Stefan Meier, ABB Substation Automation Systems, 2014-11-04

Digital Substation Introduction

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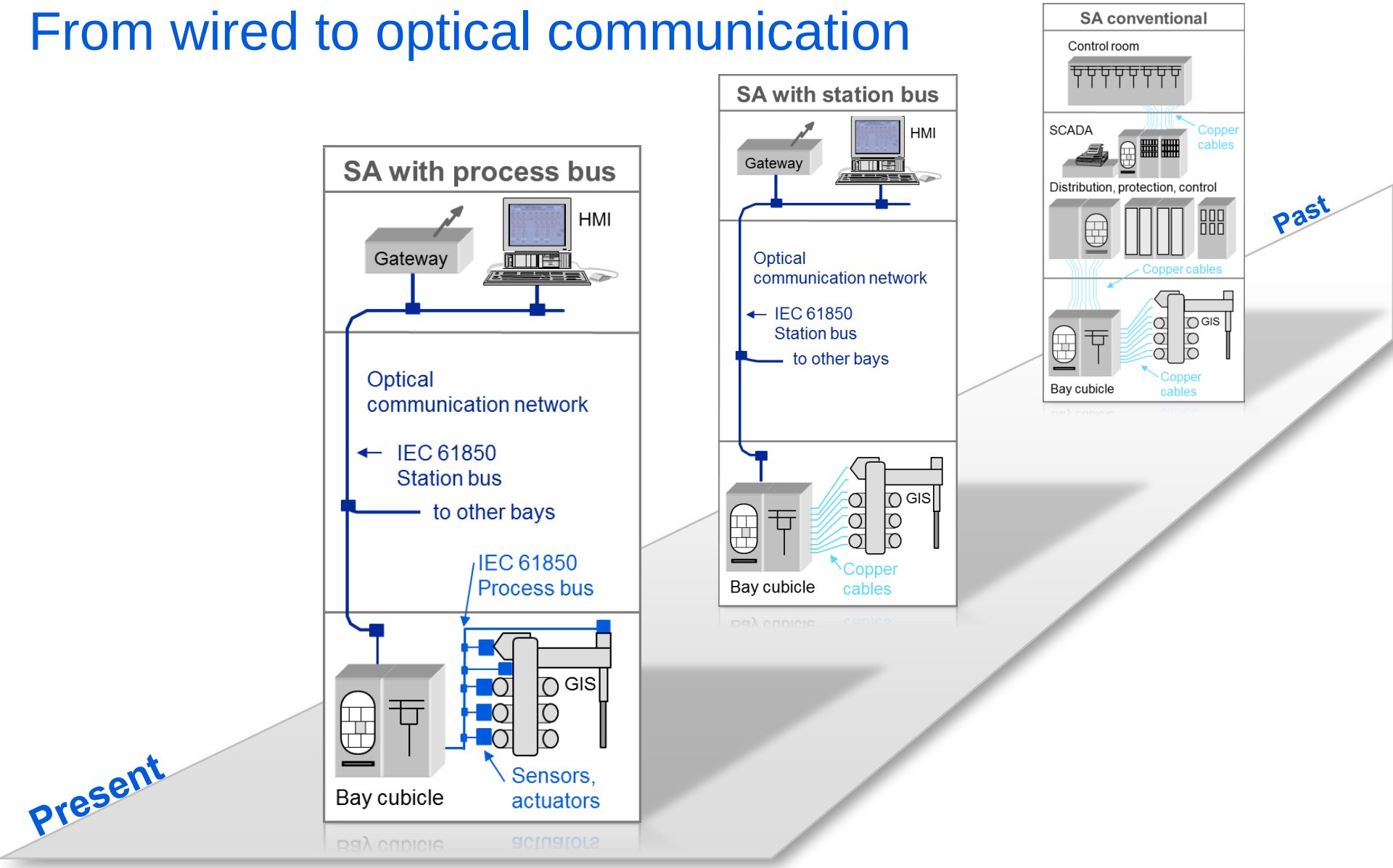
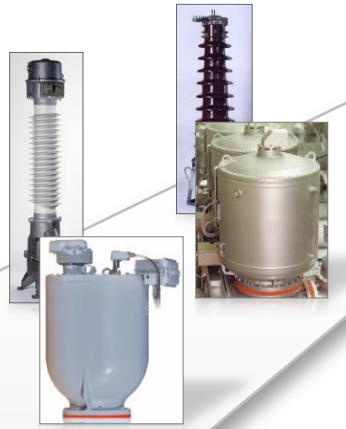
Evolution of substation automation
From wired to optical communication

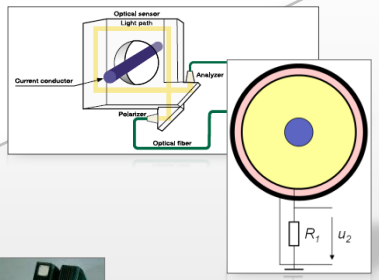


Evolution of current and voltage transformer
From conventional CTs and VTs to NCITs*

Evolution of conventional VTs and CTs



Sensors for current and voltage



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

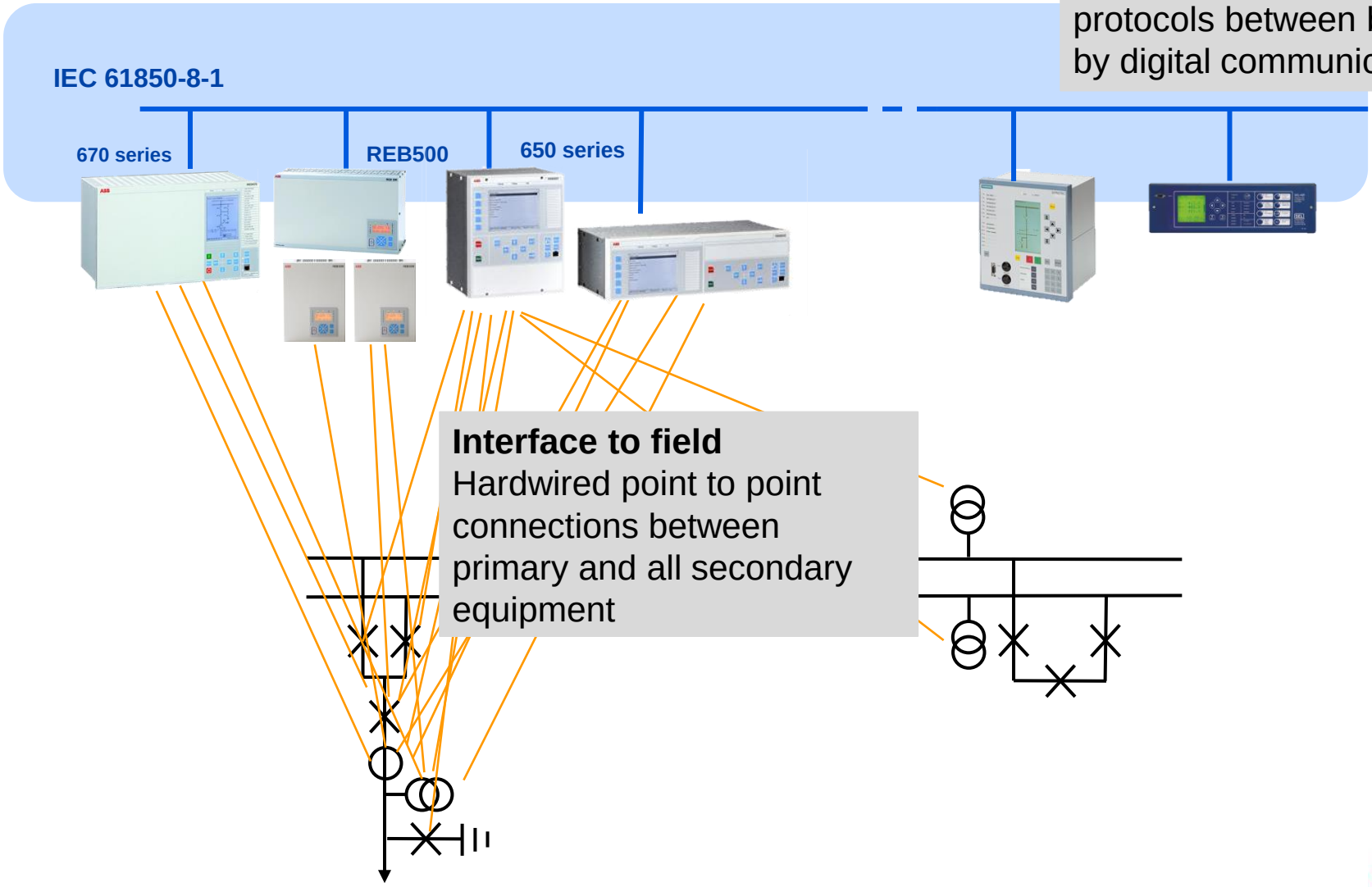
Standardized integration of protection, control and metering with **IEC 61850**

Present

*NCITs = non-conventional instrument transformers

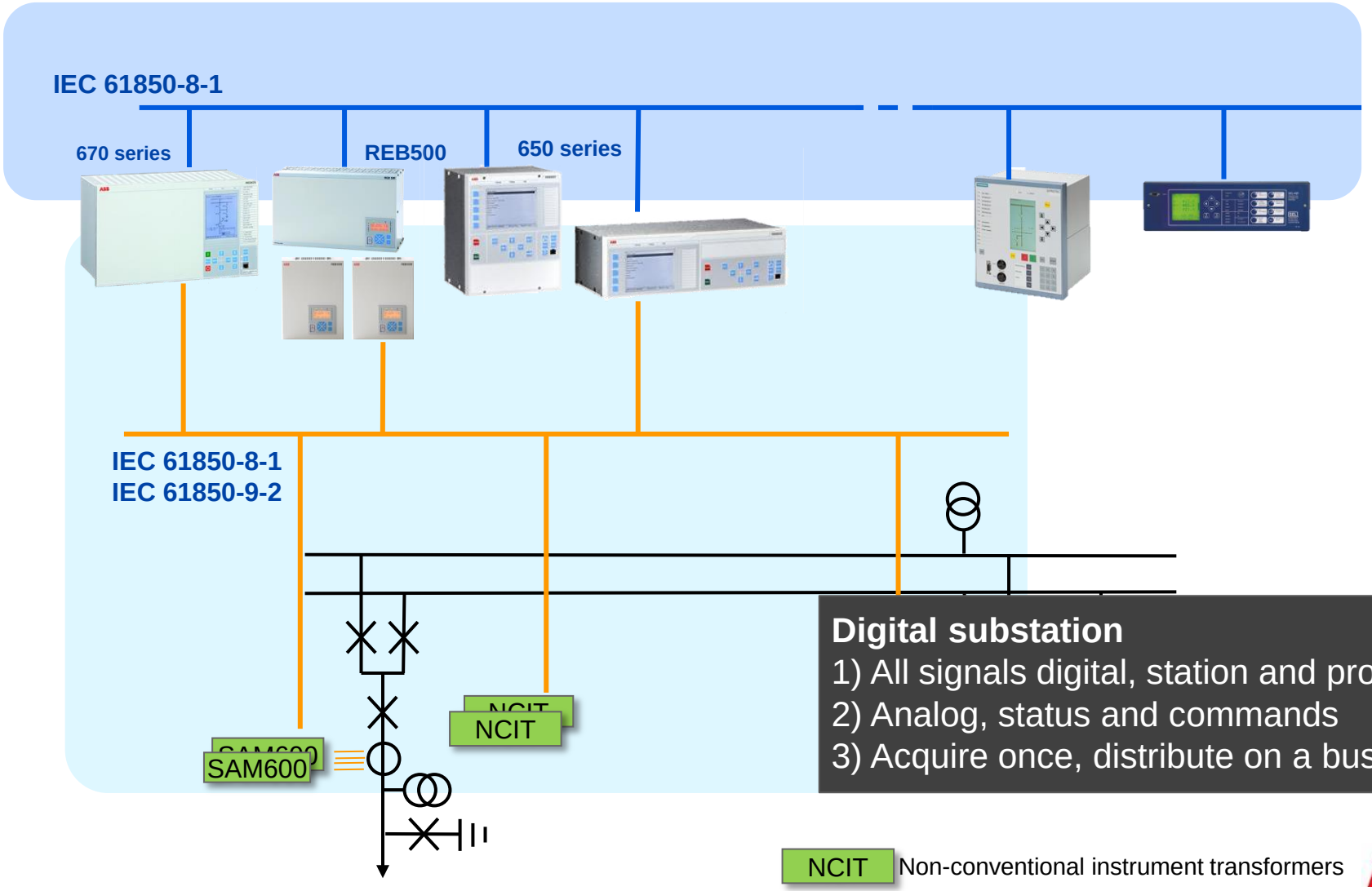
Digital Substation and IEC61850 Today

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



Interface to field
Hardwired point to point connections between primary and all secondary equipment

