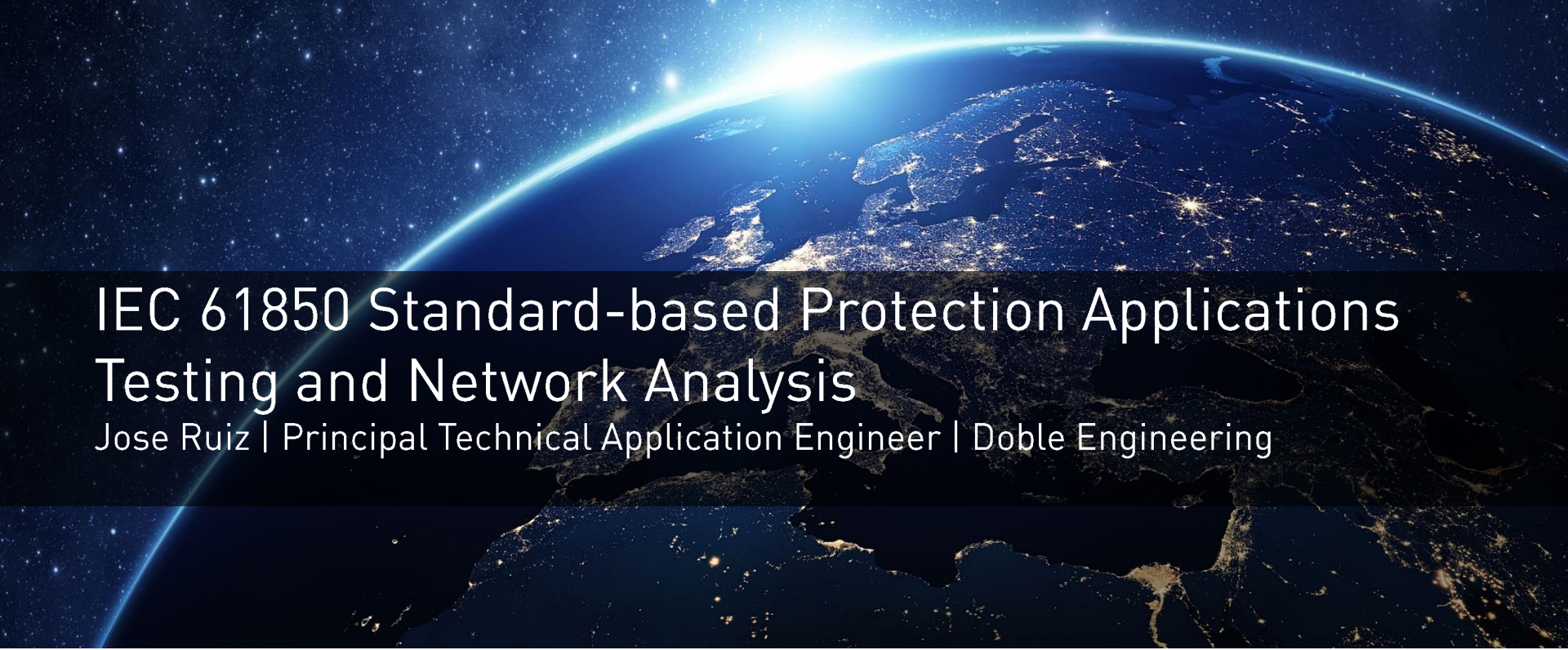
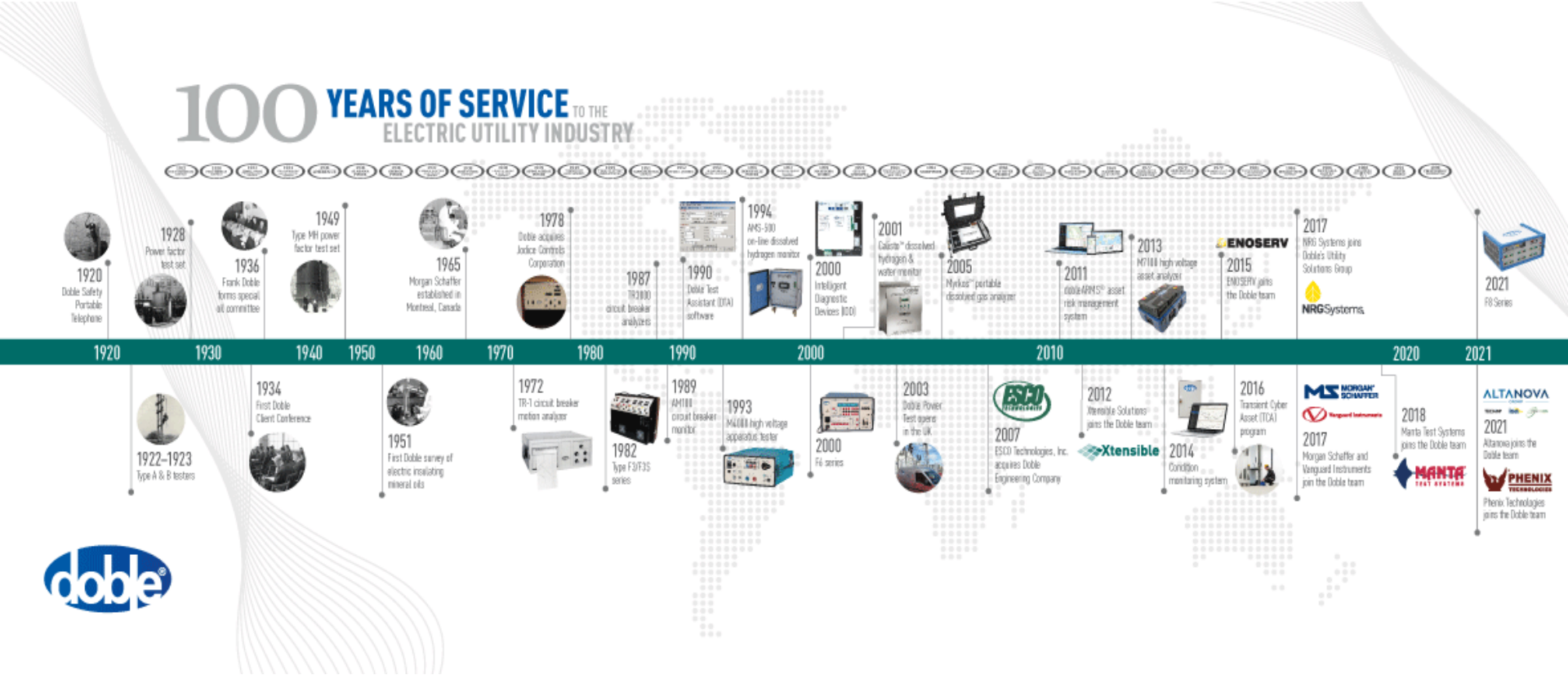


