Process Bus Fundamentals: Merging Units

Hitachi ABB Power Grids

Bharadwaj Vasudevan and Galina S. Antonova

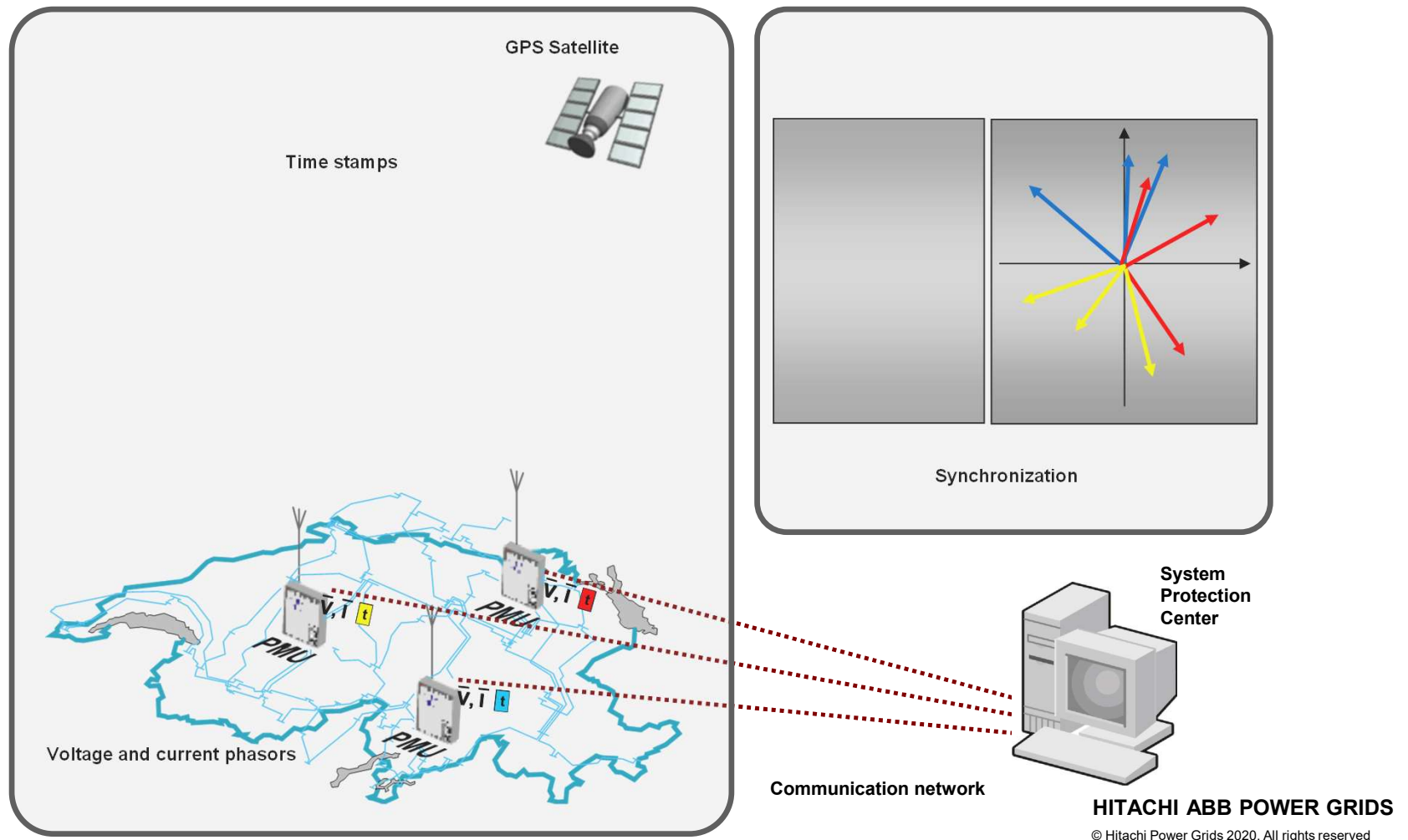**POWERING GOOD FOR SUSTAINABLE ENERGY**

Wide-Area Monitoring and Control System

GPS Satellite

Time stamps

Synchronization

Voltage and current phasors

System Protection Center

Communication network

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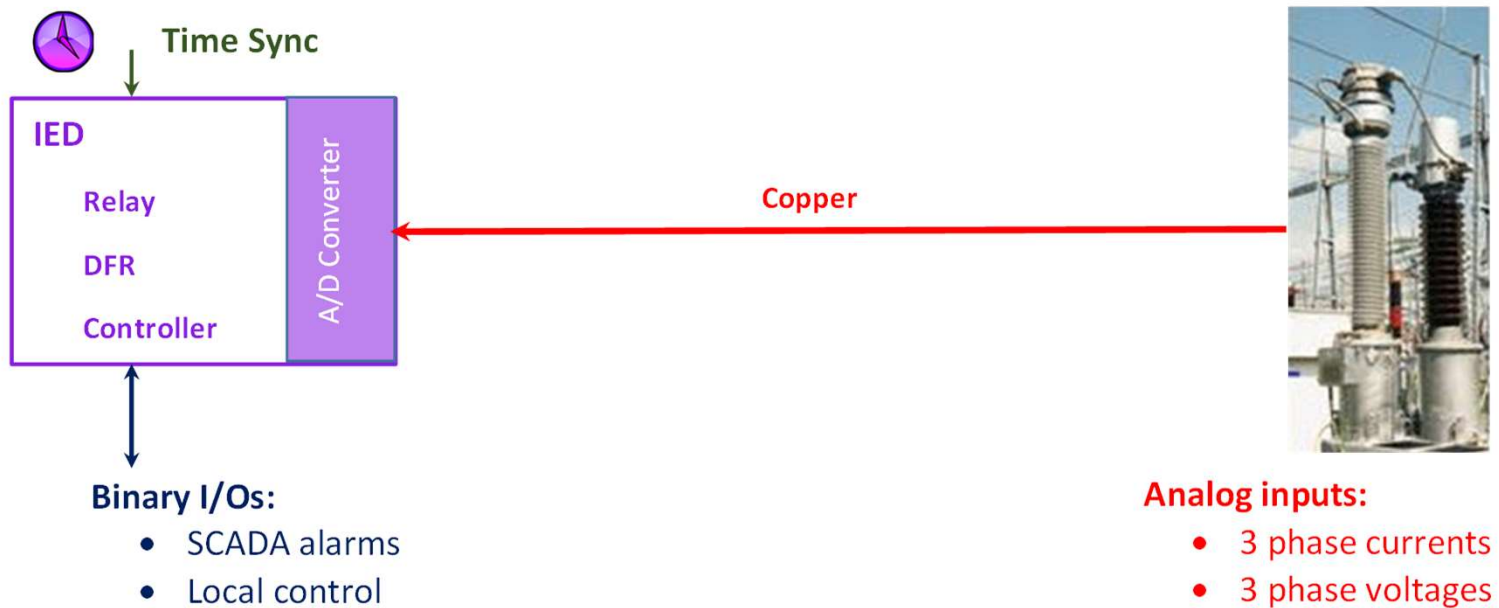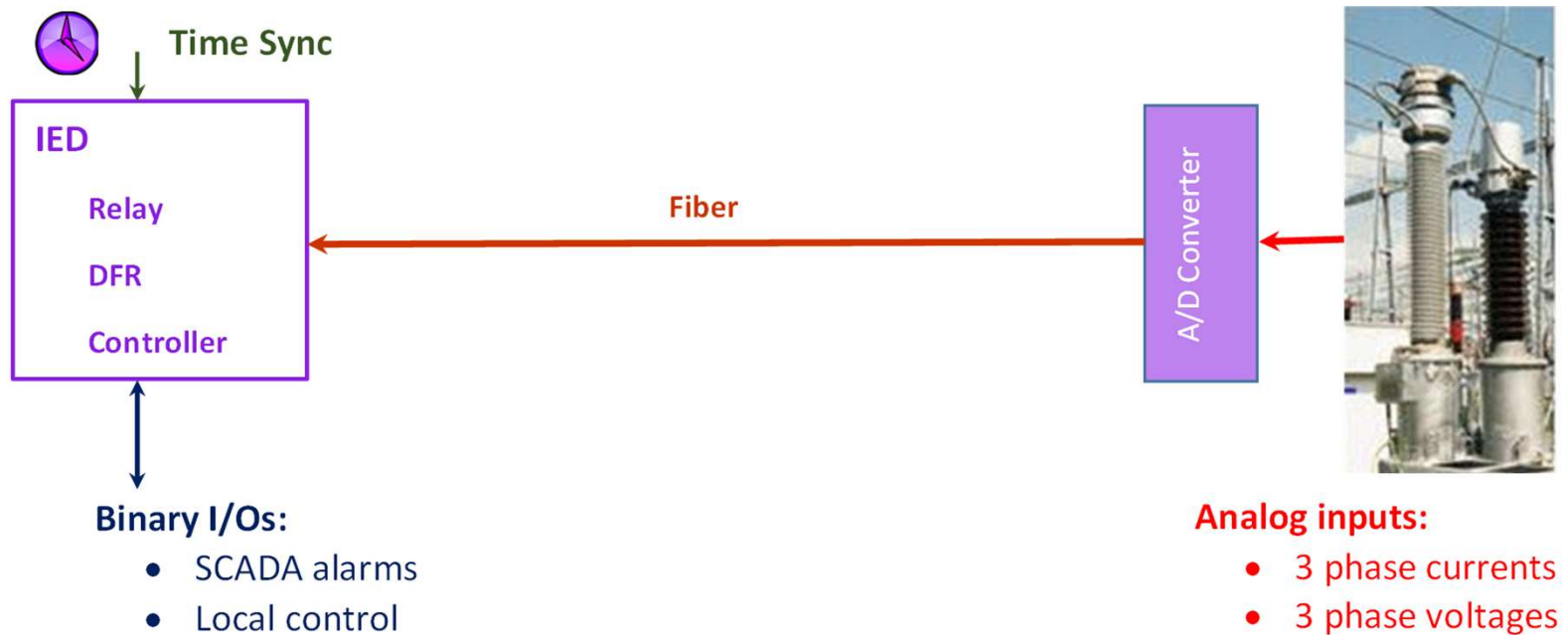
2

