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ABB Protective Relay School Webinar Series
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ABB Protective Relay School Webinar Series

Overview of IEC 61850

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July 8, 2014

Presenter

Alejandro Schnakofsky

Alejandro Schnakofsky graduated from Florida International University in Miami, FL with a BS in Electrical Engineering. During his studies he conducted research in the field of digital relays and centralization of protection functions within the substation (multi object protection systems).

In 2002 Alejandro joined Bussiere Communications were he engineered, deployed and tested Ethernet networks.

In 2005 he joined ABB Inc. were he has contributed in a variety of roles from Application Engineering to Management.

Alejandro is now global lead product manager for ABB's bay level products business.

Learning objectives

- History of IEC 61850
- IEC 61850 standard data model and SCL
- Client – Server
- GOOSE
- Sampled Measured Values

Introduction
UCA 2.0/IEC 61850 start-up

- UCA Project Origin:
  - Utility Communications Architecture (UCA) - enterprise-wide unified scheme to share all operating and management information
  - 1994 - EPRI member utilities called for common standard for IEDs in substations
  - EPRI RP 3599 defined requirements; looked at UCA compatible technologies for substations
  - 1996 - UCA demonstration initiative by AEP and other major utilities.
    - Pushed to identify Ethernet protocol to be used for all data sharing, plus high-speed control
    - Solicited IED vendor and user participation
    - Specified replacing control wiring with LAN
- IEC 61850 Origin
  - 1980s - Large European manufacturers were selling expensive LAN-based substation control systems (SCS)
  - Each design unique, and user committed to one vendor’s equipment
  - Later - IEC developed Standard 870-5 (now 60870-5)
  - 1995 - IEC TC 57 began 61850 Standard to define next generation of LAN-based substation control

Introduction
UCA 2.0/IEC 61850 harmonization

- Two projects were underway at same time:
  - UCA™ for substations - EPRI
  - IEC 61850 - Communication networks and systems in substations
- UCA and IEC Join Forces
  - Harmonization Goal - avoid two complex and incompatible standards
- 1997 - Two standards management teams committed to create an aligned standard
  - One technical approach for the whole world
  - Two standards aim at different details and different levels of system design.

A global standard for IEC and ANSI ...

- Today UCA International Users Group heavily involved in technical issue resolution and device level conformance testing
- IEC TC57

Substation automation
ABBs brief history with IEC61850

1994-2003

- Active IEC work with up to 13 permanent delegates in all key working groups
- Extensive interoperability test amongst key suppliers

2004

- Finalization and release of IEC 61850
- 1st project delivered by ABB, EGL 380kV in Switzerland
- 1st IEC61850-8-1 multi-vendor project world wide

2005

- UCA certification for the ABB System Verification Center

2008

- 1st ABB pilot IEC61850-9-2 process bus installation

2010

- 1st UCA certification for IEC61850-9-2 Merging Unit world wide

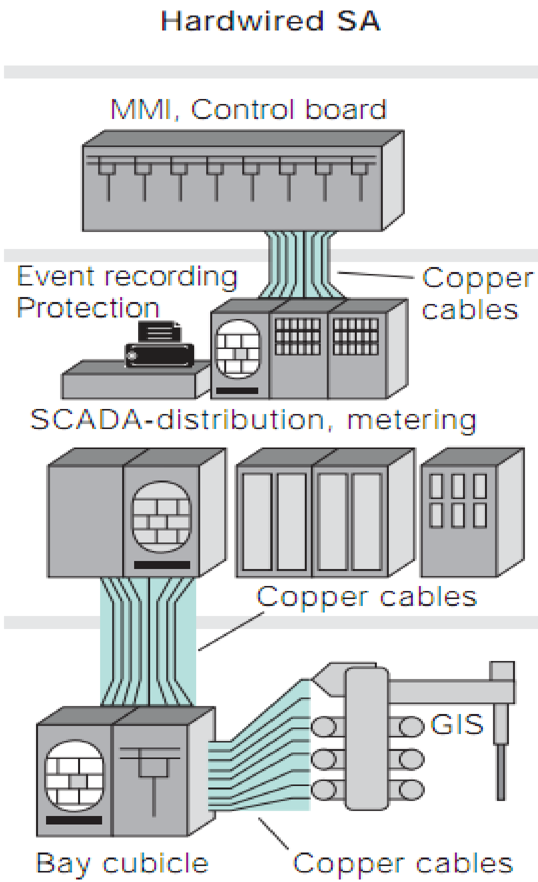
2011

- Globally > 1200 ABB SA-Systems based on IEC61850 delivered

ABB

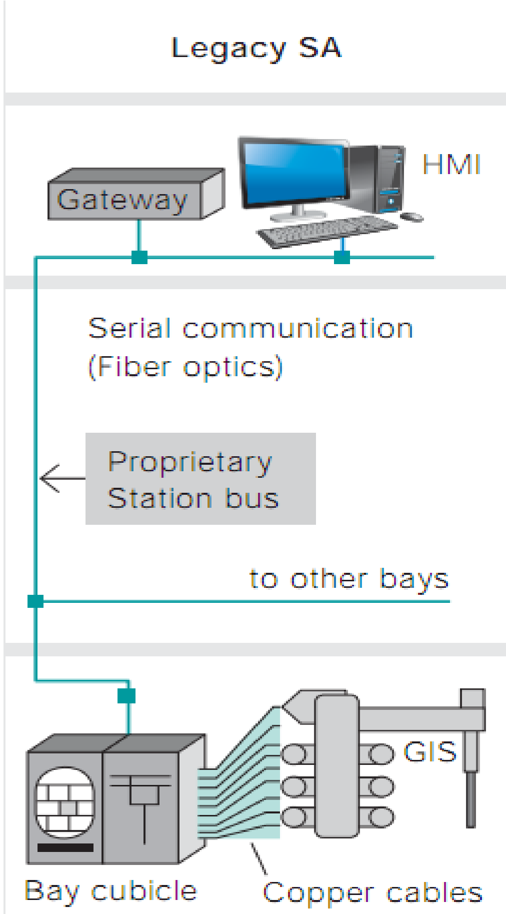
SA system architecture
RTU / hardwired

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



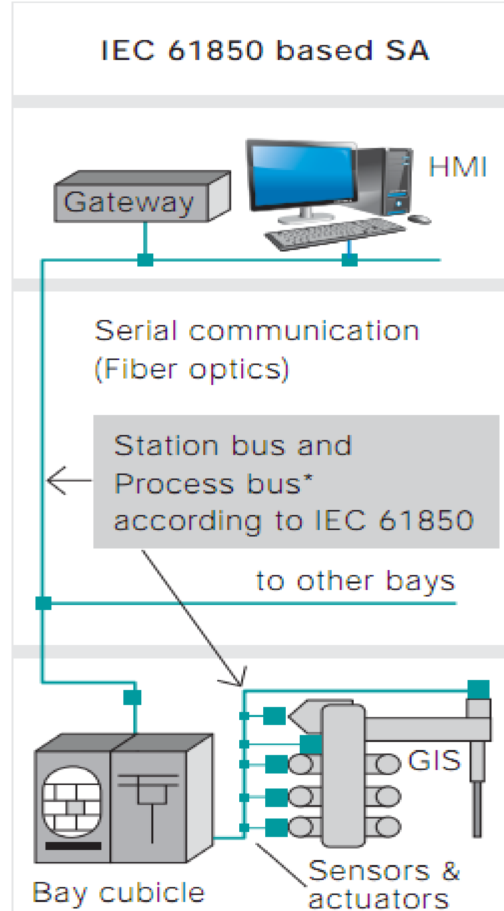
SA system architecture
DNP / Modbus

- 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

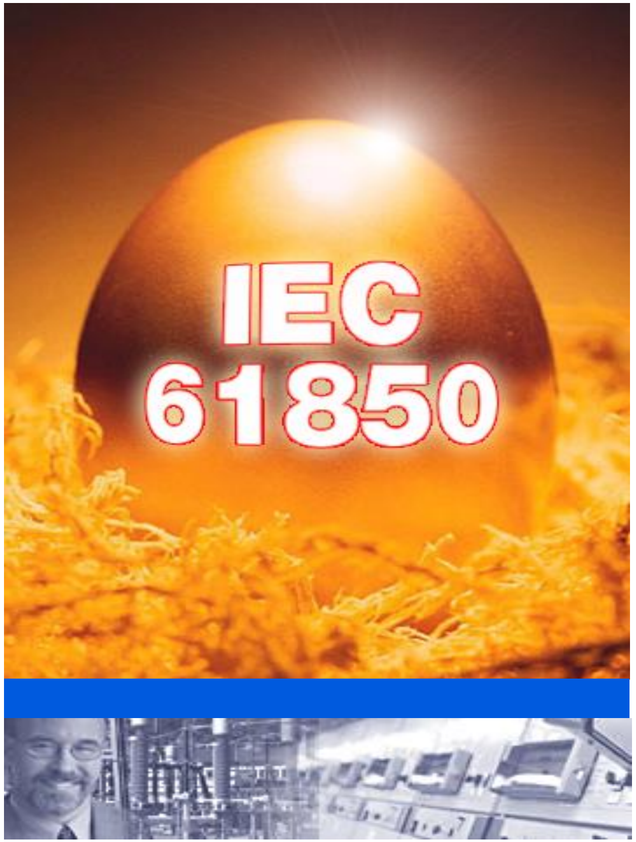
- Integration of status monitoring, protection, automation, and control into IEDs
- Digitization of copper wires
  - 61850-8-1
  - 61850-9-2
- Modeling of the substation, equipment and functions
- Protocol stack
- Interoperability by standardization and **verification**



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

IEC 61850 based SA systems



"Combining the best properties in a new way..."