IEC 61850 Standard-based Protection Applications Testing and Network Analysis

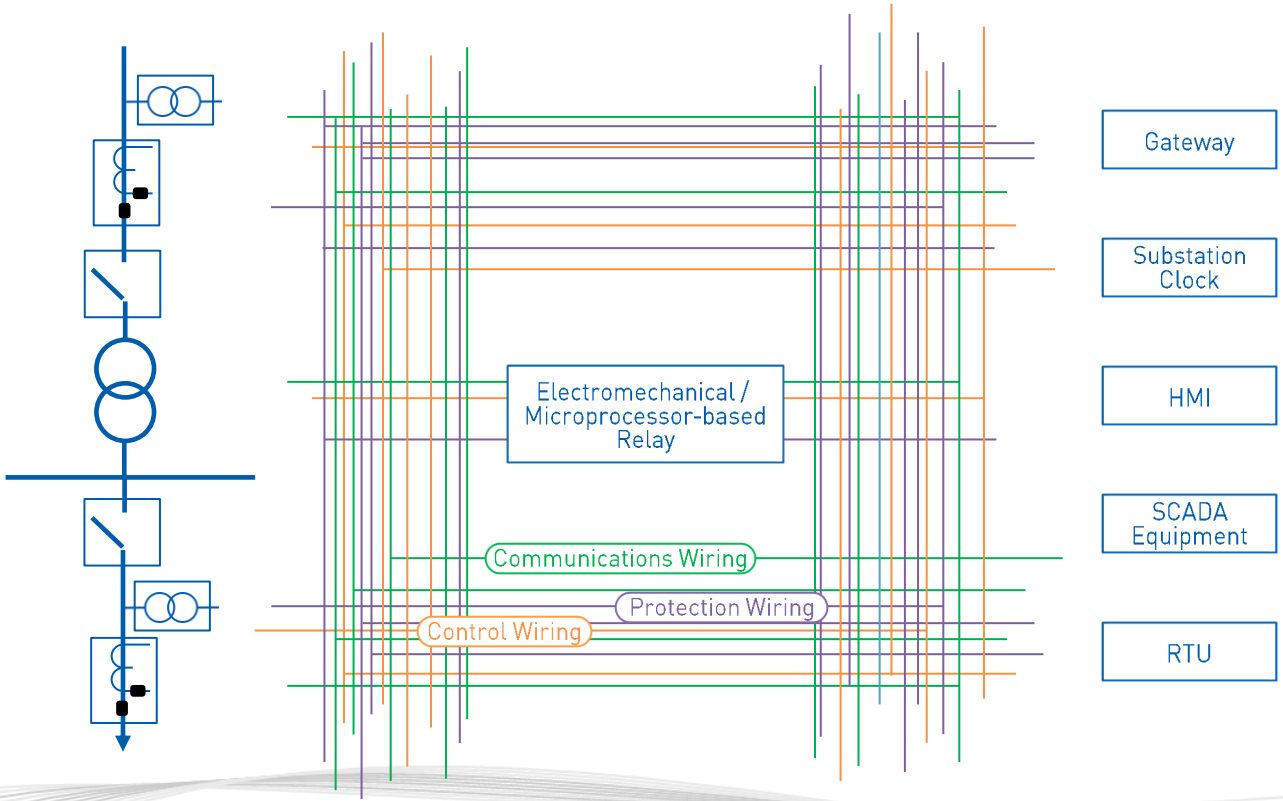
Jose Ruiz | Principal Technical Application Engineer | Doble Engineering

Who is Doble Engineering?



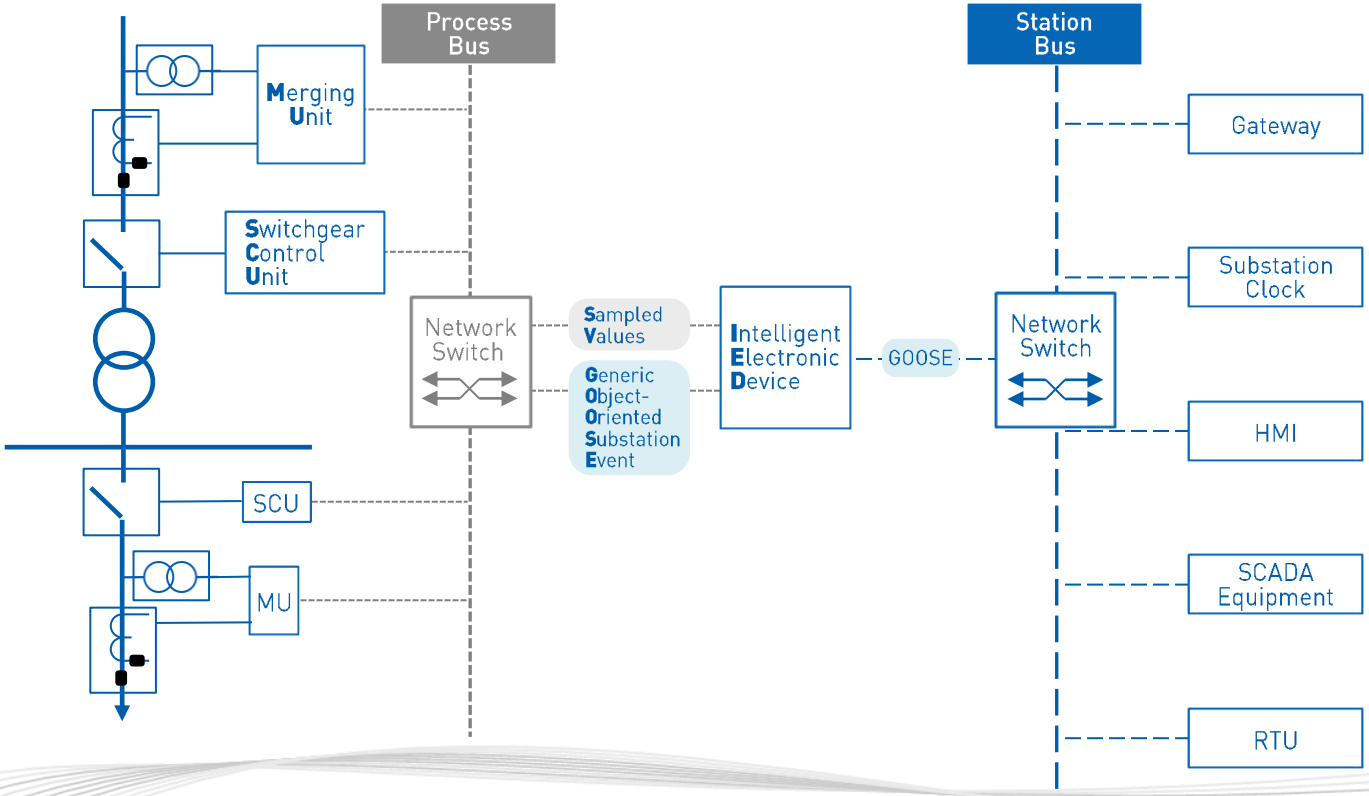
What is IEC 61850?