From Synchrophasors to Merging Units Technology

- Like Synchrophasors, Merging Units rely on
  - *Reliable Communications* (fiber optic Ethernet), and
  - *Precise Time Synchronization*

- Like Synchrophasors, Merging Units require Time synchronization to *±1 microsecond accuracy*
  - but *traceability to UTC time is NOT required* (digital sample count is used instead)

- Like Synchrophasors, Merging Units send magnitudes and angles for I and V
  - *local reference is used* for angles

- Data rates differ
  - Synchrophasors transmit data for up to 240 frames/second (4 frames per power system cycle)
  - Merging Units send *80-256 Ethernet* frames per power system cycle (16.66ms for 60Hz)

- Coverage area and communication protocols differ
  - Synchrophasors are transmitted over Wide Area and typically use TCP/UDP at Layer 4 over IP
  - Merging Units use *Local Area Networks* and operate on Layer 2 Ethernet

Conventional Analog Inputs

IED = Intelligent Electronic Device

A/D Conversion at Primary Equipment

Time Sync

IED

Relay

DFR

Controller

Fiber

A/D Converter

Binary I/Os:
- SCADA alarms
- Local control

Analog inputs:
- 3 phase currents
- 3 phase voltages

Fiber Ethernet Interface

Time Sync

IED

Relay

DFR

Controller

Fiber

A/D Converter

Binary I/Os:
- SCADA alarms
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Time Sync

IED

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- 3 phase currents
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IEC 61850 Services over Ethernet

Client-Server

– Point-to-point communication TCP/IP/Ethernet com for central monitoring and control

– Commands, reporting, logs, file transfer, etc

GOOSE

– Layer 2 Ethernet real-time multicast com for station-wide monitoring, control, protection

– Binary data, indications, trip commands
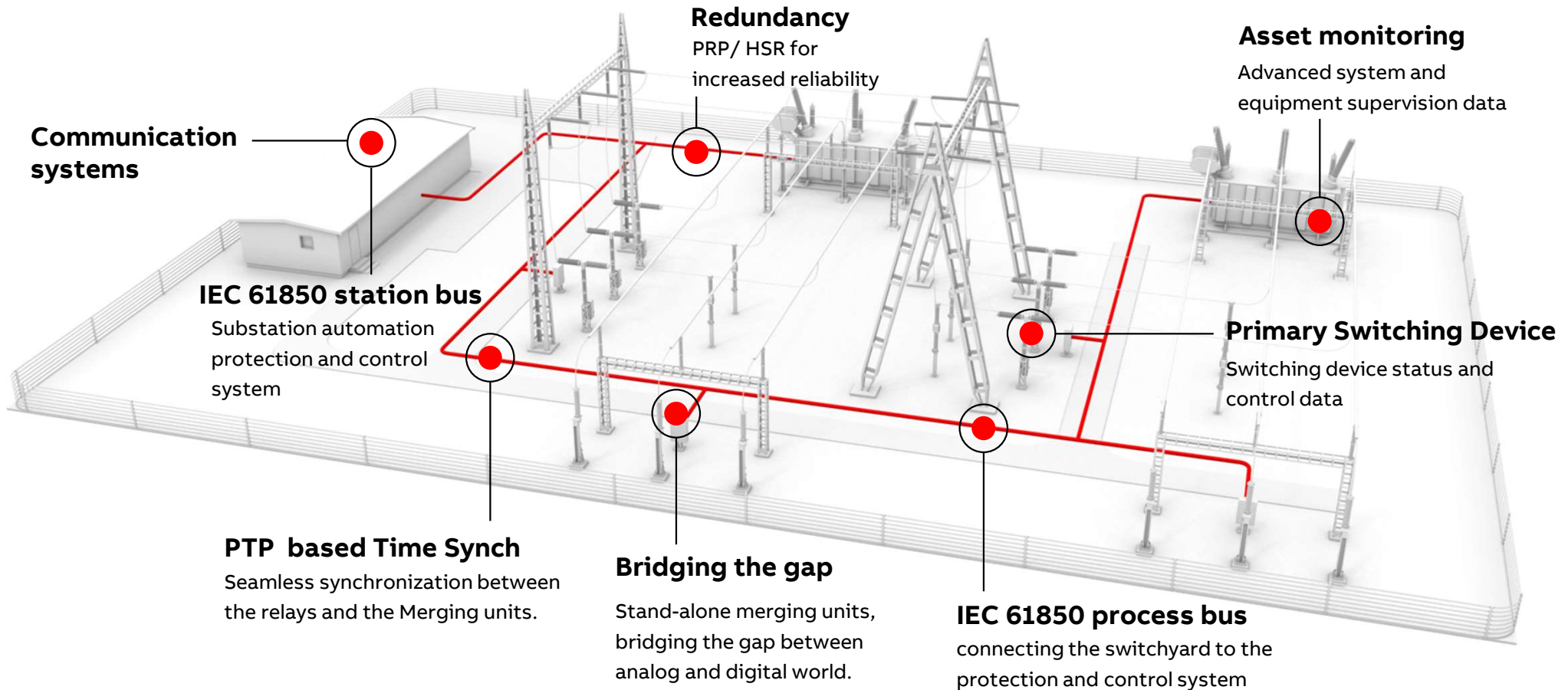
Sampled Values (SV)

– Layer 2 Ethernet real data multicast com for analog measurements for control and protection

– Analog sampled values for currents and voltages

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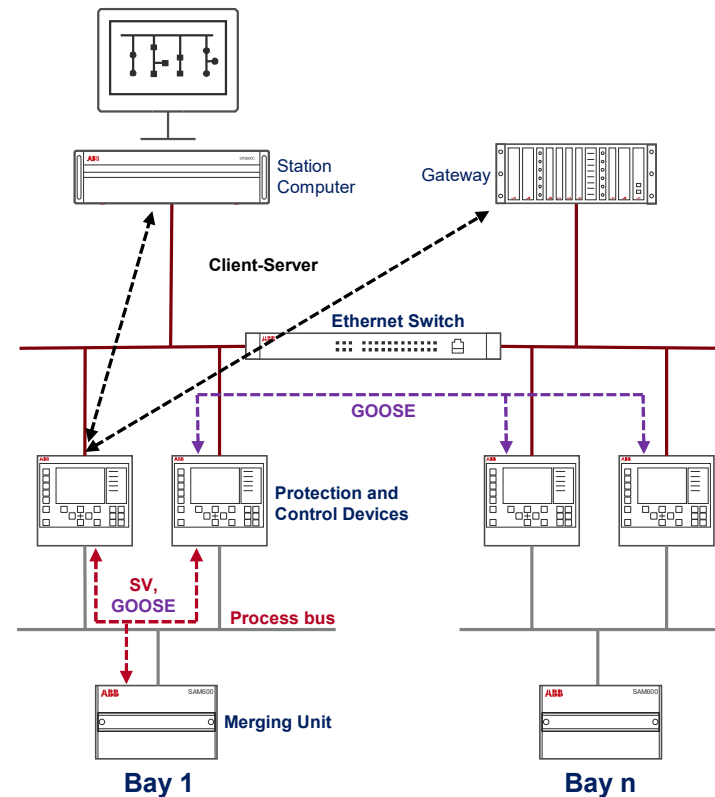
Process bus – Foundation for Digital Substation of the future   HITACHI   ABB

Embracing digital protection, control and communications

Redundancy
PRP/ HSR for
increased reliability

Asset monitoring
Advanced system and
equipment supervision data

**Communication
systems**

IEC 61850 station bus
Substation automation
protection and control
system

Primary Switching Device
Switching device status and
control data

PTP based Time Synch
Seamless synchronization between
the relays and the Merging units.