Basics:

- Fast Ethernet (100 MBps to 1 GBps)
- Station Bus 61850 8-1
- Process Bus 61850 9-2
- Data Model
- Substation Configuration Language

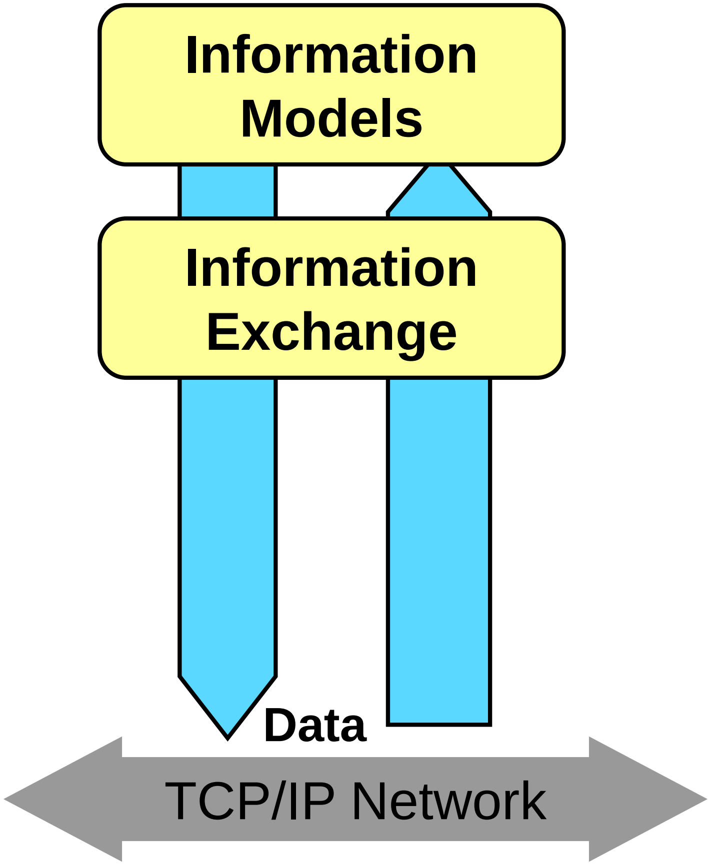
Much more than a protocol:

- Modularization and structuring of data
- On-line meaningful information
- Free allocation of functions in IEDs
- Complete description of configuration
- Structured engineering & services
- Testing, validation, and certification

IEC 61850 10 parts and growing…
Communication networks and systems in substations

- 61850-1 Introduction and overview
- 61850-2 Glossary
- 61850-3 General requirements
- 61850-4 System and project management
- 61850-5 Communication requirements for functions and device models
- 61850-6 Substation configuration language
- 61850-7-1 Basic Communication Structure
- 61850-7-2 Abstract communication service interface
- 61850-7-3 Common data classes
- 61850-7-4 Compatible LN classes and DO classes
- 61850-8-1 Specific communication service mapping (SCSM)
- 61850-9-1 Sampled values over serial point to point link
- 61850-9-2 Sampled values over ISO/IEC 8802-3
- 61850-10 Conformance testing

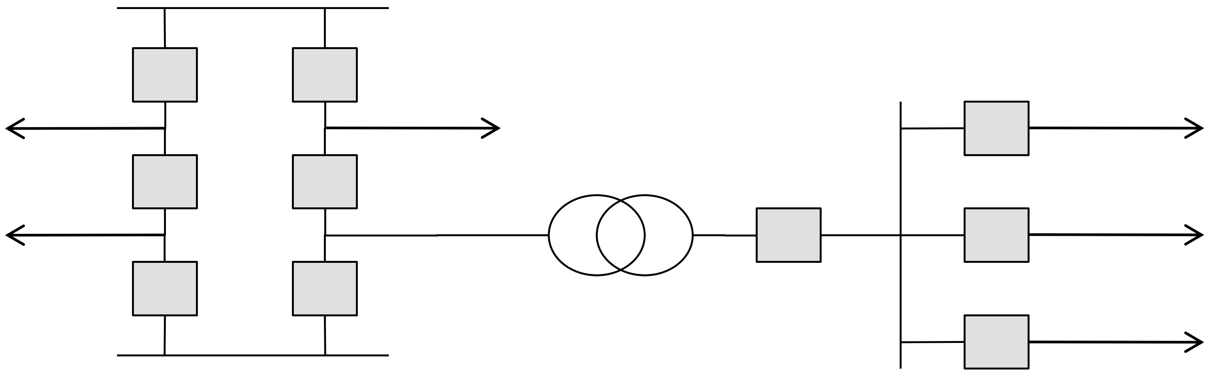
IEC 61850 much more than a protocol
Application data and communication



- Logical Nodes and Data
- (IEC 61850-7-4 / -7-3)
- Service Interface (Abstract)
- (IEC 61850-7-2)
- Mapping to e.g. MMS and TCP/IP/Ethernet
- IEC 61850-8-1 Station Bus and IEC 61850-9-2 Process Bus

Data model

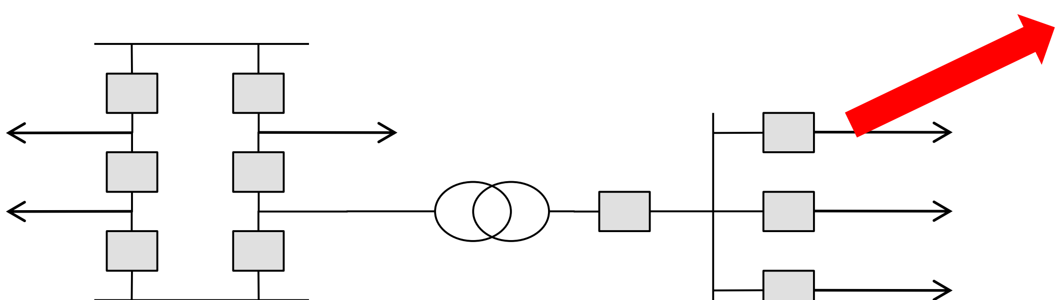
- The core of 61850 is the standard representation of functions and equipment, its attributes, and its location within a system



WHY IS THIS IMPORTANT?

Modbus / DNP

- DNP and Modbus are communication protocols that define data type (binary, analog, counters, etc) and reporting structures
- This way, IEDs can transfer information that can in turn be used
- Modbus defines:
  - Coils (status of IED binary data) Input/Holding registers (status of IED inputs, binary or analog)
  - A polling reporting structure
  - No connection between data and application



Brk1 Phase A current =

4x register 245

Signed or unsigned?

12, 16, or 32 bit?

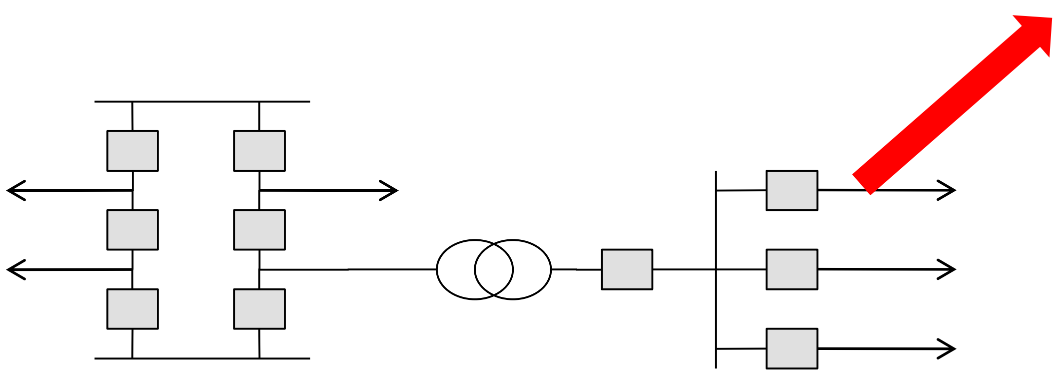
Primary or secondary?

Modbus / DNP

DNP defines:

- Several objects (binary, analog, counters, etc) with variants (32 vs. 16 bit)
- Several indexes per object
- Polling as well as unsolicited reporting
- Still no connection between index/object (data) and the application

Moreover, there is no connection between data, application, object, and location within the substation!



Brk1 Phase A current =

Object 30, index 5

Signed or unsigned?

12, 16, or 32 bit?

Primary or secondary?

I-N-T-E-G-R-A-T-I-O-N
Where does 61850 help?

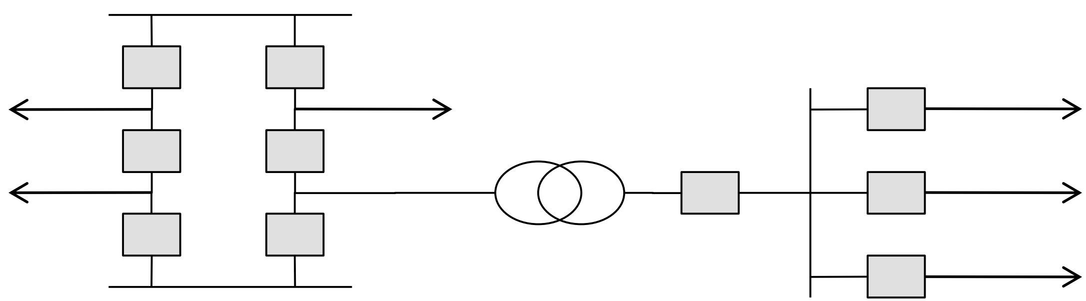
In a nutshell it involves gathering the information from IEDs

- Media and protocol converters when using multiple protocols
- Understanding each device's unique memory/point/register map
- Programming the data concentrator to accept such information
  - Data types
  - Reporting structure