Conventional Protection & Control

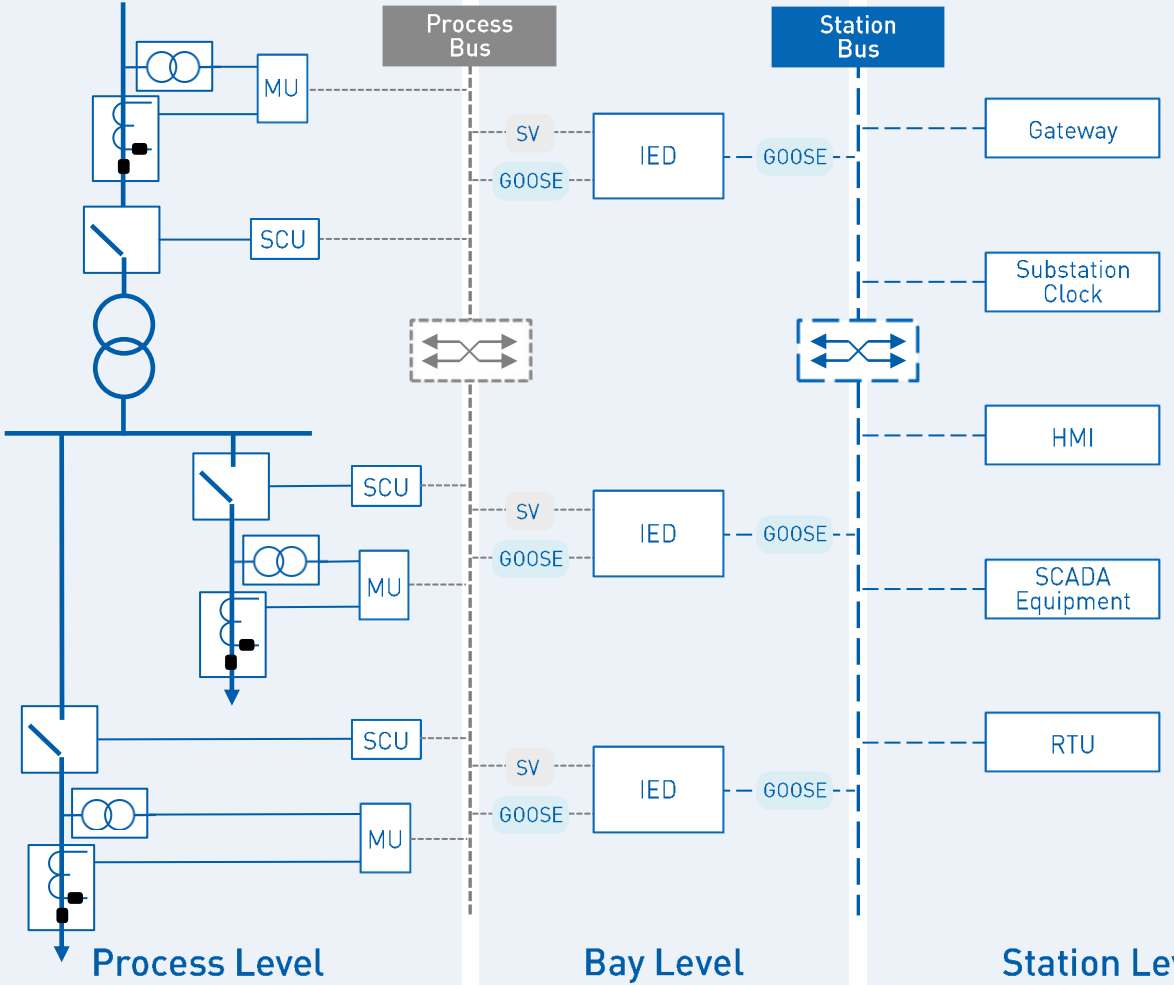


- Expensive and complex wiring
- Numerous point-to-point checks when commissioning
- Physical and proprietary constraints
- Many variables station-to-station

