

# This webinar brought to you by the Relion<sup>®</sup> product family

## Advanced protection and control IEDs from ABB

### **Relion.** Thinking beyond the box.

Designed to seamlessly consolidate functions, Relion relays are smarter, more flexible and more adaptable. Easy to integrate and with an extensive function library, the Relion family of protection and control delivers advanced functionality and improved performance.



# ABB Protective Relay School Webinar Series

## Disclaimer

ABB is pleased to provide you with technical information regarding protective relays. The material included is not intended to be a complete presentation of all potential problems and solutions related to this topic. The content is generic and may not be applicable for circumstances or equipment at any specific facility. By participating in ABB's web-based Protective Relay School, you agree that ABB is providing this information to you on an informational basis only and makes no warranties, representations or guarantees as to the efficacy or commercial utility of the information for any specific application or purpose, and ABB is not responsible for any action taken in reliance on the information contained herein. ABB consultants and service representatives are available to study specific operations and make recommendations on improving safety, efficiency and profitability. Contact an ABB sales representative for further information.

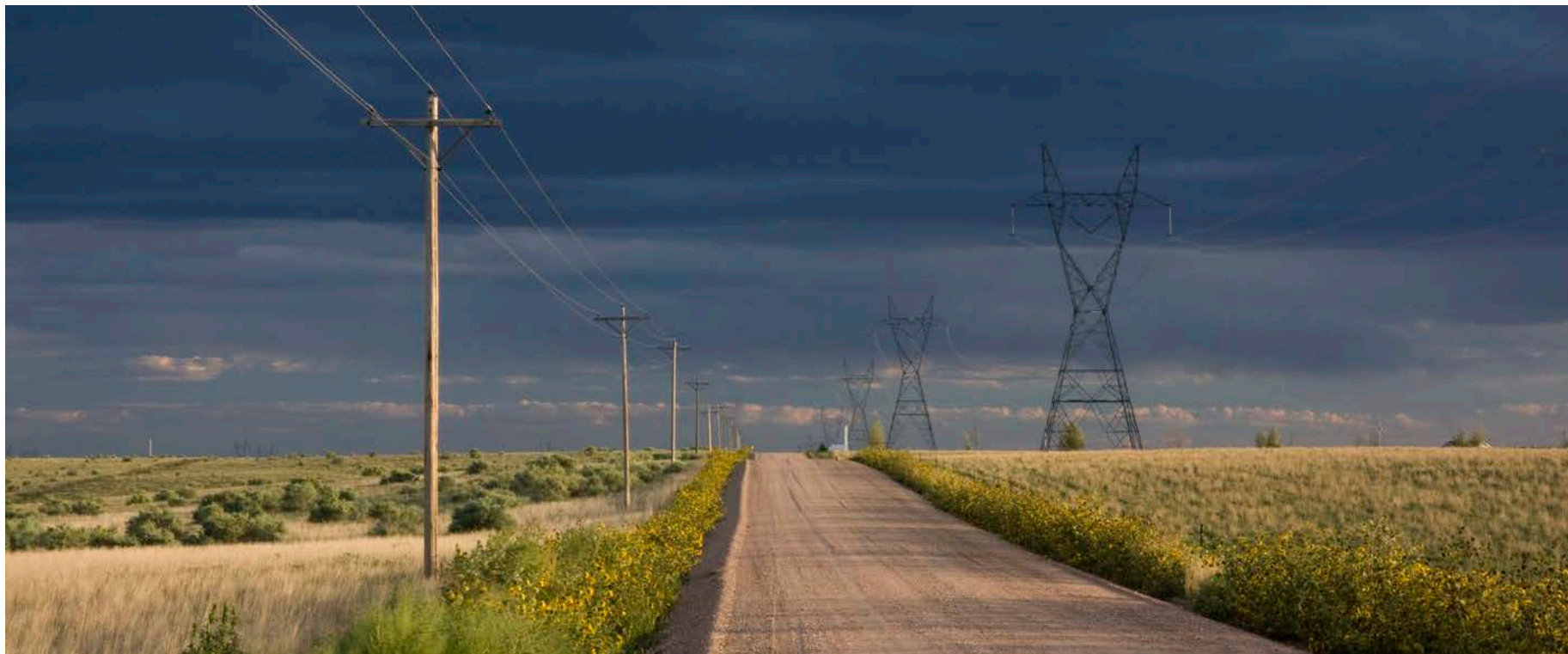


ABB Protective Relay School Webinar Series

# Realizing the digital substation: Introduction to the process bus (IEC 61850-9-2)

David Hart & Jose Ruiz

August 13, 2013

# Presenter



David G. Hart, Ph.D.

Dr. David G. Hart is Executive Director Automation Solutions at ABB in Raleigh, NC. Dr. Hart is a native of Union, SC and holds a Ph.D. in Electrical Engineering and a MS in Electrical Engineering from Clemson University, in Clemson, SC.

In 1992, Dr. Hart joined what was then ABB Transmission Technology Institute where he held various engineering and managerial positions. His initial areas of focus included generator protection, transmission protection, and distribution protection and control. His later position in ABB was working on distribution and feeder automation. After moving to ABB Meters (later Elster), he was the Senior Vice President of Systems and Products, responsible for the Product Management, Engineering, and Quality organizations.

Dr. Hart has numerous technical disclosures and patents in smart metering, power system protection and control, and in automation. Dr. Hart is a Senior Member of the IEEE.

# Presenter



Jose Ruiz

Jose L. Ruiz is with ABB Substation Automation Products group, North America. He joined ABB as a post graduate student.

During his graduate study, he learned and tested IEC 61850 with different vendor relays. In his current role with ABB, Jose shares his expertise in IEC 61850 with customers in the power industry in trainings, projects, and providing technical support.

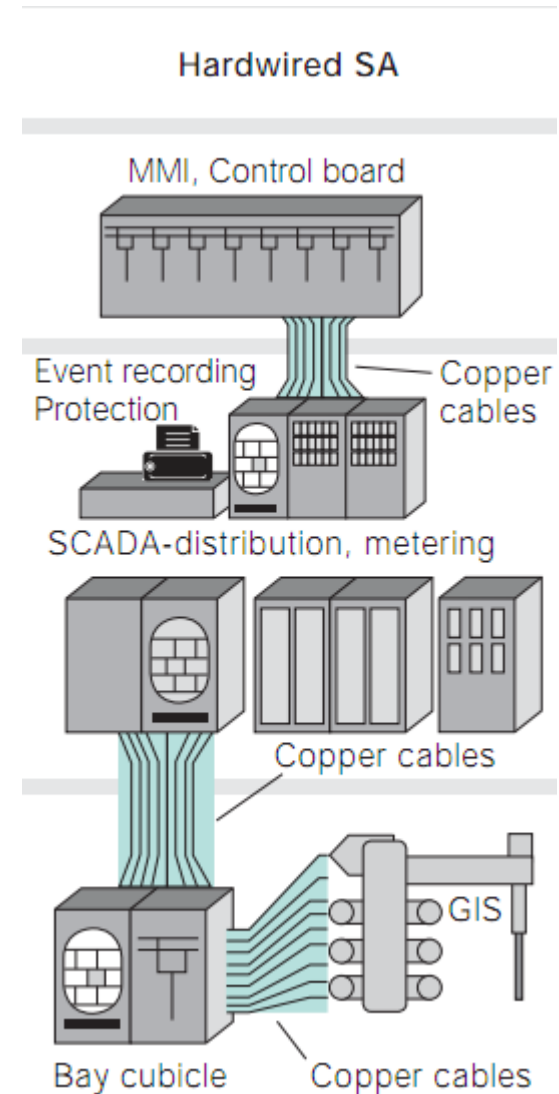
Jose received his M.S. degree in Electrical Engineering from the University of Tennessee at Chattanooga in 2012 and is a member of the IEEE PES.

# Learning objectives

- Brief introduction to IEC 61850
- IEC 61850 Process Bus
- UCA Implementation Guidelines
- System Architecture
- Project example

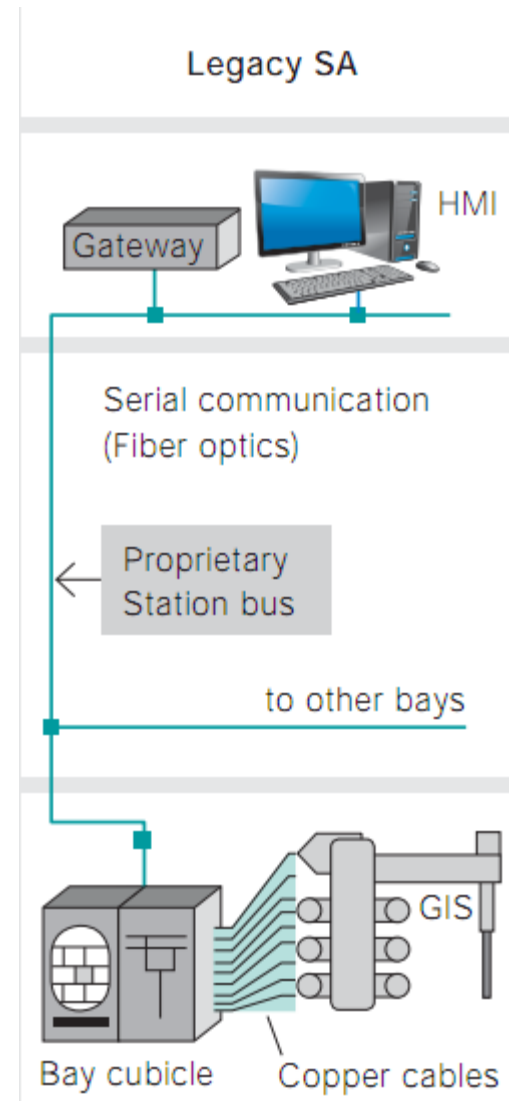
# SA System Architecture - RTU / Hardwired

