MONDAY, JUNE 22, 2020

IEC61850 and Ethernet Redundancy

Introduction and Application

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IEC 61850 and Ethernet Redundancy

- Introduction
- IEC 61850 Standard Scope
- Data Modeling Approach
- Communication Services in Substation
- GOOSE and Sample Values
- Engineering
- Conformance Testing
- Ethernet Redundancy
- Summary
- Questions and Answers

IEC 61850 and Ethernet Redundancy

IEC 61850 Protocol

IEC 61850 and Ethernet Redundancy

Much more than a protocol

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

Standardizing of function/equipment, data attributes & location within the system

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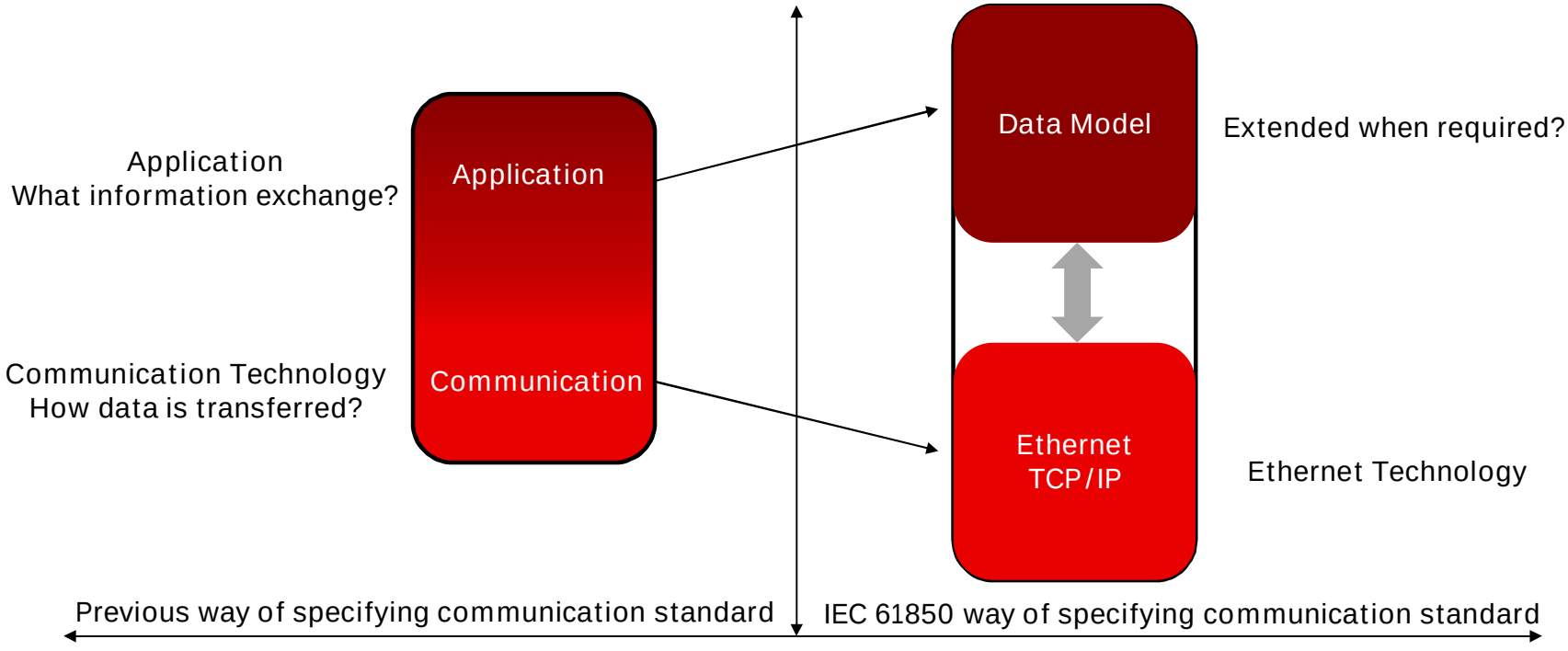
Why IEC 61850 is unique?



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IEC 61850 standard scope

WHAT?	What is Communicated? Data Model “Vocabulary”, “Words” of the communication
HOW?	How it is Communicated? Communication Services “Grammar”, “Structure” of the communication
BY WHAT?	By What is Communicated? Mapping (Protocols) “Channel”, “Medium” of the communication
ENGINEERING	Definition of the communication between configuration of tools of different vendors SCL (System Configuration Language)
TESTING	To ensure interoperability, Conformance/Performance/Functional Testing

