Substation Automation Process Bus System design and experiences with IEC 61850-9-2 and NCITs
Agenda

- Evolution in substation automation
- Introduction to process bus
- Standards around process bus
- Process bus experiences
- Trends and outlook
Evolution of substation automation
From wired to optical communication
Evolution of current and voltage transformer
From conventional CTs and VTs to NCITs*

New applications like combined current and voltage NCITs for metering and protection

Standardized integration of protection, control and metering with IEC 61850

*NCITs = non-conventional instrument transformers
Today's substations
Potential for optimization through NCIT & process bus

1. Voltage transformer
   - Increase safety
   - Increase availability
   - Reduce space, weight, price

2. Current transformer
   - Increase safety
   - Simplify Customization, dimensioning

3. ES/ DS drives
   - Reduce auxiliary contacts

4. CB drive
   - Reduce auxiliary contacts

5. Cabling
   - Reduce wires (around 800 wires per feeder)

6. Control and protection
   - Simplify signal marshalling
   - Remove CT circuits
   - Remove VT MCBs
   - Improve isolation from process
   - Simplify maintenance and testing
Benefits against conventional technology
Non-conventional instrument transformers

- Increased operational safety
  - Total absence of oil, NCITs can not explode
  - No iron core, therefore no ferroresonance

- Lower environmental impact
  - No oil and reduced volume of $\text{SF}_6$
  - Lower power consumption

- Reduced life-cycle costs
  - Permanent and comprehensive system supervision supports efficient maintenance
  - Software configurable nominal values

- High accuracy for protection and metering
  - One device for protection and metering applications

- Simplified project execution
  - No CT calculations
  - Simplified switchgear design because of constant dimensions
  - VT does not need to be disconnected during HV testing

- Lower space requirements
  - Reducing switchgear footprint
Benefits against conventional technology

Process bus

- Increased operational safety
  - Handling of CT and VT circuits is obsolete
  - Isolation from process

- Reduced life cycle costs
  - Permanent real-time system supervision increases system availability by increasing maintenance cycles and reducing outage times
  - Computer based tools enable simple measurement, eg, without the need to short circuit and disconnect CT terminals

- Reduced copper cabling
  - By replacing parallel copper wires with optical process bus

- Independent signal distribution
  - Signal distribution is virtually independent from cable length
  - CT burden is independent from connected devices

- Future-proof interoperable design
  - By applying the established IEC 61850 standard
- Evolution in substation automation
- Introduction to process bus
- Standards around process bus
- Process bus experiences
- Trends and outlook
Introduction to process bus
What is process bus?

- IEC 61850 describes all communication in the substation
- The station bus transmits information between the bay level IEDs, and between the station level and the bay level
- The process bus connects the process to the bay level

**Station level**

IEC 61850 station bus

**Bay level**

IEC 61850 process bus

**Process level**

MU = merging unit
NCIT = non-conventional instrument transformer

MU
NCIT
NCIT

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Introduction to process bus
Station- and process bus: physical allocation

Station bus
- Serial connection between station level devices…
  - eg, station computer, gateway
- … and bay level IEDs
  - eg, protection and control IEDs

Process bus
- Serial connection between bay level IEDs and process interfaces of at the primary apparatus
  - Disconnectors, earthing switches, circuit breaker, …
  - Power transformers, current and voltage transformers, …
Introduction to process bus
IEC 61850 services on station bus

Station bus
- Data is transferred mainly according IEC 61850-8-1:
  - Control service
    - Commands
  - Report service
    - Indications to IEC 61850 clients
  - GOOSE service
    - Indication and information exchange between bay level IEDs
  - File transfer service
    - Transmission of disturbance records
Introduction to process bus
IEC 61850 services on process bus

Process bus

- Data transfer according IEC61850-8-1 for:
  - GOOSE service
    - Binary states like switch positions
    - Trips
    - Commands