- IEDs do not have communication capability
- Status monitoring and control via RTU hardwired connections
- Significant amount of connections / documentation



# SA System Architecture - DNP / Modbus

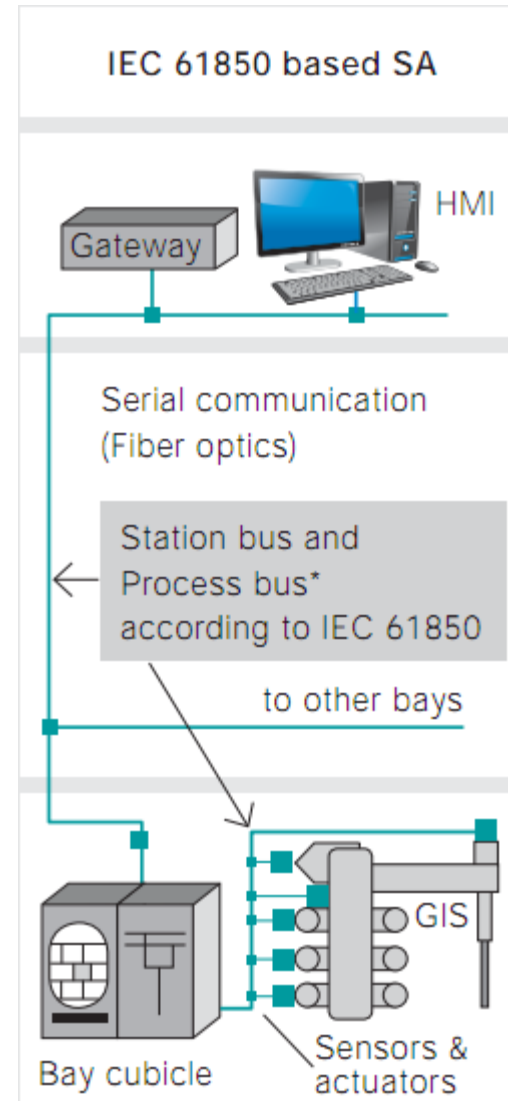
- Integration of status monitoring into IEDs
- Reduction/elimination of RTU cabinet
- Defined protocol stack
- Non standard modeling of substation equipment and functions
- Non standard data format
- Integration requires intimate knowledge of each device
- Protocol conversion may be necessary





# 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
- Interoperability by standardization and **verification**



# IEC 61850 - Goal of the Standard

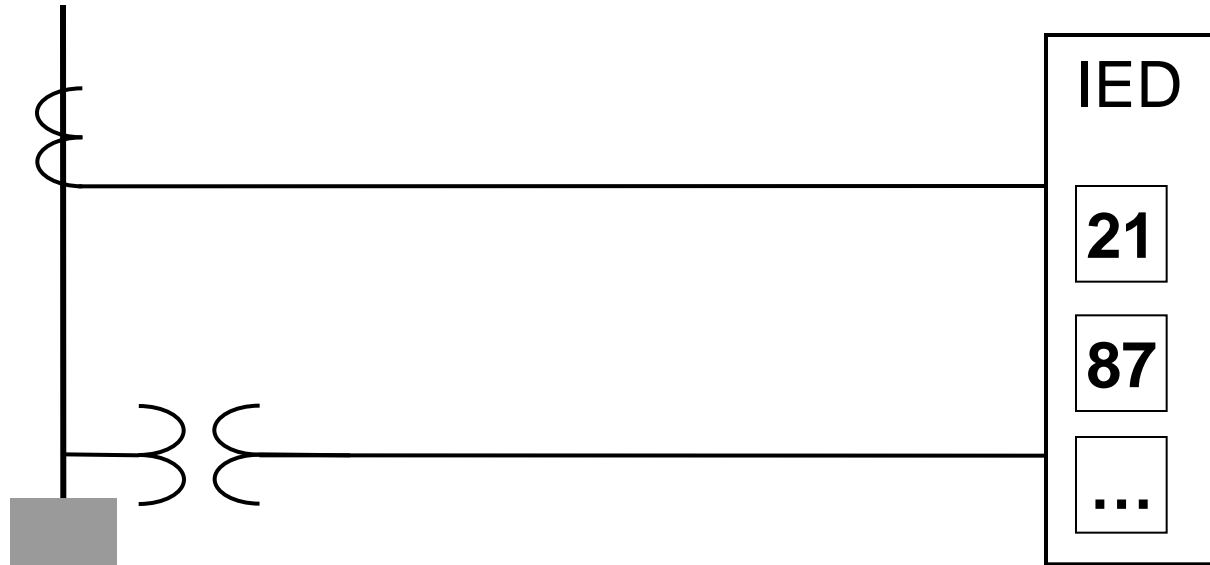
- **Interoperability**
  - Exchange information between IED's (Intelligent Electronic Device) from several manufacturers
  - IEDs use this information for their own function
- **Free Configuration**
  - Free allocation of functions to devices
  - Support any philosophy of customer – centralized or decentralized systems
- **Long Term Stability**
  - Future proof
  - Follow progress in mainstream communication technology
  - Follow evolving system requirements needed by customers

# Introduction to process bus

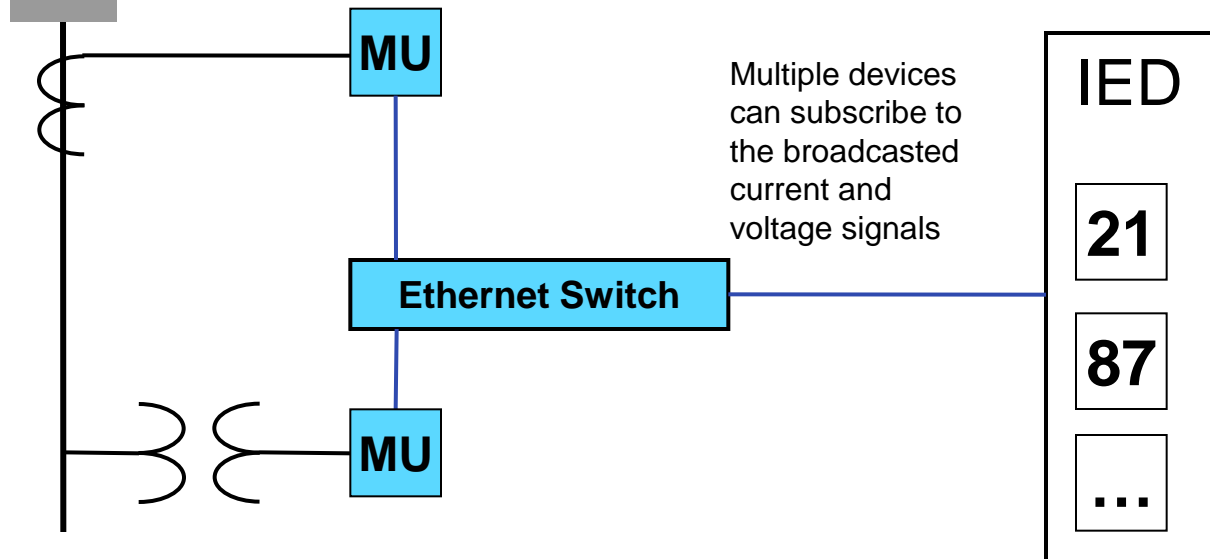
- The process bus is i.e. a communication network at the process level
- It is responsible for publishing the quantities related to the process; i.e.
  - Voltage
  - Current
- IEC 61850 9-2 Defines the mapping of “Sampled Values” over Ethernet
- “Sampled Values” are current and voltage samples obtained from CTs and VTs
- IEC61850 9-2 define the communication protocol over Ethernet that enables the publication of such samples for the purposes of protection, monitoring, and metering