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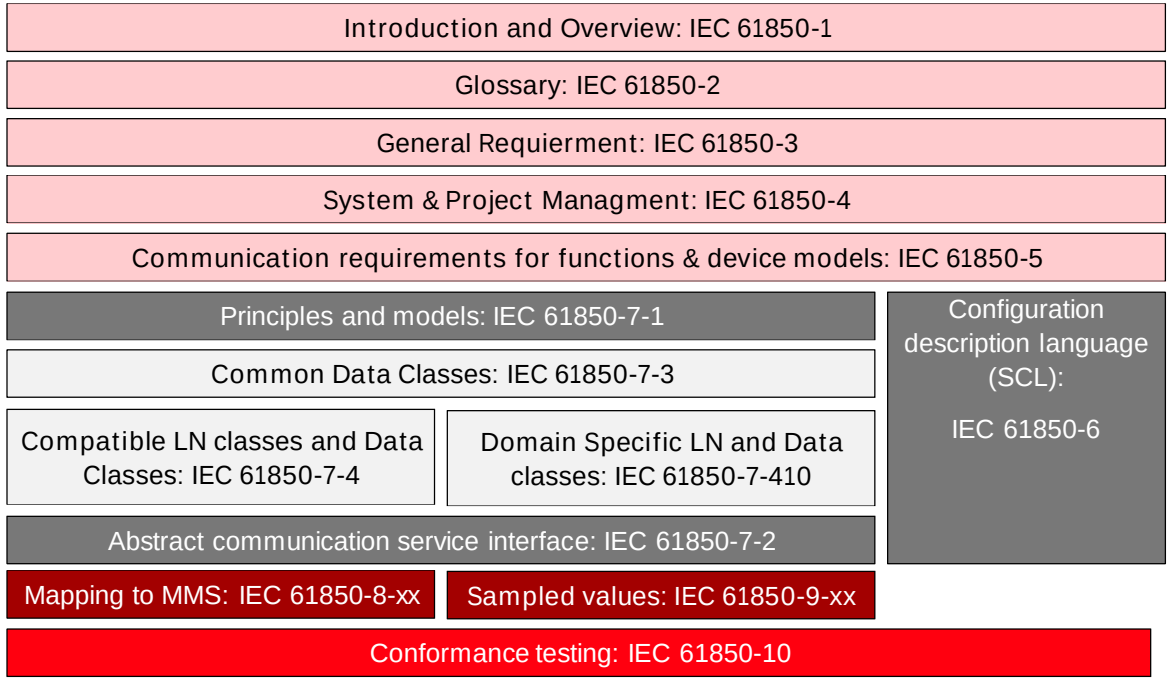
Structure of IEC 61850

Legend

- System aspects
- Configuration definition
- Data models and Basic communication structure
- Mapping to real Communication Networks
- Testing



IEC 61850 and Ethernet Redundancy

Latest parts of IEC 61850

Part 1: Introduction & overview

Part 2: Glossary

Part 3: General requirements

Part 4: System & project management

Part 5: Communication requirements for functions & device models

Part 6: Configuration description language for communication in electrical substations related to IEDs

Part 7-1: Basic communication structure – Principles & models

Part 7-2: Basic communication structure – Abstract communication service interface (ACSI)

Part 7-3: Basic communication structure – Common data classes

Part 7-4: Basic communication structure – Compatible logical node classes & data classes

Part 7-410: Hydroelectric power plants – Communication for monitoring & control

Part 7-420: Basic communication structure – Distributed energy resources logical nodes

Part 7-5: IEC 61850 – Modelling concepts[1]

Part 7-500: Use of logical nodes to model functions of a substation automation system[1]

Part 7-510: Use of logical nodes to model functions of a hydro power plant

Part 7-520: Use of logical nodes to model functions of distributed energy resources[1]

Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 & ISO 9506-2) & to ISO/IEC 8802-3

Part 80-1: Guideline to exchange information from a CDC based data model using IEC 60870-5-101/104

Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3

Part 90-1: Use of IEC 61850 for the communication between substations

Part 90-2: Using IEC 61850 for the communication between substations & control centres[1]

Part 90-3: Using IEC 61850 for condition monitoring[1]

Part 90-4: Network Engineering Guidelines - Technical report[1]

Part 90-5: Using IEC 61850 to transmit synchrophasor information according to IEEE C37.118

Part 10: Conformance testing

IEC 61850 consists of the above parts, under the general title *Communication networks and systems for power utility automation* (all parts may have not been published yet).

[1] Under consideration.

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Edition 1 and 2 differences in general

Edition 1

- The first parts of the standard SERIES IEC 61850 have been published between 2001 & 2004.
- These standards was foreseen for Substation automation only

Edition 2

- More primary equipment to be modelled, hierarchical modeling functions, e.g. bay protection / distance protection / protection zone / impedance protection
- Broadens the application space of the base standard (Substation automation) to further application areas.
- Added more details & more options for the available communication redundancy protocols, available client services, limits of data flow engineering
- Allowing a more fitting IED selection as well as a more secure IED system engineering by a system tool