- Data transfer according IEC61850-9-2 for:
  - Sampled value service
    - Sampled current- and voltage measurements
Introduction to process bus
IEC 61850 logical nodes

- The smallest part of a function that exchanges data is called logical node (LN) in IEC 61850
- Logical nodes are allocated to logical and physical devices
Introduction to process bus
Allocation of logical nodes

Protection IED
PTOC
PDIS
PTRC

PTOC
PDIS
PTRC

PTOC
PDIS
PTRC

PTOC
PDIS
PTRC

Protection IED

Merging Unit IED
TVTR
TCTR
XCBR

TVTR
TCTR
XCBR

TVTR
TCTR
XCBR

TVTR
TCTR
XCBR

IEC61850 supports free allocation of functions

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Introduction to process bus
What is a merging unit

- Transmission of current and voltage sampled values according to IEC 61850-9-2
  - Merging and timely correlation of 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
• Evolution in substation automation
• Introduction to process bus
• Standards around process bus
• Process bus experiences
• Trends and outlook
Introduction to process bus
Process bus for sampled analogue values

International standard
IEC 61850-9-2

- Standardized distribution of sampled analog values from merging units to protection and control IEDs, as well as revenue meters
- All telegrams contain quality information about the status of sensor and merging unit
- Suitable for all applications from protection to metering and power quality
- Implementation follows the guideline from UCA International Users Group*

* Not-for-profit corporation, consisting of utility user and supplier companies, that is dedicated to promoting the integration and interoperability of electric utility systems through the use of international standards-based technology such as IEC 61850.
Introduction to process bus IEC 61850-9-2 standard and implementation guideline

The standard: IEC 61850-9-2

- Standard for communication networks and systems in substations, part 9-2: “Specific Communication Service Mapping (SCSM) - Sampled values over ISO/IEC 8802-3”

- The standard is very broad, leaving wide room for interpretation, which complicates interoperability

Implementation Guideline for digital Interface to instrument transformers using IEC 61850-9-2

- To facilitate implementation and enable interoperability, the UCA International Users Group created a guideline that defines an application profile of IEC 61850-9-2

- Commonly referred to as IEC 61850-9-2LE for “light edition”
### Introduction to process bus
Standard IEC 61850 and implementation guideline

<table>
<thead>
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<th>Standard IEC 61850-9-2</th>
<th>Implementation guideline IEC 61850-9-2LE</th>
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<tbody>
<tr>
<td>Sampling rate of analog values</td>
<td>Free parameter</td>
<td>80 samples per period for protection and metering 256 samples per period for power quality</td>
</tr>
<tr>
<td>Content of dataset</td>
<td>Configurable</td>
<td>3 phases current + neutral current values and quality 3 phases voltage + neutral voltage values and quality</td>
</tr>
<tr>
<td>Time synchronization</td>
<td>Not defined</td>
<td>Optical pulse per second (1PPS)</td>
</tr>
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Standardization

Two distinct types of merging unit for analog values

**Merging unit for a specific NCIT**
- With interface to NCIT
- The MU is developed for, and verified with, a specific NCIT
- Dynamic behavior at the 9-2 output is known

**Merging unit for conventional CTs/VTs**
- With interfaces to conventional CTs/VTs (SAMU*)
- Allow connection of any conventional current/voltage transformer
- Dynamic behavior at the 9-2 output is not yet defined

*SAMU: stand-alone merging unit
Standardization
Dynamic behavior

Conventional

- Current transformer: Principle: magnetic
- Protection device:
  - Sampling
  - A/D conversion
  - Filtering
  - Internal data exchange

NCIT with related merging unit

- Current transformer: Principle: magnetic, optical, etc.
- Merging unit:
  - Sampling
  - A/D conversion
  - Filtering
- Transmission of values: IEC61850-9-2

Independent transformer and merging unit

- Current transformer: Principle: magnetic
- Stand alone merging unit:
  - Sampling
  - A/D conversion
  - Filtering
- Transmission of values: IEC61850-9-2