Digital P&C Based on IEC 61850 Standard

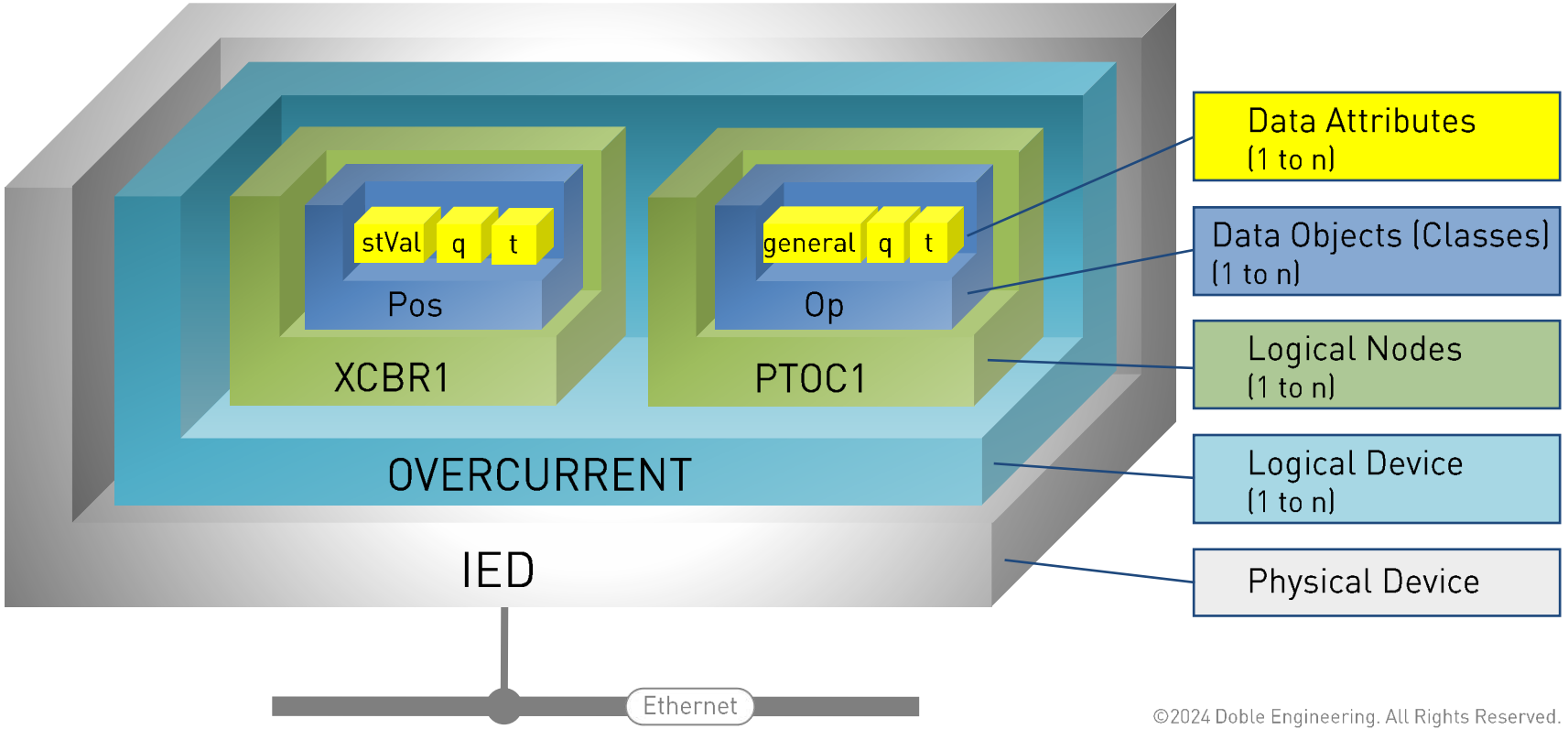


- Simplified connections
- Fewer on-site commissioning steps
- Virtually limitless possibilities
- Promotes standardization



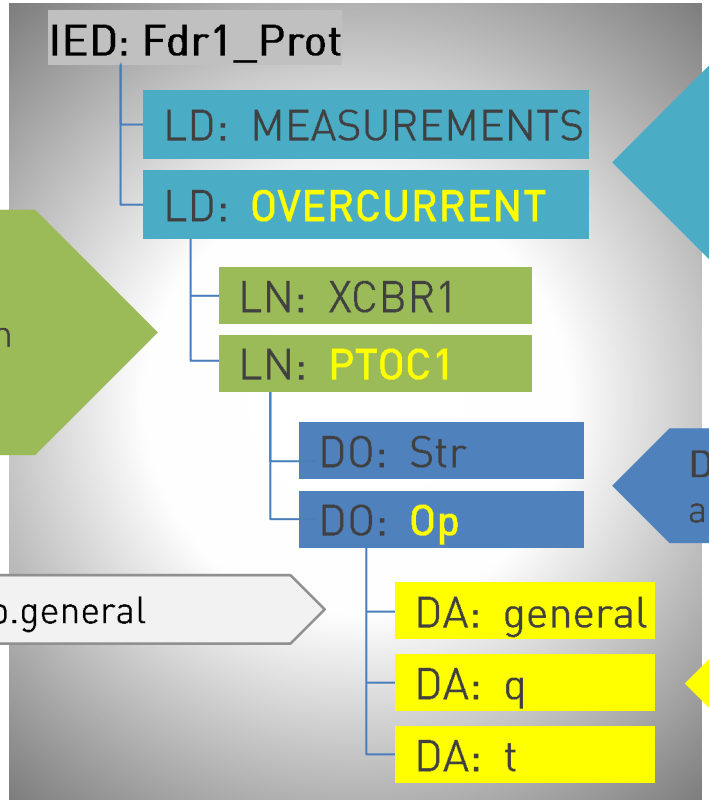
- Same protection, communication, and control tests
- Must test data packets – configurations, send/receive, etc.

Packet Structure



Hierarchical View

Physical Device has an application specific name



A **Logical Device** is a grouping of related functions. No specific arrangement rule. Names are vendor product specific or application specific.

Logical Nodes: prefix + **Logical Node Class** name *(standardized)* + instance-Id. Whole LN name can be vendor product specific or application specific.

Data Object / Data Class names are standardized

OVERCURRENT/PTOC1.Op.general

Data Attribute names are standardized

Data Attribute Types

- **Boolean** [true (**1**) or false (**0**)]
- **Dbpos** (Double bit position, also defined a Coded Enum below)

Enum Value	Bit Pair	Usual meaning (ex. for CB)
0	0 0	Intermediate state
1	0 1	Off (or Open)
2	1 0	On (or Closed)
3	1 1	Bad state

- **Integer**
- **Floating point**
- **Enumerated**
- **Timestamp**
- **Visible string**
- **etc.**