Digital Substation and IEC61850
Tomorrow



Digital substation
1) All signals digital, station and process
2) Analog, status and commands
3) Acquire once, distribute on a bus

NCIT Non-conventional instrument transformers

Benefits of a digital substation
Motivations for EPCs and Utilities

EPCs

Faster project delivery
Reduce material (cabling)
Reduced risk on cable engineering

High degree of standardization
pre-engineered building blocks, e.g. panels, kiosks

Easier handling of late changes
as all communication is digital IEC61850

Utilities

Increased safety by digitizing all signals right at their source reduces the risk of electrical hazards

Integration of NCITs by adherence to standards and by that further increase safety & availability

Outage time reduction
faster installation due to through pre-tested process bus systems

Cost effective maintenance
more supervision and diagnostics, reduced spare parts

Lower requirements on CTs/VTs by reducing burden from cabling and minimizing No of circuits

From conventional to digital substation automation

ABB‘s portfolio for process bus applications

Standardization and interoperability

Maintenance and testing

Digital substation experiences

Summary

ABB‘s portfolio for process bus applications
Overview

Station level

- SAS600 series of substation automation solutions with IEC 61850 station bus

Bay level

- 670 series control and protection IEDs
- REB500 Busbar protection system
- IEC 61850 system engineering: IET600
  IEC 61850 testing: ITT600 SA Explorer
- UnigearDigital with 615 series IEDS, 9-2 and GOOSE

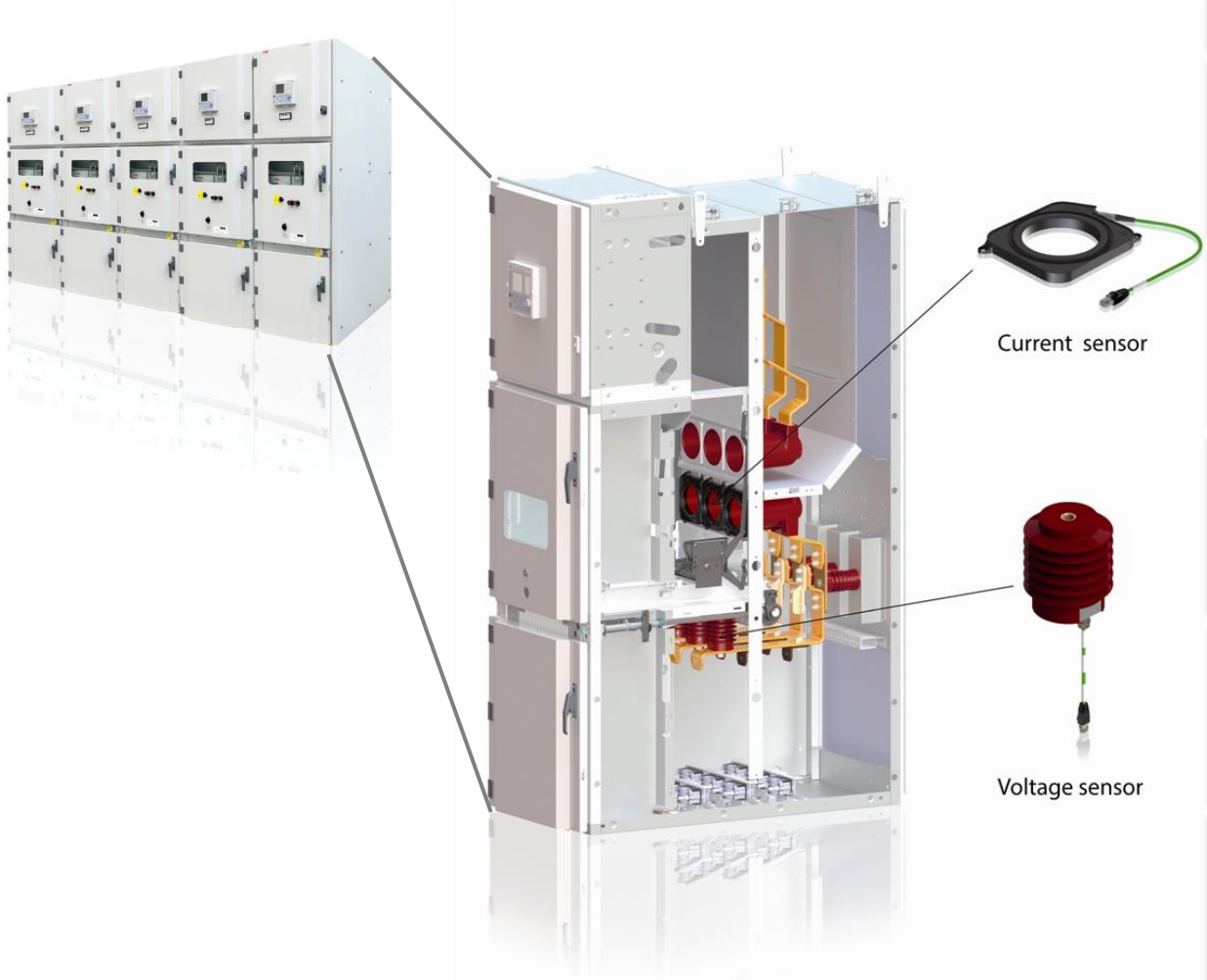
Process level – NCIT

- ABB NCITs for GIS, CP-MU merging unit for ELK-CP14 and ELK-CP3 (current and voltage)
- Fiber Optic Current Sensor FOCS-MU (current only). Freestanding or integrated in DCB

Process level – stand-alone merging units

- SAM600 modular process bus IO system

Optimized medium voltage switchgears
Potential for process bus solutions



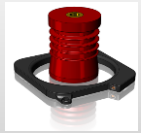
Shorter delivery times thanks to application of NCITs and reduced wiring efforts

Simpler purchasing as no CT and VT calculations are required

Simpler commissioning as due to reduced wiring and testing steps

Increased availability thanks to permanent system supervision and due to fewer insulation components

Increased safety thanks to elimination of CT and VT circuits



Reduced space requirement as NCITs can be installed in any feeder

ABB’s process bus product portfolio
NCIT for metal-clad switchgear

Nominal values:
100 … 4000A
175 … 550 kV/√3

- Fully redundant, combined current and voltage sensor (Rogowski coils, capacitive dividers)
- 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 process bus product portfolio
Merging unit to integrate NCIT

The world's first UCA-certified merging unit

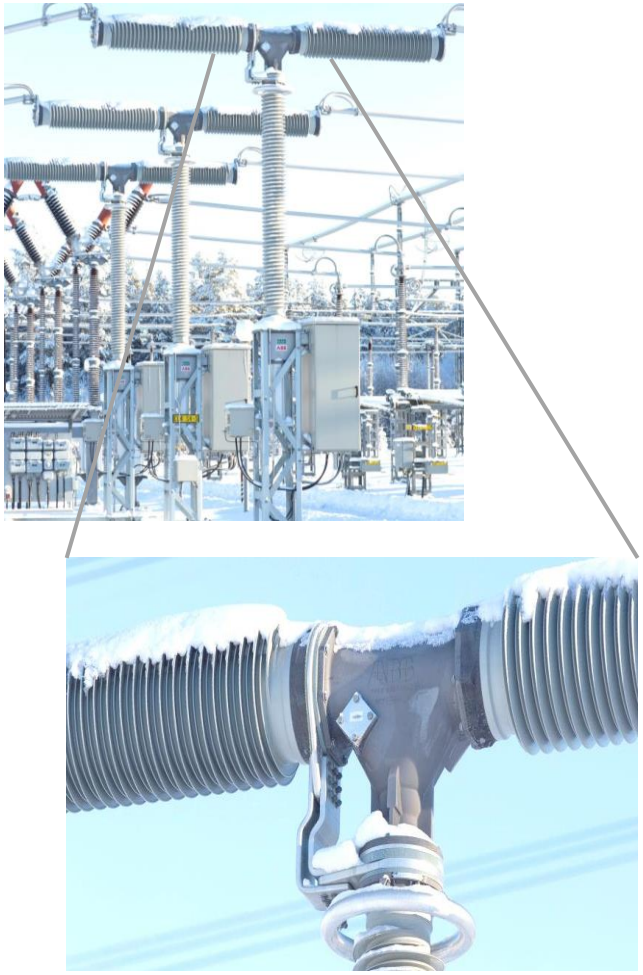
- IEC 61850-9-2LE-compliant
- Merges the U and I values from the individual phases into a IEC 61850-9-2LE stream
- Multiple Ethernet ports and connections to NCITs offer high flexibility to system design
    - Reducing the need for Ethernet switches in protection circuits

The UCA International Users Group is a not-for-profit corporation focused on assisting users and vendors in the deployment of standards for real-time applications for several industries with related requirements.

Product portfolio
FOCS-FS, Free-standing optical CT

- Free-standing optical CT
  - 245 to to 800kV
  - IEC 61850 9-2LE
  - Redundancy as option
- Meets modern performance requirements (0.2S; 5TPE) in terms of accuracy
- Being filled with N2 at <0.5 rel bar, it is intrinsically safe and environmentally friendly
- It does not require modification in substation layout, where conventional CTs are installed

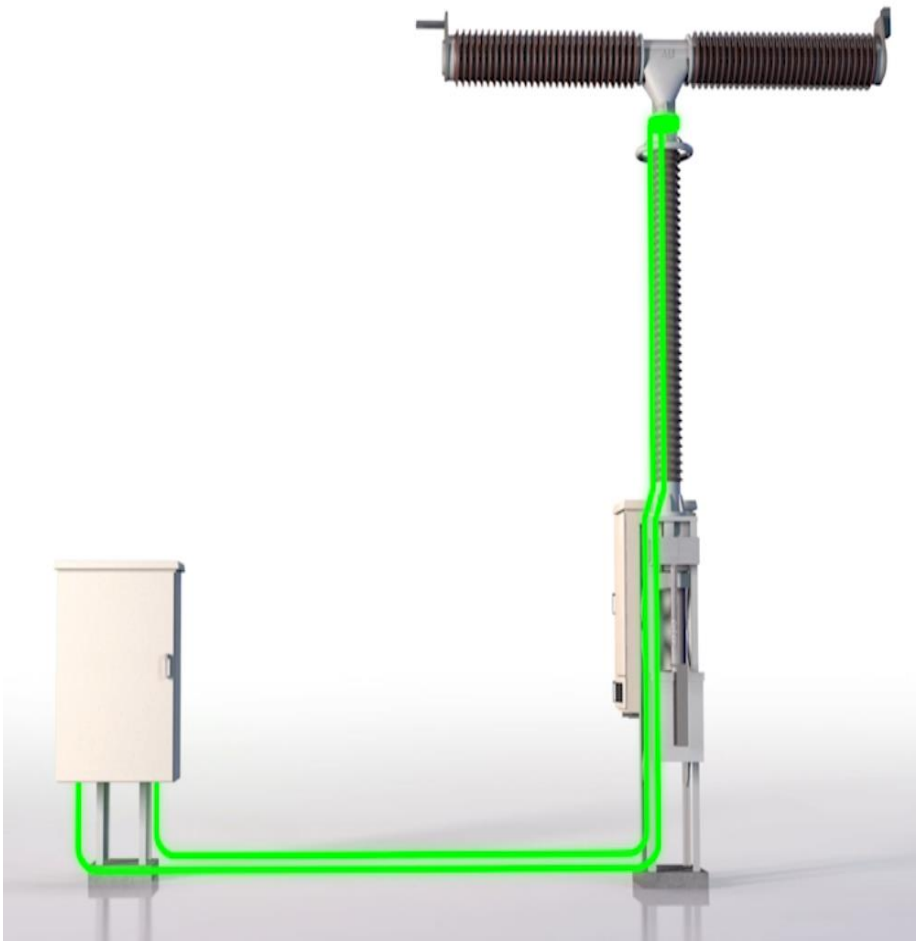
Product portfolio
DCB with integrated FOCS



ABB's functionally modular AIS platform is fully flexible to customer needs

- DCB
  - Integration of disconnecting function into circuit breaker (=disconnecting circuit breaker, DCB)
- FOCS
  - Integration of redundant optical current sensors to LTB with IEC 61850-9-2LE process bus interface

Application example
Optical CT integrated in disconnecting CB



Redundant system setup

- The FOCS system comprises of redundant three-phase light source and signal processing.
- Redundant fiber optics integrated to the DCB pole.
- A primary sensor head with redundant fiber optic coils per phase of DCB.
- “Plug & Play” solution. Fully “hot swappable” redundant system.