Tying the information to the application

- Point 1 from Device 1 = 52A

The end result helps establish a decision/operation support system



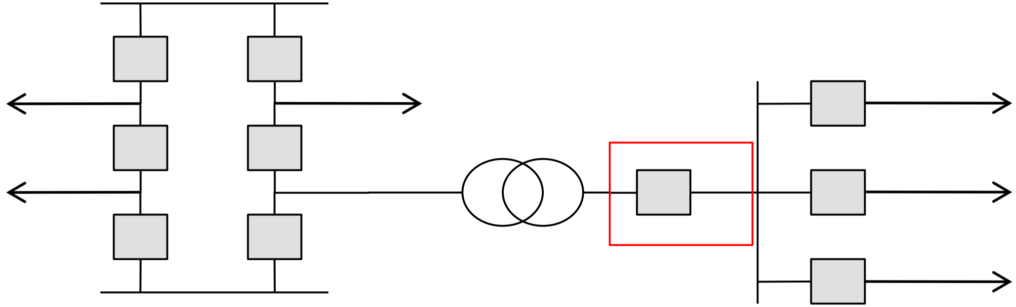
Data model

Function / Equipment

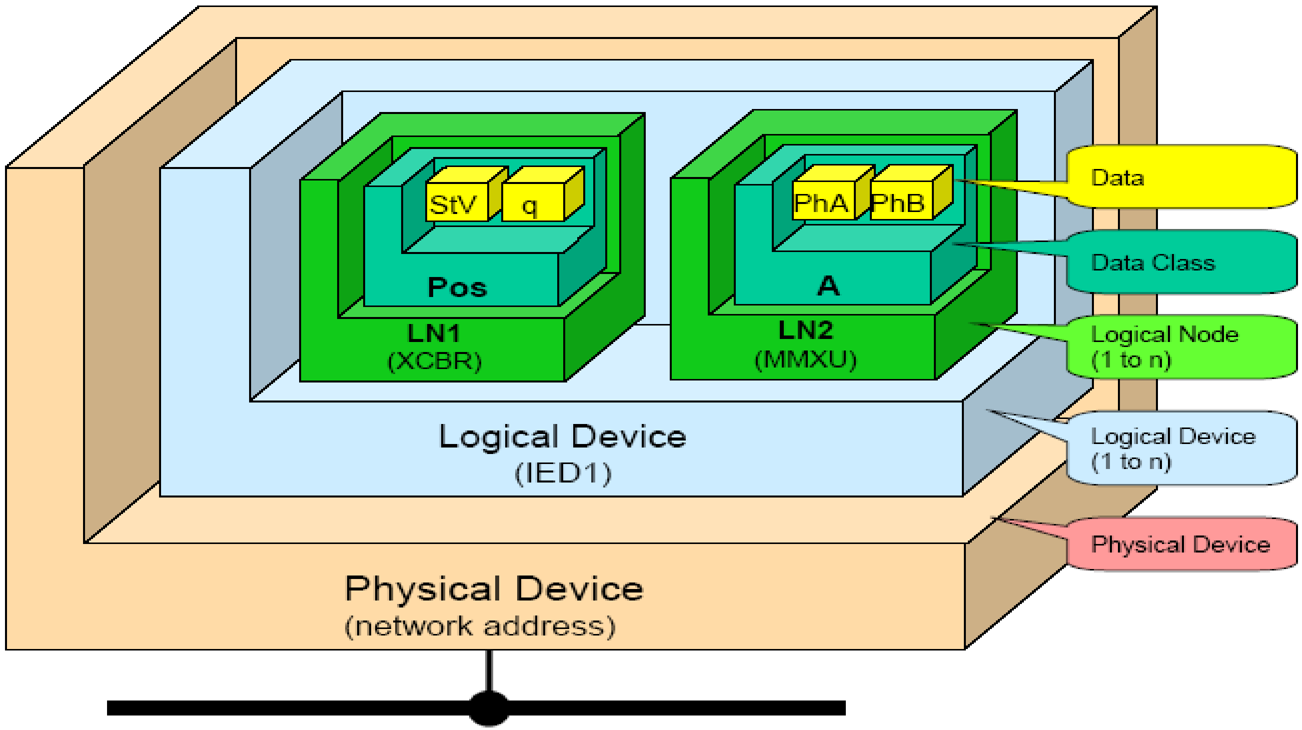
- Position of Breaker1
  52A = Device 5, BI #4
  52B = Device 5, BI #5
- Breaker1 Current
  PhA = Device 5, AI #10
  PhB = Device 5, AI #11
  PhC = Device 5, AI 12
- Breaker 1 51P and 50P targets
  51P = Device 5, BI #6
  50P = Device 5, BI #7

Logical Node

- Breaker = XCBR
  Position = XCBR.Pos.stVal
- Measurements = MMXU
  Current PhA = MMXU.A.phsA
  Current PhB = MMXU.A.phsB
  Current PhC = MMXU.A.phsC
- 51P Target
  51P = PTOC.Op.general
  50P = PIOC.Op.general



Data model
Logical Node



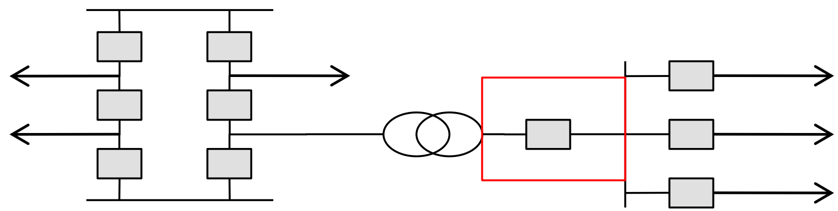
"UCA & 61850 for Dummies." – Douglas Proudfoot

Different kinds of Logical Nodes

- LLN0, LPHD: IED and function management
- Pxxx: protection (PTOC, PIOC, PDIS, PDIF,….) (28)
- Rxxx: protection related (RREC, RSYN, RDRx, ….) (10)
- Cxxx: control related (CSWI, CILO, CALH, CCGR, CPOW)
- Mxxx: measurements (MMXU, MMXN, MMTR, MHAI, MDIF, MSTA)
- Axxx: automatic functions (ATCC, ANCR, ARCO, AVCO)
- Gxxx: generic functions (GGIO, GAPC, GSAL)
- Sxxx: sensor/monitoring interface (SIMG, SIML, SARC, SPDC)
- Txxx: instrument transformer (TCTR, TVTR)
- Xxxx: switchgear process interface (XCBR, XSWI)
- Yxxx: transformer process if (YPTR, YLTC, YEFN, YPSH)
- Zxxx: further power related equipment (ZBAT, ZGEN, ZMOT,…)
- Ixxx: interfacing and archiving (IHMI, ITCI, IARC, ITMI)

Data model

- Thanks to such representation, functions can then be allocated to objects within the substation
- Addressing scheme takes this into consideration tying the data with the application, object, and location within the substation