Bridging the gap
Stand-alone merging units,
bridging the gap between
analog and digital world.

IEC 61850 process bus
connecting the switchyard to the
protection and control system

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What is a Merging Unit?

Communication interface according to IEC 61850-9-2

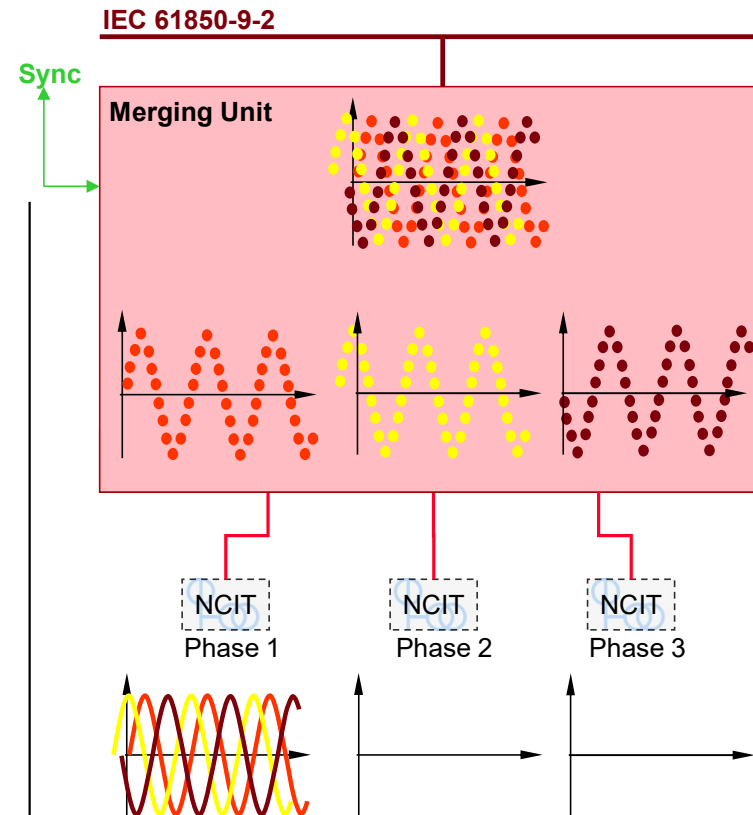Merging and timely correlation current and voltage values from the three phases

Sampling or re-sampling of current and voltage values

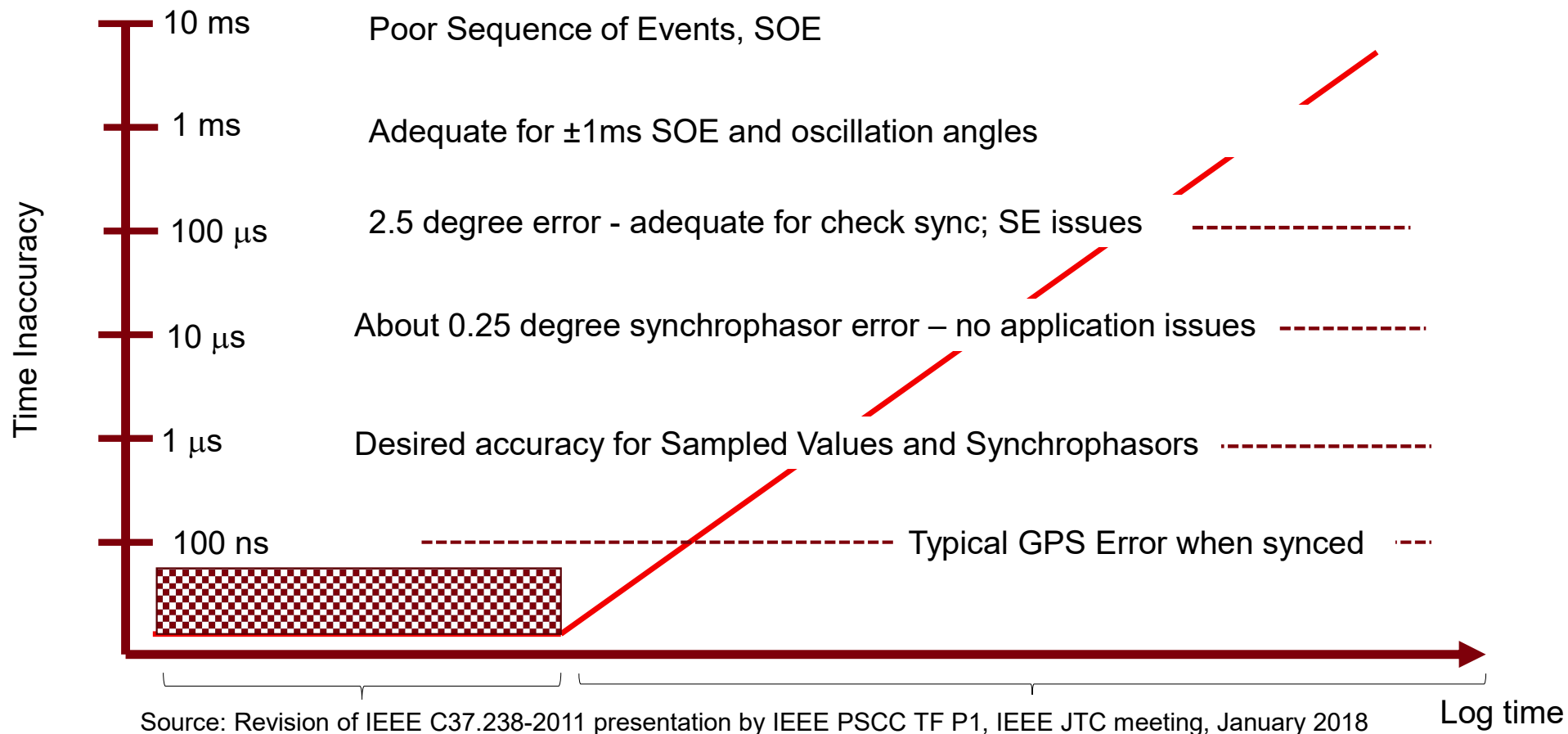Technology specific interface between NCIT/CIT and MU

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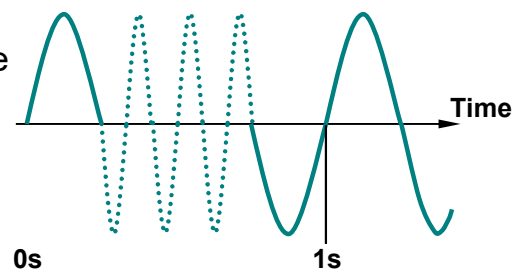   Receive time synchronization when acting as time slave, if required

IEC 61850-9-2

Sync

Merging Unit

NCIT
Phase 1

NCIT
Phase 2

NCIT
Phase 3

Clock Drift and Time Inaccuracy

Time Inaccuracy (vertical axis)

Value	Description
10 ms	Poor Sequence of Events, SOE
1 ms	Adequate for ±1ms SOE and oscillation angles
100 μs	2.5 degree error - adequate for check sync; SE issues
10 μs	About 0.25 degree synchrophasor error – no application issues
1 μs	Desired accuracy for Sampled Values and Synchrophasors
100 ns	Typical GPS Error when synced

Log time

Source: Revision of IEEE C37.238-2011 presentation by IEEE PSCC TF P1, IEEE JTC meeting, January 2018

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Merging Units' Time Synchronization

Analog value
current/ voltage

0s   1s

Time

Sampled value
current/ voltage

...

Sample No

0   0

1PPS   1PPS
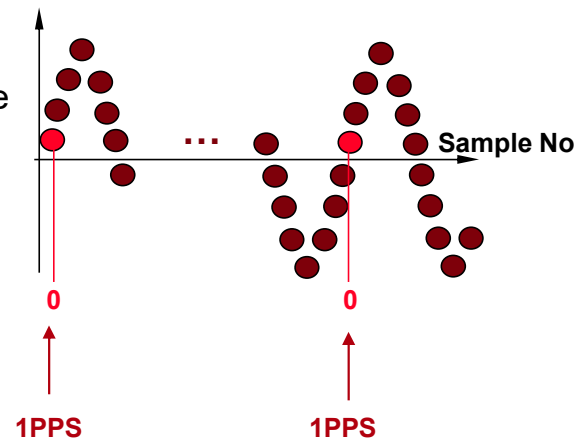
UCA IEC 61850-9-2 LE specifies