Constructed Data Attribute Types

- Quality

Quality type definition		
Attribute name	**Attribute type**	**Value/Value range**
	PACKED LIST	
validity	CODED ENUM	good | invalid | reserved | questionable
detailQual	PACKED LIST	
overflow	BOOLEAN	DEFAULT FALSE
outOfRange	BOOLEAN	DEFAULT FALSE
badReference	BOOLEAN	DEFAULT FALSE
oscillatory	BOOLEAN	DEFAULT FALSE
failure	BOOLEAN	DEFAULT FALSE
oldData	BOOLEAN	DEFAULT FALSE
inconsistent	BOOLEAN	DEFAULT FALSE
inaccurate	BOOLEAN	DEFAULT FALSE
source	CODED ENUM	process | substituted DEFAULT process
test	BOOLEAN	DEFAULT FALSE
operatorBlocked	BOOLEAN	DEFAULT FALSE

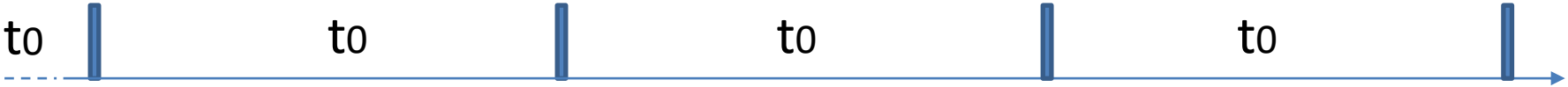
Published by IEDs and seen by sniffers as **a string of 13 bits**

SCL File Types

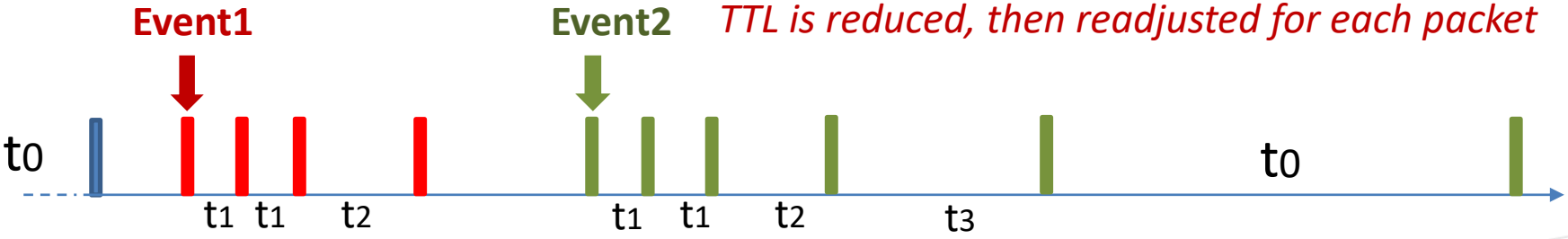
SSD	System Specification Description	System equipment connections, functions, logical nodes.
ICD	IED Capability Description	Data model and items supported by an IED.
IID	Instantiated IED Description	Instantiated data and published or transmitted messages.
CID	Configured IED Description	Actual configuration (instantiated objects/data, published messages, and IEDs/messages and data subscribed to.
SCD	System Configuration Description	Actual configuration of entire system or sub-system (multiple IEDs).
SED	System Exchange Description	Messages and datasets that need to be exchanged between projects.

GOOSE Retransmission

- *Periodic maximum retransmission (heartbeat) of GOOSE with time t0*
- *Time to live (TTL) is initially time t0; Loss of packet can be detected*

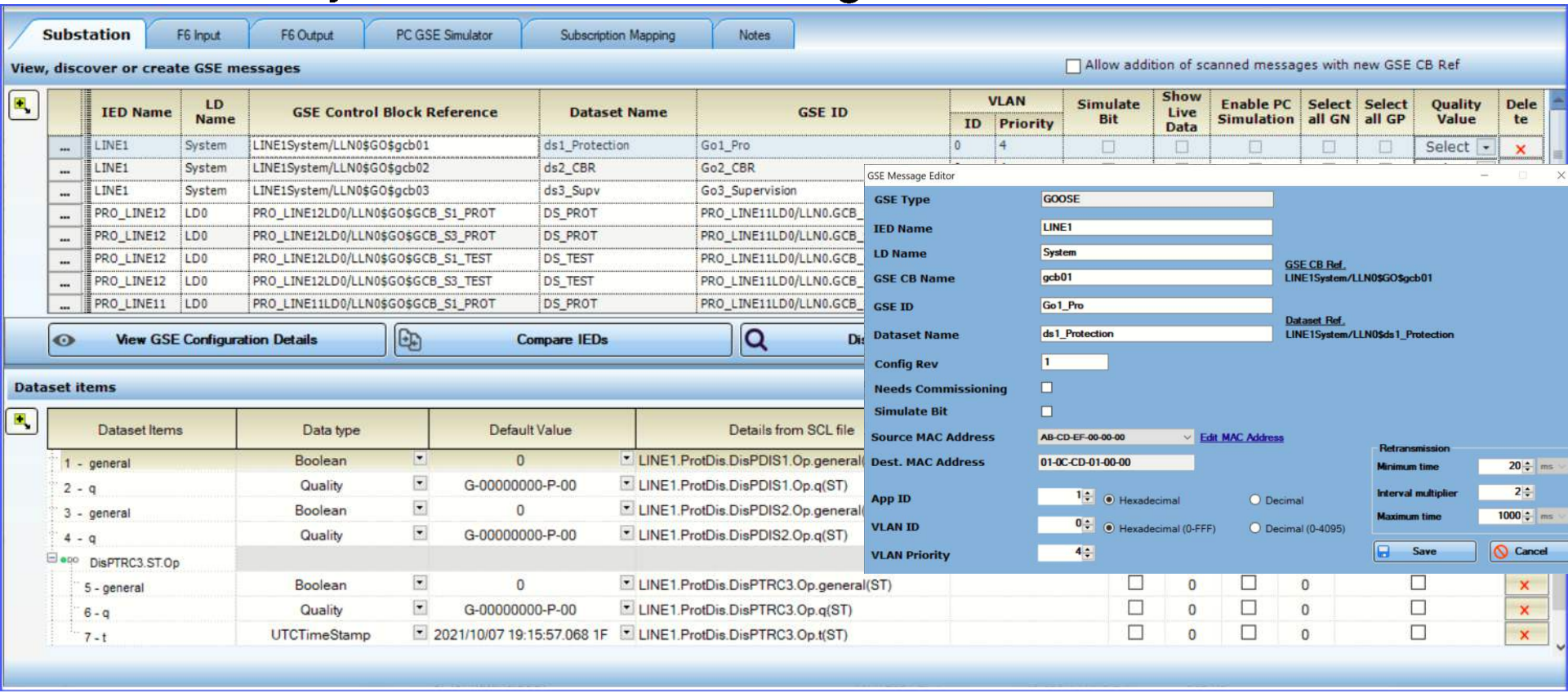


- *On a data change (Event1), GOOSE is published immediately and rapidly at gradually increasing time t1, t2, t3 until it reaches max. time t0*