Measurement Platform

- Electro optic module and measurement coil delivering sampled values according to IEC 61850 9-2 LE

Product portfolio
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
  - Generator protection REG670
- 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

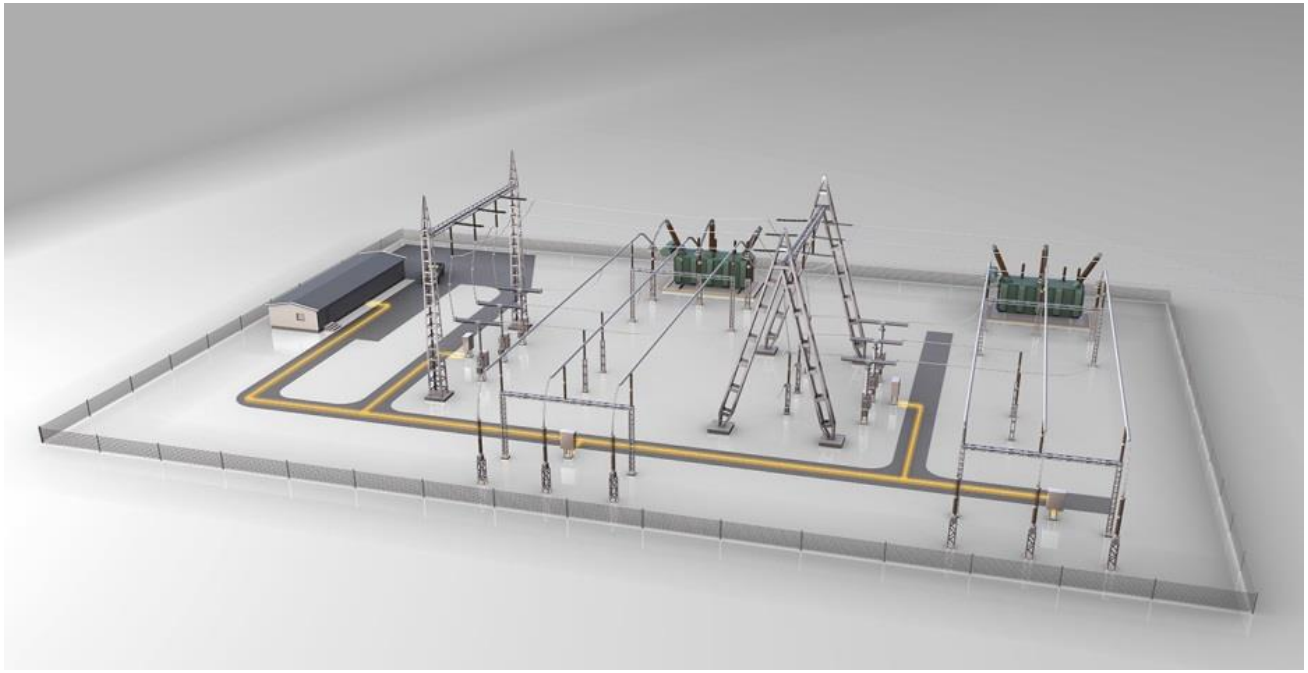
Product portfolio
REB500 busbar and breaker failure protection

- 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

SAM600 process bus IO system

SAM600 process bus IO system



SAM600 process bus IO system enables digital substations by integrating conventional switchgear equipment into IEC 61850 process bus.

SAM600 – ABB's process bus IO system
Digitizing primary signals made easy

SAM600-CT

SAM600-VT

SAM600-TS

Modular IO system for interfacing

- One hardware module per primary object philosophy
- Conventional current or voltage transformers
- Time synchronization
- Modules can be chained in order to adapt to different application types

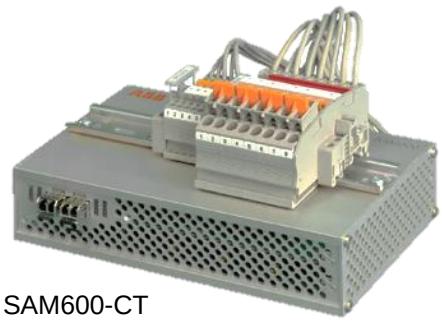
Optimized form factor

- Indoor - bay cubicles for retrofit applications
- Outdoor - marshalling kiosks, VT terminal boxes for new or retrofit installations
- DIN-rail mountable for fast installation and replacement

Termination of primary cabling on SAM600 module

- One hardware module per primary object terminating all signals, including supervision (e.g., fuse failure)
- Process interface terminals are part of SAM600 and can be customized
- Usage of standard cabling

SAM600 – ABB's process bus IO system
Digitizing primary signals made easy



SAM600-CT

SAM600-VT

SAM600-TS

IEC61850-9-2LE

- 9-2LE with 80 samples/cycle for protection and operational metering
- 9-2LE quality indicates test switch and fuse failure inputs
- Simulation mode for testing purposes

Time synchronization

- Supports synchronization against 1PPS or IEEE1588-2012 and PC37.238 (1588 power profile)
- Provides 1PPS outputs for synchronizing IED devices
- Accuracy 1us or better

Communication

- IEC61850 9-2LE process bus traffic on two ports per module

Environmental

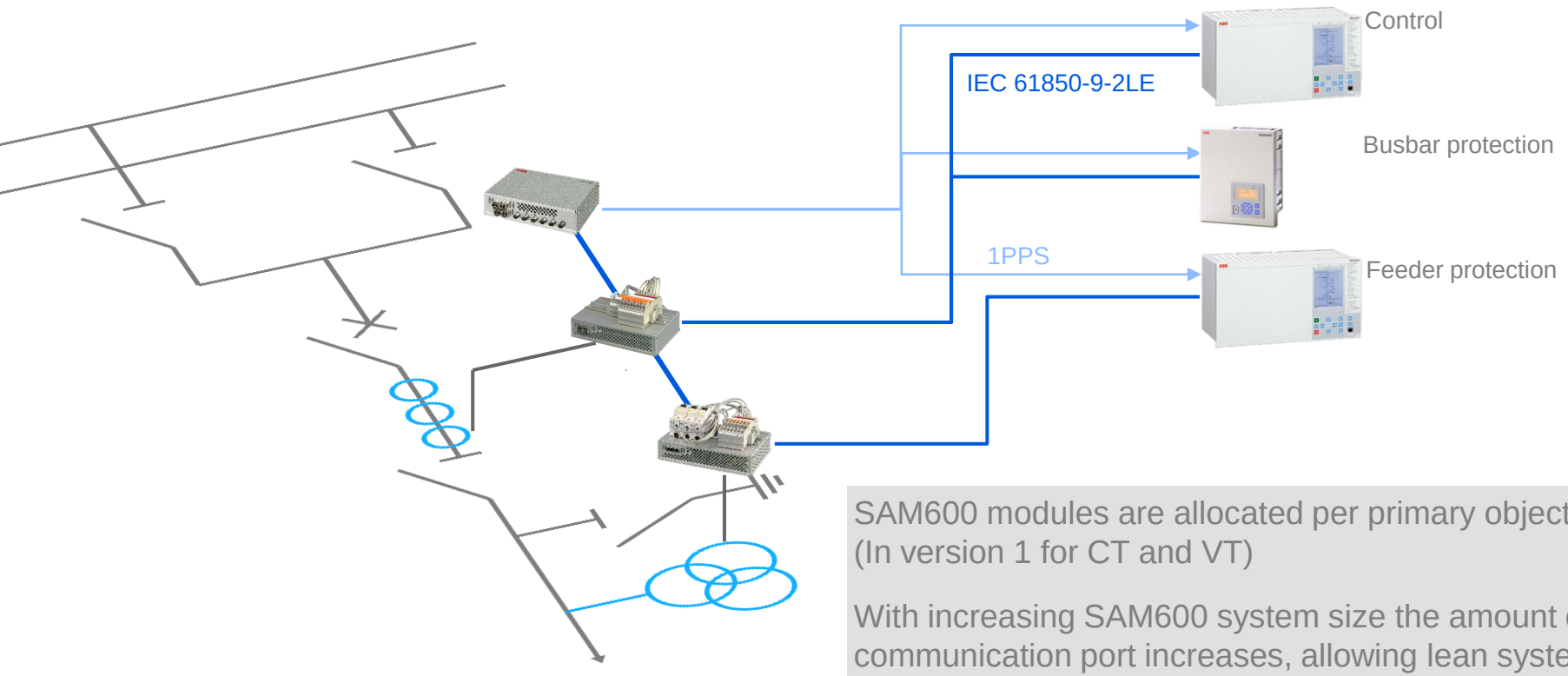
- Operating temp range: -40°C .. +70°C ambient
- IP class: IP20

SAM600 – the digital substation enabler
Flexible placement, scalable communication

SAM600 modules per primary object

IEC 61850-9-2LE process bus

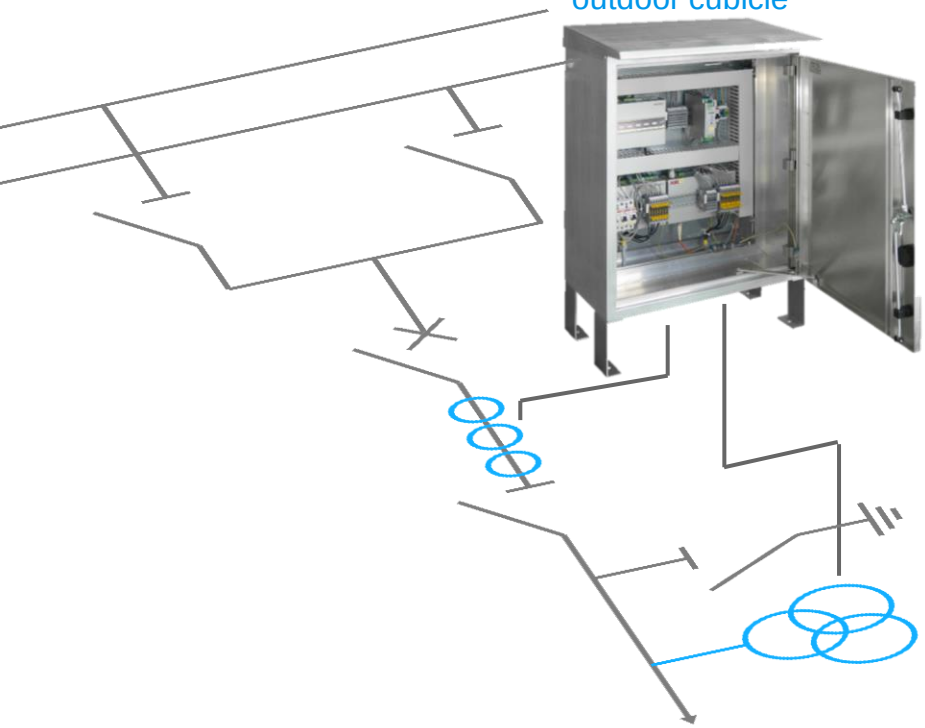
Protection and control IEDs



SAM600 modules are allocated per primary object. (In version 1 for CT and VT)

With increasing SAM600 system size the amount of communication port increases, allowing lean systems with minimum Ethernet switches.