# Introduction to process bus

Conventional

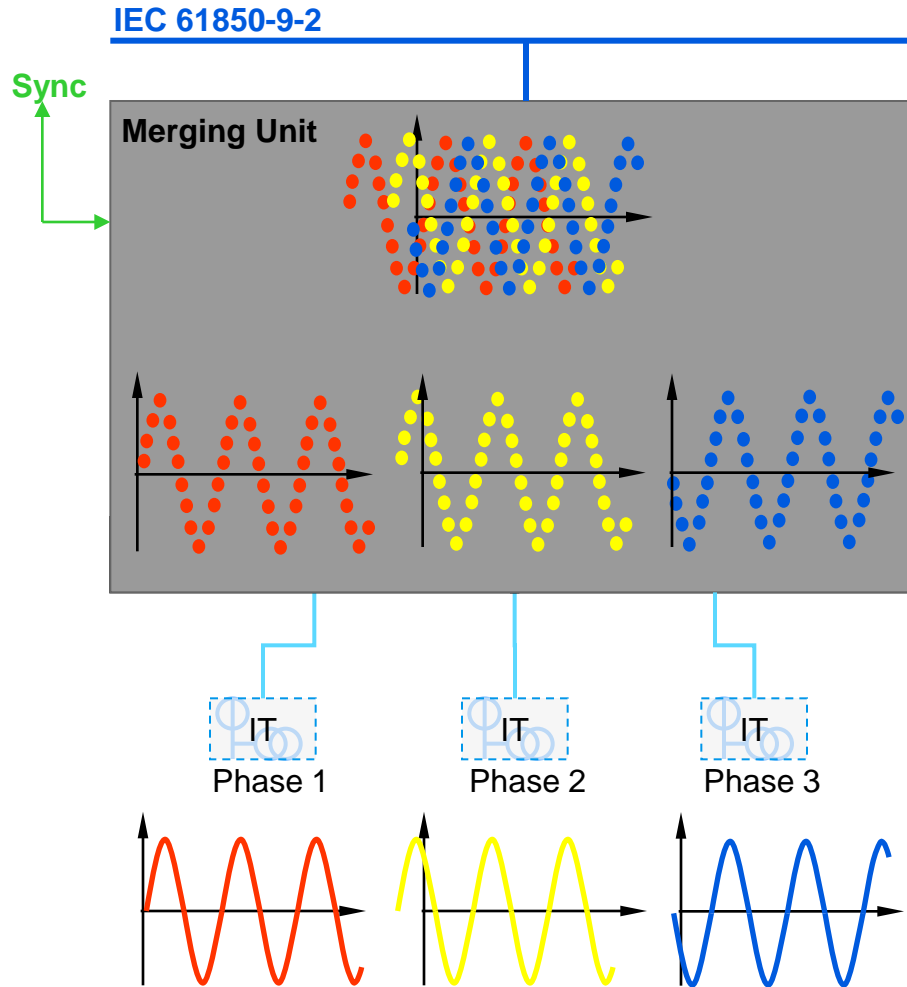


IEC61850  
Process Bus



# Introduction to process bus

## What is a merging unit



Communication interface according to IEC 61850-9-2

Merging and timely correlation current and voltage values from the three phases

Sampling or re-sampling of current and voltage values

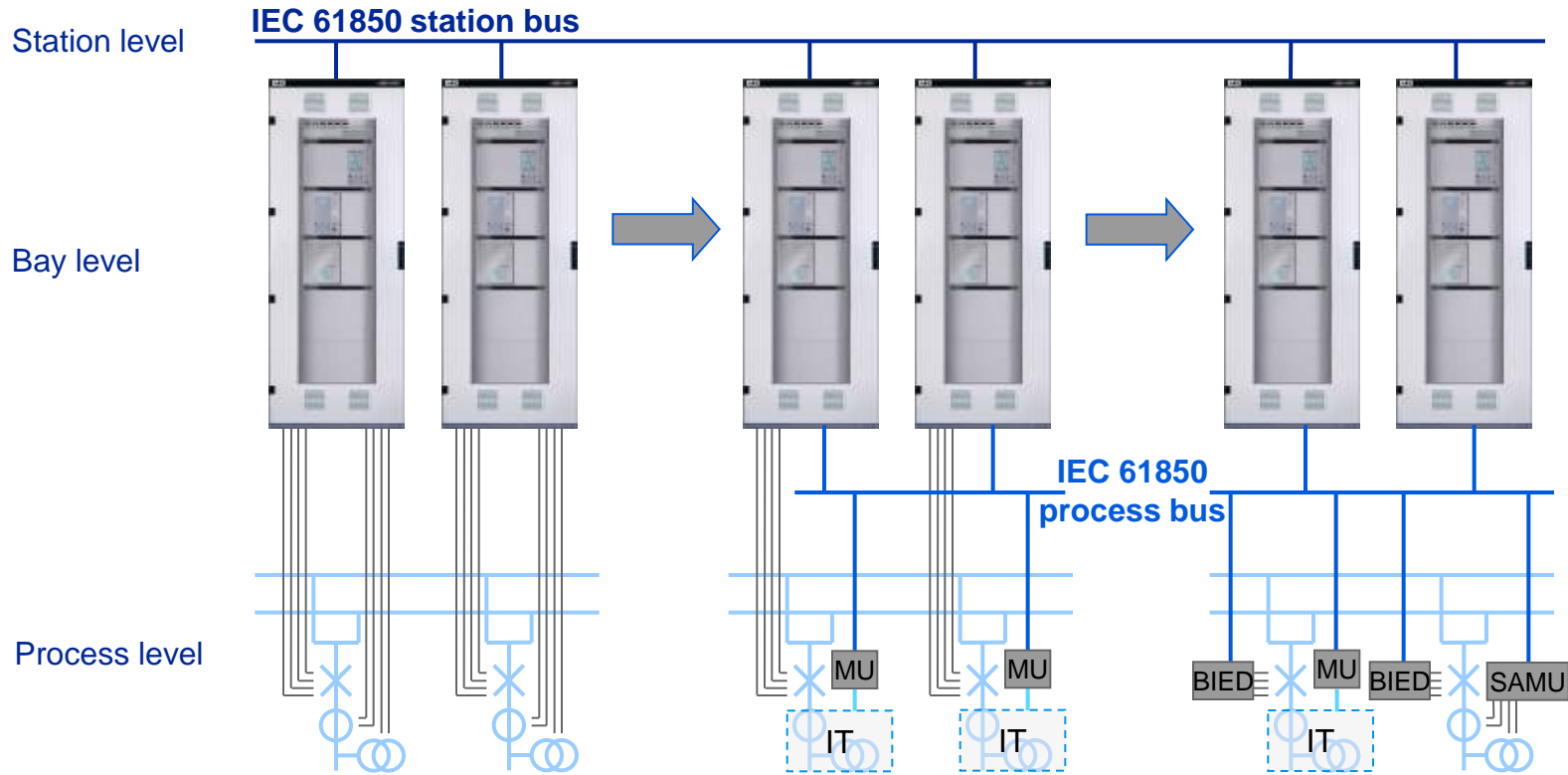
Technology specific interface between NCIT/CIT and MU

Time synchronization

Synchronize IEDs or other MUs when acting as time master, if required

Receive time synchronization when acting as time slave, if required

# Introduction to process bus

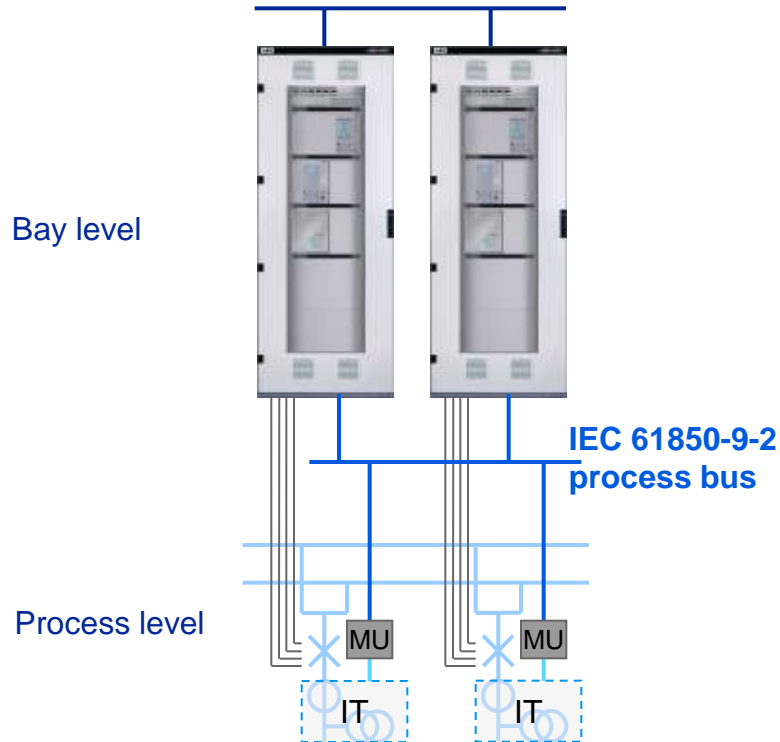


Conventional connections to CT/VT and drives

Process bus to merging units for current and voltage sensors – **conventional and non-conventional ITs**

Process bus to merging units for current, voltage and binary signals

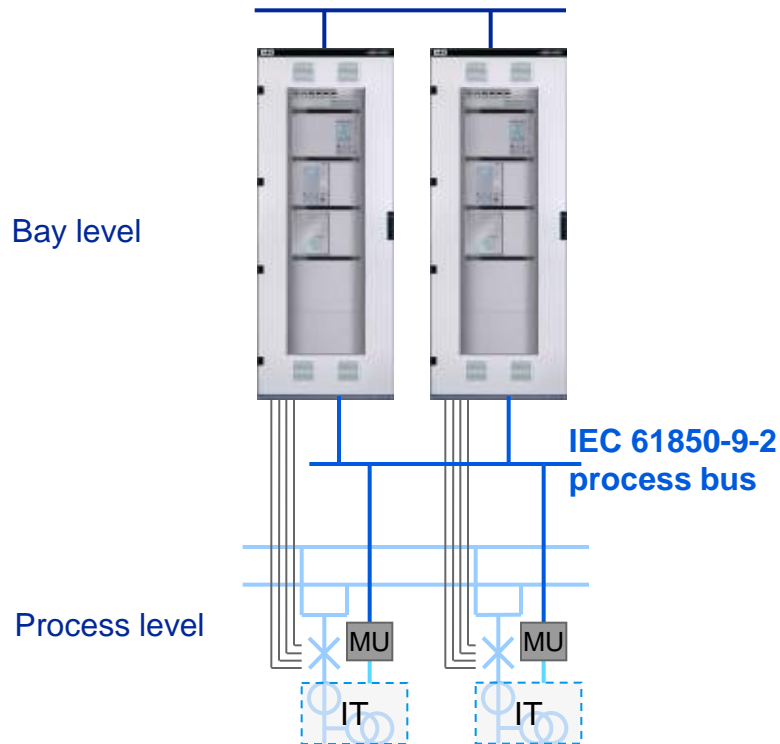
# Introduction to process bus



- The process bus is a communication network on process level, and also connecting the process to the bay level
- IEC 61850-9-2 describes the transmission of sampled analogue values over Ethernet
- IEC 61850 also allows transmission of binary data on process level (GOOSE, MMS)