- One pulse per second (1PPS) through a dedicated optical fiber

- Time source accuracy: 1µs

- System accuracy: 4µs

Maximum error of 4µs results in:
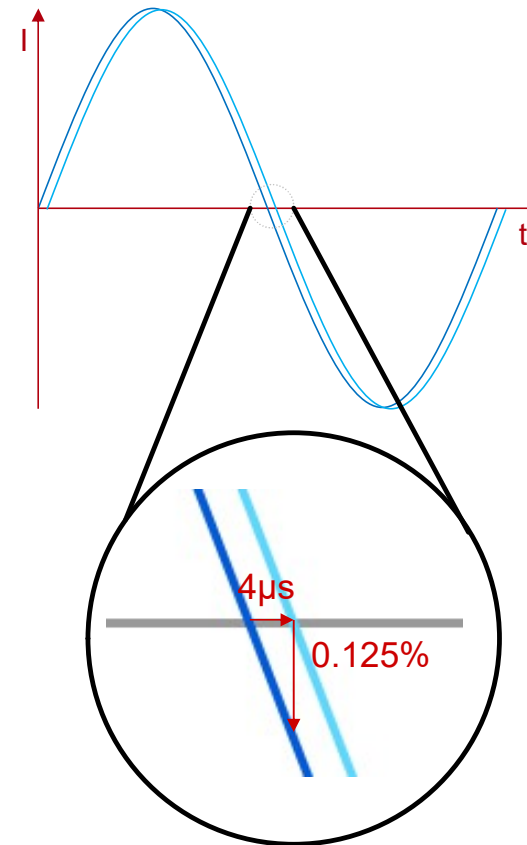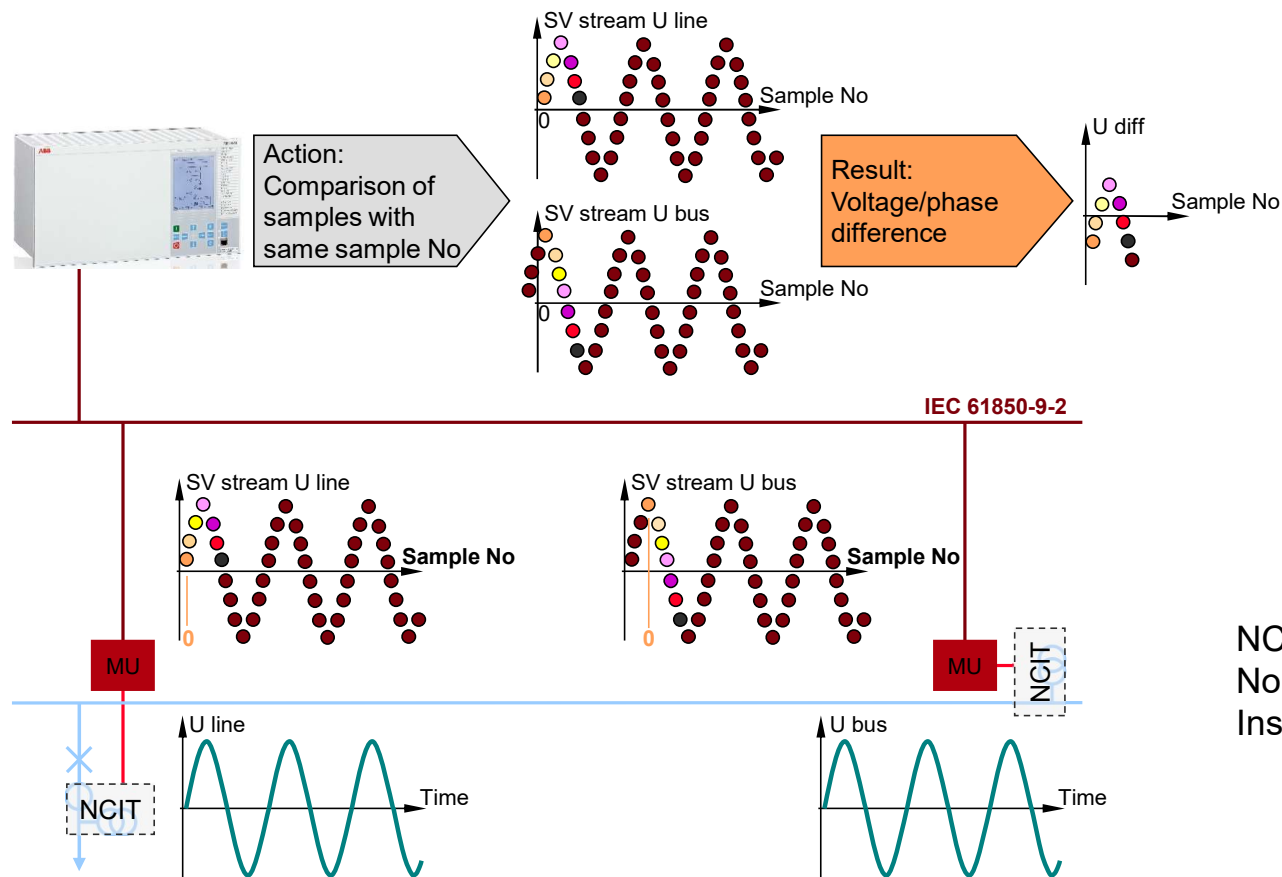
– Angle error: 0.07° (= 4.3`)

– Max. amplitude error:
  0.125% (e.g, 125A at 100kA$_{peak}$)

Errors of CT/VT with accuracy class 0.2:
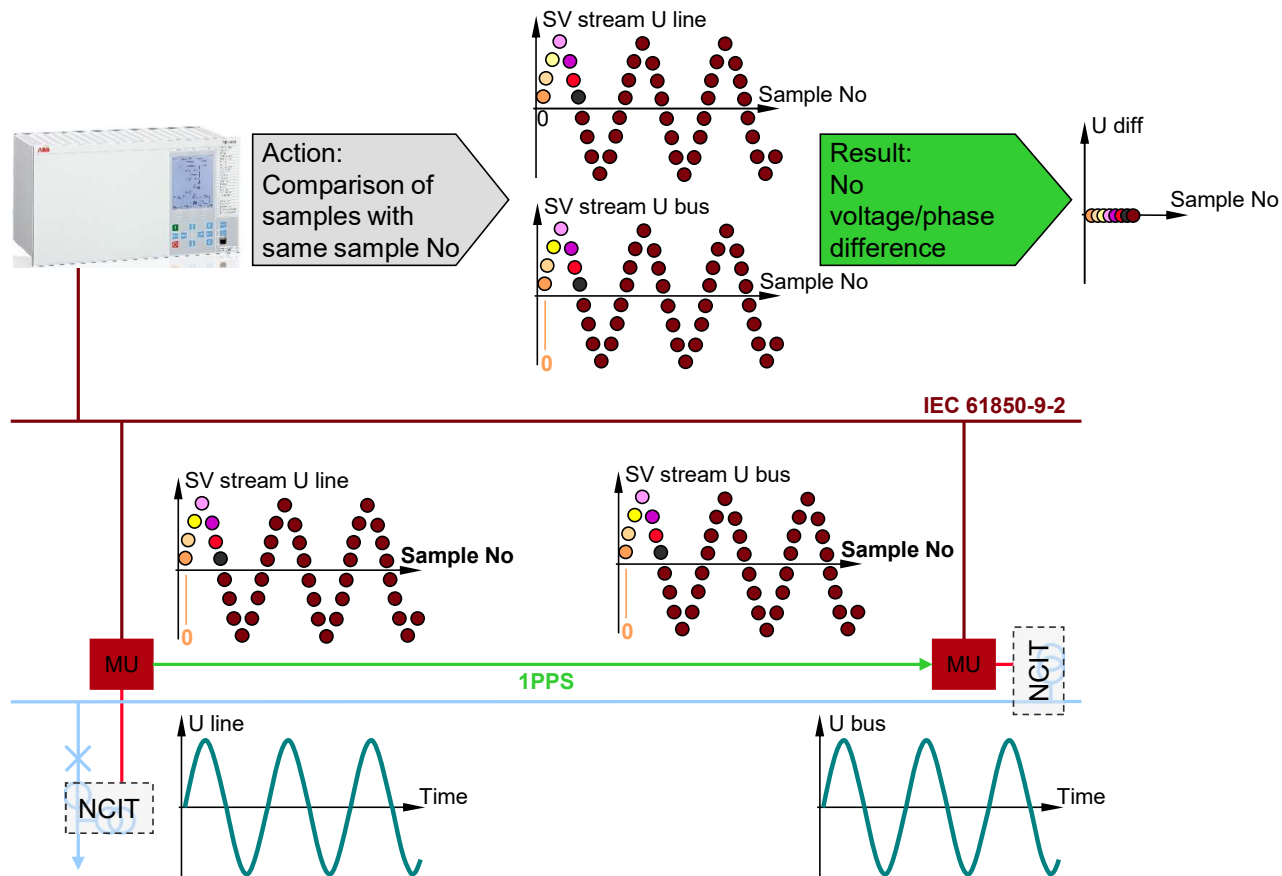
– CT: 10 to 30` (0.17 to 0.5°)

– VT: 10`(0.17°)