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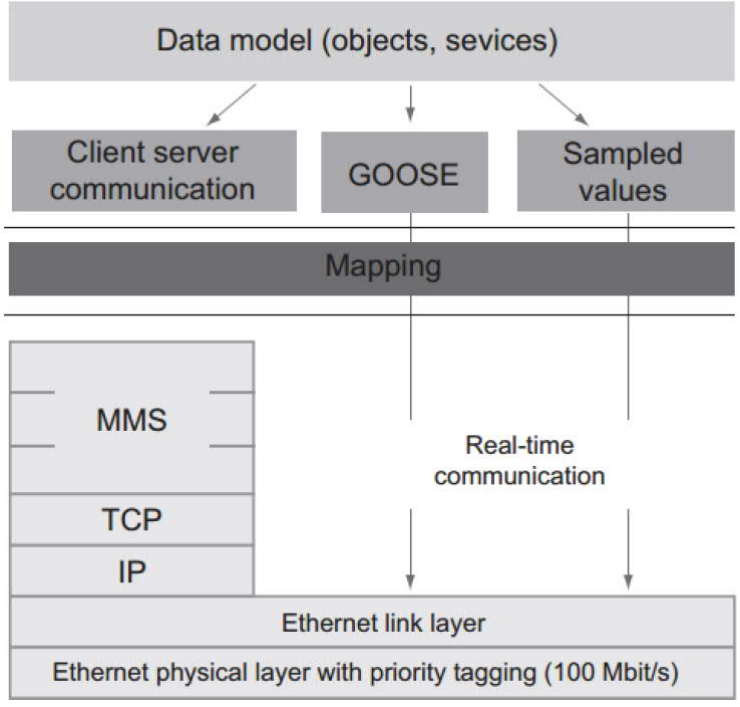
Communication stacks and mapping used in IEC 61850



- The standard defines an XML description language for substation automation systems.
- The language facilitates efficient integration of devices into systems in an automated fashion.
- Additionally the standard supports a comprehensive & consistent system definition & engineering, which makes not only the devices, but also their tools & systems interoperable

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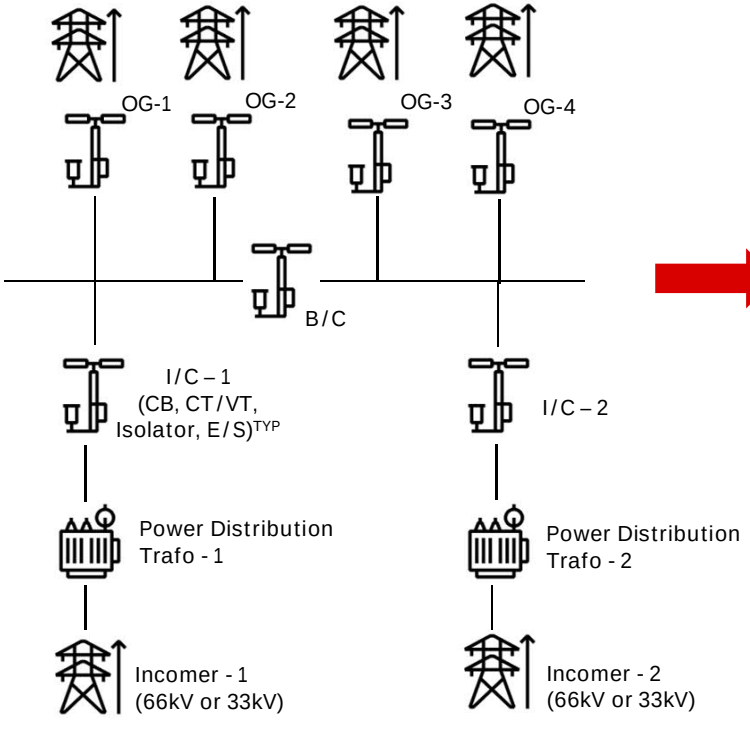
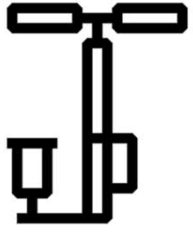
Data modeling approach