# Introduction to process bus

## What is process bus for sampled analogue values



- Sampled analogue values are transferred as multicast messages and can be received by all IEDs on the same network
- The receiving IEDs decide whether to process the data or not
- The transmission time of the messages on the network is not deterministic
  - A time reference is required to align samples from different sources



# Introduction to process bus

- IEC 61850 9-2 allows protection relays to operate based on digitized current and voltage signals that are distributed on a communication network in the form of Ethernet frames
- Voltage and current signals from different CTs and VTs are “published” on the network and available to all devices that are connected to it
- Galvanic CT and VT inputs to the relays are no longer necessary
  - Safety
  - Wire reduction
- CT and VT signals are processed by the Merging Unit (MU), an intelligent device that samples the current and voltage signals, creates their digital IEC 61850 9-2 form, and publishes them on the network
- Allows integration of non-conventional Instrument Transformers (IT) for improved performance
  - e.g. Can use Rogowski technology for current sensing – output is not at 1A or 5A - to avoid traditional CT saturation issues for protection

# Introduction to process bus IEC 61850-9-2 standard and implementation guideline



- **The standard: IEC 61850-9-2**
  - Communication networks and systems in substations  
Part 9-2: Specific Communication Service Mapping (SCSM) - Sampled values over ISO/IEC 8802-3
    - The standard leaves wide room for implementation and considerable effort is required for full implementation



- **Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2**
  - To facilitate implementation, the UCA International Users Group created an implementation guideline that defines a subset of IEC 61850-9-2.
    - Commonly referred to as IEC 61850-9-2LE for “light edition”

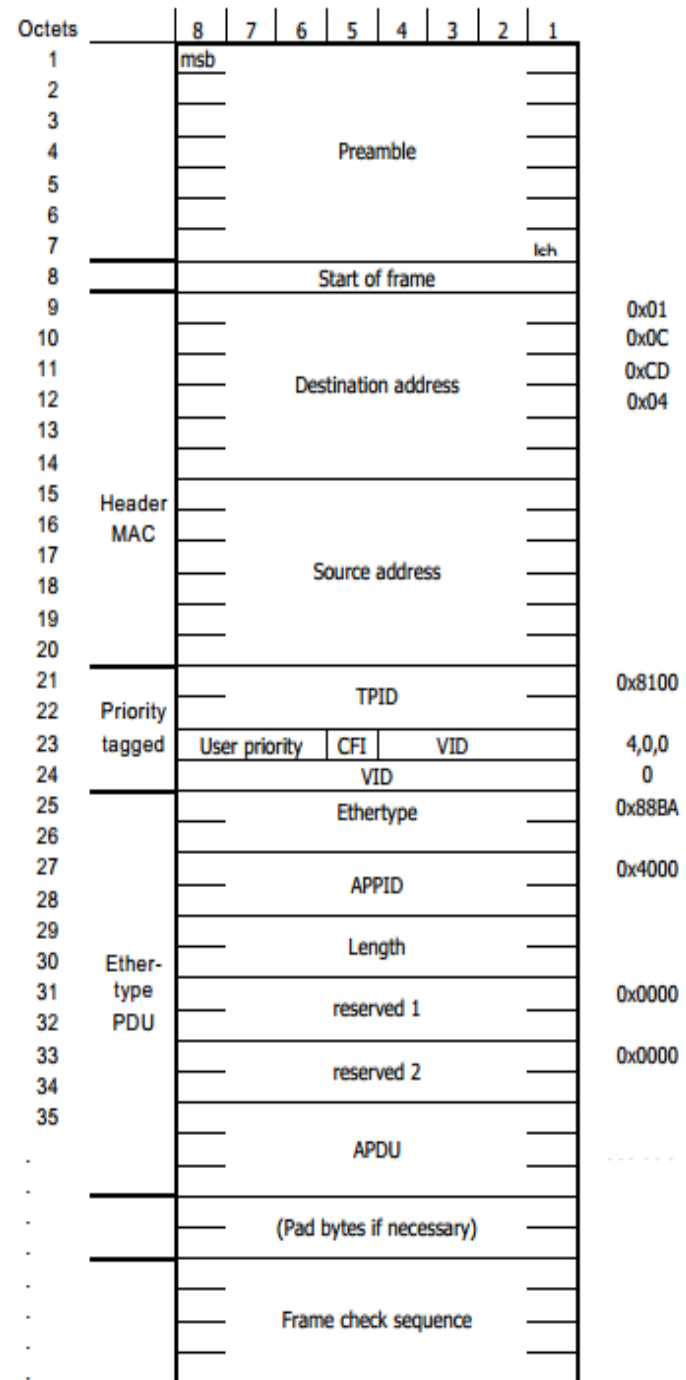
# Introduction to process bus

## Difference between IEC standard and implementation guideline

Area	Standard IEC 61850	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 3 phases voltage + neutral voltage
Time synchronization	Not defined	Optical pulse per second (1PPS)
Logical device "Merging Unit"	Content and naming is not specified	Specified with rules for logical device name and contained logical nodes

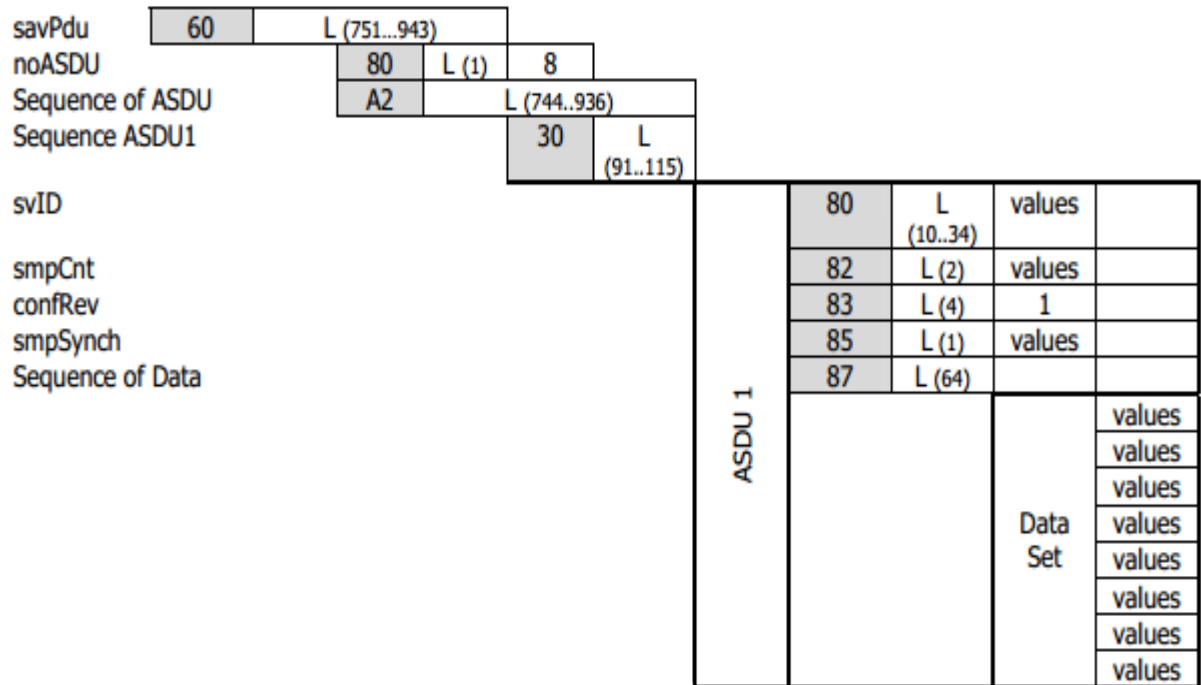
# 61850 9-2 Ethernet Frame

- Destination: multicast mac address
- Source: source mac address
- Vlan info (Priority tagged)
- Ethertype: 0x88BA
- Ethertype APPID: 0x4000
- Sampled Values Protocol Data Unit (APDU)