- *On any new data change (Event2), GOOSE rapid publishing is restarted until it reaches time max time t0*

Anatomy of GOOSE Messages



Process Bus

- Sampled Values (SV)
  - Stand-alone Merging Units (SAMU)
    - Used with Conventional CTs and VTs to convert analog values to Sampled Values
  - Non-conventional Instrument Transformers (NCIT)
- Process digital signals
    - GOOSE signals
      - Handled thru I/O units or SCUs (switchgear control unit)
    - Client-Server (MMS)

Combined in one device: Process Interface unit (PIU): MU + SCU

Sampled Values - UCAIUG 9-2 LE Implementation Guideline

- Purpose of implementation guideline
  - Support fast market introduction of the standard
  - Define a subset to facilitate first implementations
- Logical device **merging unit** name: xxxx**MU**nnyy
  - xxxx : alphanumeric name (up to 28 characters)
  - MU : fixed, stands for merging unit
  - nn : merging unit number
  - yy : 01 for protection (80 samples/cy), 02 for metering (256 samples/cy)
  - Example: LINE1**MU**0401
- Fixed dataset
  - 4 currents and 4 voltages
  - Phases A, B, C and neutral

Sampled Values – New Standard

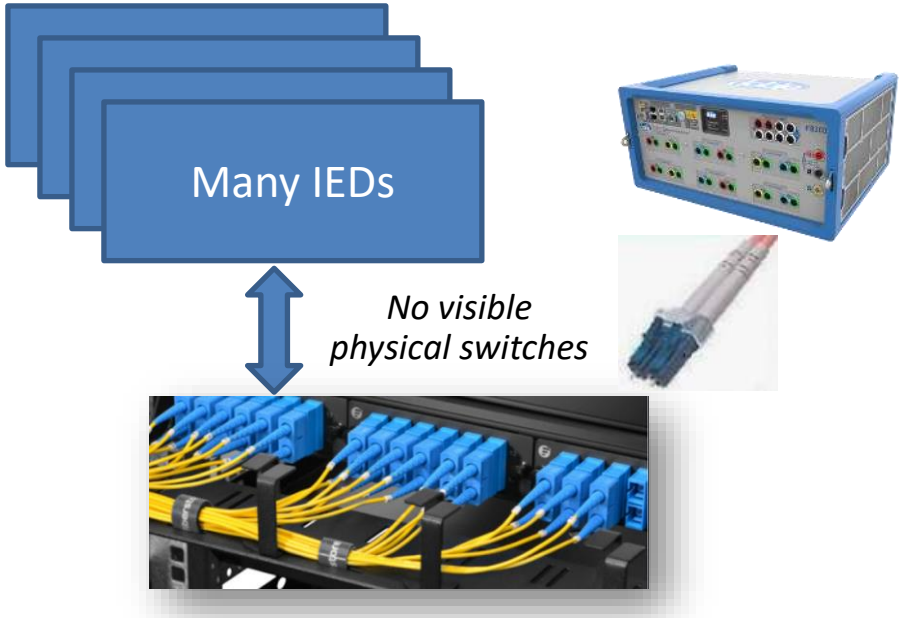
IEC 61850-9-2 Edition 2 and IEC 61869-9 (2016 April)

- Naming is more flexible
- Preferred variants: datasets can have a single quantity of voltage or current up to a maximum of 24 (such as 8 voltages and 16 currents)
- Sample rate of 4800 samples/s *(not samples/cycle)* for protection for all nominal frequencies
- Existing 9-2 LE is fully supported as a legacy variant
- Time synchronization:
  - IEC 61588 (PTP, also known as IEEE 1588), 1 PPS is supported

Testing IEC 61850 Standard-Based PACS

Testing – Isolation Challenges

Conventional test switch



IEC 61850 Ethernet connection

Testing – Isolation Challenges (2)

- Unplugging Ethernet connectors to devices for isolation is not allowed. It causes loss of messages and alarms in the subscribers.
- Test signals (SV and GOOSE) are seen by DUT as well as devices in normal service – a source of confusion and **major security concern**

- "**Virtual switches**" replace conventional physical test switches for **isolating device under test (DUT)** and the **injected test signals** from the rest of the system in normal service

Test Features – Isolation during Maintenance

Test signals injected by test set should be:

- **Accepted only** by Devices *(IEDs or Logical devices)* under test (**DUT**)
- **Ignored** by devices that are in normal service

Simulation:

- Test set publishes SV and GOOSE messages with Simulation flag = true
- **DUT set to Simulation mode** will process messages with Simulation flag = true
- Devices in **normal service** (Simulation not set) will ignore or not process simulated messages

Output Signals of DUT

- Outputs signals should be **ignored** by other devices that are in normal service
- Hard-wired (physical) outputs of the DUT must be **blocked** from operating on the process