Classes
TPX, TPY, TPZ
IEC60044/IEC61869

Protection algorithm

Transient / dynamic behavior is not standardized

Standard under preparation by IEC Technical Committee TC38
Standardization
New standard for instrument transformers

IEC 61850
Communication networks and systems in substations

Part 9-2
Sampled values over Ethernet

IEC 61850-9-2LE
Implementation Guideline from UCAIug

IEC 61869
Instrument transformers

Part 9 *
Digital interface for instrument transformers

Part 13 *
Stand alone merging unit

* Under preparation by IEC TC38 WG37
Standardization activities

- IEC 61869-9 “Digital interface for instrument transformers”
  - Release mid of 2013
- IEC 61869-13 “Stand alone merging unit”
  - Release beginning of 2014
- IEC 61850 Edition 2
  - Eg, introduction of communication redundancy
- IEEE1588 (power system profile)
  - Precision time protocol over Ethernet will allow to replace the dedicated optical fibre for the one pulse per second time synchronization
- Evolution in substation automation
- Introduction to process bus
- Standards around process bus
- Process bus experiences
- Trends and outlook
Introduction to customer and project
Powerlink, the customer

- Powerlink owns, operates, develops and maintains Queensland’s world-class $6 billion high voltage electricity transmission network, which transports electricity in bulk from power generators to the regional distribution networks which then supply around two million electricity customers.

- Queensland:
  Capital: Brisbane
  Area: 1’800’000km²
  Population: 4’580’700
ABB and Powerlink Queensland have commissioned 6 substations between 1998 and 2001 with ABB NCITs and IEDs with proprietary process bus.

- The systems with over 300 CP-type sensors are in continuous operation since more than 10 years.

- Convinced by the concept, Powerlink decided to start refurbishing the substations to IEC 61850 compliant systems with process bus.
Introduction to customer and project Loganlea secondary system upgrade

- Powerlink performed a cost-benefit analysis comparing a solution deploying the new IEC 61850-9-2 solution and their standard conventional solution.

- The 1st substation, Loganlea is located next to Brisbane and the Gold Coast.

- With the Loganlea secondary system upgrade ABB undertook its first commercial IEC 61850-9-2 process bus installation with NCITs and protection and control IEDs.

- The upgrade has been completed in December 2011.
Customer requirements

- Replacing the existing SA system with proprietary communication on process and station level with a new fully IEC 61850 compliant system
  - IEC 61850 station bus
  - IEC 61850-9-2LE process bus system
- Two fully redundant and independent protection systems
- Application of released products that are part of the active product portfolio
- Step-wise substation retrofit with only minimal service interruption
ABB’s solution

- ABB’s SAS600 series substation automation system featuring MicroSCADA Pro as station HMI and two RTU560 as gateways to the network control center

- Protection and control IEDs from ABB’s Relion family 670 series as well as the REB500 busbar protection system
  - Supporting IEC 61850-9-2LE
  - Fully IEC 61850 compliant

- Upgrade of the NCITs with new secondary converters (sensor electronics) to interface with ABB’s conformance certified IEC 61850-9-2LE merging unit CP-MU
ABB’s solution
IEC 61850 compliant SA system

SAS600 series
Substation Automation System

Station bus

Process bus
ABB’s solution
670 series protection and control IEDs

- 670 series high-end protection and control IEDs with IEC 61850-9-2LE:
  - Bay control IED REC670
  - Line distance protection REL670
  - Line differential RED670
  - Transformer protection RET670

- All IEDs can have a 1PPS input for synchronized sampling

- All devices support mixed mode with conventional CT and VT interfaces eg, transformer low-voltage side for transformer differential protection

- Line differential protection runs with conventional and 9-2 remote-end substations
ABB’s solution
REB500 busbar and breaker failure protection system

- REB500 decentralized busbar protection system is fully compliant with IEC 61850-9-2LE
  - Busbar protection
  - Breaker failure protection
  - End-fault protection

