual User Accounts
- Malware protection
- Firewall
- Router
- Encryptet communication
- Industrial Defender Agent
Advanced Tools - System Data Management
Powered by IEC 61850/62351 standards!

Data Management
- Disturbance Recorder Data Management
- Disturbance Recorder Data Evaluation

Automatically collect, store and provide evaluation for disturbance recorder files.

Cyber Security Management
- Central User Account Management
- Central Cyber Security Logging

Provide centralized User Account Management and security logging.

Service and Maintenance
- Tracking IED Software Versions
- Tracking IED Configuration Revisions

Documentation of Firmware and configuration revisions of the supervised IEC 61850 IEDs.
# Advanced Tools - System Wide Data Management

## Disturbance recorder data management features

<table>
<thead>
<tr>
<th>Collect</th>
<th>Analyze</th>
<th>Notify</th>
<th>Interface</th>
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</thead>
<tbody>
<tr>
<td>- Automatic IED vendor independent DR file collector for</td>
<td>- Short Report for any DR file</td>
<td>- Send DR info and Short Report via email</td>
<td>- Export DR files to file system for integration into another system</td>
</tr>
<tr>
<td>- IEC 61850-8-1 (MMS)</td>
<td>- Embedded ABB WaveWin application for DR Analysis</td>
<td></td>
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<tr>
<td>- FTP</td>
<td>- Alternative application can be configured by the user</td>
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<tr>
<td>- Windows File System</td>
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</table>
Advanced Tools - System Wide Data Management

Management of disturbance recorder data

Independent and automatic

- Automatic upload of disturbance recorder (DR) files from IEDs
- Polling the IEDs for new files
- No IEC 61850 engineering required
- No Interaction with an existing SAS system
- Seamless integration also into existing substation automation system
- Visualization of DR Data
Advanced Tools - System Wide Data Management

Disturbance recorder data visualization

**Short report**
- For any uploaded DR file
- Fast evaluation of disturbances
- PDF format - easy to annotate, email etc.

**Evaluation software**
- For any uploaded DR file
- Detailed analysis using integrated ABB WaveWin application.
Advanced Tools - System Wide Data Management

The cyber security process

Protect
Is my system protected against an attack?
Active protection includes physical security, virus scan, etc.

Monitor
Do I know what happens on my system?
Monitors the security related events of the system

Manage
Can I sustain the security of my system?
Centrally manages your user accounts
Advanced Tools - System Wide Data Management

System wide cyber security event logging

Monitor your system

- Securely store all user activities and other security events from IEDs or system level components
- Built in visualization and reporting
- Integrate SDM600 into an existing event logging system
Advanced Tools - System Wide Data Management

Central user account management

Manage your users

- System wide user management
- Role based access control (RBAC) according IEC 62351-8
- Enforce password policies
- Supports NERC CIP account management requirements
Digital Substation Benefits
Assessment of cost impact

- Overall reduced time to engineer, install and commission substations
- Up to 50% reduction in real estate requirements
- >70% reduction in copper wiring – installation, maintenance, and debug
- Reduced operational costs using tools to improve installation and troubleshooting needs

<table>
<thead>
<tr>
<th>Project Management</th>
<th>Base/Concept Design</th>
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<tr>
<td>SA Engineering</td>
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<tr>
<td>Panel and cable engineering</td>
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<tr>
<td>Protection, control devices</td>
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<tr>
<td>SAM600 devices</td>
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<tr>
<td>Panel mfg + testing</td>
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<tr>
<td>Kiosk mfg + testing</td>
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<tr>
<td>Fiber mat., laying, connecting</td>
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<tr>
<td>Copper mat., laying, connecting</td>
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<tr>
<td>Signal test</td>
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<tr>
<td>Commissioning</td>
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<td>Retrofit outage time</td>
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<td>Maintenance</td>
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<tr>
<td>Total costs</td>
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Digital Substation Benefits
Assessment of operations impact

- Improved safety for personnel
- Improved documentation
- Increased flexibility for future expansion
- Reduced outage time for retrofits
- Safeguards investment with a future-ready solution that provides migration to the digital substation
What is so special about the digital substation? 
Footprint, copper wires, safety, reliability and cost
Questions?

TCP/IP
Modbus Plus
LAN/WAN
IEC 61850

Ethernet
DNP 3.0
UCA 2.0
MMS

RP-3599
Contact Information

For questions, please contact:

Steven Kunsman
VP Business Development and Marketing
Substation Automation North America
ABB Inc.
Raleigh, North Carolina
Mobile  +1 (610) 392-8371
E-mail: steven.a.kunsman@us.abb.com
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