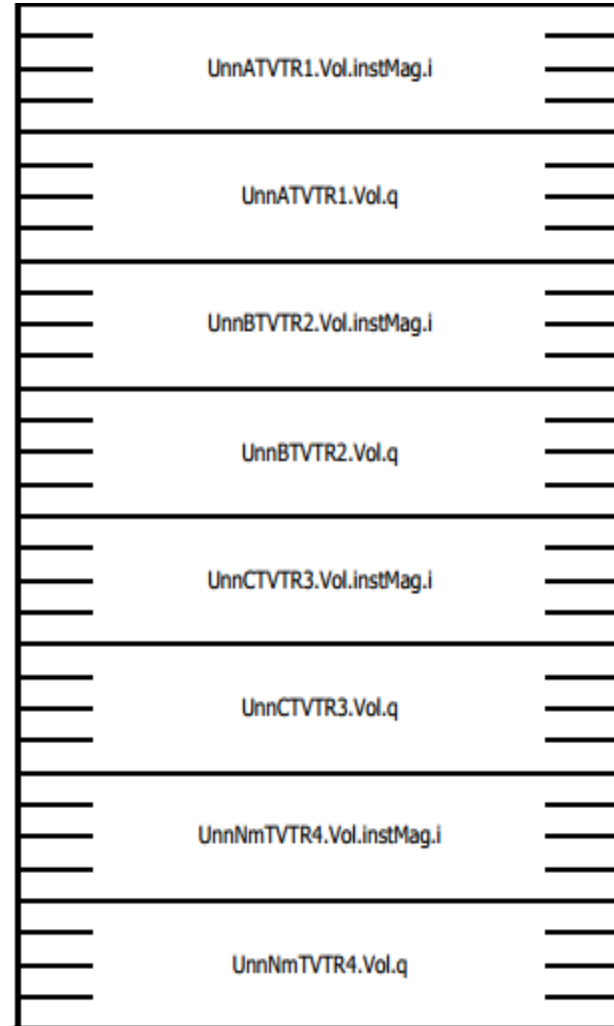
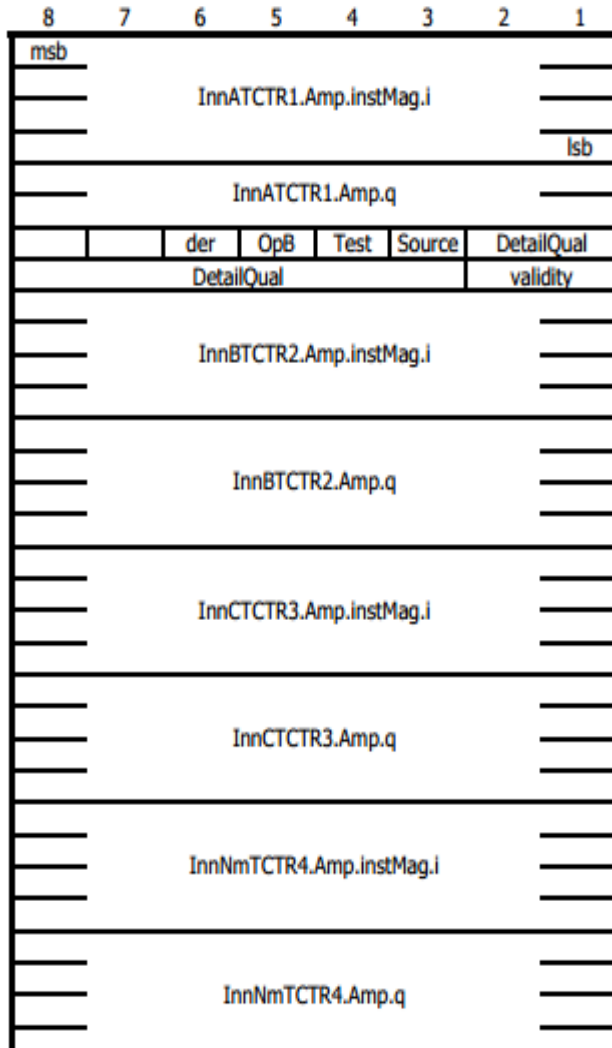


# 61850 9-2 Ethernet Frame

- ASDU:  
Application  
Service Data Unit
- svID: Sampled  
Values ID
- Each Ethernet  
frame contains 1  
sampled of Va,  
Vb, Vc, Vn, Ia,  
Ib, Ic, In
- For protection  
applications the  
transmission rate  
is 80 frames per  
cycle (4800 per  
second)



# 61850 9-2 Ethernet Frame



# Introduction to process bus Time Synchronization

- Time synchronization is needed for IEDs to properly align the current and voltage samples
- Pulse Per Second (PPS) is the defined source of time synchronization in the current implementation guidelines published by UCA
- The source must have an accuracy of  $\pm 1$  micro second
- IEDs are given a small period of time to ride through any transient loss of time synch. This is based on the magnitude of the drift the IED's clock has

# 61850 9-2 Sample Project



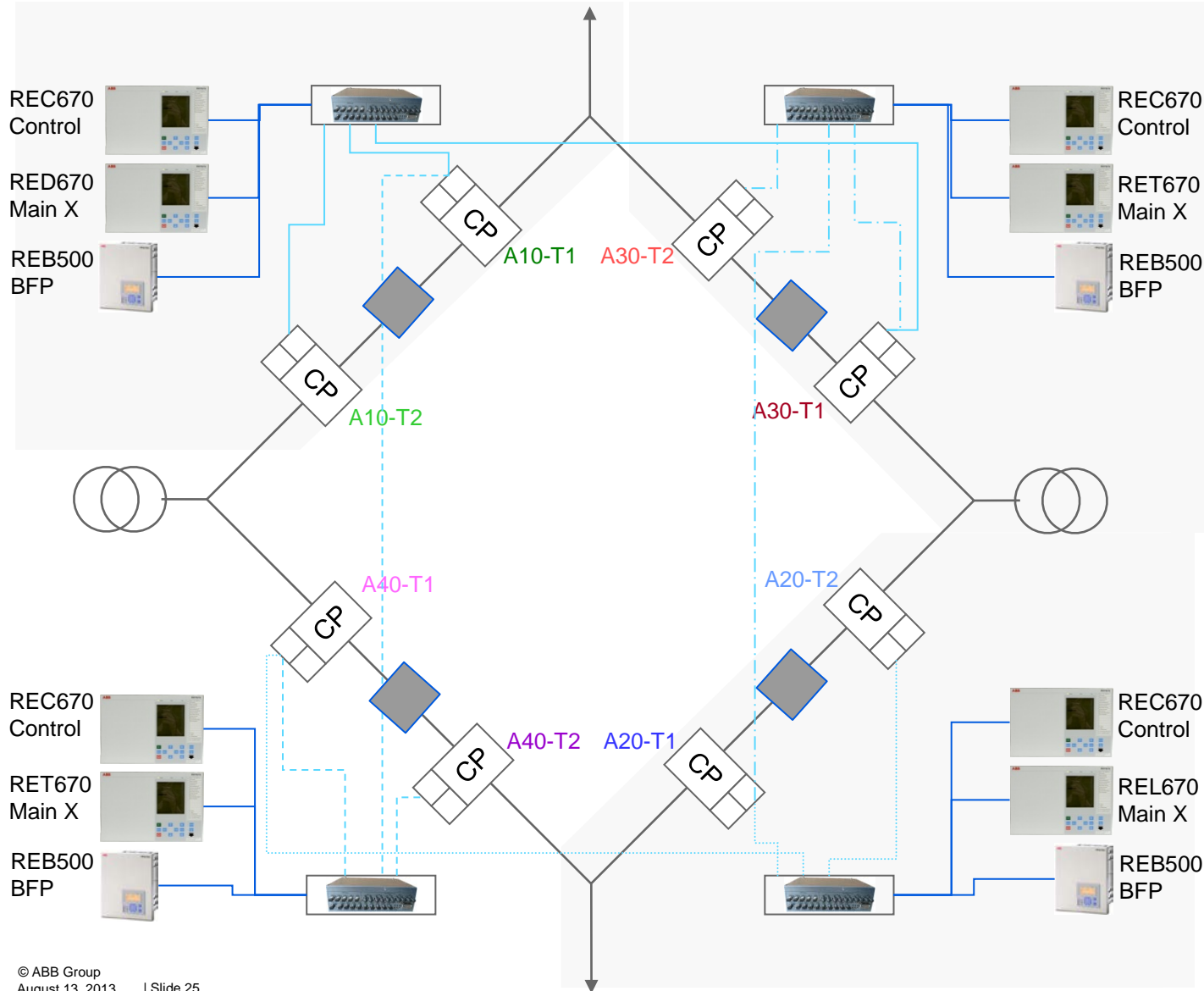
- Powerlink Queensland's 275kV substation is located next to Brisbane in Australia
- The substation is supplying parts of Brisbane and the tourist region Gold Coast with electrical energy
- With the Loganlea secondary system upgrade ABB undertook its first commercial NCIT installation with IEC 61850-9-2LE process bus and protection and control IEDs
- The station has been completed and handed over to the customer in December 2011

IEC 61850-9-2**LE** stands for "Implementation Guideline for digital Interface to instrument transformers using IEC 61850-9-2". Defined by UCA International Users Group.