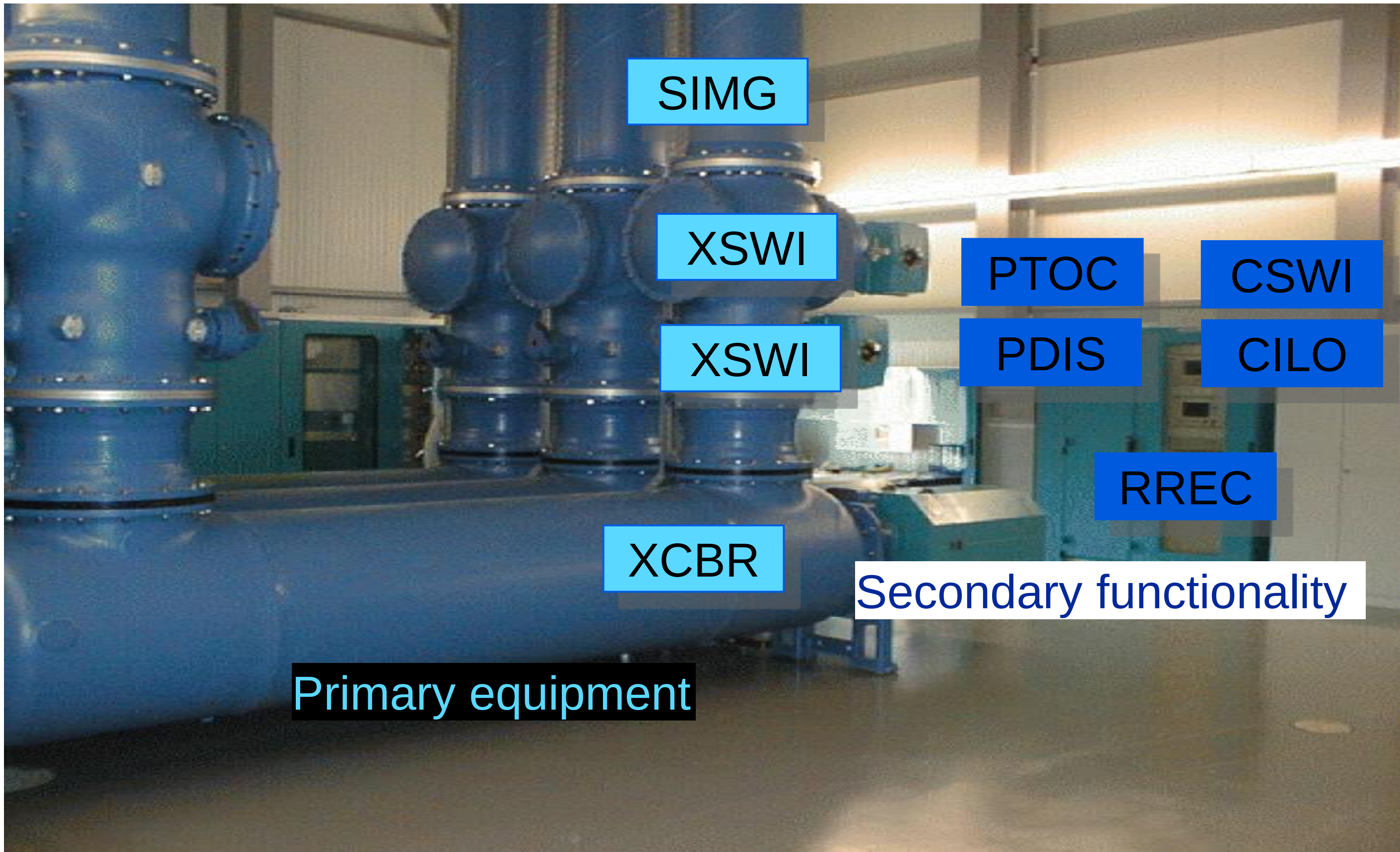
Bradley.J1.Q08.A01.LD0.MMXU1.A.phsA

Bradley.J1.Q08.A01.LD0.MMXU1.A.phsB

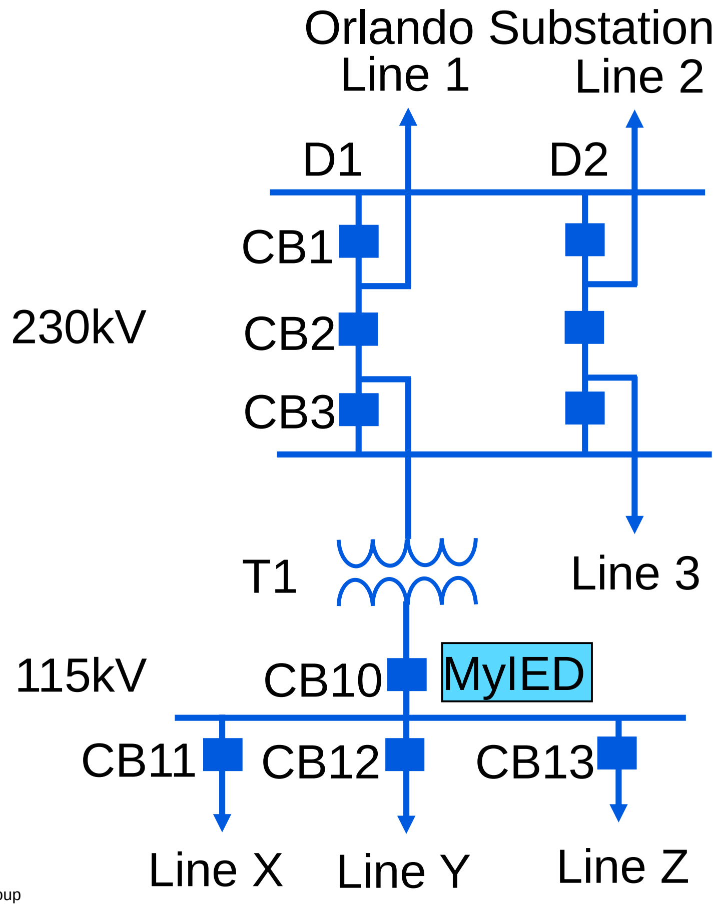
Bradley.J1.Q08.A01.LD0.PTOC.Op.general

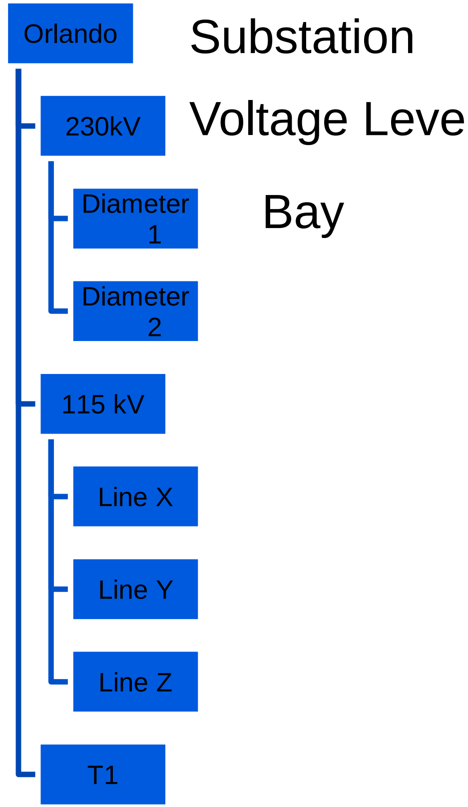
Bradley.J1.Q08.A01.LD0.XCBR1.Pos.stVal

Logical nodes



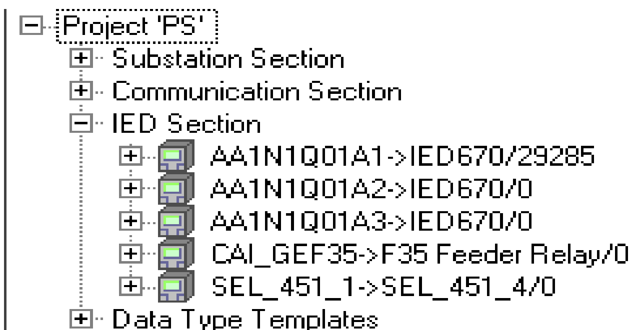
Modeling
Substation structure





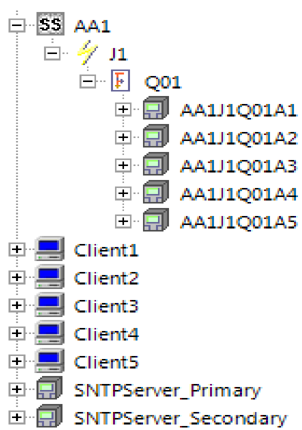
SCL and modeling in 61850

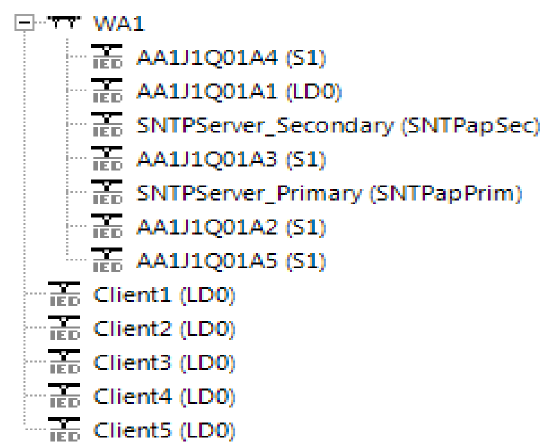
- 61850 defines a common language where all compliant manufacturers can exchange information regarding the “functions” (Logical Nodes) and related data available inside their equipment.
- Substation Configuration Language
- Offers 4 file formats (Ed. 1)
  - SSD: Substation Specification Description
  - ICD: IED Capabilities Description
  - CID: Configured IED Description
  - SCD: Substation Configuration Description



SCL and modeling in 61850

- Documenting complete projects in SCD file
  - IEDs and their connection to the application
  - Functions and their connection to the application
  - Communication network
  - Connections between IEDs
  - Reporting mechanism



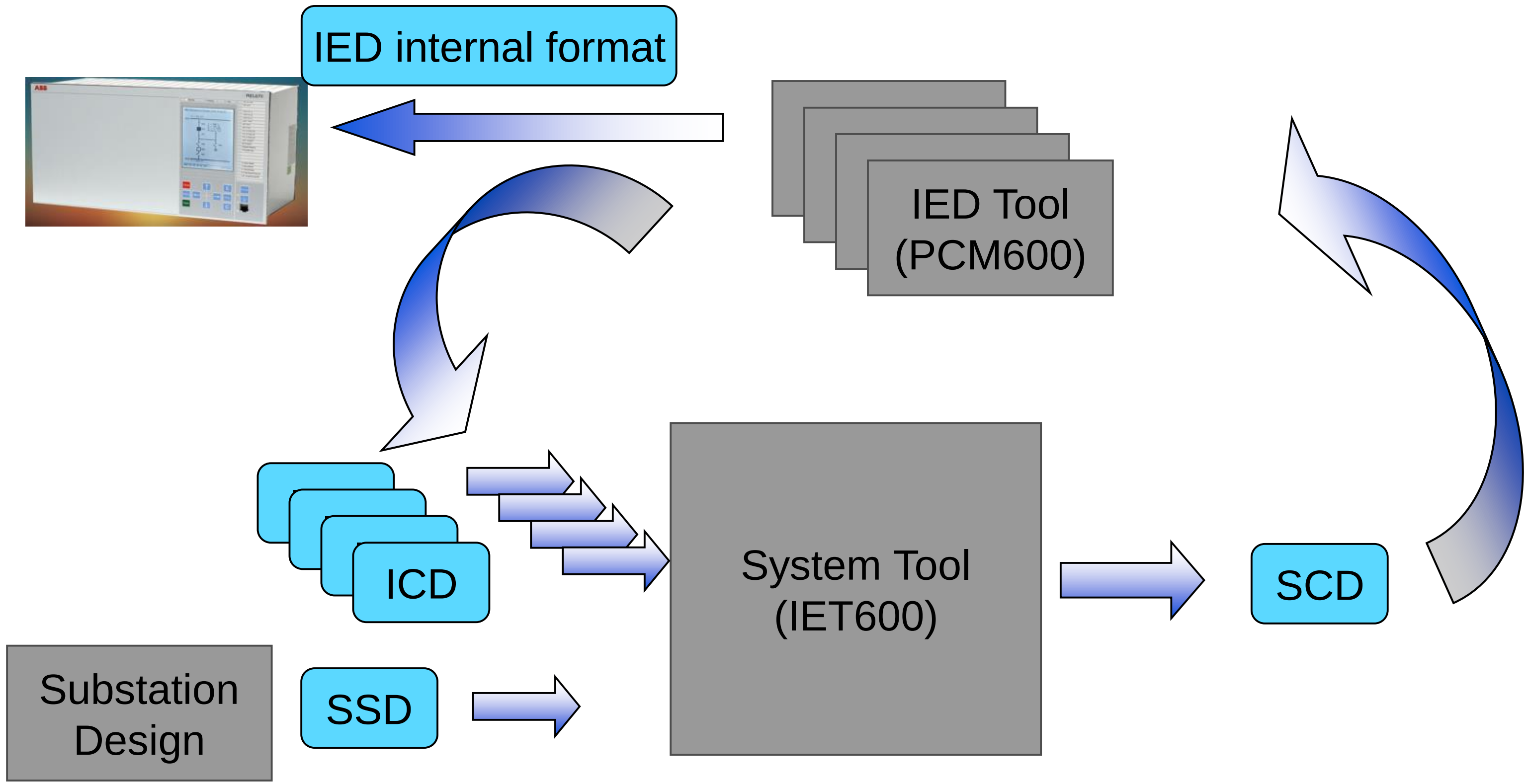


Engineering with SCL

System tool approach

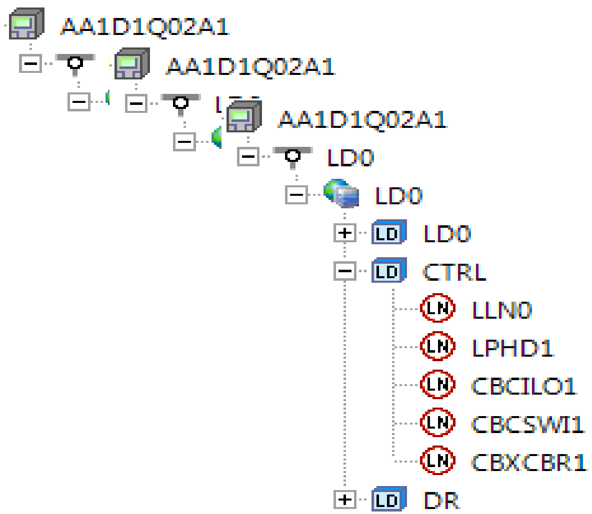
- Thanks to common file format engineering of the SAS system can be performed under a single tool
- This provides a single point of interaction with the configuration files of all devices regardless of manufacturer
- End result (SCD file) must be part of the final system documentation just like DC and AC elementary are