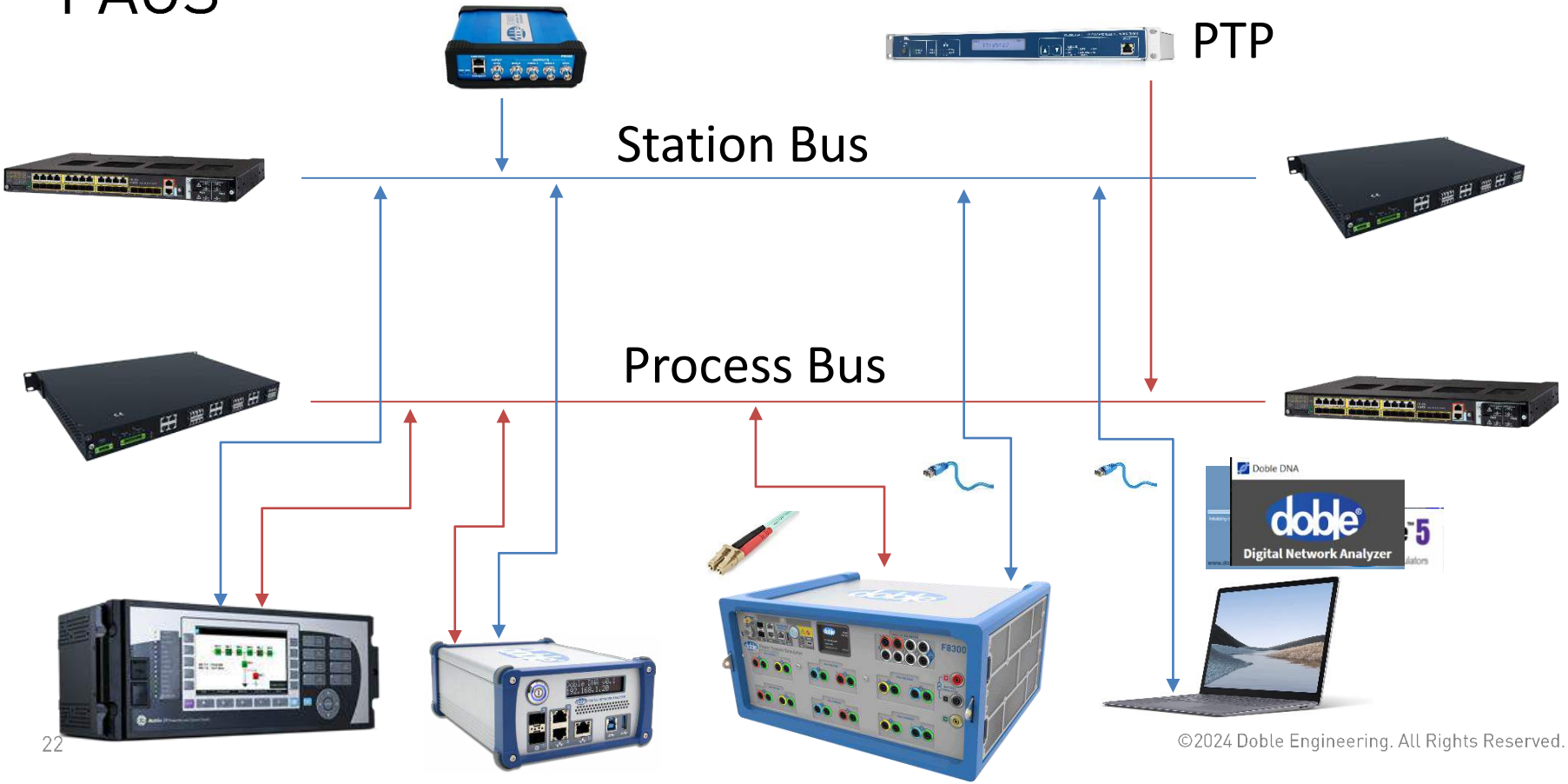
Mode/Behavior: – On, Test, Test/blocked

- GOOSE outputs of DUT (Beh=Test) identified with **q.test=true**
- Devices in normal service (Beh=On) **ignore** (or process as Invalid) signals with q.test=true
- Devices in test mode process **all** signals