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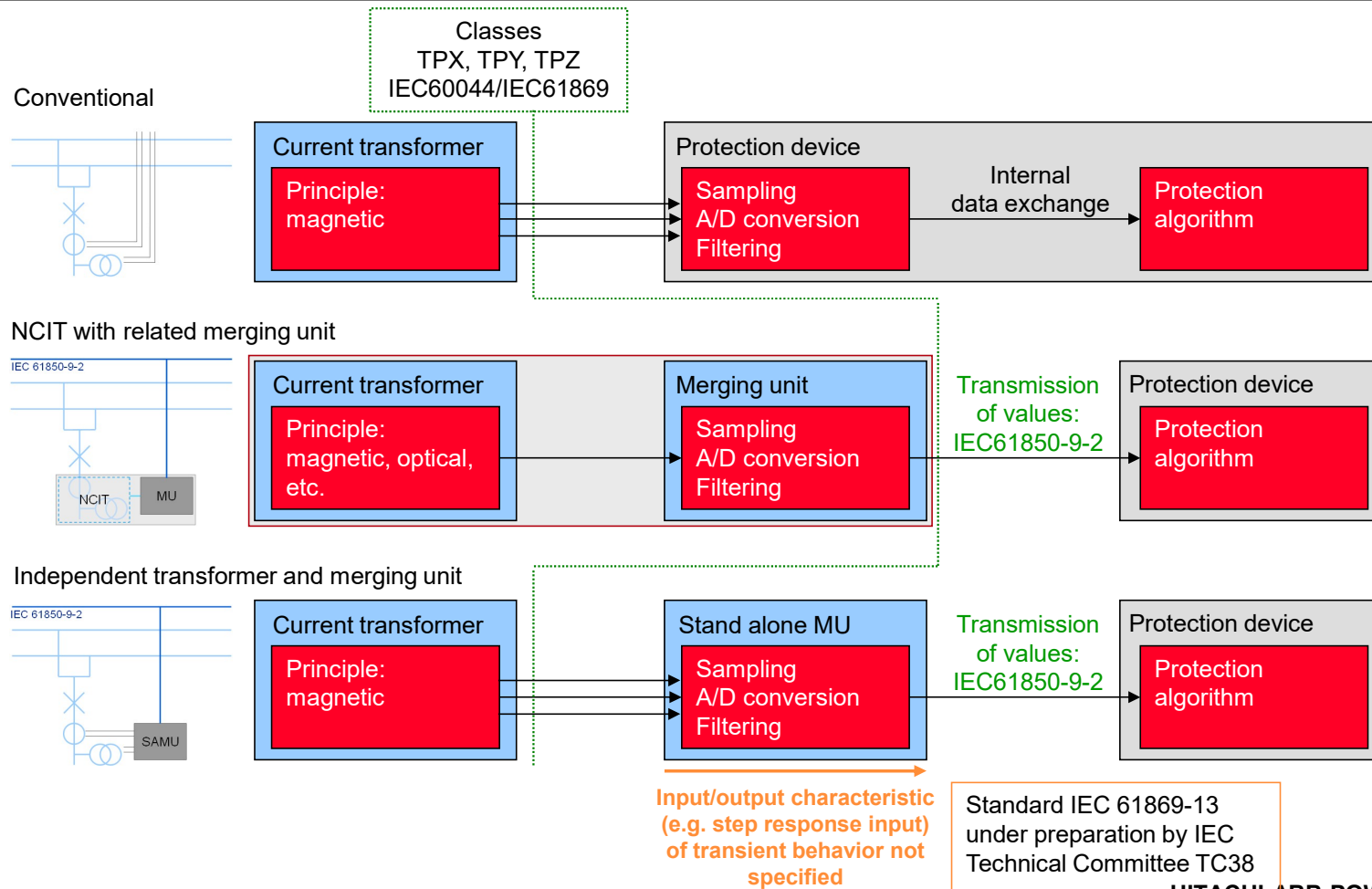# Time Synchronization: Example without Synchronization

SV stream U line

Sample No

0

Action:
Comparison of
samples with
same sample No

U diff

Sample No

Result:
Voltage/phase
difference

SV stream U bus

Sample No

0

IEC 61850-9-2

SV stream U line

Sample No

0

SV stream U bus

Sample No

0

MU

MU

NCIT

NCIT is a
Non-Conventional
Instrument Transformer

U line

Time

NCIT

U bus

Time

Time Synchronization: Example with Synchronization

SV stream U line

Sample No

0

SV stream U bus

Sample No

0

Action:
Comparison of
samples with
same sample No

Result:
No
voltage/phase
difference

U diff

Sample No

IEC 61850-9-2

SV stream U line

Sample No

0

SV stream U bus

Sample No

0

MU

1PPS

MU

NCIT

NCIT

U line

Time

U bus

Time

Standardization and Interoperability

Conventional

Classes
TPX, TPY, TPZ
IEC60044/IEC61869

Current transformer

Principle:
magnetic

Protection device

Sampling
A/D conversion
Filtering

Internal
data exchange

Protection
algorithm

NCIT with related merging unit

IEC 61850-9-2

NCIT   MU

Current transformer

Principle:
magnetic, optical,
etc.

Merging unit

Sampling
A/D conversion
Filtering

Transmission
of values:
IEC61850-9-2

Protection device

Protection
algorithm

Independent transformer and merging unit

IEC 61850-9-2

SAMU

Current transformer

Principle:
magnetic

Stand alone MU

Sampling
A/D conversion
Filtering

Transmission
of values:
IEC61850-9-2

Protection device

Protection
algorithm

**Input/output characteristic
(e.g. step response input)
of transient behavior not
specified**

Standard IEC 61869-13
under preparation by IEC
Technical Committee TC38

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	IEC 61850-9-2LE	Why issue?	IEC 61869-6/9
DataSet Content	**Fixed 4I+4U**	**Use of modern sensors – only current sampling**	**Content can be defined and is described** **9-2LE profiles always support as backward compatible**
Time synchronization	**PPS, sync/no sync**	**Separate physical network** **No graceful degradation („local sync")**	**Preferred support for IEEE 1588:2009**
Input/output characteristics	**Not defined**	**Each pair of devices must be tested for interoperability, performance of protection functions**	**Defines input/output characteristics, response „envelope"**
Sampling rates	**80s or 256s per power system cycle**	**Sampling depending on power system frequency; no multiples for protection and power quality**	**Sampling per second – 4800 Hz. Power quality is multiple of base sampling frequency (3x). Transmit rate is ½ of sampling (2400 Hz)**

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Merging Units' Benefits

Easy to use

– The module-per-primary object concept allows for intuitive and flexible system design

Unrivalled flexibility

– SAM600 modules fit to any substation layout (double busbar,
  1½ breaker, …)

– Large number of communication ports minimize the need for switches in process bus

Cost saving retrofits

– Modular system enables "non-invasive" retrofit with minimum outage time and step-wise commissioning

Station bus (PRP)   LAN A
                           LAN B

SAM600-IO

Process bus (HSR)

SAM600-CT   SAM600-TS

SAM600-VT   SAM600 System bus
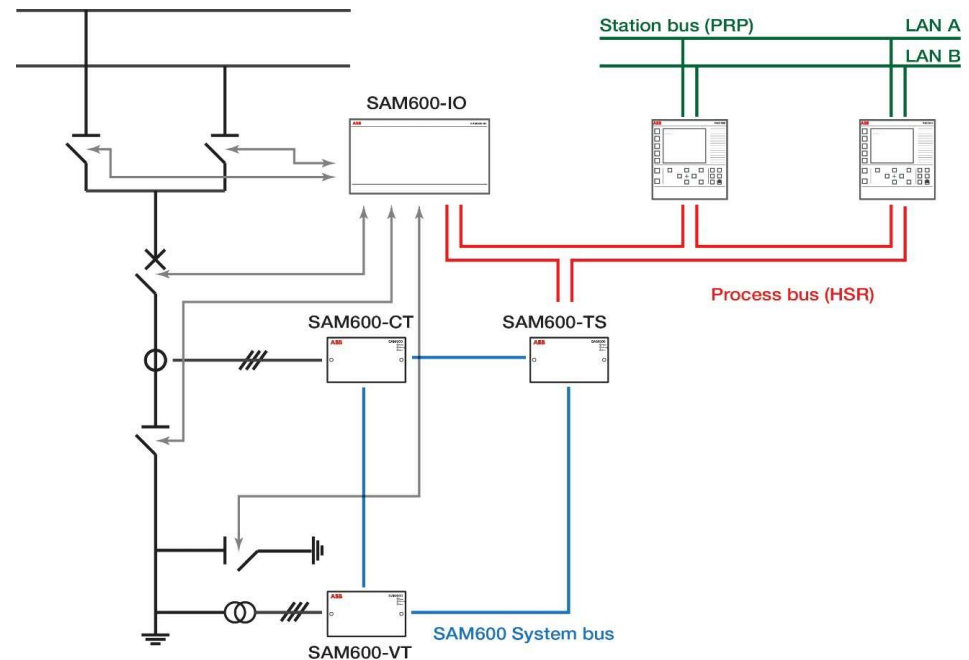
Modular Approach increases Flexibility

Merging Unit Example: SAM600

UCA IEC 61850-9-2LE

– 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

– Time synchronization with 1PPS and IEEE 1588 (IEC/IEEE 61850-9-3)