Engineering with SCL

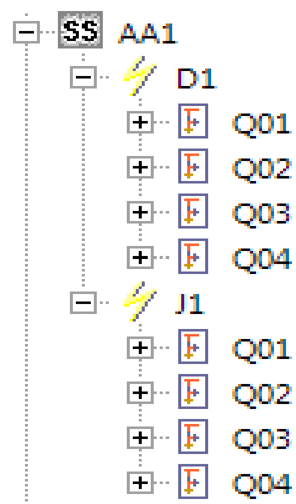


Engineering with SCL

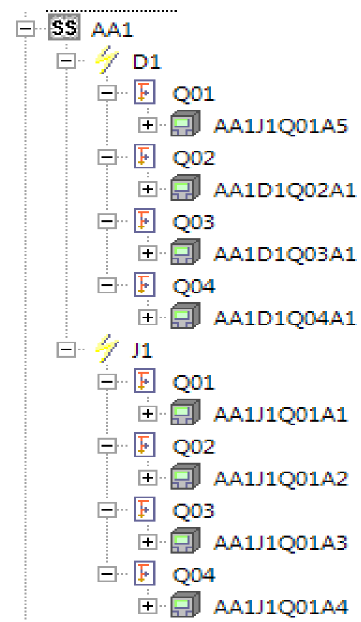
Individual IEDs

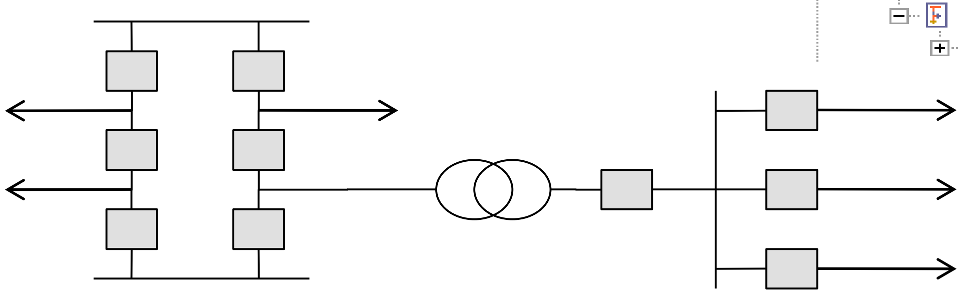


Substation layout



IEDs assigned to bays

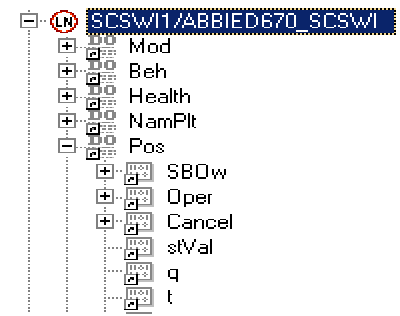




Client - Server

Client-Server

- Get information from relays and meters
- Higher resolution of information
- Lower integration costs
  - Drag and drop process thanks to SCL file
  - All manufacturers with same naming convention
  - Less chances for mistakes



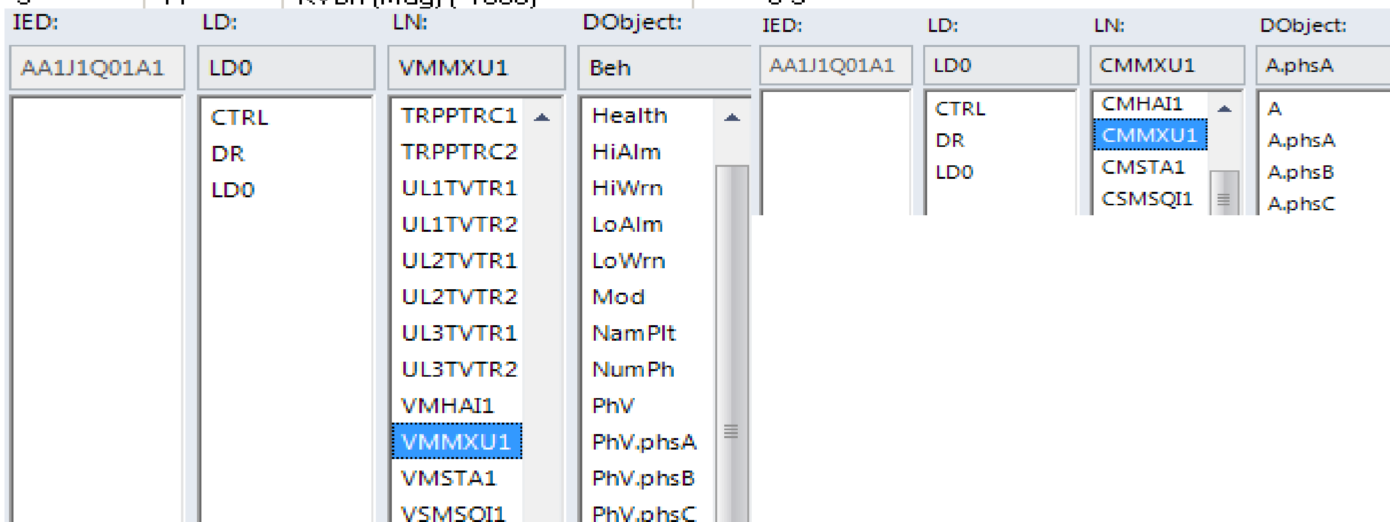
Point#	Refer#	Variable	Class
0	0	Ia (Load Currents)	0 3
1	2	Ib	0 3
2	4	Ic	0 3
3	6	In	0 3
4	9	KVan (Mag) (*1000)	0 3
5	11	KVbn (Mag) (*1000)	0 3

Point#	Refer#	Variable	Class
0	9	KVan (Mag) (*1000)	0 3
1	11	KVbn (Mag) (*1000)	0 3
2	13	KVcn (Mag) (*1000)	0 3
3	0	Ia (Load Currents)	0 3
4	2	Ib	0 3
5	4	Ic	0 3
6	6	In	0 3
7	15	KWan	0

SXSWI: 3.OPENPOS	CircuitSwitch, Apparatus open position
SXSWI: 3.CLOSEPOS	CircuitSwitch, Apparatus closed position
VNMMXU: 3.V_C	VoltagePhasors, V_C Amplitude, magnitude of reported value
VNMMXU: 3.V_B	VoltagePhasors, V_B Amplitude, magnitude of reported value
VNMMXU: 3.V_A	VoltagePhasors, V_A Amplitude, magnitude of reported value
CMSQI: 3.3I0	CurrentSequenceComponents, 3I0 magnitude of reported value

Client - Server

Point#	Refer#	Variable	Class
0	0	Ia (Load Currents)	0 3
1	2	Ib	0 3
2	4	Ic	0 3
3	6	In	0 3
4	9	KVan (Mag) (*1000)	0 3
5	11	KVbn (Mag) (*1000)	0 3



Client - Server

- Other features:
  - Discoverable mode
    - Client can connect to an IED and read the data model, this makes it possible to know what functions are available inside an IED without the need for files or documentation
  - Browse: the data model of an IED can be browsed by a client
  - Reporting structure
    - Browse
    - Cyclic
    - Buffered reports, an IED can cave several configured with different clients for each
    - Unbuffered, an IED can cave several configured with different clients for each

Client - Server

- Reports have several configurable triggers
  - Data change
  - Quality change
  - Data update
  - Cyclic

Digitize Copper

Digitize copper (GOOSE + SMV)

- Thanks to Ethernet technology and previously mentioned data model we are able to digitize copper:
  - Binary signals (GOOSE)
  - Analog signals (GOOSE)
  - Analog signals as input to protection and metering functions (SMV in the Process Bus)

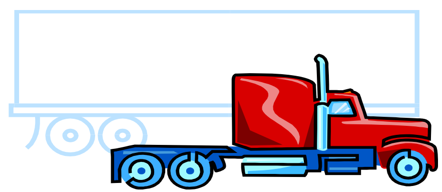
What is a GOOSE message?

- Generic Object Oriented Substation Event
- Fast and reliable distribution of information
  - Status (breaker position, trip, pickup, alarms, etc.)
  - Analog (counter values, etc.)
- Performance
  - Fast messages Type 1A (Class P2/P3) received within 3ms.
  - This includes transmission time into the other IEDs (similar to an output to input connection between 2 relays)

What is a GOOSE message?

- GOOSE messages are based on change event
- GOOSE messages include diagnostic functions (a “heart beat” to all devices subscribed is sent periodically)
- GOOSE messages are managed by GCBs (GOOSE control block) inside IEDs
- GOOSE messages send “Data Sets” upon changes of state

Data set

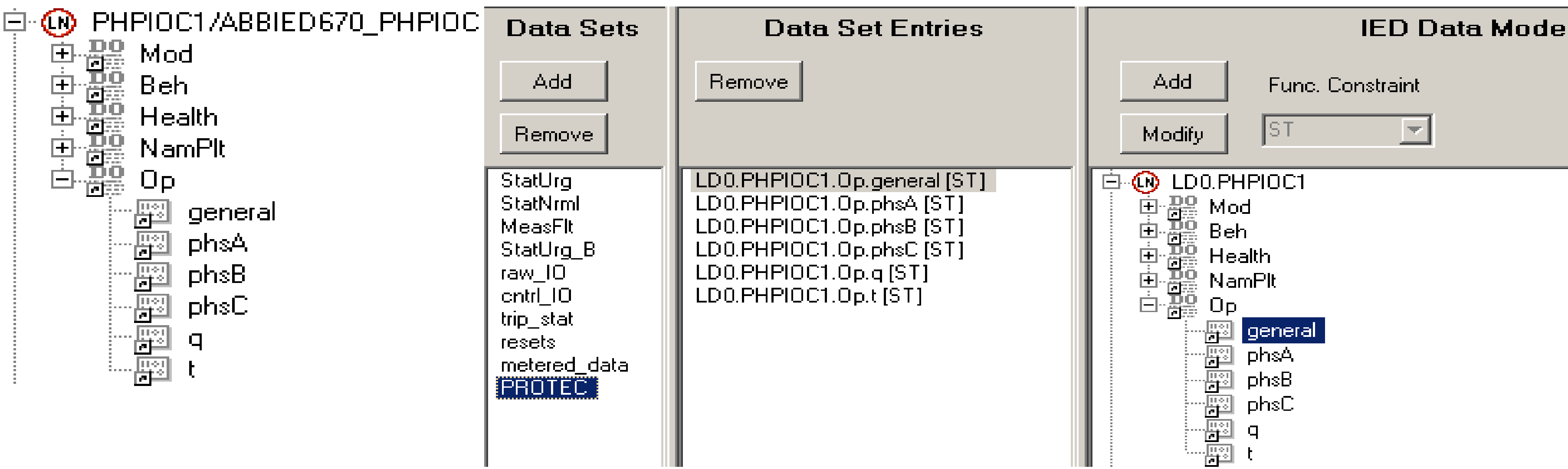


GCB

Network

What is a GOOSE message?