# ABB's solution

## Process bus overview

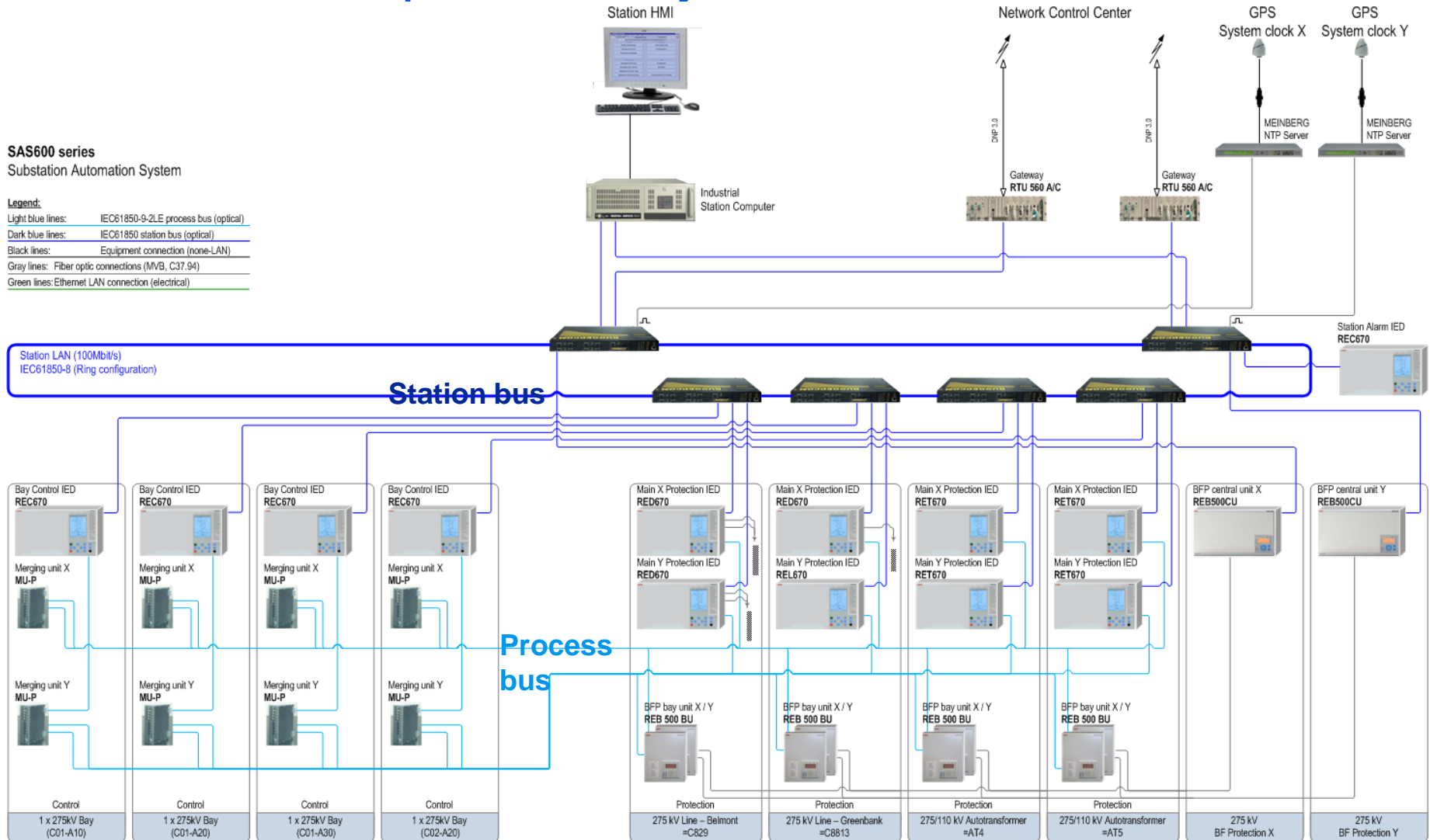


The picture shows simplified one of two fully redundant protection systems

# ABB's solution IEC 61850 compliant SA system

**SAS600 series**  
Substation Automation System

**Legend:**  
 Light blue lines: IEC61850-9-2LE process bus (optical)  
 Dark blue lines: IEC61850 station bus (optical)  
 Black lines: Equipment connection (none-LAN)  
 Gray lines: Fiber optic connections (MVB, C37.94)  
 Green lines: Ethernet LAN connection (electrical)



# ABB's solution

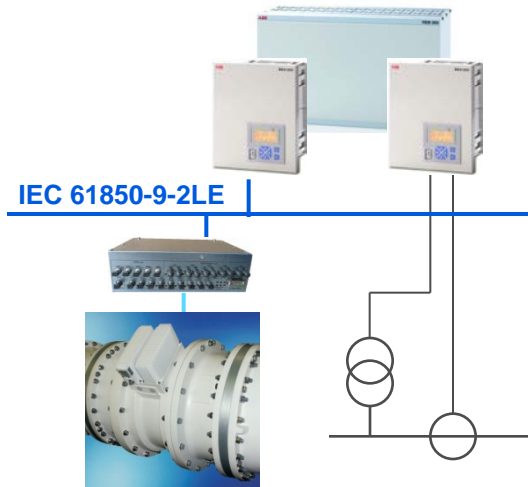
## 670 series protection and control IEDs



- 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

## 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/ $\sqrt{3}$

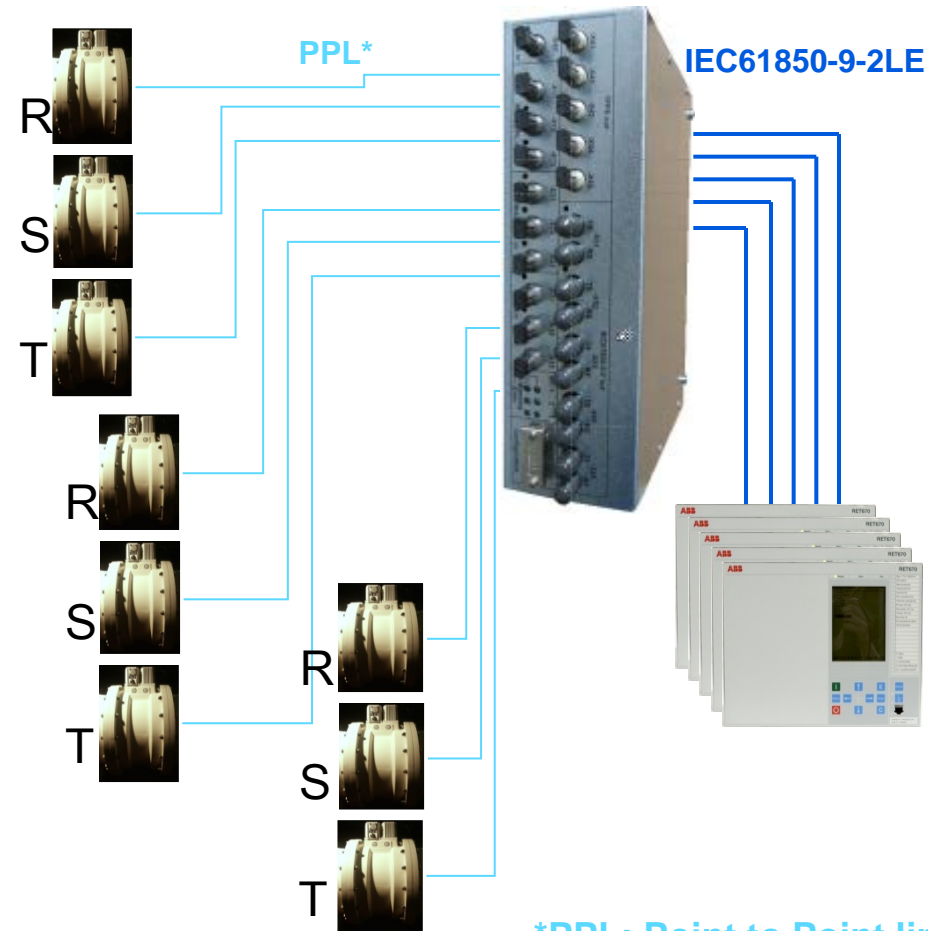


The already installed sensors are early versions of today's ELK-CP sensor. That are...

- 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 for protection CP-MUP**
- 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-MUP 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

## Retrofit to conventional sensors

- Hybrid solution can use conventional ITs and convert to digital process bus
  - Utilize IEC 61850-9-2LE with 80 samples/cycle for protection and operational metering