– 1PPS input and outputs for synchronizing IEDs or sensors

Communication

– Configurable UCA IEC 61850 9-2LE process bus traffic on two ports per module

– Communication redundancy via IEC 62439-3 (PRP and HSR)

Environmental

– Operating temp range: -40°C .. +70°C ambient

– IP class: IP20

PRP = Parallel Redundancy Protocol
HSR = High-availability Seamless Redundancy

Process Bus Deployment Example

Front view

Rear panel view
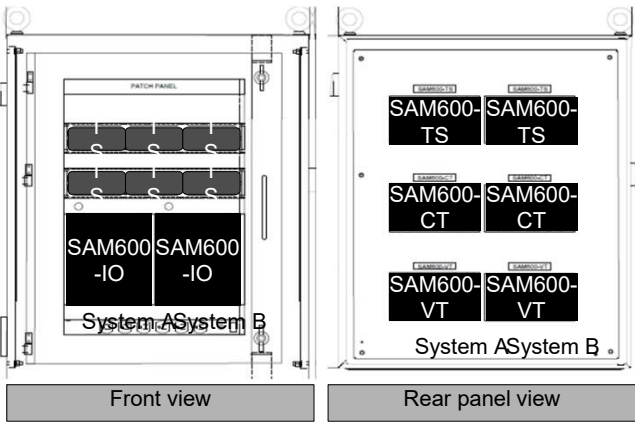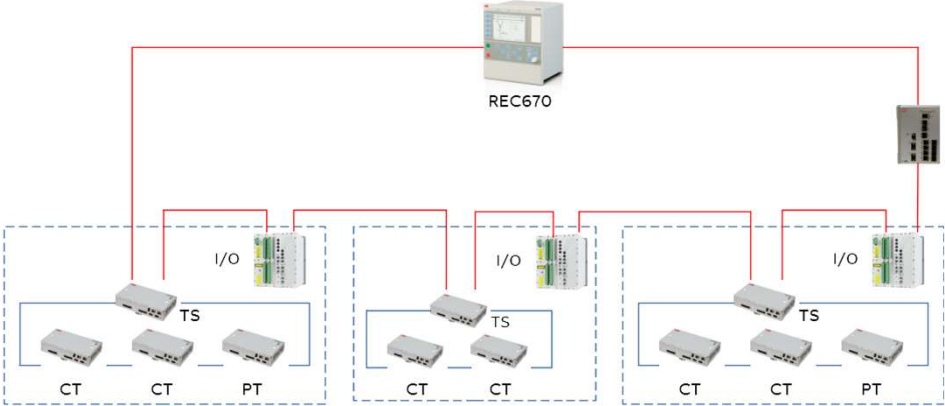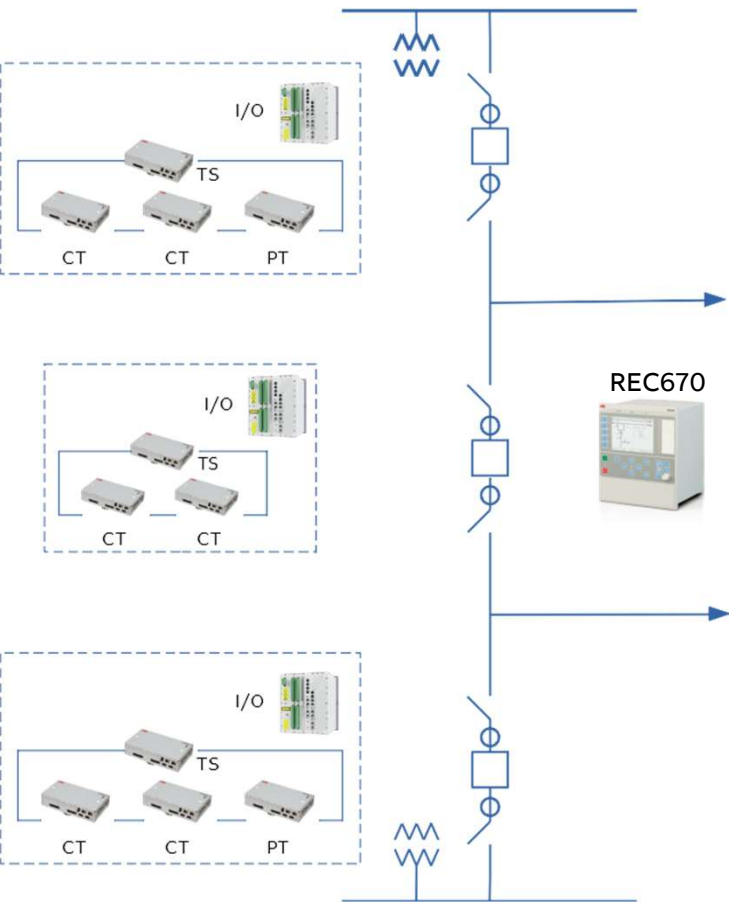
Time Synchronization Learnings: Project 1

- Project Scope included process bus use for all distribution station protections, specifically 87L, 87T, 87B, 87B-HIZ, 21, 50/51, 27, 59 and 81)

- Simple Network Time Protocol (SNTP) used for time synchronization at IEC 61850 Station Bus – 1ms time accuracy

- Initially the relays 's hardware time synchronization was set for electrical IRIG-B. No valid samples were received. Protection functions were blocked.

- UCA IEC 61850-9-2LE Implementation Agreement specifies 1 PPS as time synchronization source. Optical 1 PPS is recommended to achieve 4-1us time accuracy

- Electrical to optical 1PPS converters were added, relays were reconfigured for optical 1 PPS and sample synchronization was achieved.

- Once valid samples were received, protection functions were successfully tested.
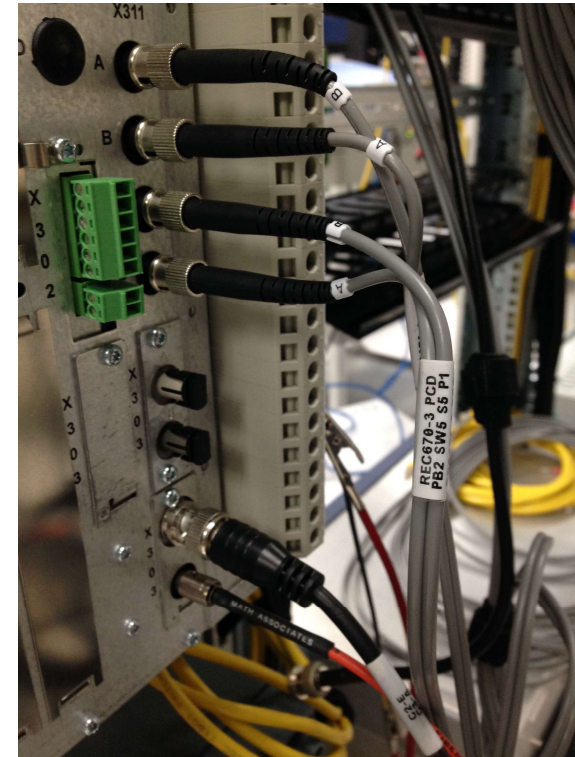
Time Synchronization Challenge: Project 2

- Project Scope: transmission line differential 87L and high-speed distance (21) protection

- Relay time synchronization alternatives include Electrical and Optical IRIG-B and 1 PPS, initially only electrical IRIG-B was configured

- Optical 1 PPS was added and set, and electrical IRIG-B was kept for date and time information

- There was no plan to use SNTP for date and time

- Result – time sync error was reported by local and remote relays. Line current differential protection was blocked as samples could not be trusted.
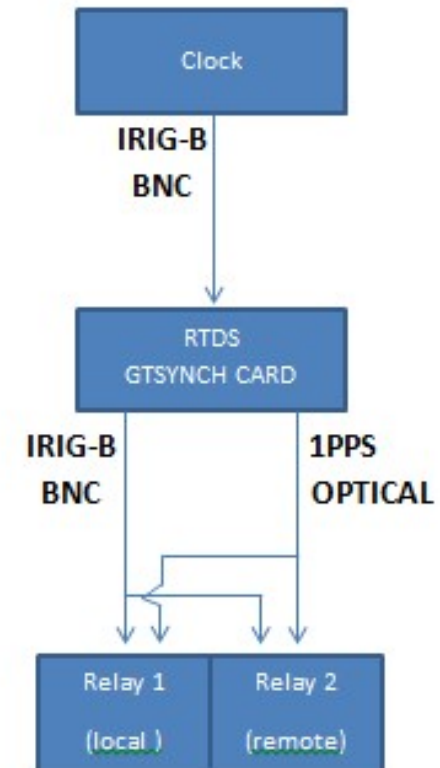
Time Synchronization Resolution

- It had to be learned that it is possible to combine IRIG-B code and 1PPS signal in the same cable.

- IRIG-B and 1PPS can be combined when unmodulated DC shift is used.