SAM600 – the digital substation enabler
Efficient upgrade for conventional substations

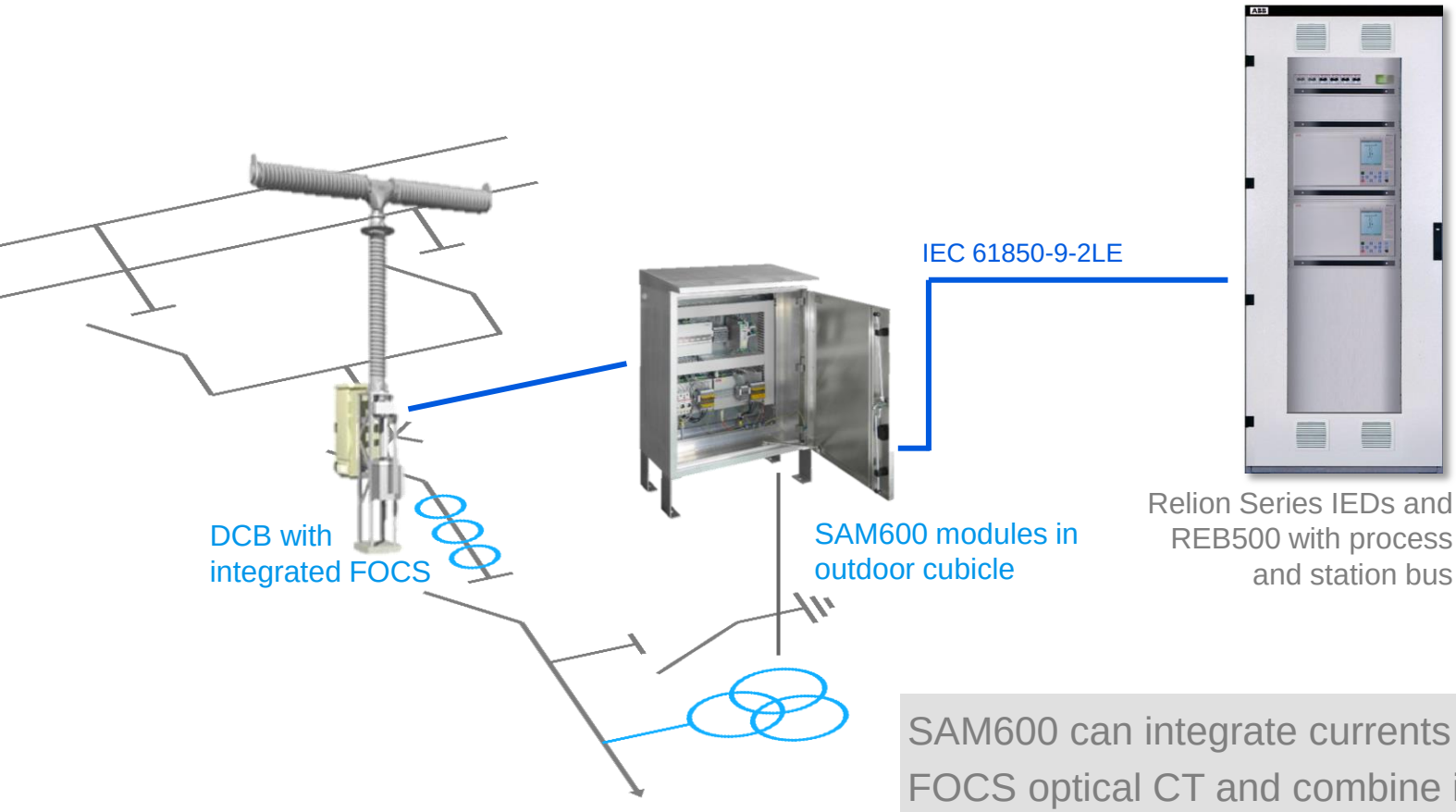


IEC 61850-9-2LE

Relion Series IEDs and
REB500 with process
and station bus

Application example with SAM600 modules mounted in outdoor marshalling kiosk.

SAM600 – the digital substation enabler
Integrates with modern FOCS



SAM600 can integrate currents from ABBs FOCS optical CT and combine it with conventional voltage.

From conventional to digital substation automation

ABB‘s portfolio for process bus applications

Standardization and interoperability

Maintenance and testing

Digital substation experiences

Summary

Introduction to process bus
IEC 61850 on station and process level

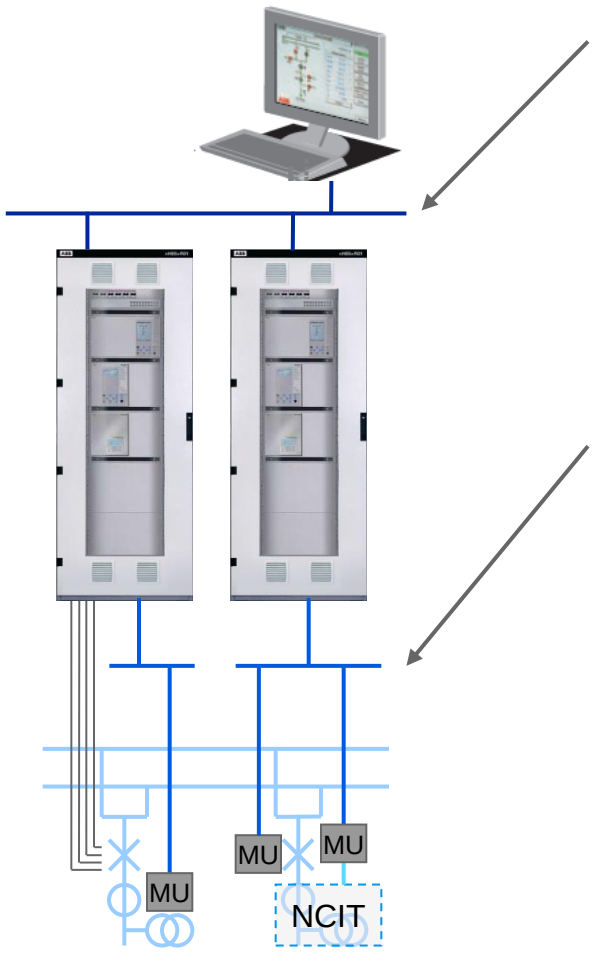
Station level

IEC 61850 station bus

Bay level

IEC 61850-9-2 process bus

Process level

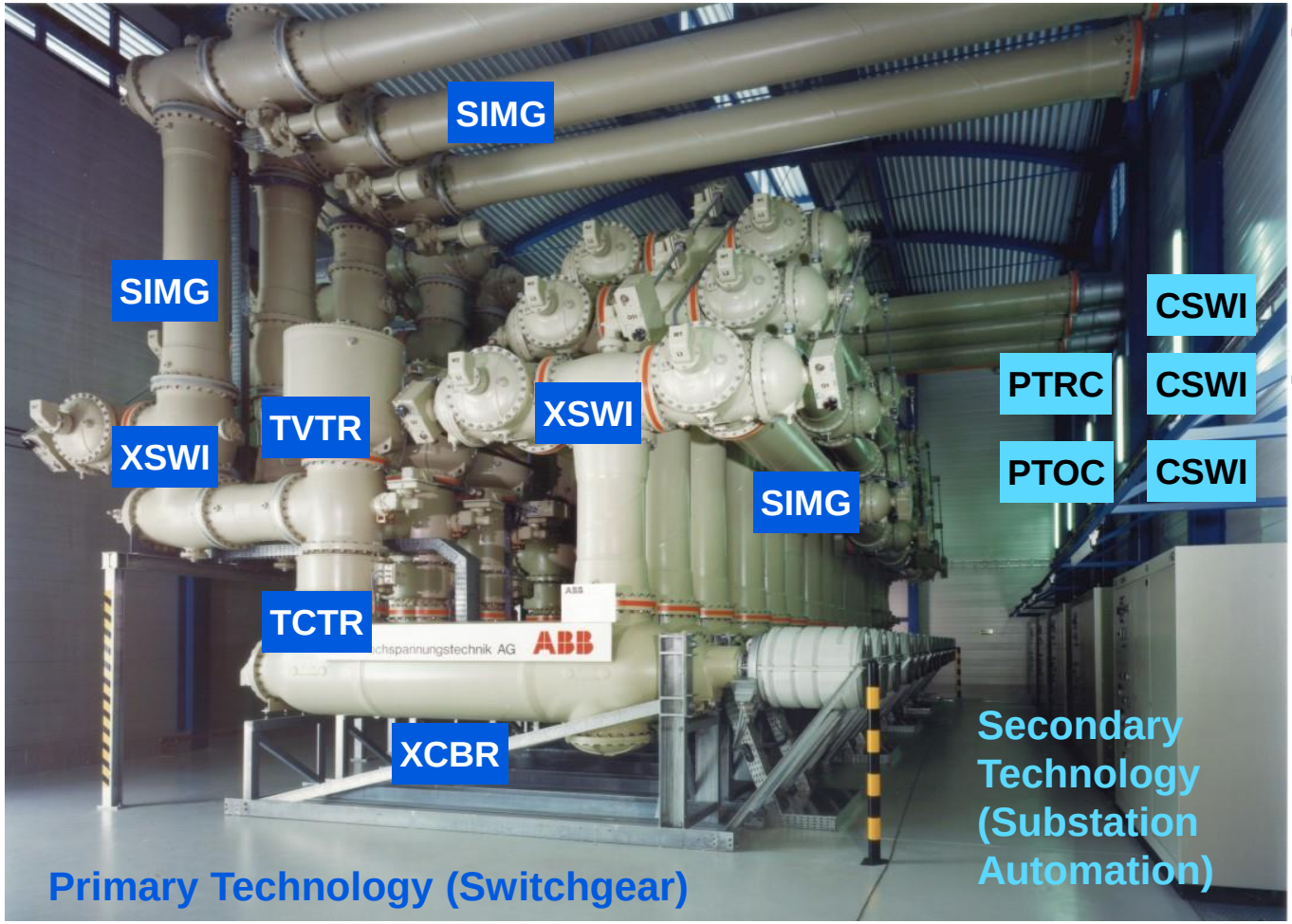


- The station bus connects IEDs and substation automation system
- It transmits information between the station level and the bay level as well as between IEDs (GOOSE)

- The process bus connects the process to the bay level
- Binary data as GOOSE messages between merging units and IEDs
- Sampled analog values are transferred via Ethernet according IEC 61850-9-2
- Implemented according to UCAIug implementation guideline “IEC 61850-9-2LE”