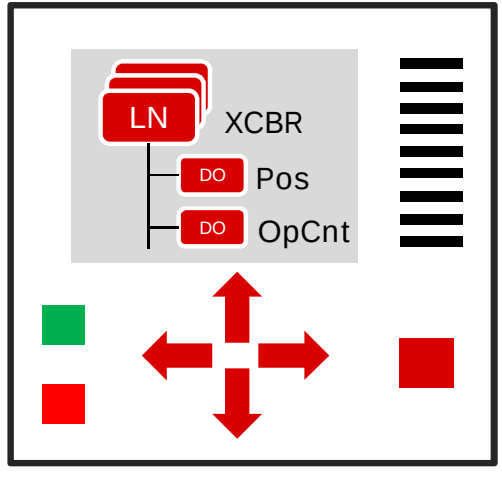


Real World Device



Circuit Breaker

Virtual World
Device Modelled in the Data
Model of IEC 61850



Numerical Relay

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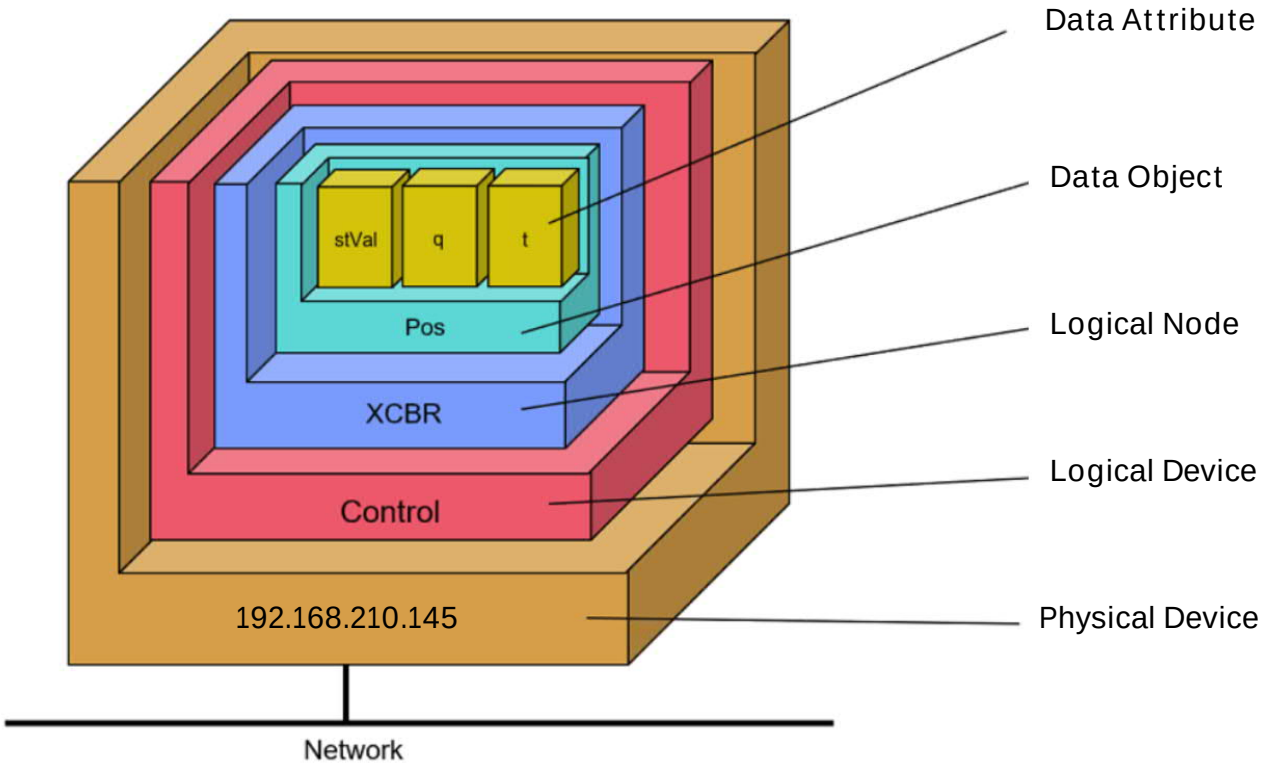
Data modeling approach contd.



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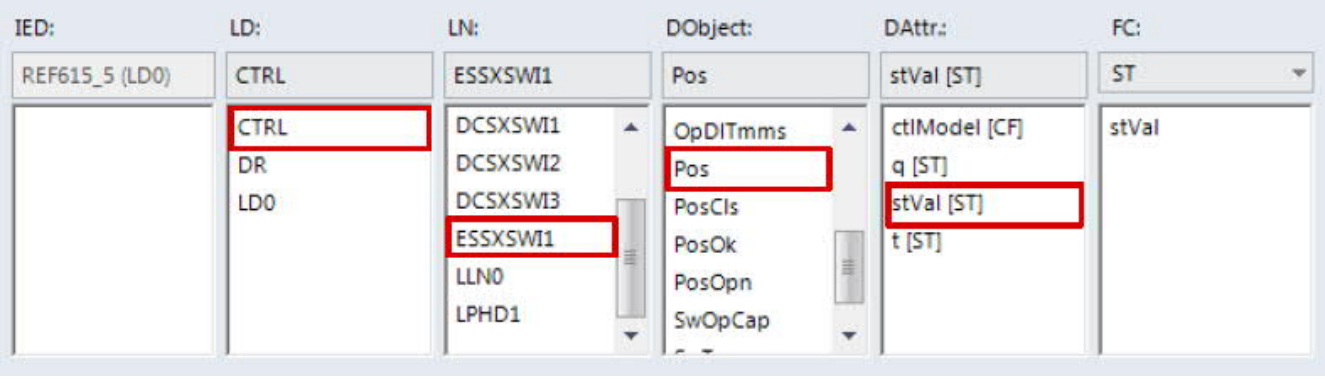
Data modeling approach example

CTRL.ESSXSWI1.Pos.stVal



Logical Device represents a function group
Logical Node contains separate function
Data Object specifies a part of information provided by function
Data Attribute keeps a particular value