- If Amplitude Modulation (AM) is used, separate cable or dedicated wavelengths in the same fiber cable are needed.
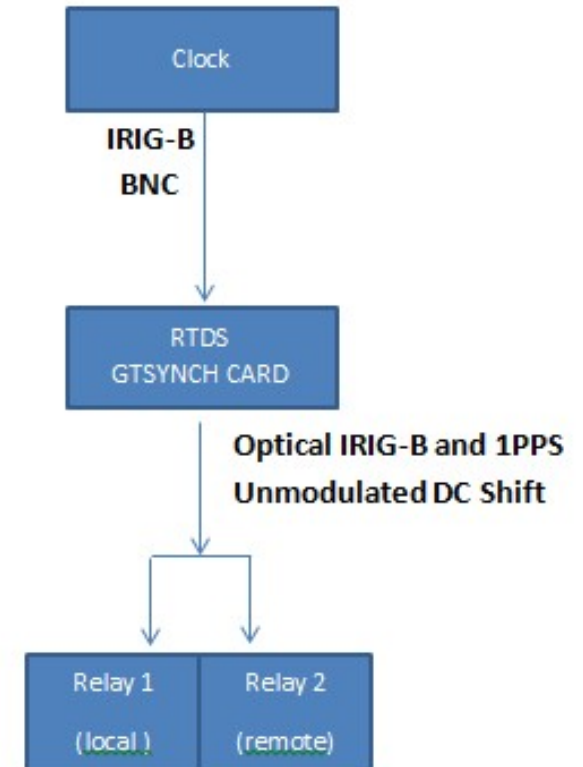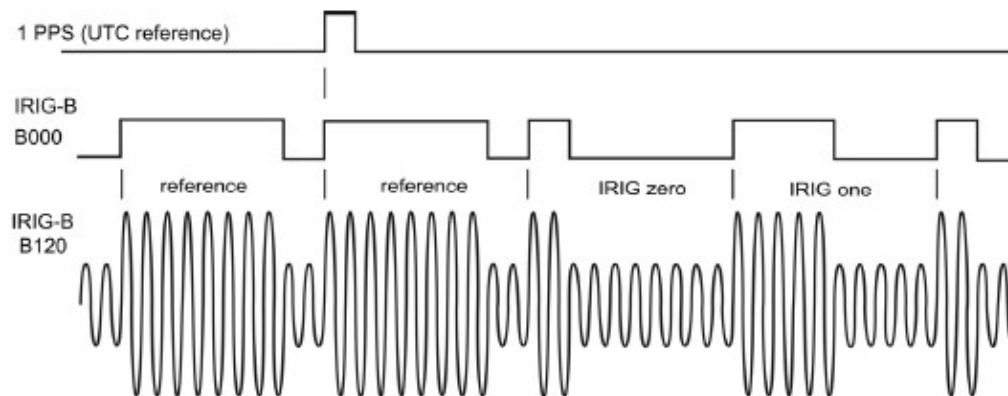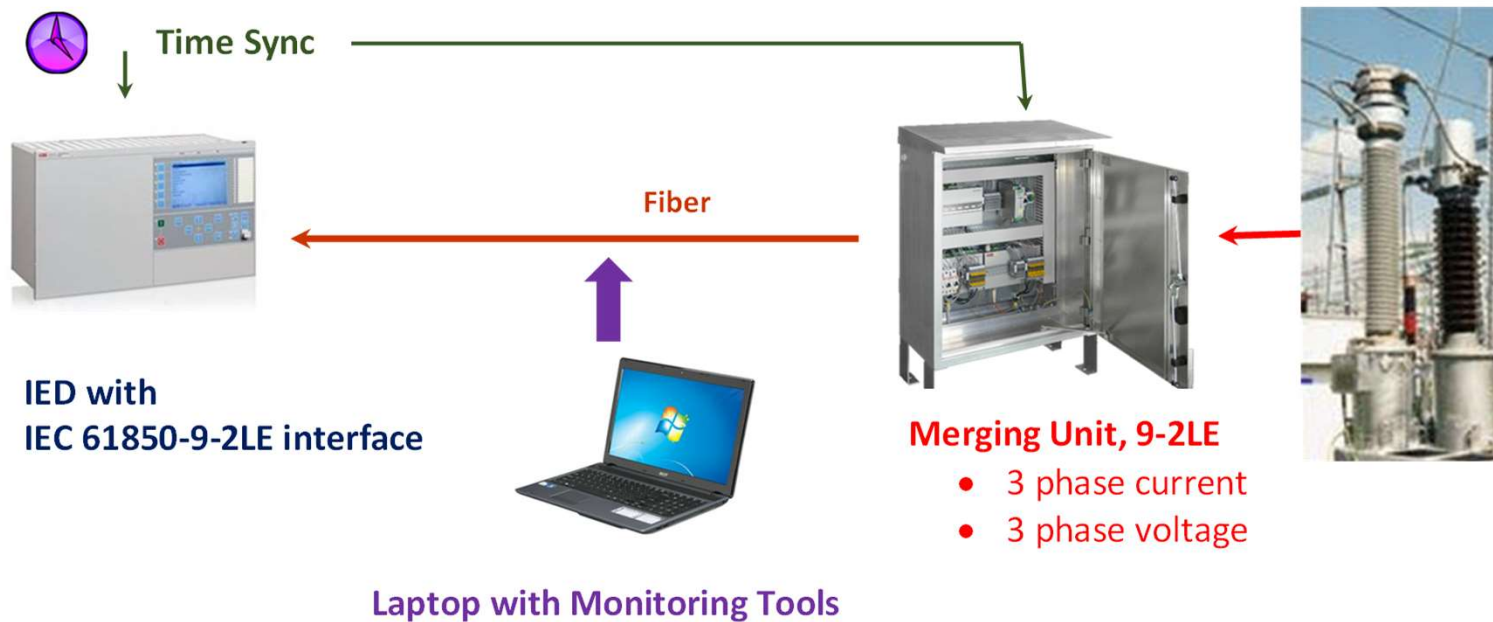
Time Synchronization Evolution

- Moving to Ethernet-based time synchronization using Precision Time Protocol (PTP) profiles, IEC/IEEE 61850-9-3:2017
- Interface conversions to be supported for 1PPS and PTP to be used in the same system (1PPS over ST, LC for Ethernet)

Source: Revision of IEEE C37.238-2011 presentation by IEEE PSCC TF P1, IEEE JTC meeting, January 2018

What about testing ?

Time Sync

IED with
IEC 61850-9-2LE interface

Fiber

Laptop with Monitoring Tools

Merging Unit, 9-2LE
- 3 phase current
- 3 phase voltage
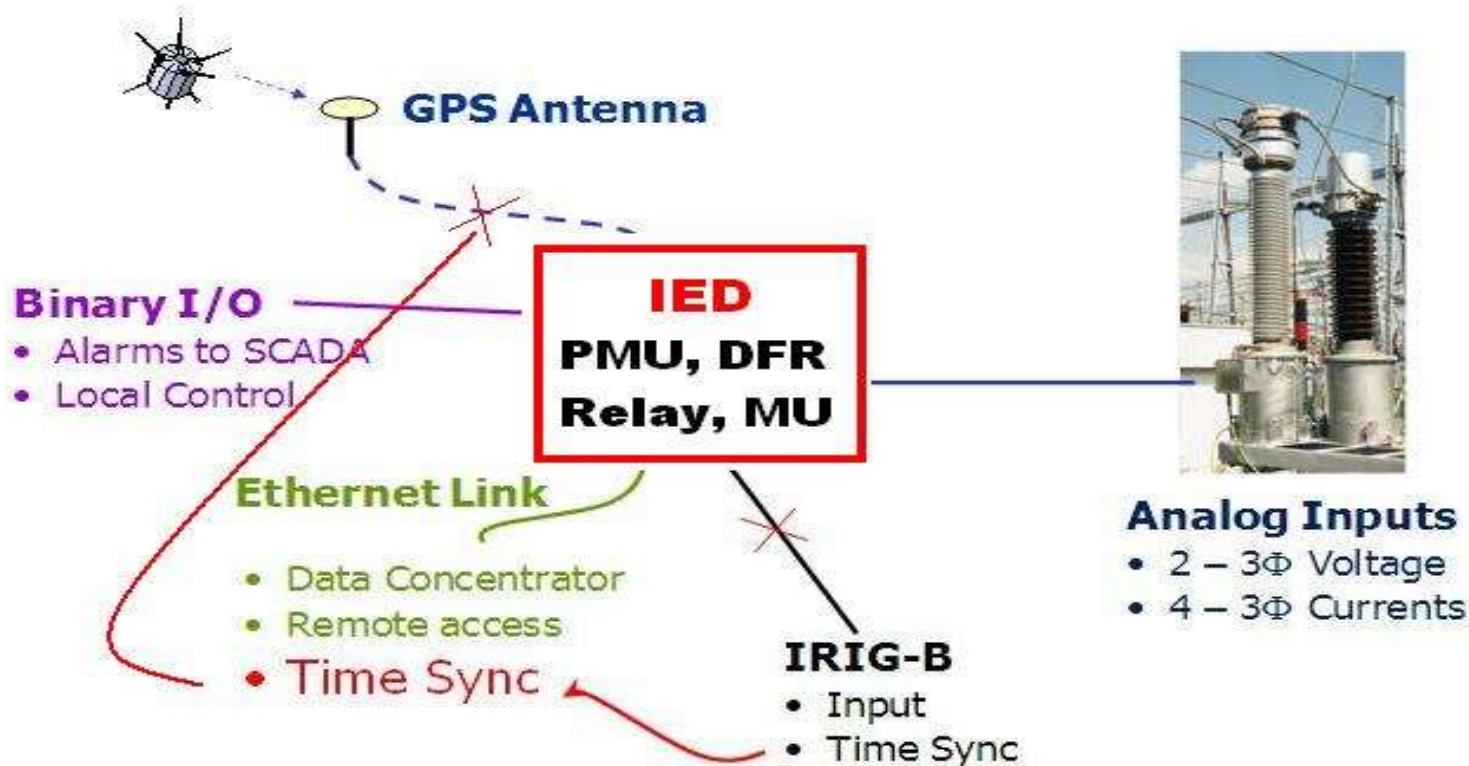
Binary signals testing