- Can send 1 or several data attributes from 1 or several functions



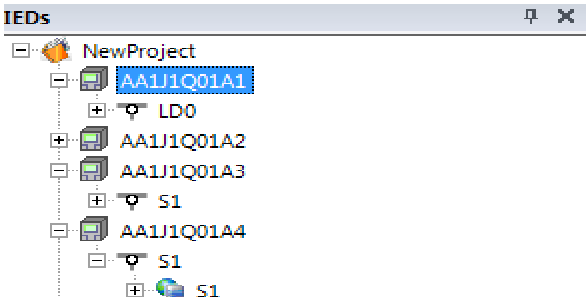
What is a GOOSE message?

Descr.	DataSet	Name	Identifier.	Config. Ref.	Type
	raw_IO	gcb_IO1	gcb_IO1	1	GOOSE
	PROTEC	PROTEC	IED1	1	GOOSE

Descr.	MAC Address	APPID	VLAN ID	VLAN Prio	MinTime	MaxTime
01-0C-CD-01-00-	01-0C-CD-01-00-03	0003	000	4	4	1000

- Once Data Set is created the GOOSE Control Block must be defined
    - MAC Address: Multicast address for GCB
    - APPID: filtering criteria
    - Application Identifier: used to subscribe to the message
    - DataSet: information being sent

What is a GOOSE message?



Drag a column header here to group by that column.

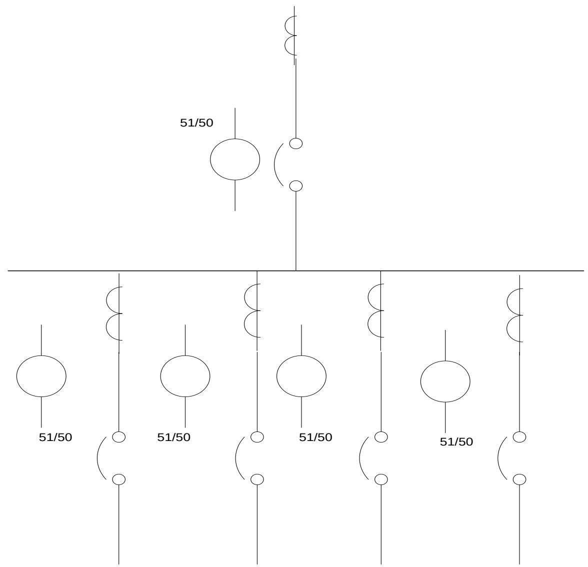
	IED Name	LD	LN	GCB	Attached Dataset	AA1J1Q01A1 (LD0)	AA1J1Q01A2 (S1)	AA1J1Q01A3 (S1)	AA1J1Q01A4 (S1)	AA1J1Q01A5 (S1)
▶	AA1J1Q01A1	LD0	LLN0	gcb_A	PROTEC		x	x	x	x

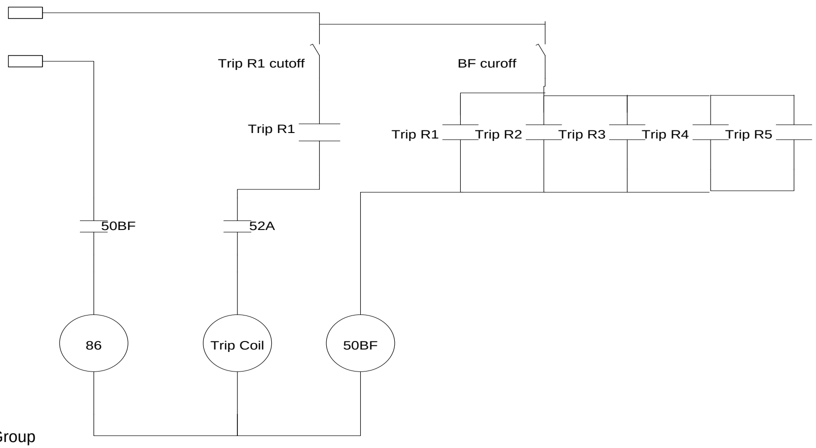
	Dataset Entries	FC	Attr.
	LD0.DPHHPTOC1.Op.general	ST	1

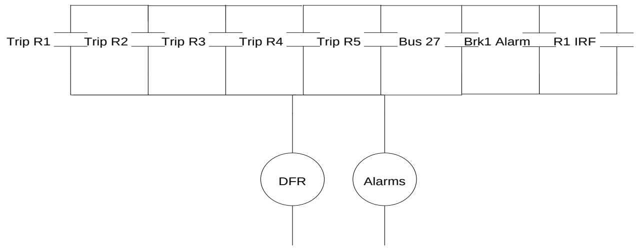
What is a GOOSE message

Sample applications

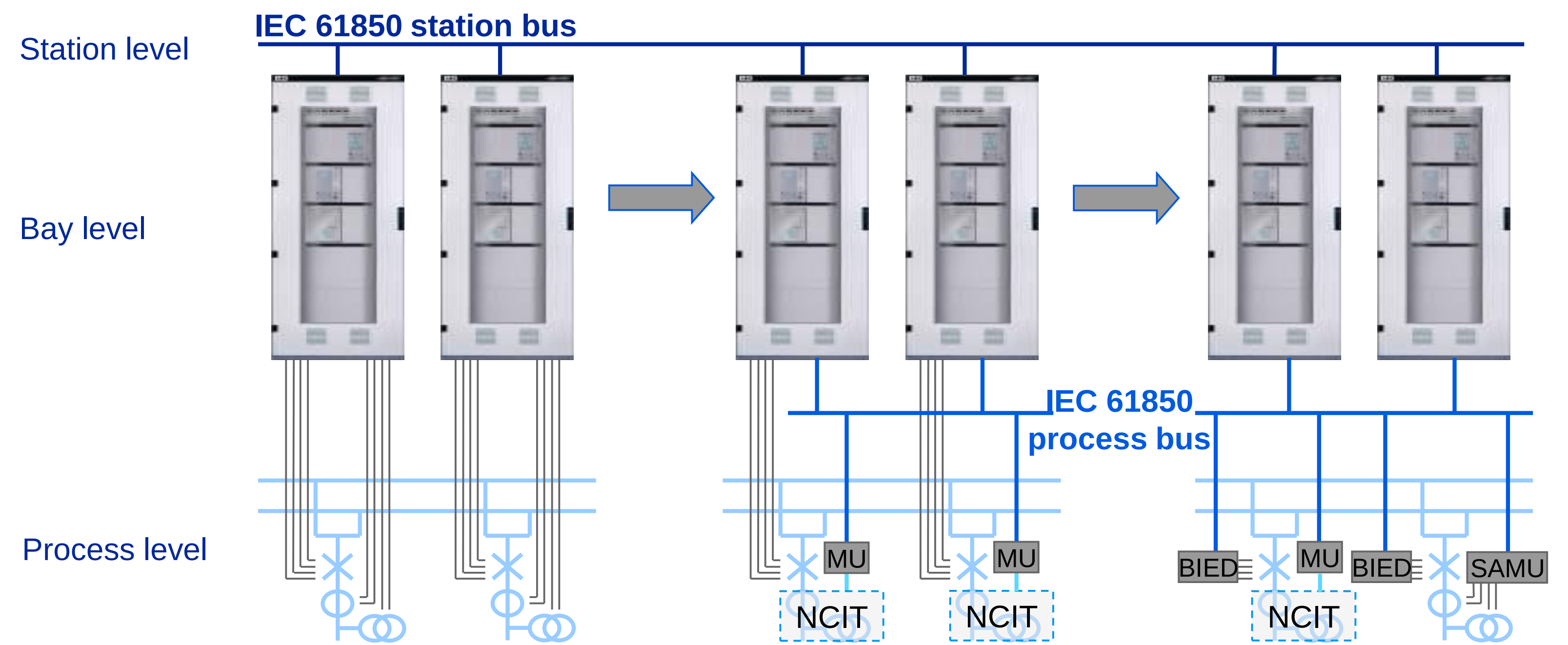
- Anything that requires the exchange of information within relays (done today via hardwired connections)
- Breaker Failure
- DFR
- Transfer Scheme
- Reclosing in multi breaker arrangements