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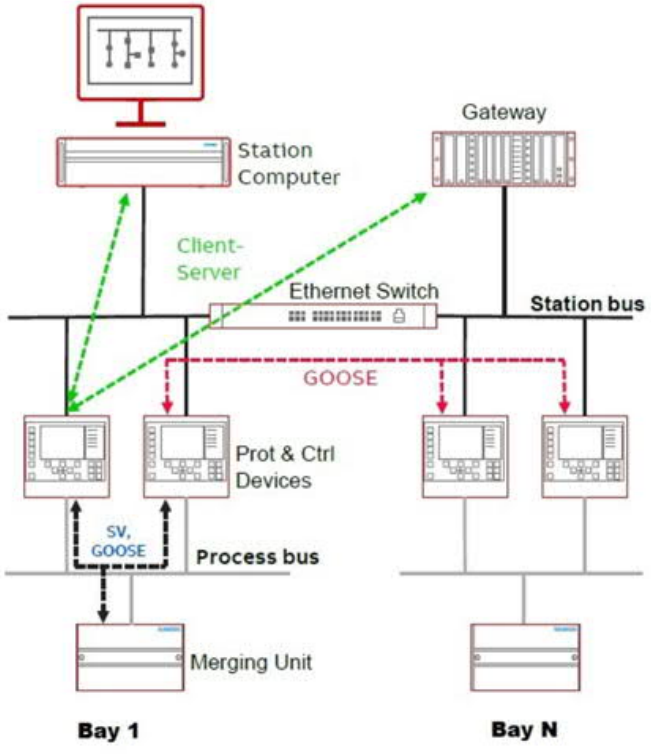
Communication services in substation



- Thanks to IEC 61850-8-1 part which allows the elimination of copper wires between relays on horizontal level i.e. relay-to-relay communications - substation bus & IEC 61850-9-2LE which allows sharing of digitized information from instrument transformers or sensors in a standardized way to other relays- process bus. These services are classified as:

Client-Server Service:

- MMS traffic defined in IEC 61850-8-1, which allows an MMS client such as the SCADA, an OPC server or a gateway to access “vertically” all IED objects. This traffic flows both on the station bus & on the process bus.

Real Time Service:

- GOOSE traffic defined in IEC 61850-8-1, which allows IEDs to exchange data “horizontally” between the bays or “vertically” between process level & bay level, especially for the status signals & tripping signals, & often for interlocking. This traffic flows normally over the station bus and/or the process bus.
- SV (Sample Value) traffic defined in IEC 61850-9-2, which carries voltage and current samples. This traffic flows normally on the process bus but can also flow over the station bus, for instance, for busbar protection, centralized protection & control & phasor measurement.

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Key difference between various services

	Client / Server Services	Real Time Services
Task	SCADA / HMI	Device to Device Communication
Key Properties	Not time critical, association between client – server, unicast communication	Time critical, multicast communication
Participants	1 client + 1 server	1 Publisher + X Receiver
Example	• Control • Reports IEC 61850 Services / MMS Services LogicalDeviceDirectory / GetNameList GetAllDataValues / Read GetDataValues / Read SetDataValues / Write GetDataDirectory / GetNameList GetDataDefinition / GetVariableAccessAttributes GetDataSetValues / Read SetDataSetValues / Write …..	• GOOSE (Generic Object Oriented System Events) • Sample Value (SV)

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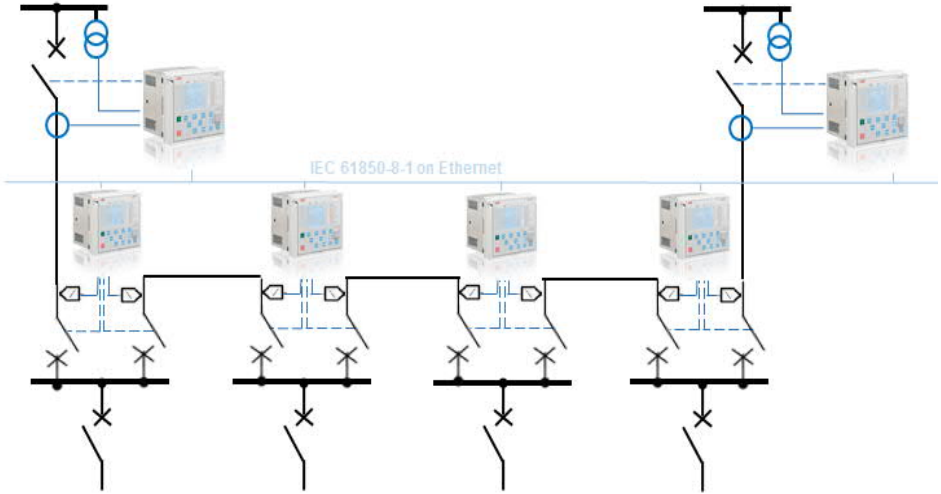
Generic Object Oriented System Events (GOOSE)



- Standardized horizontal communication
- Replaces hard-wiring between Relays & Controllers
- GOOSE is used to broadcast events between Relays in a substation.
- The GOOSE communication link between the Relays is supervised by sending data cyclically.
- Ethernet technology offers a fast and reliable station bus for transfer of data.