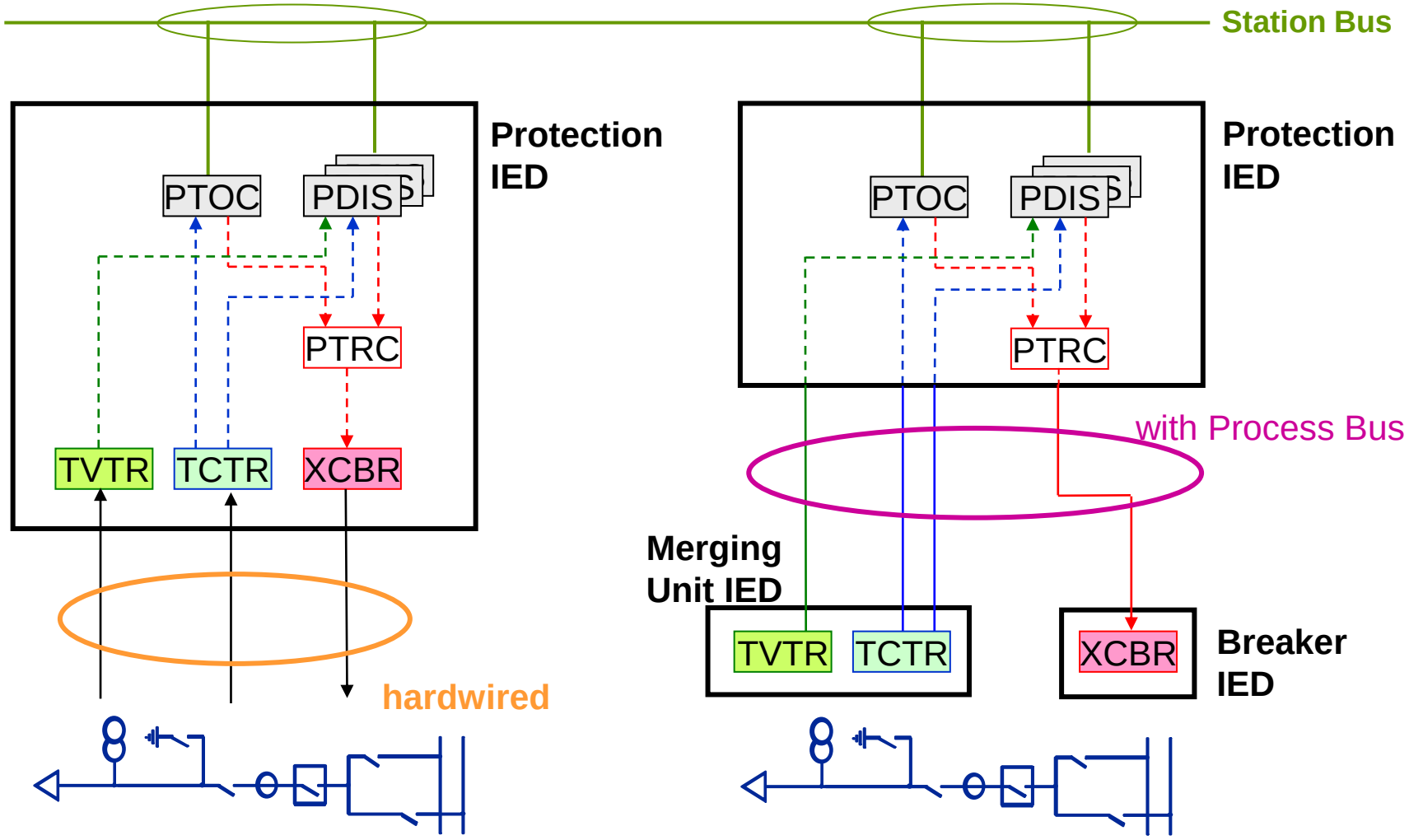
MU = merging unit
NCIT = non-conventional instrument transformer

Standardization and interoperability
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

Standardization and interoperability
Allocation of logical nodes



Standardization and interoperability
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

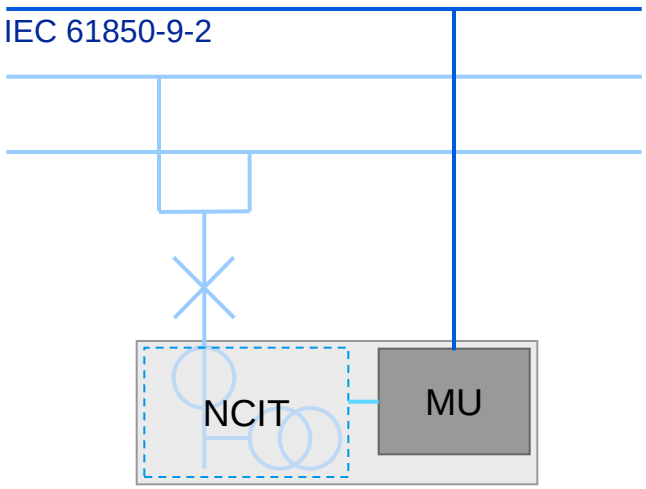
Implementation Guideline for digital Interface to instrument transformers using IEC 61850-9-2

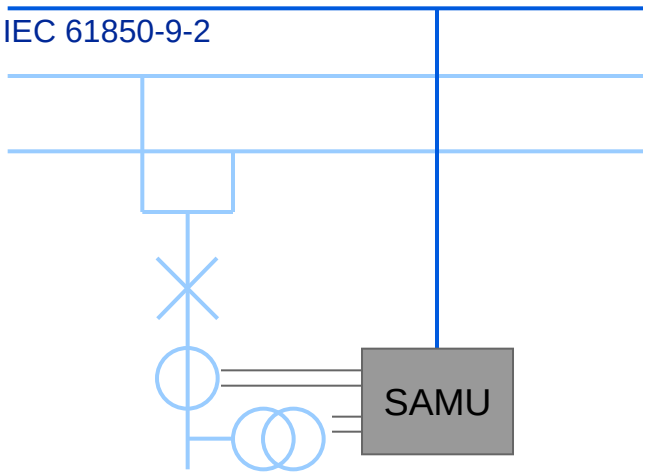
- To facilitate implementation and enable interoperability, the UCA International Users Group created a guideline that defines an application profile of IEC 61850-9-2
- Commonly referred to as IEC 61850-9-2LE for “light edition”

Standardization and interoperability
Standard IEC 61850 and implementation guideline

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

Standardization and interoperability
Two distinct types of merging unit for analog values





Merging unit for a specific NCIT

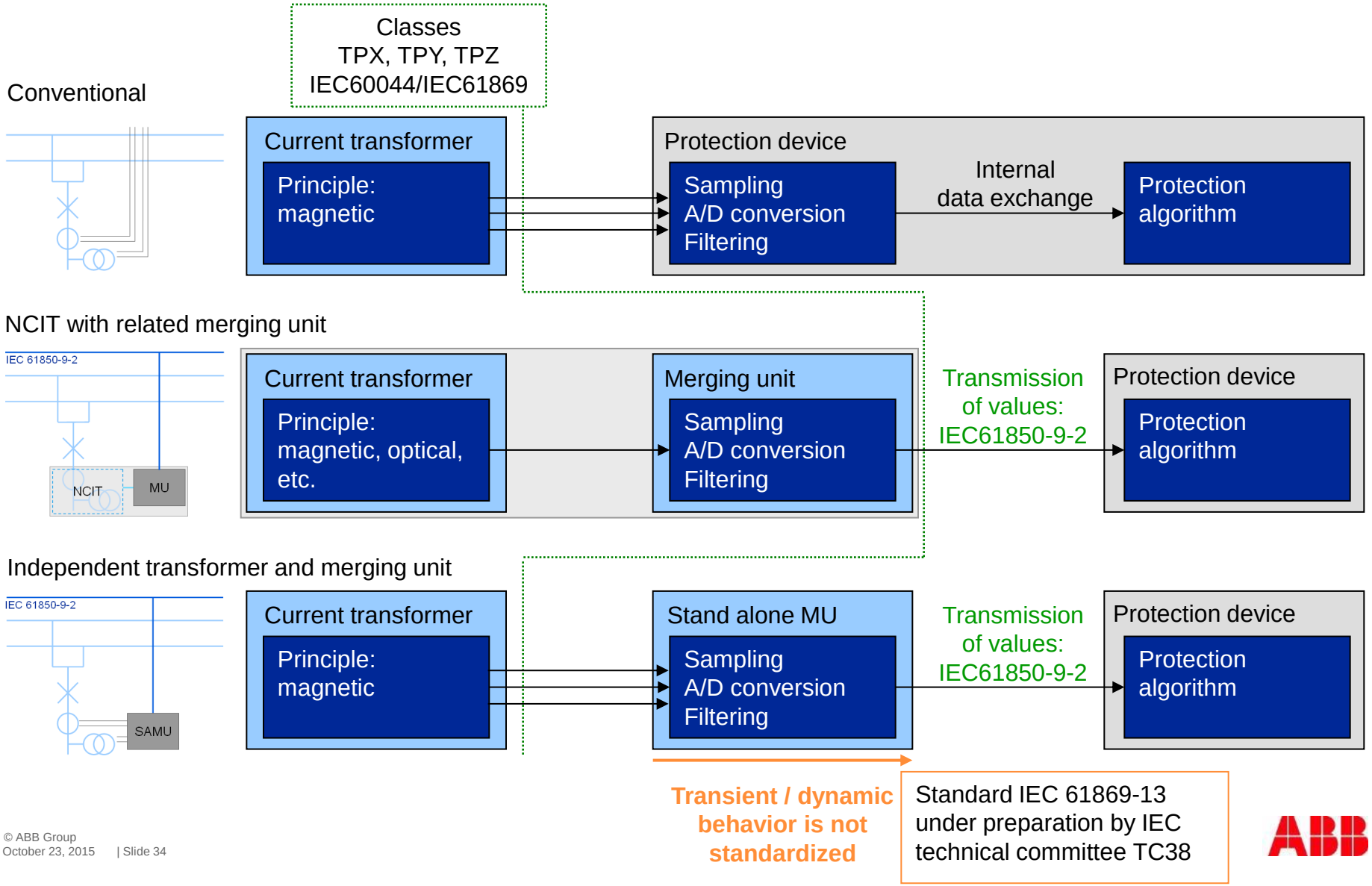
- With interface to NCIT
- The MU is developed for, and verified with, a specific NCIT
- Dynamic behavior at the 9-2 output is known

Merging unit for conventional CTs/VTs

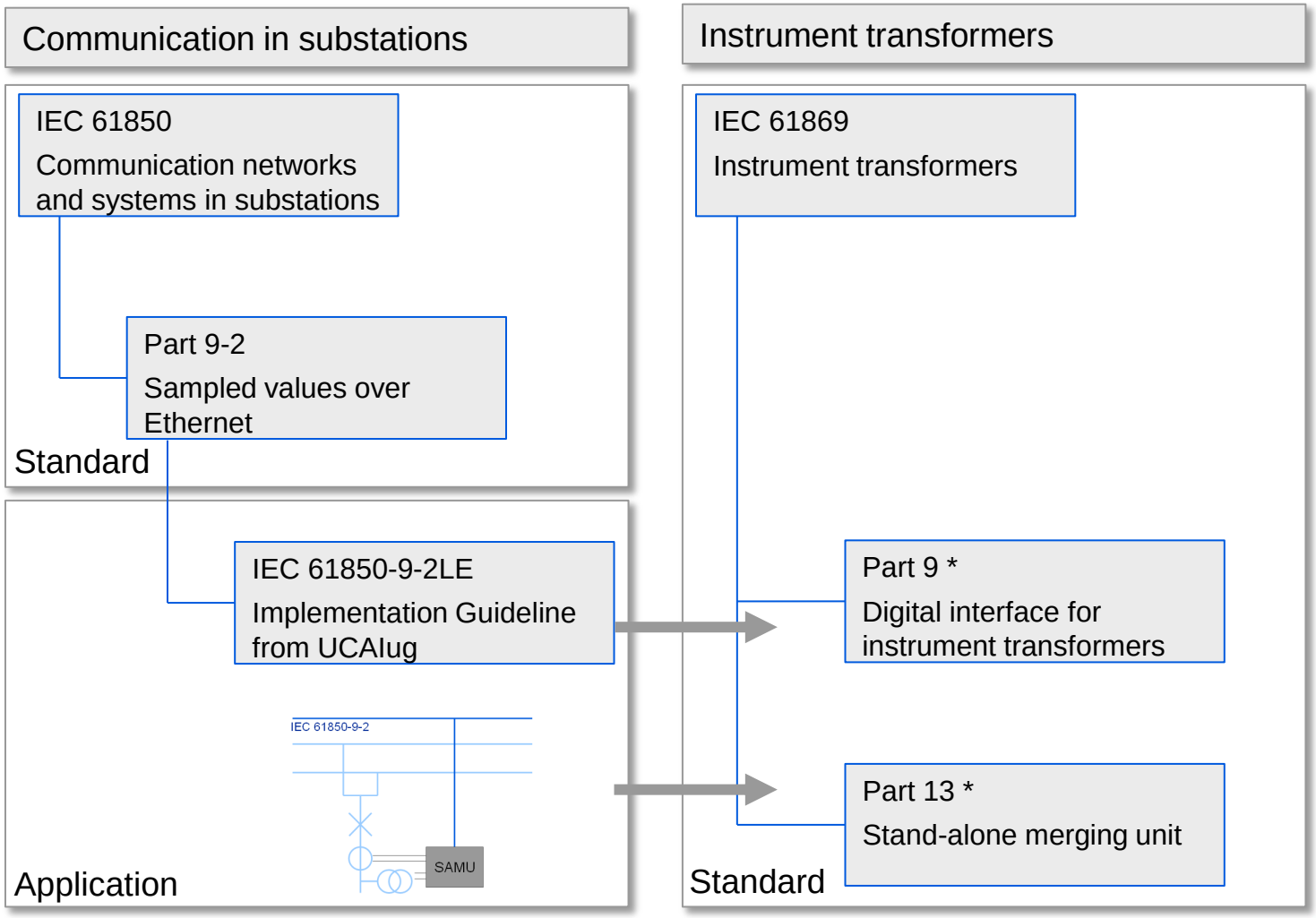
- With interfaces to conventional CTs/VTs (SAMU*)
- Allow connection of any conventional current/ voltage transformer
- Dynamic behavior at the 9-2 output is not yet defined