- Supporting the digital substation architecture





# ABB's solution

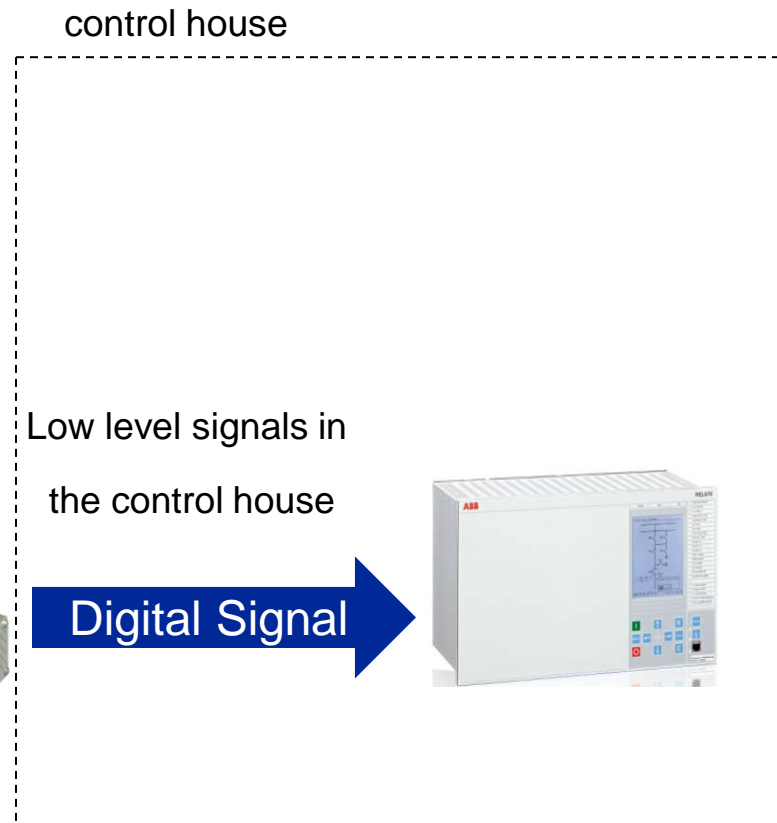
## Retrofit to conventional sensors



Analog Signal

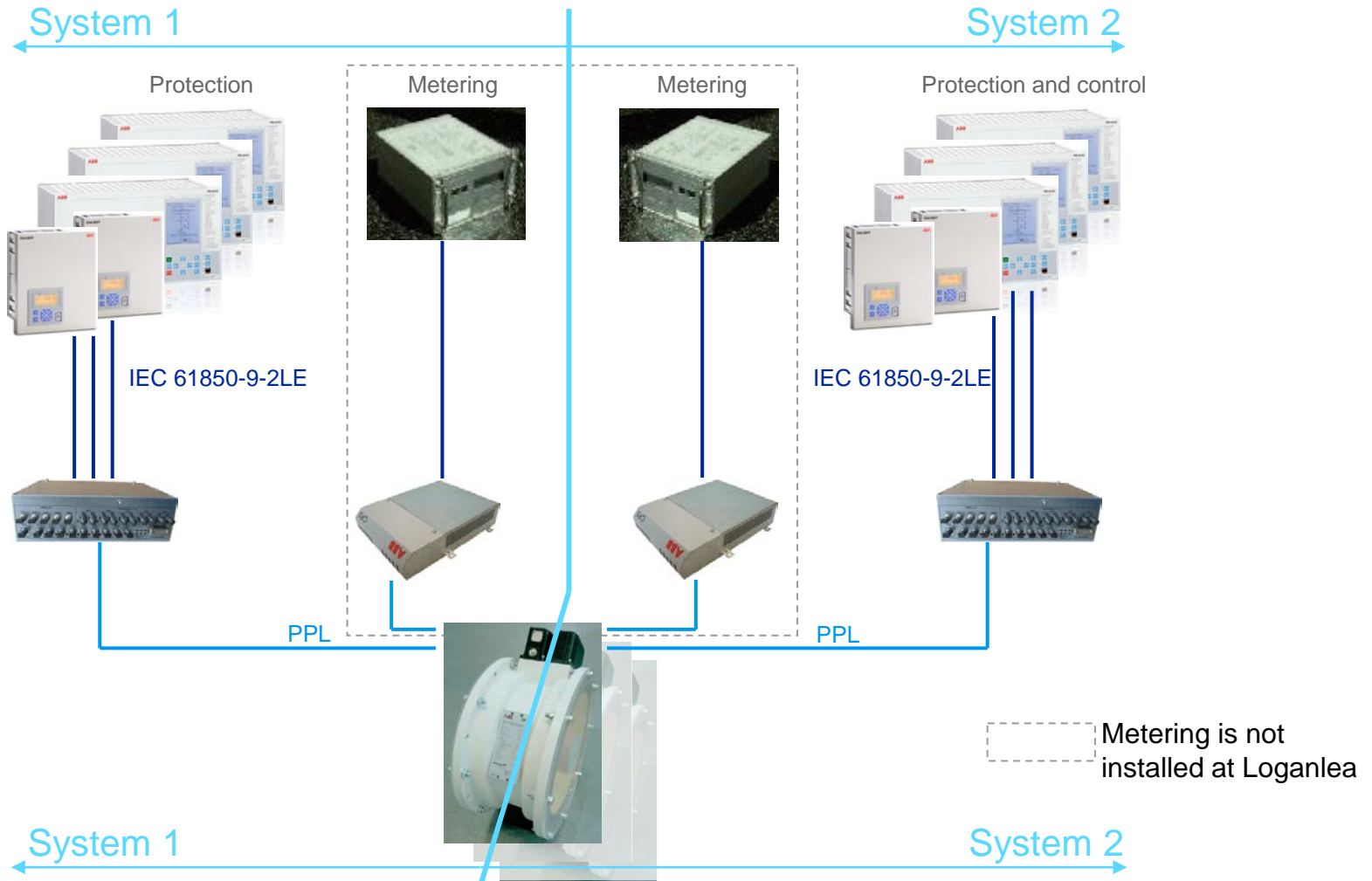


SAM600-CT



# ABB's solution

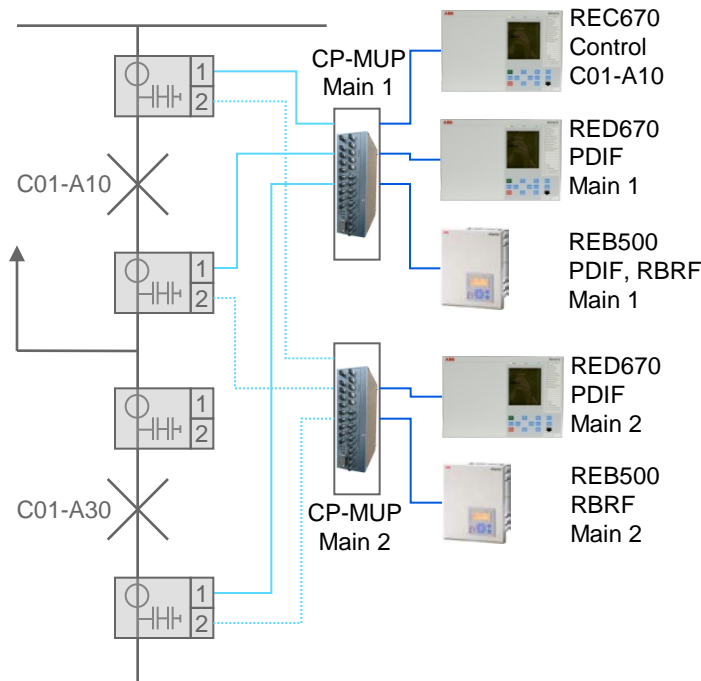
## Fully redundant and independent system design



# ABB's solution

## Highly available process bus without Ethernet switches

Extract of the applied concept:

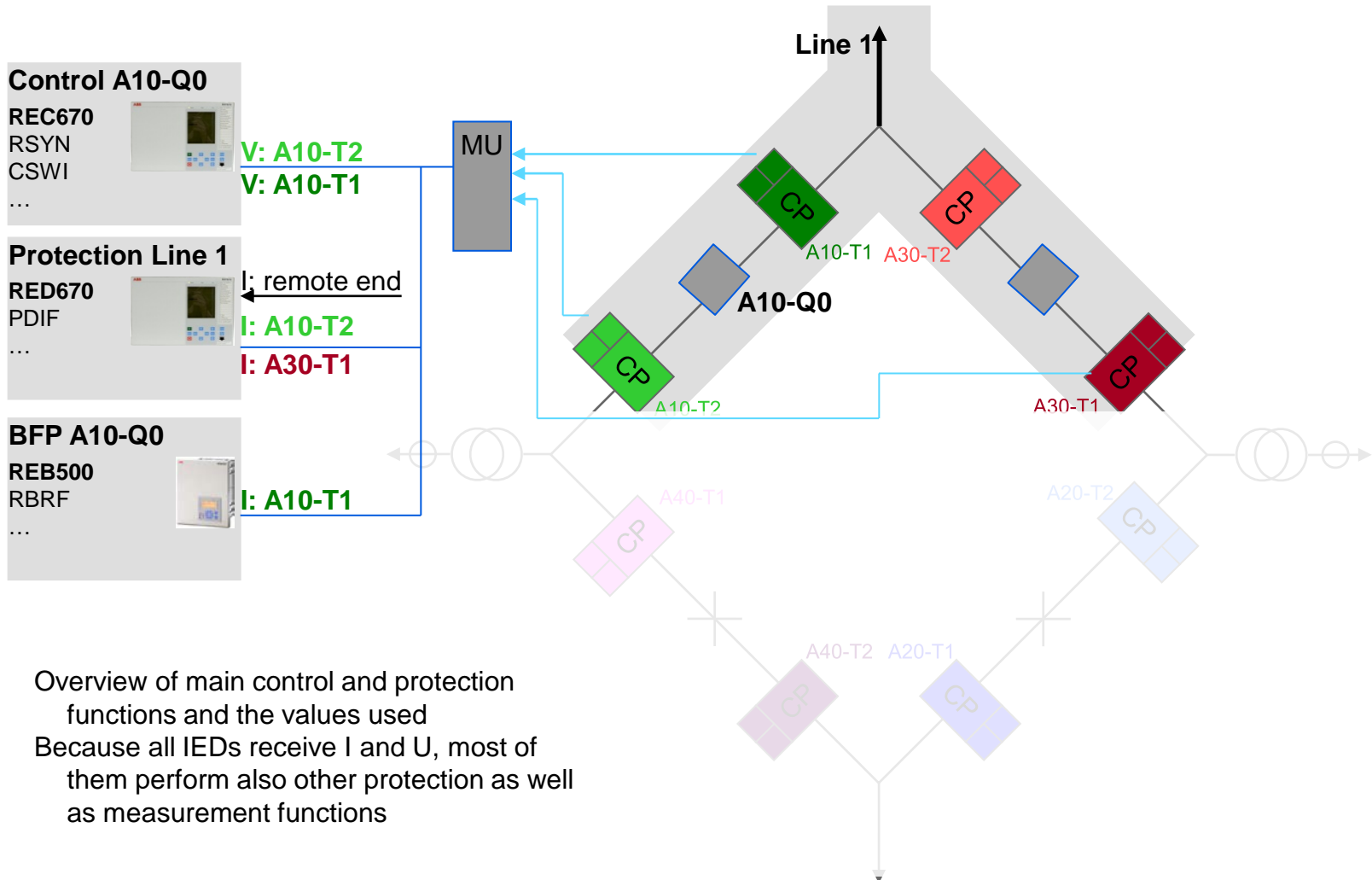


Control and redundant line and busbar/breaker failure protection

- 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

## Protection concept – Line 1 (PDIF)

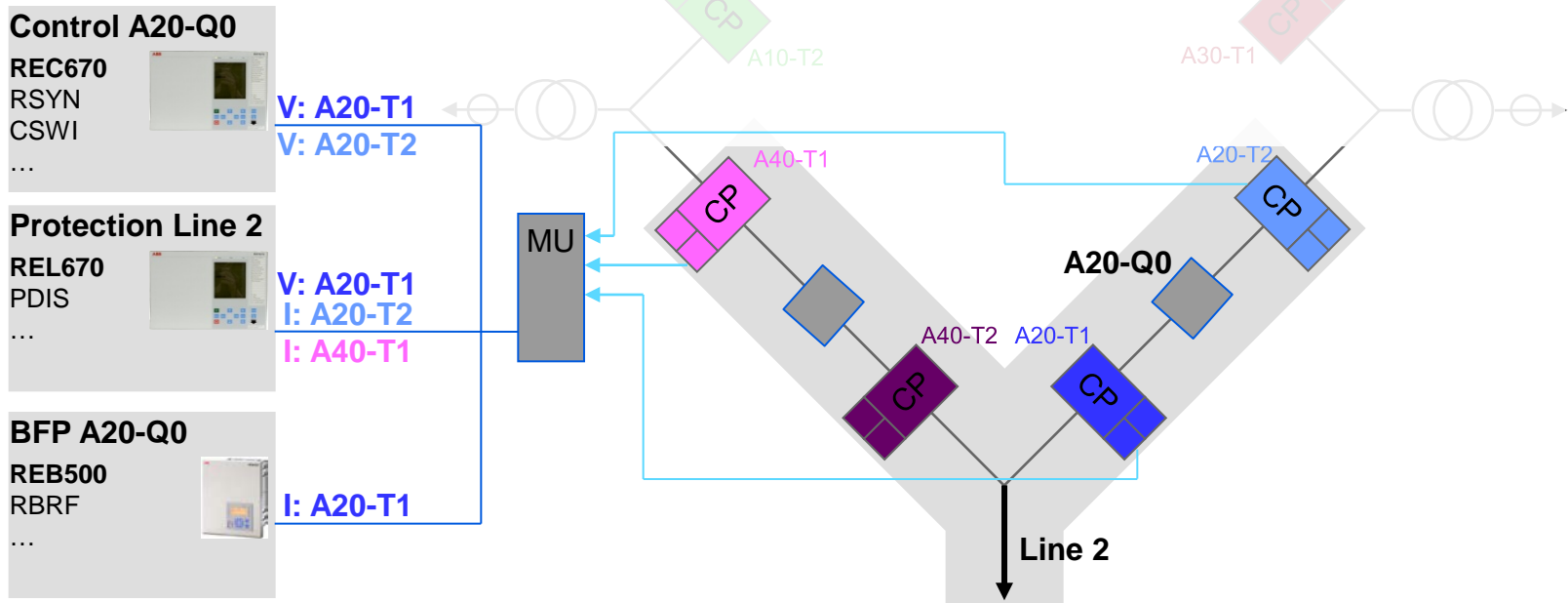


Overview of main control and protection functions and the values used  
Because all IEDs receive I and U, most of them perform also other protection as well as measurement functions

# ABB's solution

## Protection concept – Line 2 (PDIS)

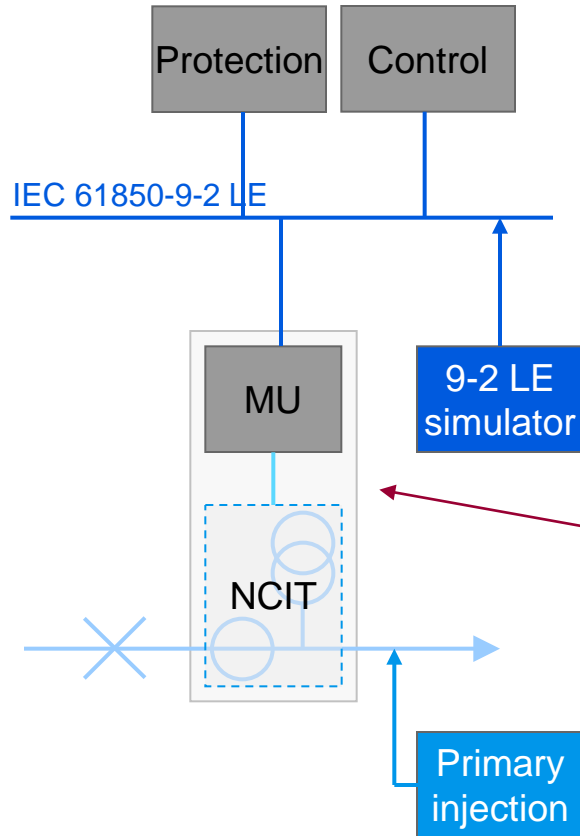
Overview of main control and protection functions and the values used  
Because all IEDs receive I and U, most of them perform also other protection as well as measurement functions





# Testing and maintenance

## Impact on protection and control testing



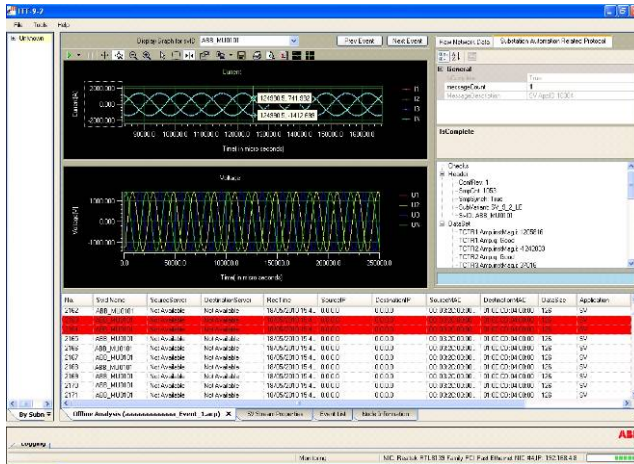
### “Wiring” test

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

### Protection and control testing

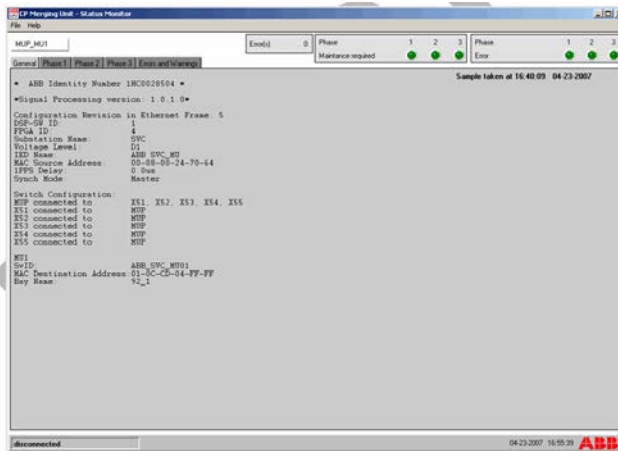
- “Non-conventional” secondary injection
  - Simulation of IEC 61850-9-2 LE traffic instead of secondary injection
- Test modes to simulate V/I, by
  - NCIT
  - Merging unit
- Primary injection
  - Primary injection for stability and directional tests

# Testing and maintenance Tool support



## Software replaces multimeter

- Intelligent software for the collection, display and evaluation of sampled value streams
  - Oscilloscope display of V/I values
  - Phasor diagram
  - Quality information of all values
- Built-in diagnostic functions in sensors, merging units and IEDs for supervision of:
  - Device health status
  - Connections
  - Time synchronization
  - Quality of samples and telegrams





# 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

### Reduced copper cabling

- By replacing parallel copper wires with optical process bus

### Future-proof interoperable design

- By applying the established IEC 61850 standard

# This webinar brought to you by the Relion<sup>®</sup> product family

## Advanced protection and control IEDs from ABB

### **Relion.** Thinking beyond the box.

Designed to seamlessly consolidate functions, Relion relays are smarter, more flexible and more adaptable. Easy to integrate and with an extensive function library, the Relion family of protection and control delivers advanced functionality and improved performance.



# Thank you for your participation

Shortly, you will receive a link to an archive of this presentation.  
To view a schedule of remaining webinars in this series, or for more  
information on ABB's protection and control solutions, visit:

[www.abb.com/relion](http://www.abb.com/relion)

# ABB Protective Relay School Webinar Series

## Disclaimer

ABB is pleased to provide you with technical information regarding protective relays. The material included is not intended to be a complete presentation of all potential problems and solutions related to this topic. The content is generic and may not be applicable for circumstances or equipment at any specific facility. By participating in ABB's web-based Protective Relay School, you agree that ABB is providing this information to you on an informational basis only and makes no warranties, representations or guarantees as to the efficacy or commercial utility of the information for any specific application or purpose, and ABB is not responsible for any action taken in reliance on the information contained herein. ABB consultants and service representatives are available to study specific operations and make recommendations on improving safety, efficiency and profitability. Contact an ABB sales representative for further information.

Power and productivity  
for a better world™