- Seamless combination of bay units with IEC 61850-9-2LE and conventional bay units in one system
  - This allows flexible extension of conventional substations
ABB’s solution
CP-MUP merging unit for protection and control

- The world’s first UCA-certified merging unit
- IEC 61850-9-2LE-compliant
- Interfaces with ELK-CP14/ELK-CP3 sensors of up to three three-phase measuring points
  - Reducing the number of components in 1½ breaker and double busbar arrangements
- Multiple Ethernet ports bring high flexibility to system design
  - Reducing the need for Ethernet switches in protection circuits
ABB’s solution
ELK-CP sensors for metal-clad switchgear

**ELK-CP14**
Nominal values:
100 ... 4000A
175 ... 300 kV/\sqrt{3}

**ELK-CP3**
Nominal values:
100 ... 4000A
330 ... 550 kV/\sqrt{3}

The already installed sensors are early versions of today's ELK-CP sensor. That are…

- **Fully redundant, combined current and voltage sensor** with Rogowski coils for current and capacitive dividers for voltage

- **Redundant secondary converter** (sensor electronics) can be replaced during operation, no calibration necessary

- **Configurable current ratings** enable future adaptation of CT ratios without the need to replace CT cores or to open gas compartments

- Covers *metering, protection and control accuracy* in a single device
ABB’s solution
Connection from primary to secondary equipment

- Merging unit CP-MU
  - Merging and timely correlation of current and voltage from the sensors
  - Supply values at IEC 61850-9-2LE interface
  - Synchronization by optical pulse per second (PPS)

- The CP-MU consists of 4 logical merging units
  - 3 logical MUs to merge and timely correlate the current and voltage values from 3 times 3 phases
  - 1 logical MU for summation of measured currents from the other 3 logical MUs

- 5 optical Ethernet ports for IEC61850-9-2LE

*PPL: Point to Point link, one fiber for U and I per sensor phase
ABB’s solution
Fully redundant and independent system design

System 1
- Protection
- IEC 61850-9-2LE
- PPL

System 2
- Protection and control
- IEC 61850-9-2LE
- PPL

Metering is not installed at Loganlea
ABB’s solution
Highly available process bus without Ethernet switches

Extract of the applied concept:
(Control of one CB, redundant protection of one line)

- Highest availability of the process bus system was achieved by
  - Building two fully independent process bus and protection systems from NCIT to protection IEDs
  - Minimizing number of components without using Ethernet switches
  - Refraining from common devices across feeders and the redundant protection system
ABB’s solution
Minimal interdependencies

- Synchronization of analog sampling, independent of station clocks
  - IEC 61850-9-2LE defines 1PPS (1 pulse per second) for sampling synchronization
  - The 1PPS does not need to be synchronous to the station clock
  - ABB’s product and system design allows local synchronization without GPS
  - Merging units act independent as time masters
ABB’s solution
Process bus overview

The picture shows simplified one of two fully redundant protection systems.
Overview of main control and protection functions and the used values
Because all IEDs receive I and U, most of them perform also other protection as well as measurement functions
Overview of main control and protection functions and the used values
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Impressions from site
- Evolution in substation automation
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Trends and outlook
Product developments

- ABB is committed to standard compliant products and solutions
- The portfolio for process bus applications is continuously extended. Eg, by:
  - Stand-alone merging unit for integration of conventional CTs and VTs
  - Fiber-optic current sensor with 9-2 interface, integrated in life tank breaker (see picture)
  - 9-2 interface for ABB’s field proven optical current sensor MOCT
  - …

Pilot installation:
Life tank breaker with integrated, redundant current sensors
Conclusion

- Already now IEC 68150 process bus systems are available
- The last gaps in standardisation need to be closed and implemented in the devices
- The number of pilot and real installations is continuously increasing
- An increasing number of conformance tested process bus devices will open doors for multi vendor systems

➢ A promising technology is taking off
Power and productivity for a better world™