*SAMU: stand-alone merging unit (will be defined in IEC 61869)

Standardization and interoperability
Dynamic behavior



Standardization and interoperability
New standard for instrument transformers



* Under preparation by IEC TC38 WG37

From conventional to digital substation automation

ABB‘s portfolio for process bus applications

Standardization and interoperability

Maintenance and testing

Digital substation experiences

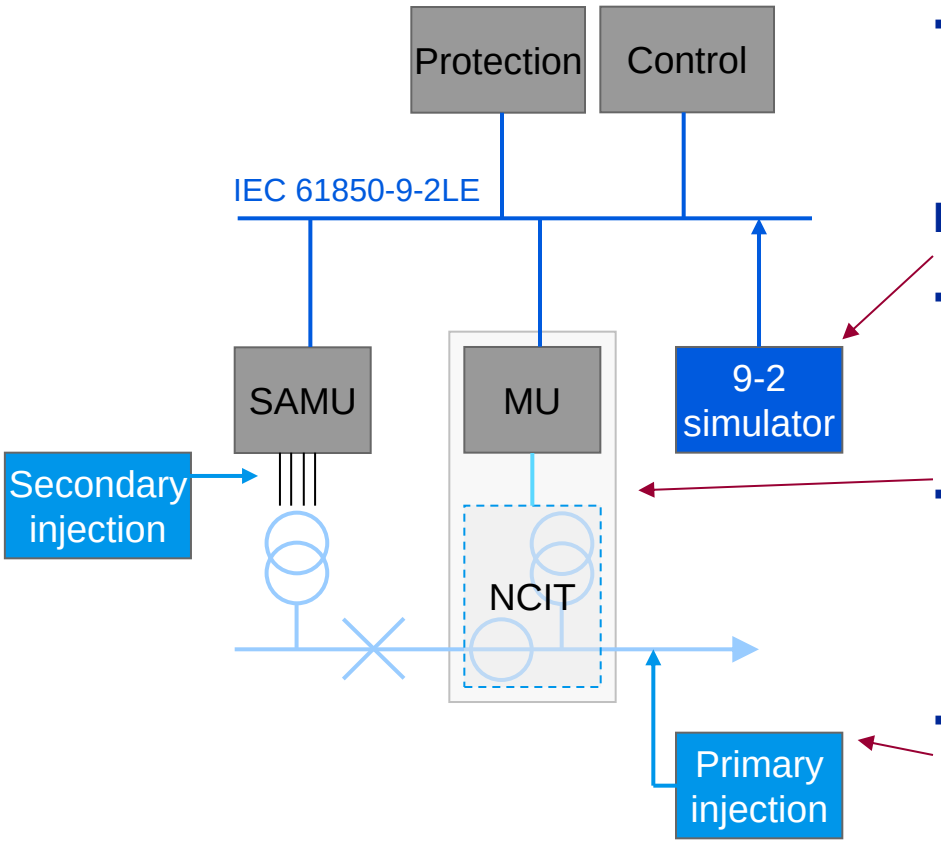
Summary

Maintainability
Workforce challenges

- IEC 61850 at working level
- Cross skilling of workforce
- New design considerations
- Change to the test equipment and testing methods
- Fault finding techniques

- System design, functions and tools need to support efficient maintenance

Commissioing and maintenance
Impact on protection and control testing



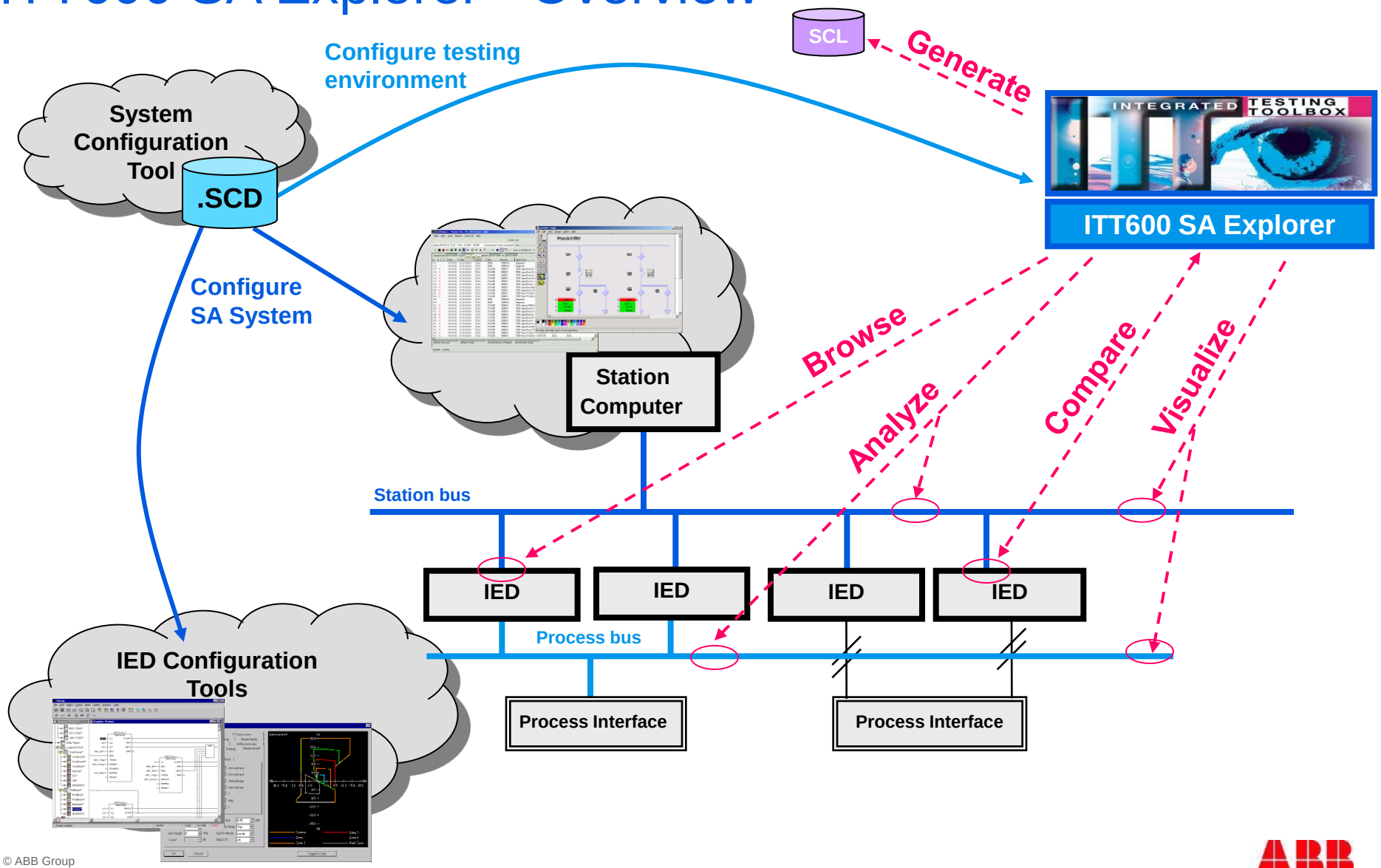
“Wiring” test

- Done automatically through self-supervision features of NCITs, MUs and IEDs

Protection and control testing

- “Non-conventional” secondary injection
  - Simulation of IEC 61850-9-2 LE traffic instead of secondary injection
- Test modes to simulate U/I, by
  - NCIT
  - Merging unit
- Primary injection
  - Primary injection for stability and directional tests

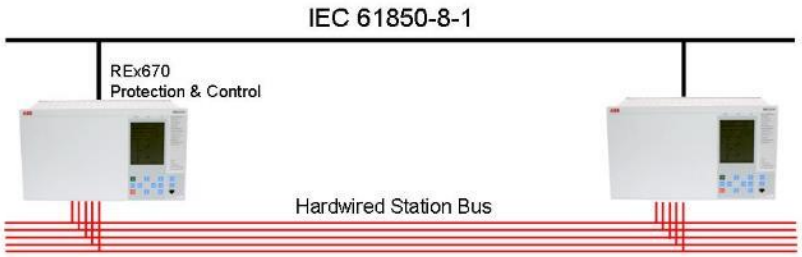
Testing tool for IEC 61850
ITT600 SA Explorer - Overview