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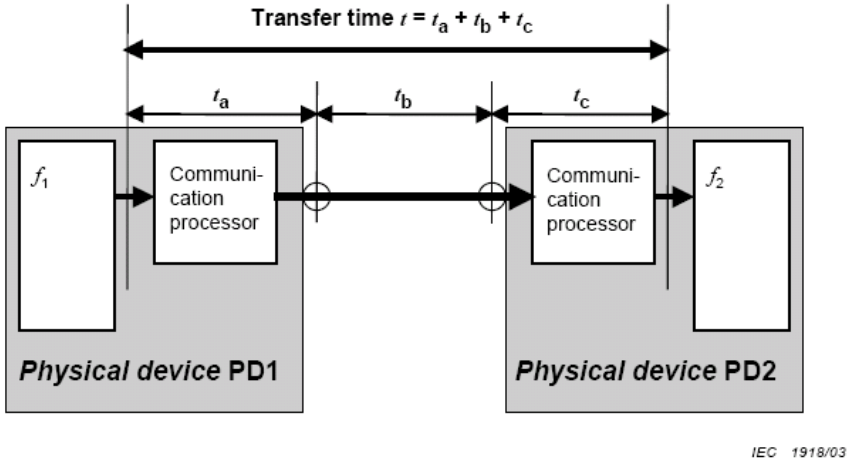
GOOSE performance



- GOOSE speed requirements from IED to IED as defined by the standard Type 1 (fast messages)
  - Type 1A (tripping)
    - Class P2/3: <3 ms (transmission)
    - Class P1: <10 ms (distribution)
  - Type 1B (others)
    - Class P2/3: <20 ms
    - Class P1: <100 ms
- Following the IEC 61850 standard means that peer-to-peer signalling is faster than traditional hard-wiring for Type 1A Class P1 or Class P2/3.
- Reduced wiring & faster response times.

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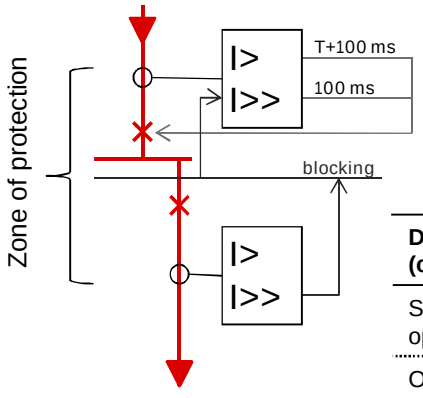
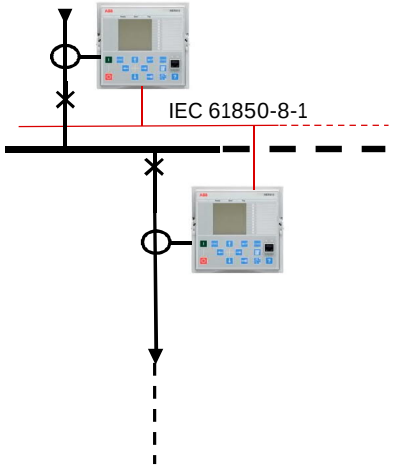
Reverse Blocking protection: GOOSE vs. conventional wiring

Conventional



Delay setting with inst. O/C protection (conventional approach)	
Safety marginal, e.g. delay in operation due to CT saturation.	**20…40 ms**
O/C protection start delay + output relay's delay	**<40 ms**
Start delay with receiving relay + retarding time for the blocking signal *)	**<40 ms**
ALL TOGETHER	**100…120 ms**

GOOSE



Delay setting with inst. O/C protection (REF615 GOOSE approach)	
Safety marginal, e.g. delay in operation due to CT saturation.	**20…40 ms**
O/C protection start delay	**20 ms**
Retardation time of inst. O/C stage blocking	**5 ms**
GOOSE delay (Type 1A, Class P1)	**<10 ms**
ALL TOGETHER	**55…75 ms**

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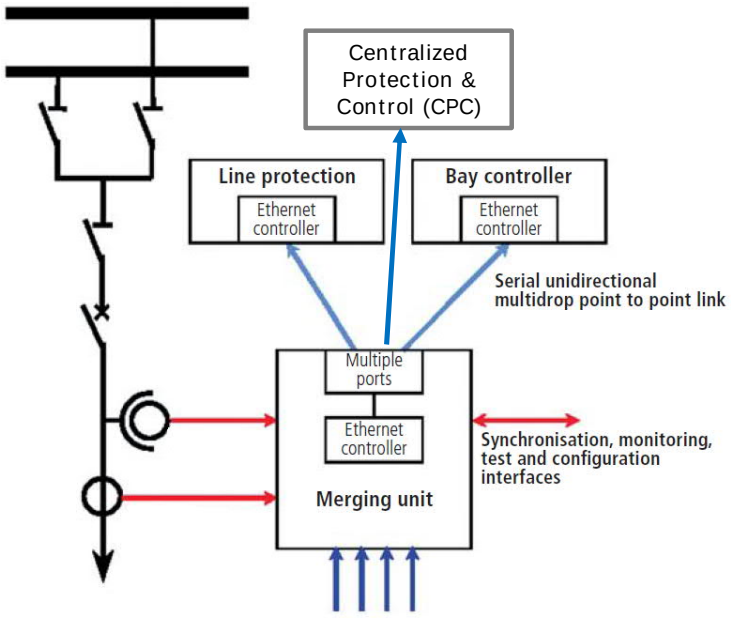
Sample Values