Introduction to process bus
What is process bus



Conventional connections to CT/VT and drives

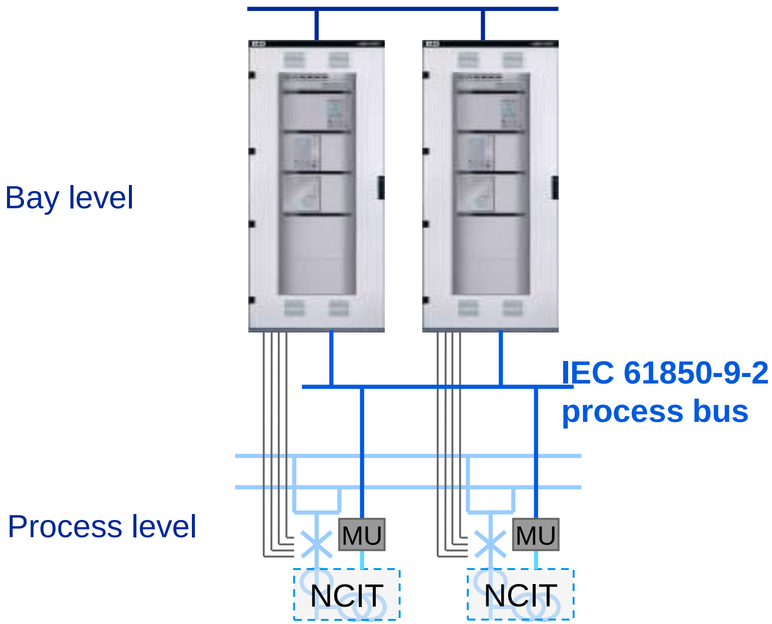
Process bus to merging units for current and voltage sensors

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

MU = Merging Unit
NCIT = Non Conventional Instrument Transformer

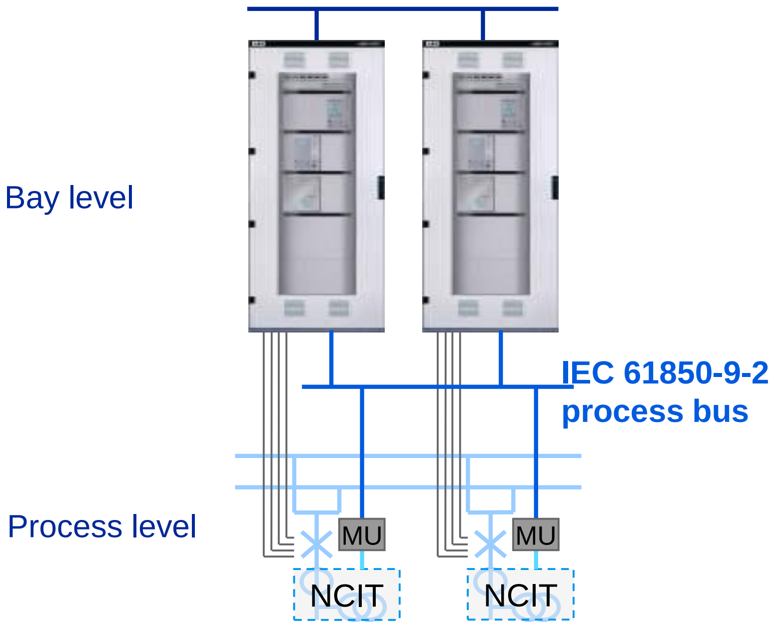
SAMU = Stand-alone Merging Unit
BIED = Breaker IED

Introduction to process bus
What is 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

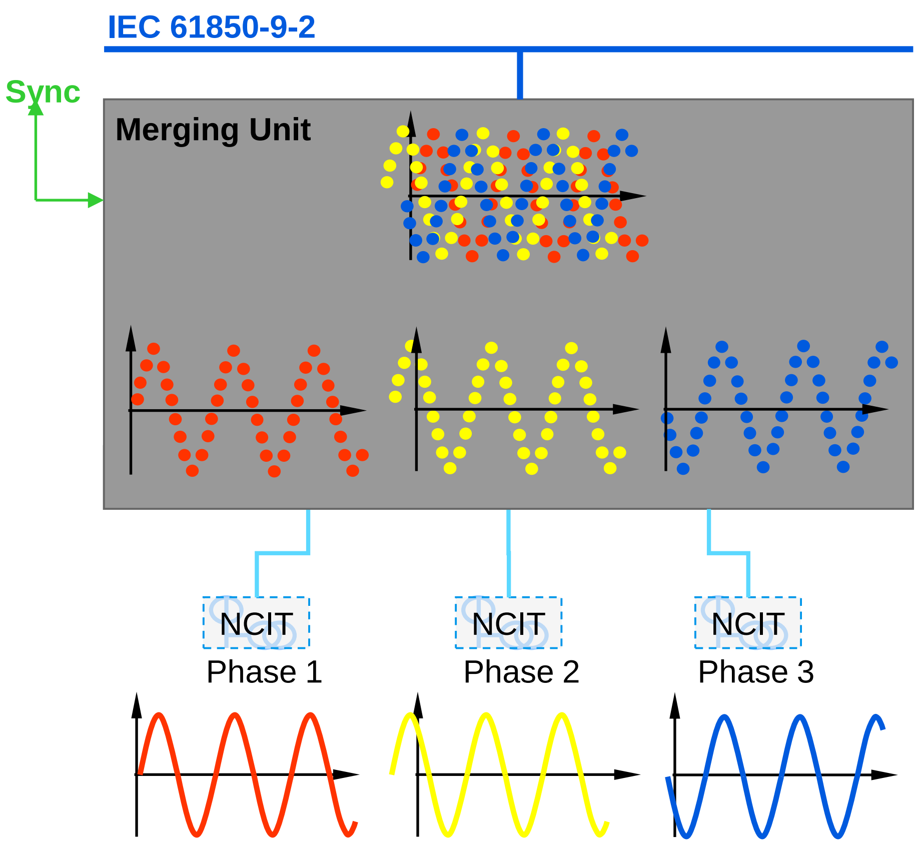
Introduction to process bus
IEC 61850-9-2 standard and implementation guideline

- **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
Differences - IEC standard and implementation guideline

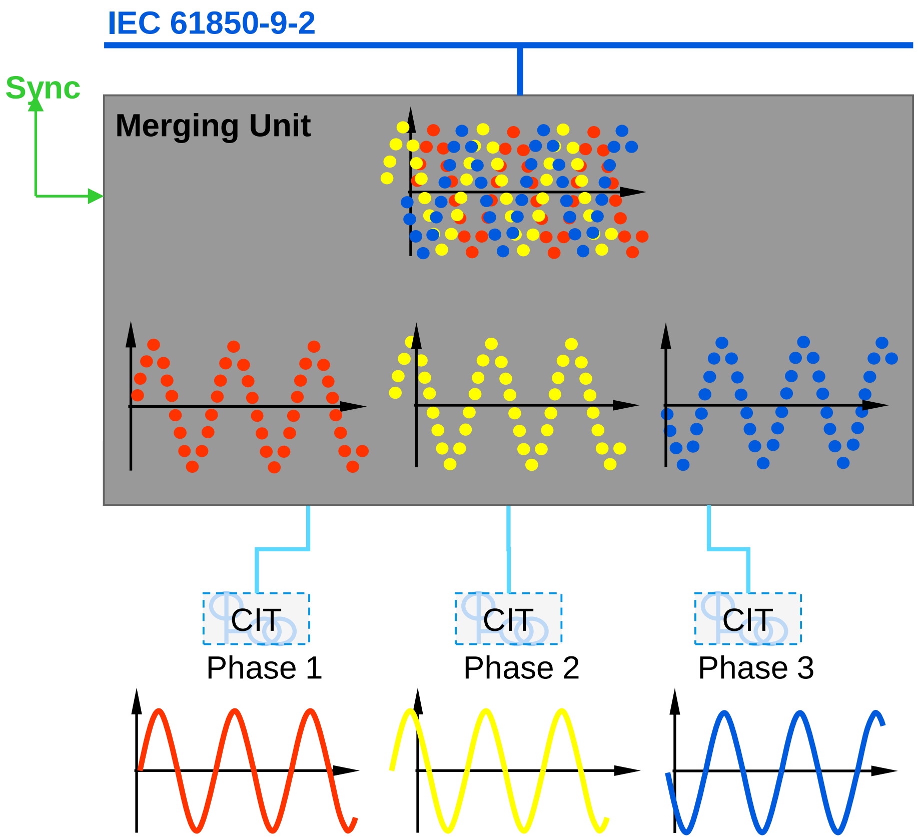
Area	Standard IEC 61850	Implementation guideline (IEC 61850-9-2LE)
Sampling rate of analog values	Free parameter	80 samples per period for protection and metering 256 samples per period for power quality
Content of dataset	Configurable	3 phases current + neutral current 3 phases voltage + neutral voltage
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

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 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
What is a merging unit



- Interfaces to conventional instrument transformers
  - Analog signal are inputs to the MU
  - MU converts to digital signals on the process bus

Benefits against conventional technology
Process bus

Increased operational safety

- Handling of CT and VT circuits is obsolete in the control house
- Isolation from process

Reduced life cycle costs

- Permanent real-time system supervision increases system availability by increasing maintenance cycles and reducing outage times

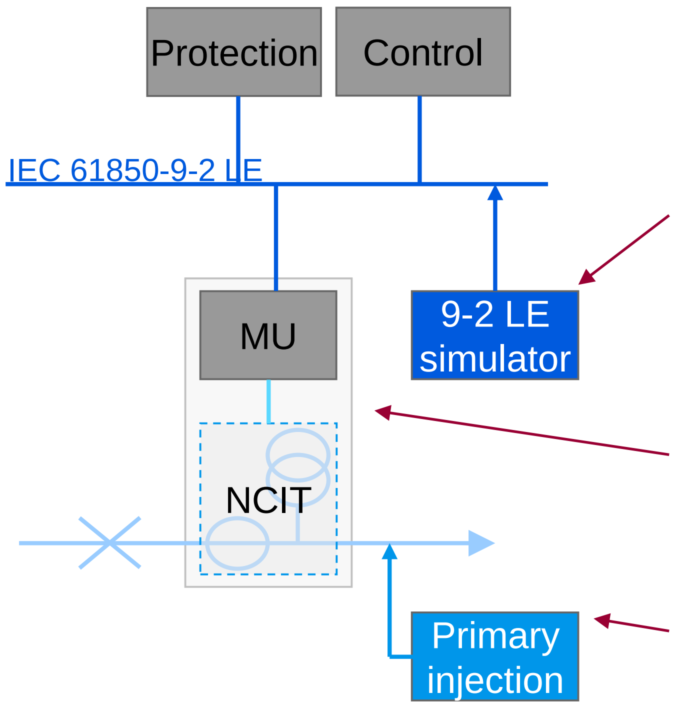
Reduced copper cabling

- By replacing parallel copper wires with optical process bus

Future-proof interoperable design

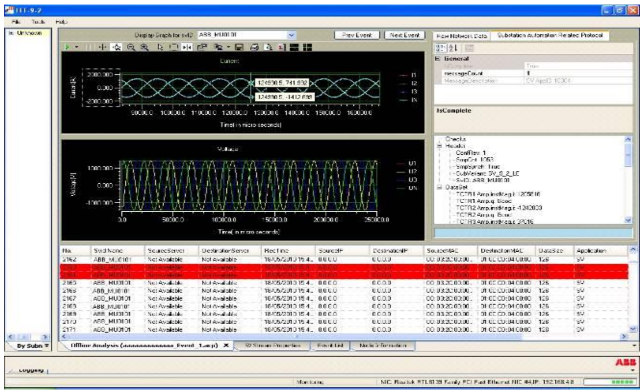
- By applying the established IEC 61850 standard