ITT600 SA Explorer
Comprehensive testing of GOOSE messaging

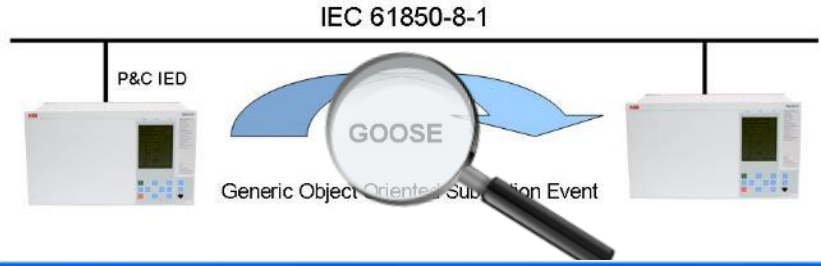
Hardwired signal exchange

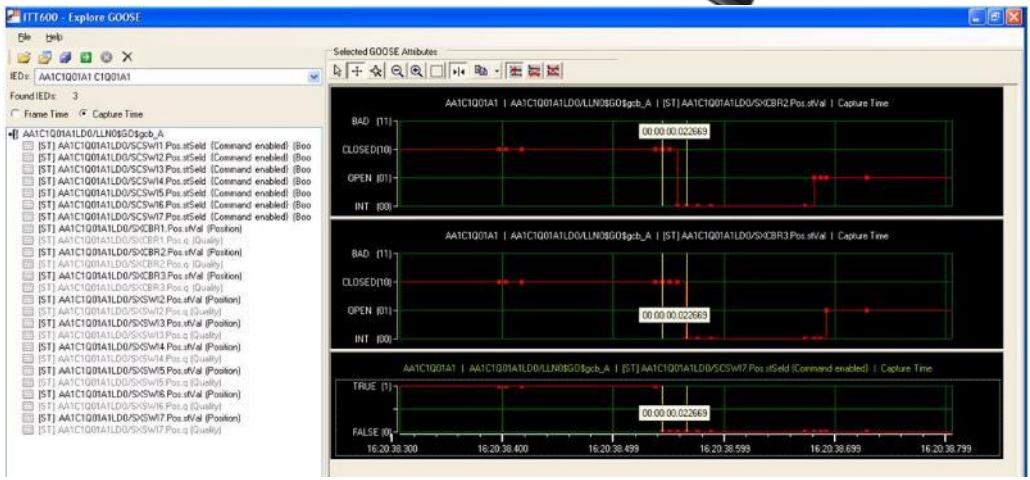
- Testing wire per wire with volt meter



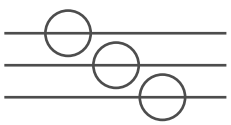
IEC 61850 GOOSE signal exchange

- Comprehensive overview of goose messages in state diagrams

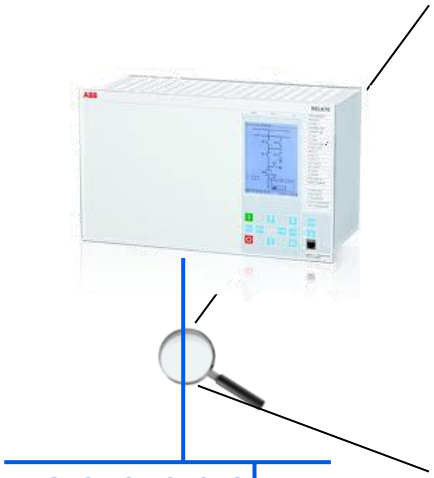


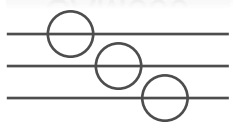


ITT600 SA Explorer
Simple testing of sampled values

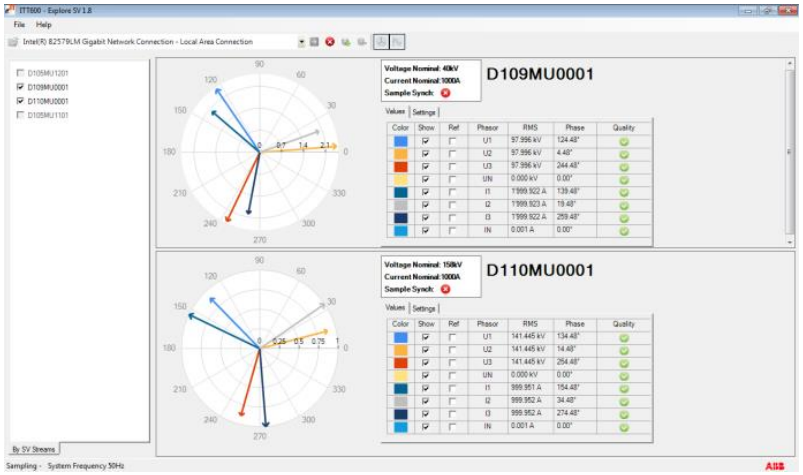


Conventional





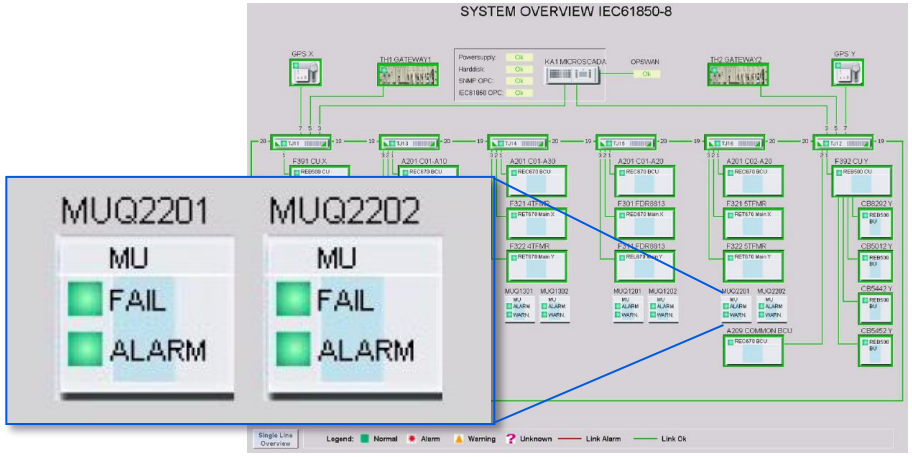
Process bus

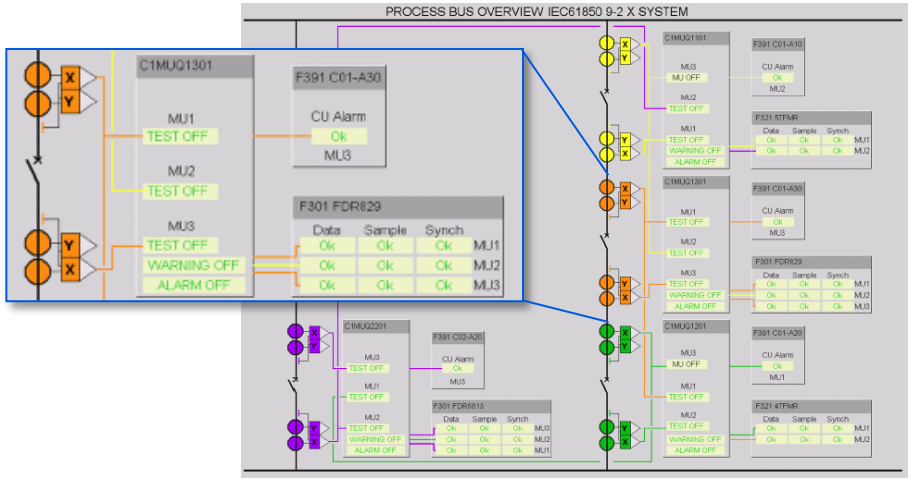


Software replaces multimeter

- Intelligent software for the collection, display and evaluation of sampled-value streams
  - Oscilloscope display of U/I values
  - Phasor diagram
  - Quality information of all values
  - Online and offline analysis

Complete system supervision
Taking advantage of modern IEC 61850 based SA





- For efficient operation and maintenance:
  Permanent system supervision of all intelligent electronic devices.
  From communication gateways to MUs and NCIT electronics
- Supervision diagrams for fast overview of the substation health
  - System overview with all substation automation, protection and control equipment as well as merging units
  - Process bus overview with detailed information about merging units and NCITs

From conventional to digital substation automation

ABB‘s portfolio for process bus applications

Standardization and interoperability

Maintenance and testing

Digital substation experiences

Summary

ABB's experience with IEC 61850-9-2 process bus
Project highlights until 2013

Pilot installation
Braemar, AU
GIS NCIT,
670series

Pilot installation
Laufenburg, CH
GIS NCIT,
670series, REB500

Pilot installation
SvK, SE
FOCS NCIT,
670series

Real installation
Loganlea, AU
GIS NCIT,
670series, REB500

Pilot installation
Nehden, DE
3rd party NCIT,
REB500

Pilot installation
BKW, CH
GIS NCIT,
670series, 3rd party

Real installation
Millmerran, AU*
GIS NCIT,
670series, REB500

Pilot installation
NG, UK
GIS NCIT,
670 series

2009 | 2010 | 2011 | 2012 | 2013

Real experience through real projects

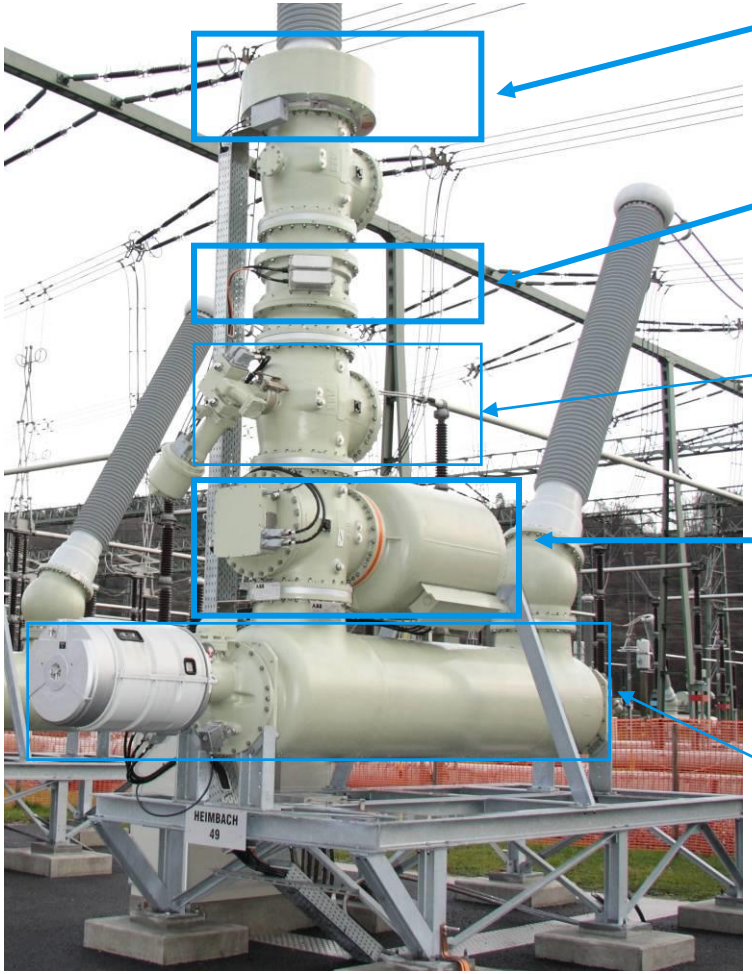
* 4 more projects in Australia are under various stages of execution

Service experience
Pilot installation Laufenburg

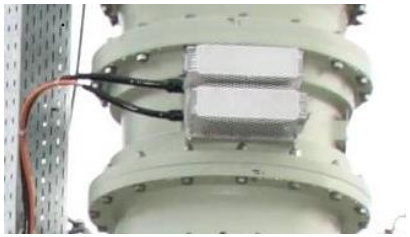
- Pilot installation at a 380kV feeder in Laufenburg, Switzerland
  - ELK-CP3 non conventional instrument transformer (NCIT) installed in addition to conventional CT/ VT
  - IEC61850-9-2 protection equipment REL670 and REB500
  - Pilot installation without connections to trip circuits
  - Direct comparison to conventional installation
  - Analysis of performance of pilot equipment

➢ Commissioned 2009-12-04

Service experience
Pilot installation Laufenburg



- Conventional current transformer
- ELK-CP3 NCIT



- Earthing switch
- Disconnector and conventional voltage transformer
- Circuit breaker

Service experience
FOCS in 420kV disconnecting circuit breaker

- Fibre optic current sensor (redundant)
- Merging units (redundant)

- Protection panel with 670 series IEDs

Service experience
Complete process bus and NCIT systems

- Between 1998 and 2001, ABB and Powerlink Queensland, AU commissioned substations equipped with NCITs and IEDs with proprietary process bus
- The systems, with over 300 NCITs, have been in continuous operation for more than 14 years
- Refurbish the substations to IEC 61850 compliant systems with process bus

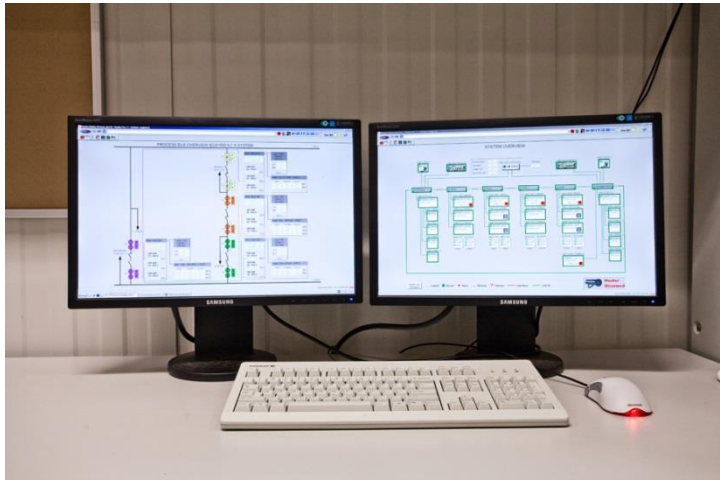
Service experience
Complete process bus and NCIT systems