Sample Value Concept



Sample Value Based Merging Unit / Relay

- Merging Unit: The interface of the instrument transformers (both conventional & non-conventional) with relays is through a device called Merging Unit (MU) or relays with MU capabilities for Centralized Protection.
- MU is defined in IEC 61850-9-1 as interface unit that accepts current transformer (CT)/voltage transformer (VT) & binary inputs (BI) & produces multiple time synchronized serial unidirectional multi-drop digital point to point outputs to provide data communication via the logical interfaces.
- IEC 61850-9-2LE or IEC 61869-9 defines a sampling frequency of 4 kHz (in 50 Hz networks) & 4.8 kHz (in 60 Hz networks) for raw measurement values to be sent to subscribers (CPC unit or protection relay in some cases) to emulate the signals from instrument transformers or sensors. The relays or CPC unit will then be able to run its protection & measurement functions without having to make any adaptions.

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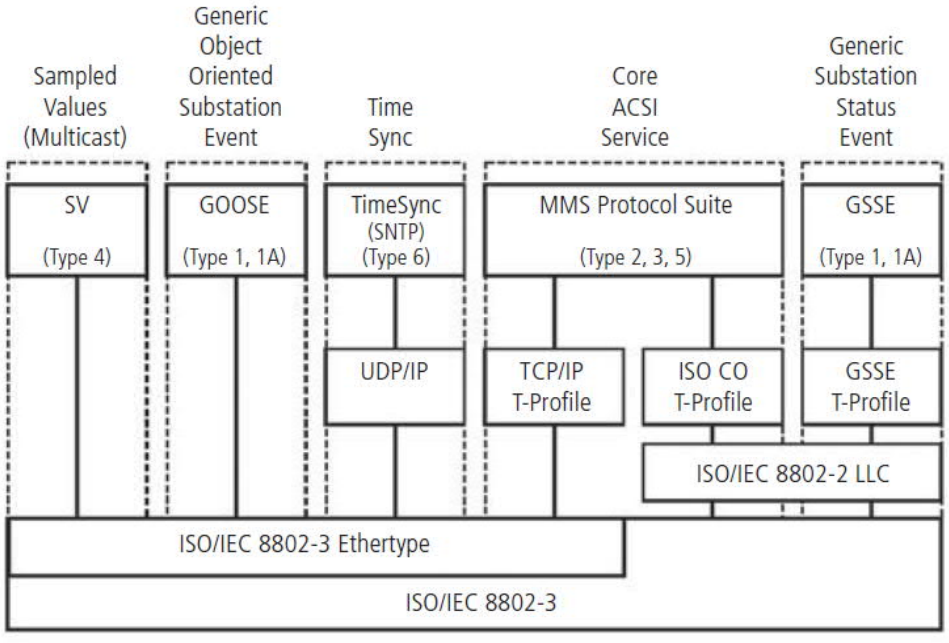
Specific Communication Mapping



- The abstract data & object models of IEC 61850 define a standardized method of describing power system devices that enables all Relays to present data using identical structures that are directly related to their power system function.
- The Abstract Communication Service Interface (ACSI) models of IEC 61850 define a set of services & the responses to those services that enables all IEDs to behave in an identical manner from the network behavior perspective.
- In addition to the mapping to the application layer, Part 8.1 defines profiles for the “other” layers of the communication stack that are dependent on the service provided. The Sampled Values & GOOSE applications map directly into the Ethernet data frame thereby eliminating processing of any middle layers; the MMS Connection Oriented layer can operate over TCP/IP or ISO; all data maps onto an Ethernet data frame using either the data type “Ethertype” in the case of Sampled Values, GOOSE, TimeSync, & TCP/IP or “802.3” data type for the ISO & GSSE messages.