Test/blocked mode: Physical outputs **blocked**

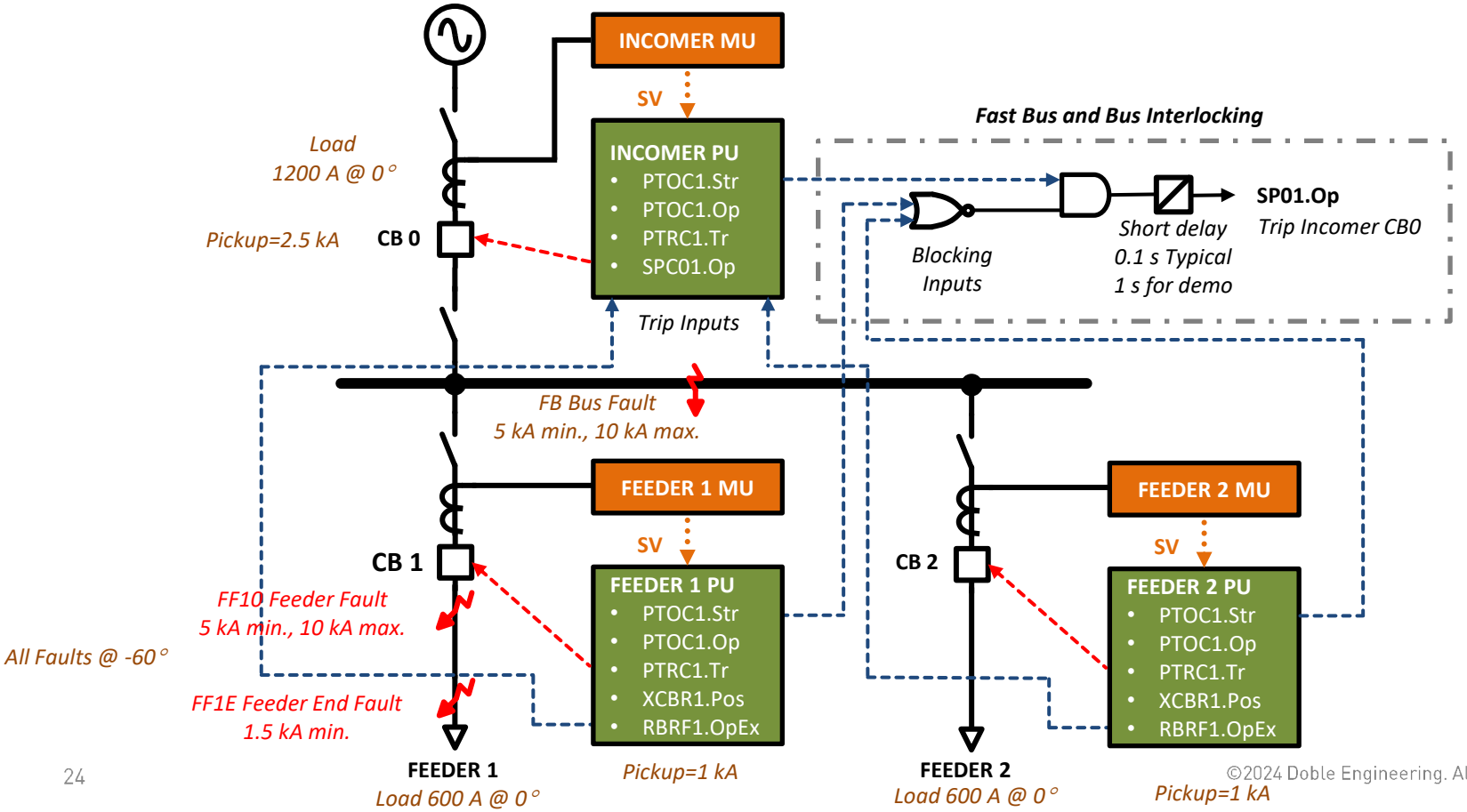
Doble Solutions

Doble Solutions for Testing IEC 61850-based PACS

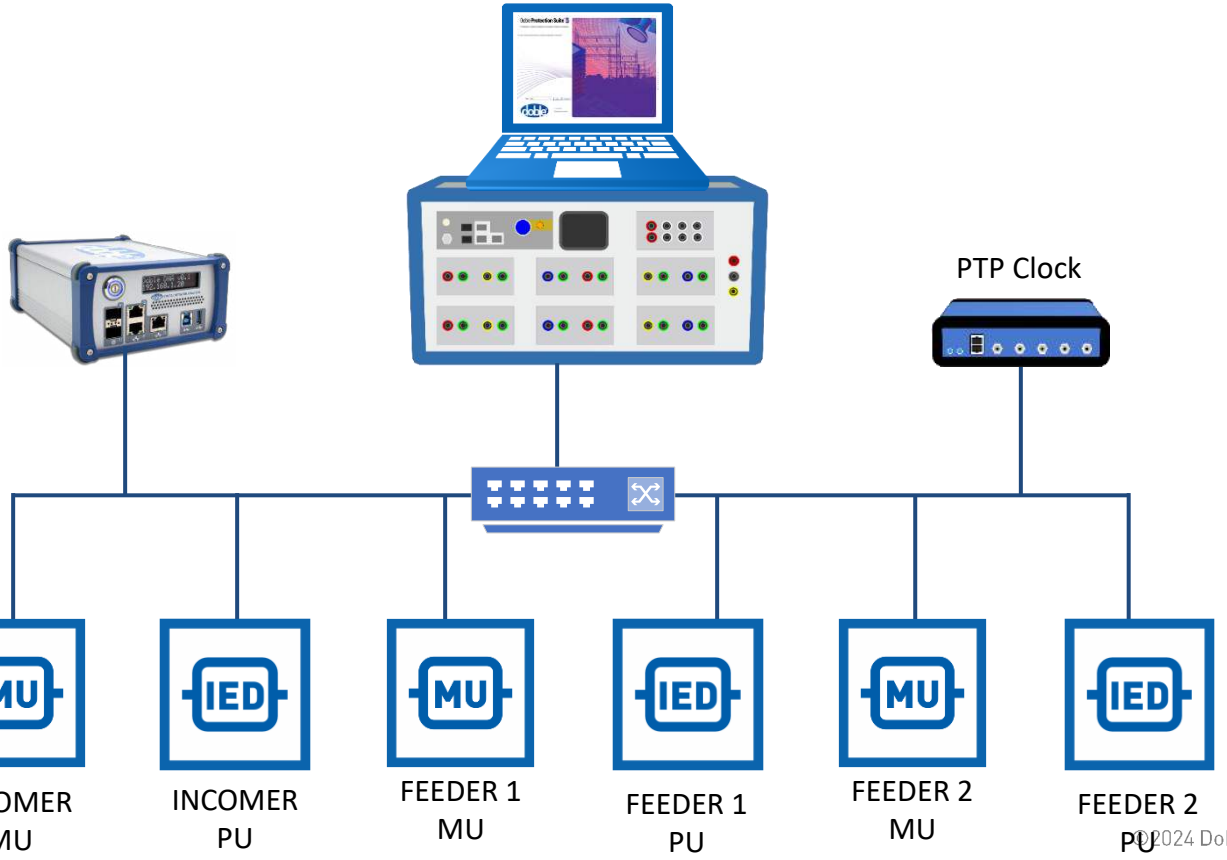


Testing Example

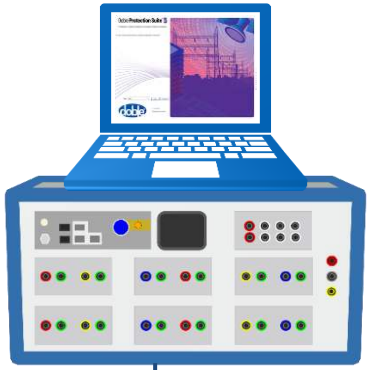
Reverse Blocking Bus Protection Scheme



Network Configuration



Network Configuration



PTP Clock

INCOMER MU

INCOMER PU

FEEDER 1 MU

FEEDER 1 PU

FEEDER 2 MU

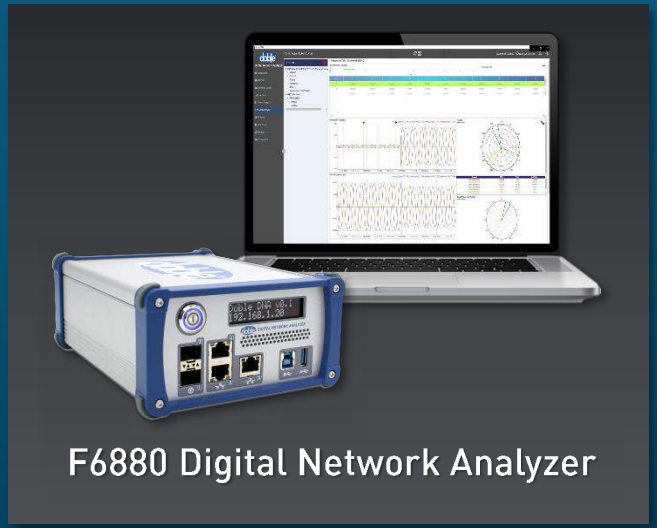
FEEDER 2 PU

IEDs not available for testing

Time for a Demonstration

Questions?

The examples presented in this webinar were sponsored by:



F6880 Digital Network Analyzer