- Secondary system upgrade at Loganlea 275kV SS
- Upgrade to IEC 61850-9-2LE compliant system by keeping primary equipment
- Main functions:
  - Control
  - Line distance protection
  - Line differential protection
  - Transformer differential protection
  - Breaker failure protection

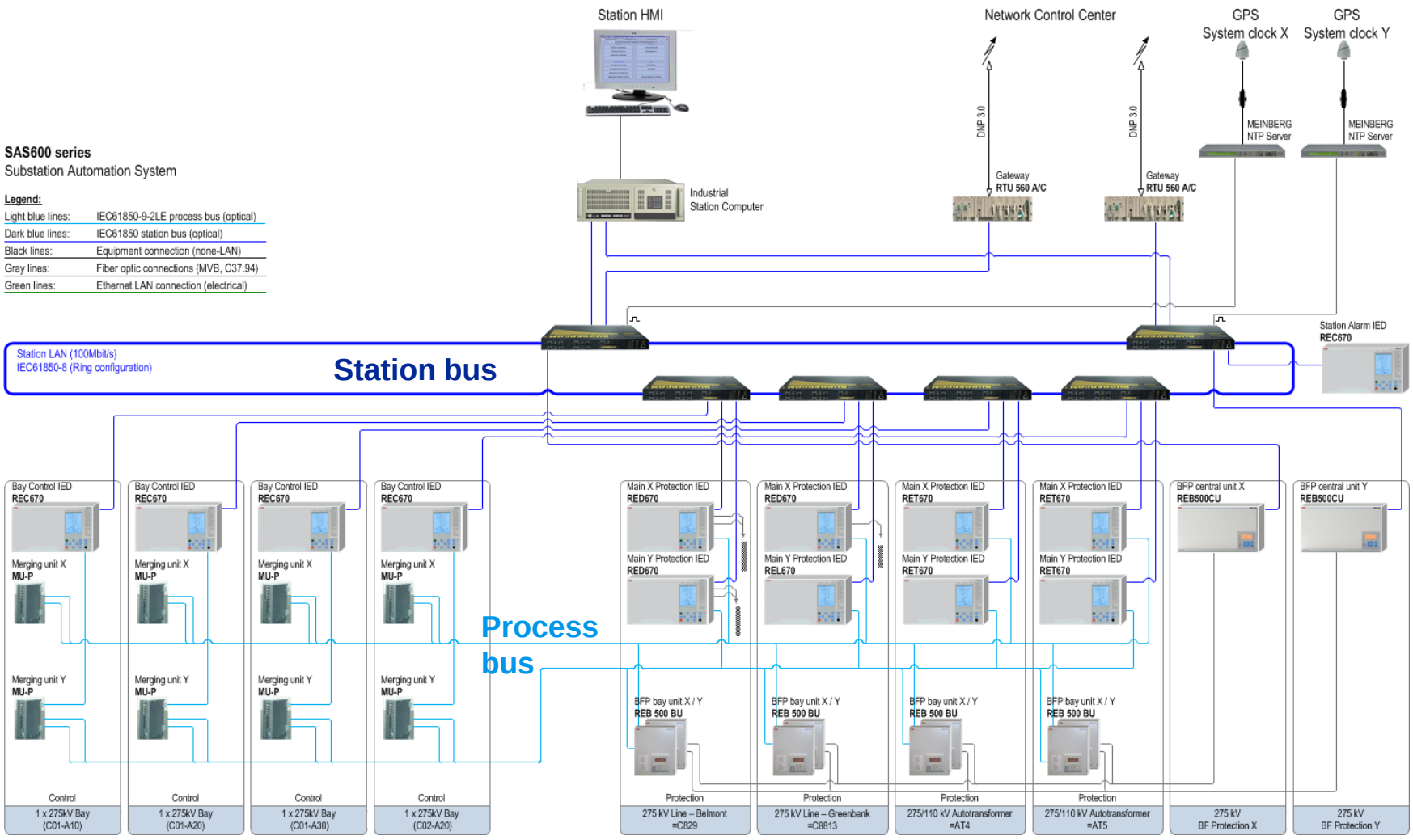
➢ Commissioned December 2011

Service experience
Loganlea site pictures (1/2)

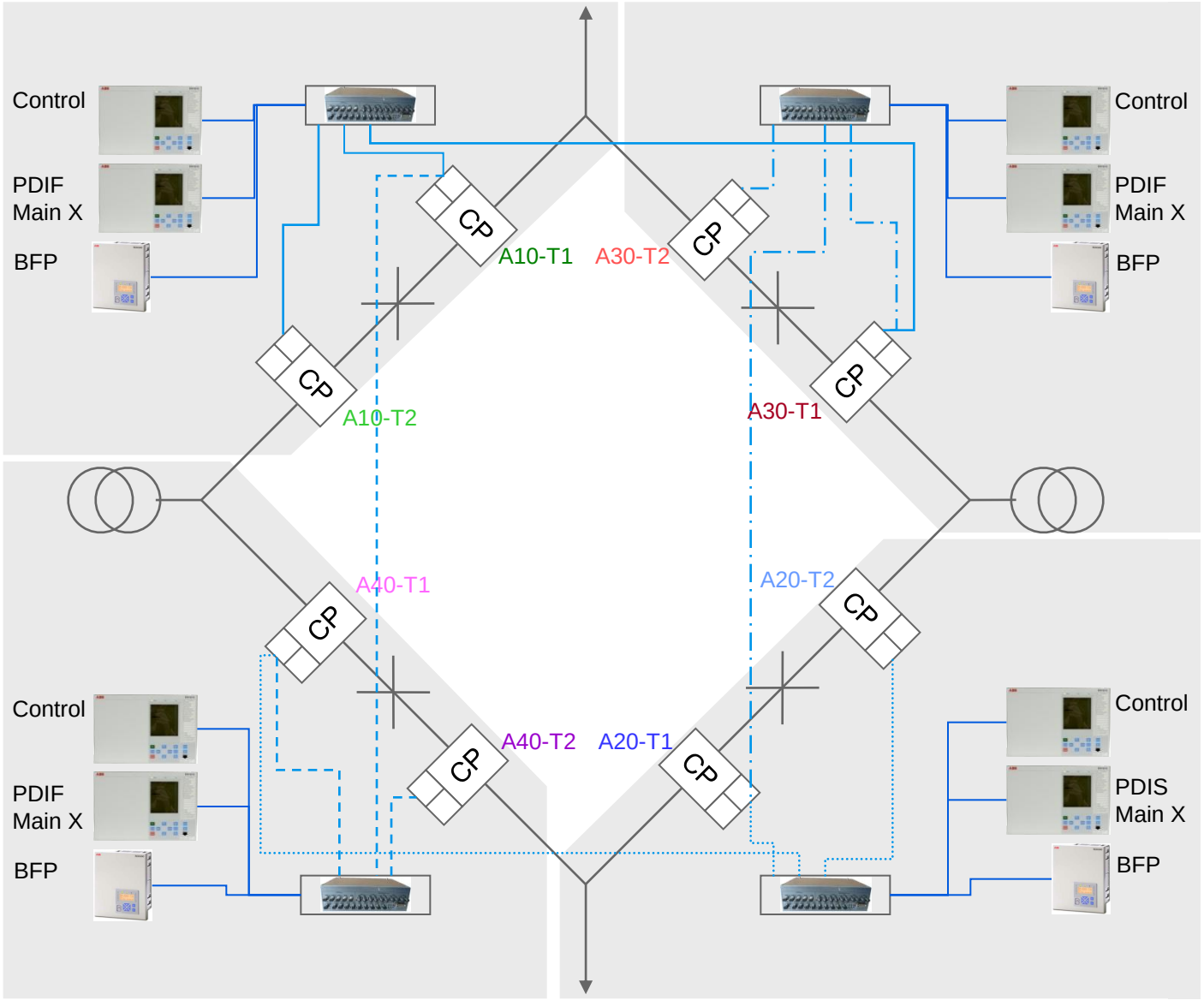
Service experience
Loganlea site pictures (2/2)



Service experience
Complete process bus and NCIT systems



Service experience
Complete process bus and NCIT systems



The picture shows simplified one of two fully redundant protection systems

From conventional to digital substation automation

ABB‘s portfolio for process bus applications

Standardization and interoperability

Maintenance and testing

Digital substation experiences

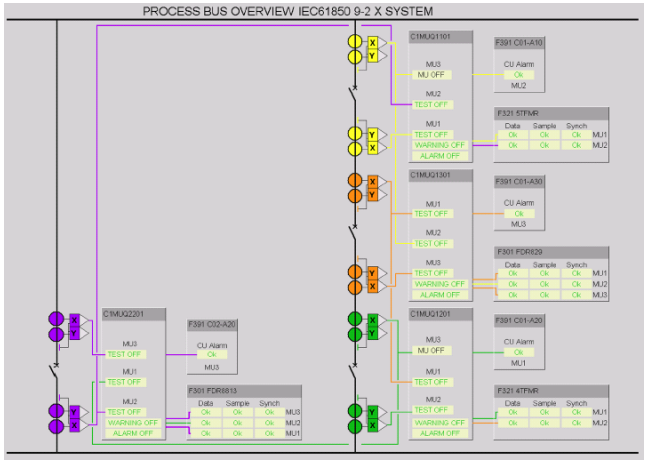
Summary

Summary

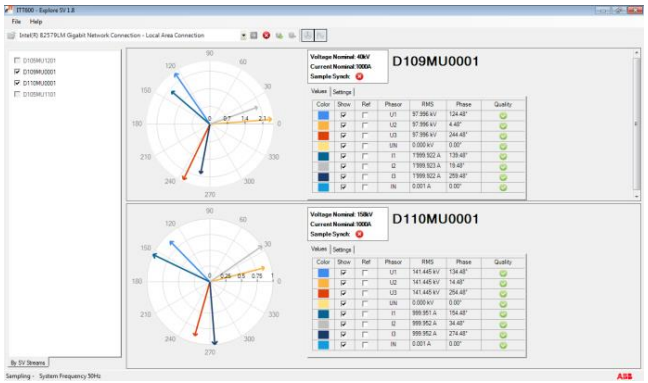
- Non-conventional instrument transformers, among other advantages, increase availability and safety of substations

- IEC 61850 prozess bus reduces field cabling simplifies engineering and enables slim and smart substation retrofit

Summary



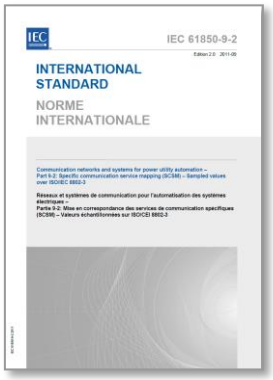
- Thought through integration of process bus in the substation automation system suports users in maintenance activities

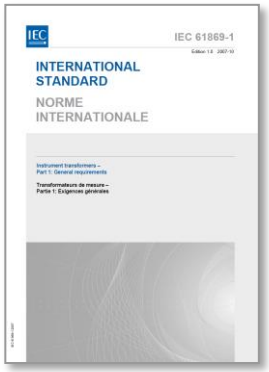


- IEC 61850 testing tools allow for effizient testing, commissioning and maintenance of prozess bus substations

Summary

- ABBs NCITs, merging units and IEDs with IEC 61850 prozess bus are in commercial operation since several years





- Designing products and systems fully compliant to IEC 61850 (and future IEC 61869) is the key to future proof and interoperable systems

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