Multimeter or oscilloscope
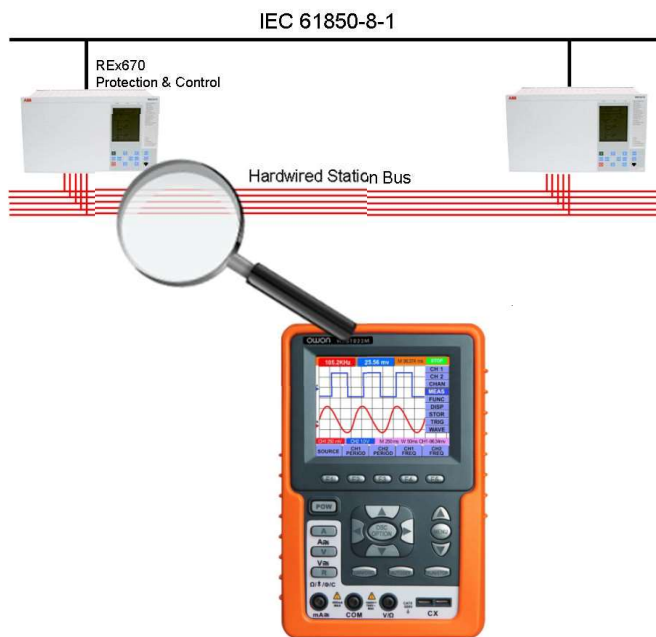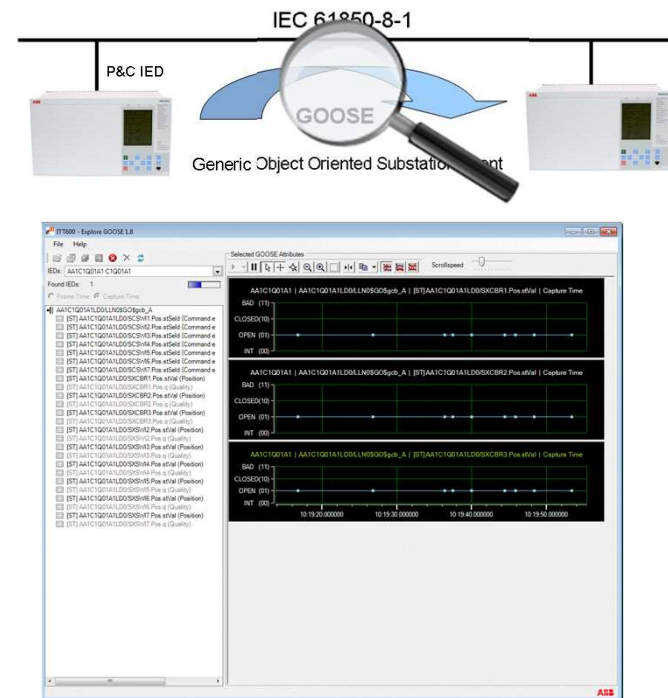

ABB ITT600 – Explore GOOSE

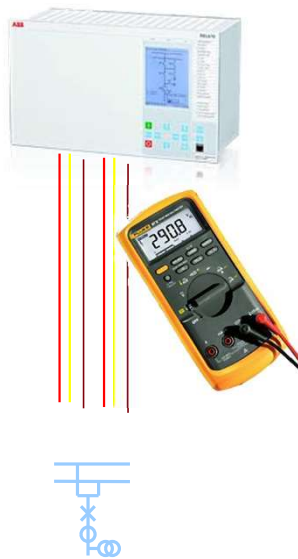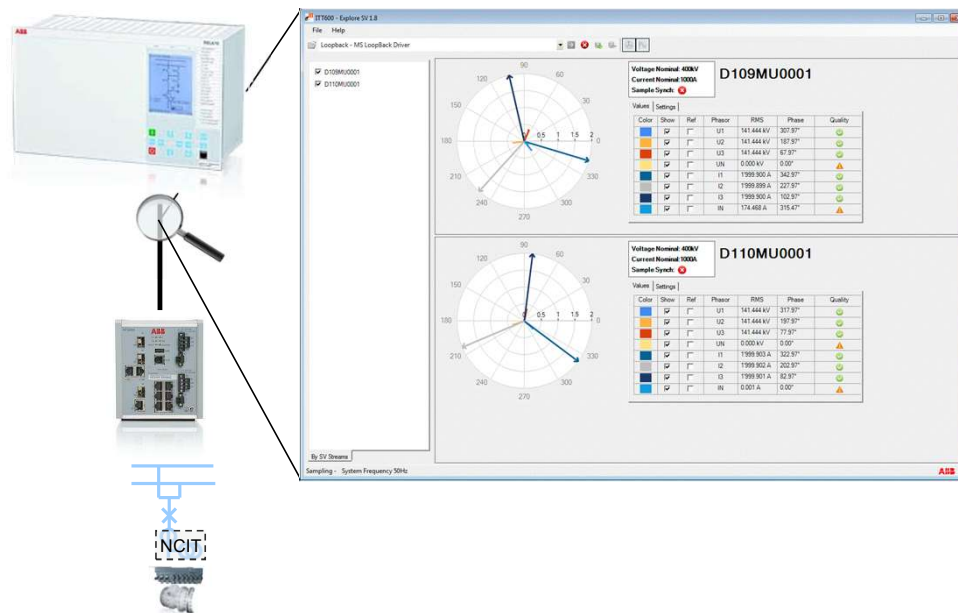# Analog signals testing

Multimeter or oscilloscope   ABB ITT600 Explore Sampled Values

Conclusions

- Merging Units technology supports transmittal of *analog data samples* (I and V phasors) over fiber optic Ethernet, instead of conventional copper analog connections

- Like Synchrophasors, MUs depend *on communications and time synchronization*
    - MUs use Local Area Layer 2 communications with higher data rates
    - MUs do not require time synchronization to global UTC time

- Two technologies have been used together for years. This is also now specified in IEC/IEEE 60255-118-1:2018 Standard's Annex E (informative)

Synchrophasor measurement using sampled value input to PMU
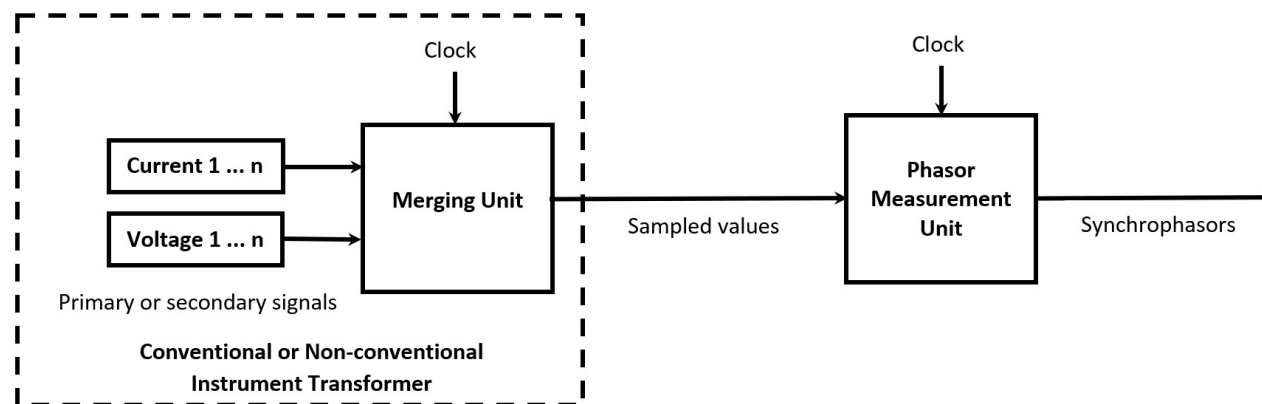
Thank you !

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