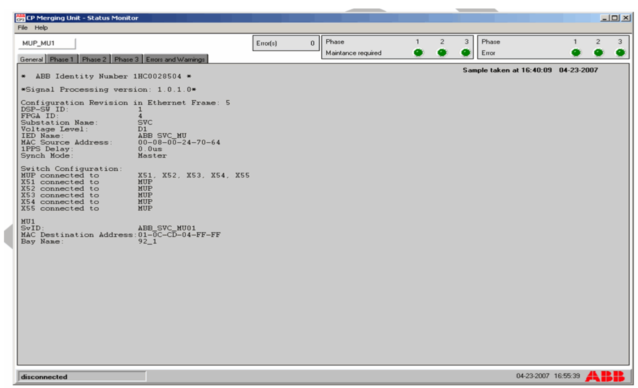
Testing and maintenance
Impact on protection and control testing



- "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 U/I, by
    - NCIT
    - Merging unit
  - Primary injection
  - Primary injection for stability and directional tests

Testing and maintenance
Tool support





Software replaces multimeter

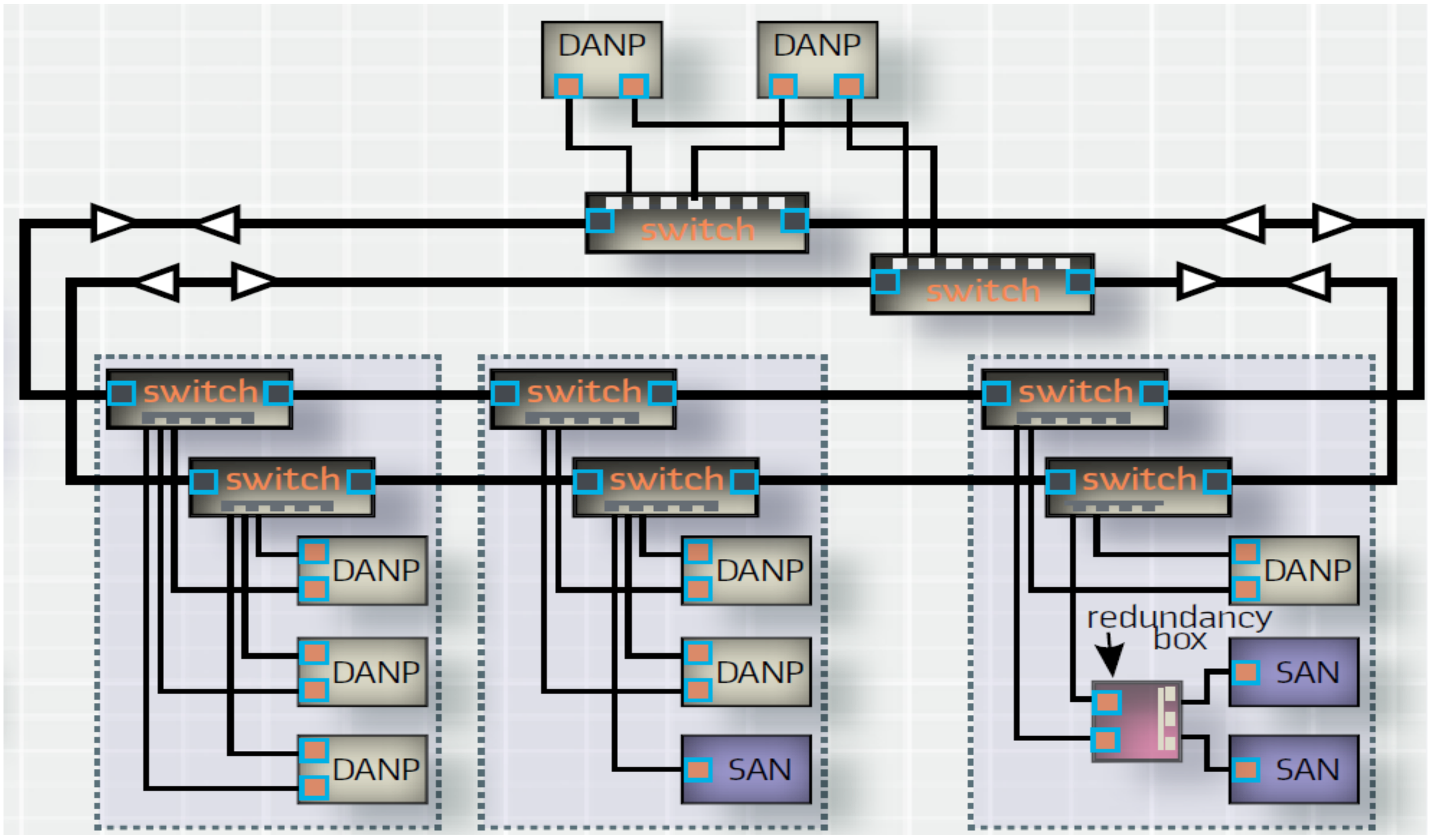
- Intelligent software for the collection, display and evaluation of sampled value streams
  - Oscilloscope display of U/I values
  - Phasor diagram
  - Quality information of all values
- Built-in diagnostic functions in sensors, merging units and IEDs for supervision of:
  - Device health status
 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

Reliability of network

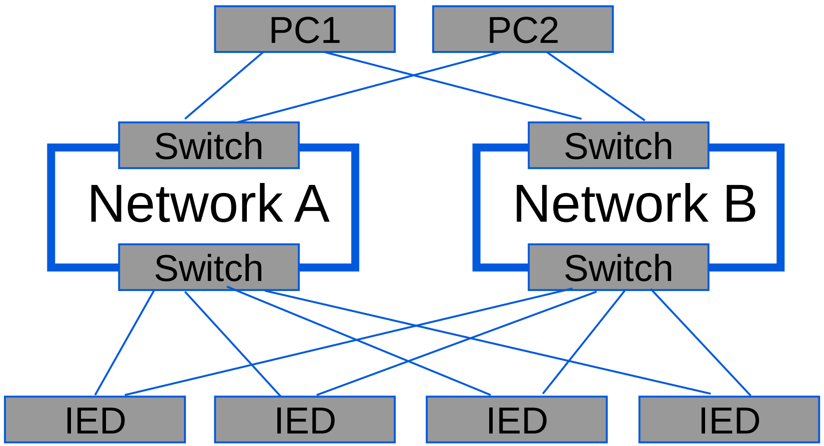
Define a network structure

- Depending on the application of GOOSE messages the network infrastructure now becomes part of the P & C team
- Switches must comply to the same quality and performance standards as other electronic P & C equipment (Dielectric, SWC, RFI, etc).
- Redundancy (Parallel Redundancy Protocol)

Reliability PRP



Parallel Redundancy Protocol (PRP)
Principle



- Operation Mode
  - 2 Ports active
  - Messages are sent / received simultaneously on both ports
  - Switch over time 0ms
- Advantages
  - No recovery time
  - No messages are lost
  - Network redundancy (Network A and B)
  - IEDs are not active part of the network
  - Standard according IEC 61850-8-1/9-2 Edition 2

Moving ahead: Edition 2

- Starting in 2009 TC57 started to publish Edition 2 of some parts of IEC 61850
- Most parts of the standard where revised
- Several new parts were added as part of the standard
  - Modeling
  - Protocols
- Standard renamed from **Communication networks and systems in substations** to **Communication networks and systems for *power utility automation*** highlighting the influence and reach of the standard

Moving ahead: Edition 2

Edition 1	Edition 2
Part 1: Introduction and overview	Part 1: Introduction and overview
Part 2: Glossary	same
Part 3: General requirements	Part 3: General requirements
Part 4: System and project management	Part 4: System and project management
Part 5: Communication requirements for functions and device models	Part 5: Communication requirements for functions and device models
Part 6: Configuration description language for communication in electrical substations related to IEDs	Part 6: Configuration description language for communication in electrical substations related to IEDs
Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models	Part 7-1: Basic communication structure for substation and feeder equipment – Principles and models
Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)	Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)
Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes	Part 7-3: Basic communication structure for substation and feeder equipment – Common data classes
Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes	Part 7-4: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes
Part 8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3	Part 8-1: Specific Communication Service Mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3	Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3
Part 10: Conformance testing	Part 10: Conformance testing

Moving ahead: Edition 2

Per 61850 part 1 Ed. 2, compared to the first edition, this second edition introduces:

- the model for statistical and historical statistical data,
- the concepts of proxies, gateways, LD hierarchy and LN inputs,
- the model for time synchronisation,
- the concepts behind different testing facilities,
- the extended logging function.

It also clarifies the following points:

- the use of numbers for data extension,
- the use of name spaces,
- the mode and behavior of a logical node,
- the use of range and deadbanded values,
- the access to control actions and others.

Moving ahead: Edition 2

In summary:

- Addresses TISSUES
- Improves interoperability
- More support for testing
- Mentions standards for network redundancy (HSR/PRP)
- New CDCs
- New Logical nodes
- 2 new SCL files:
  - IID (instantiated ied description)
  - SED (system exchange description
- Reaches outside the substation

Market requirements have been driving …

- Cost reduction in design, construction and operation
- Improved power system reliability and safety
- Safeguarding of investments
- A global, open standard
- The standard shall be future-proof, providing long term stability
- Interoperability between IEDs from different vendors
- Fit all types and sizes of substations and architectures

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