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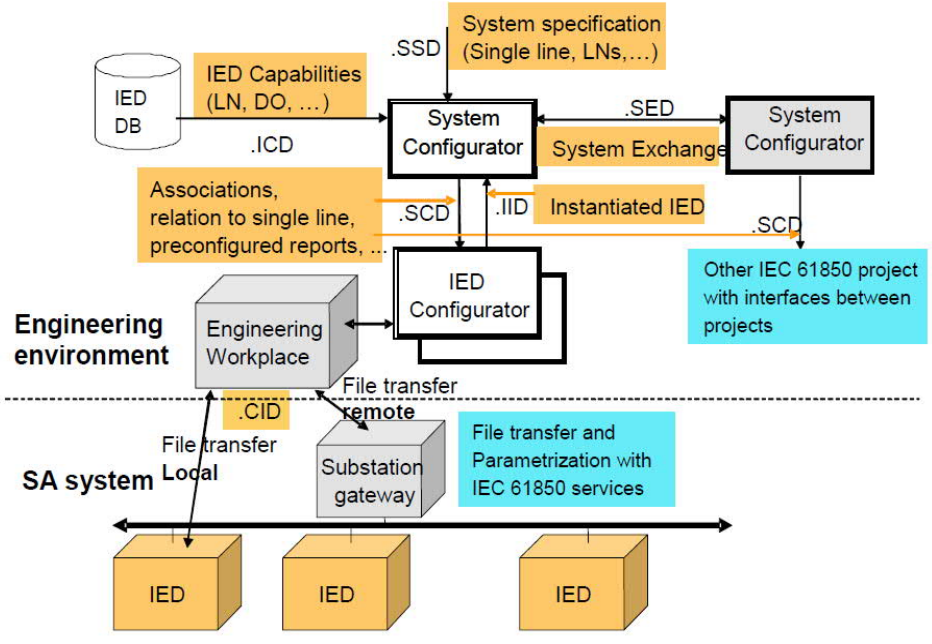
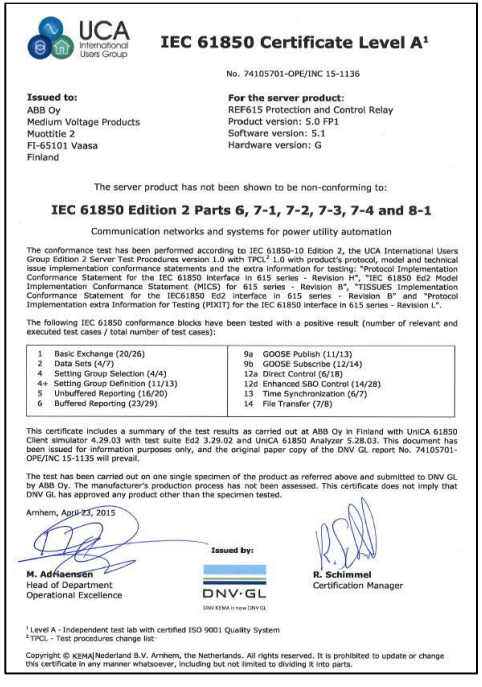
Engineering – SCL Concept



- IEC 61850-6 specifies a Substation Configuration Language (SCL) that is based on the eXtensible Markup Language (XML) to describe the configuration of IEC 61850 based systems.
- The various SCL files include system specification description (SSD), IED capability description (ICD), substation configuration description (SCD), & configured IED description (CID) files. All these fi les are constructed in the same methods & format but have different scopes depending on the need.
- SCL enables the sharing of IED configuration among users & suppliers to reduce or eliminate inconsistencies & misunderstandings in system configuration & system requirements. Users can provide their own SCL files to ensure that IEDs are delivered to them properly configured.

IEC 61850 and Ethernet Redundancy

Importance of Conformance Testing



UCA International Users Group

IEC 61850 Certificate Level A[1]

No. 74105701-OPE/INC 15-1136

Issued to:
ABB Oy
Medium Voltage Products
Muottitie 2
FI-65101 Vaasa
Finland

For the server product:
REF615 Protection and Control Relay
Product version: 5.0 FP1
Software version: 5.1
Hardware version: G

The server product has not been shown to be non-conforming to:

IEC 61850 Edition 2 Parts 6, 7-1, 7-2, 7-3, 7-4 and 8-1

Communication networks and systems for power utility automation

The conformance test has been performed according to IEC 61850-10 Edition 2, the UCA International Users Group Edition 2 Server Test Procedures version 1.0 with TPCL[2] 1.0 with product's protocol, model and technical issue implementation conformance statements and the extra information for testing: "Protocol Implementation Conformance Statement for the IEC 61850 Interface in 615 series - Revision H", "IEC 61850 Ed2 Model Implementation Conformance Statement (MICS) for 615 series - Revision B", "TISSUES Implementation Conformance Statement for the IEC61850 Ed2 Interface in 615 series - Revision B" and "Protocol Implementation extra Information for Testing (PIXIT) for the IEC 61850 Interface in 615 series - Revision L".

The following IEC 61850 conformance blocks have been tested with a positive result (number of relevant and executed test cases / total number of test cases):

1	Basic Exchange (20/26)	9a	GOOSE Publish (11/13)
2	Data Sets (4/7)	9b	GOOSE Subscribe (12/14)
4	Setting Group Selection (4/4)	12a	Direct Control (6/18)
4+	Setting Group Definition (11/13)	12d	Enhanced SBO Control (14/28)
5	Unbuffered Reporting (16/20)	13	Time Synchronization (6/7)
6	Buffered Reporting (23/29)	14	File Transfer (7/8)

This certificate includes a summary of the test results as carried out at ABB Oy in Finland with UniCA 61850 Client simulator 4.29.03 with test suite Ed2 3.29.02 and UniCA 61850 Analyzer 5.28.03. This document has been issued for information purposes only, and the original paper copy of the DNV GL report No. 74105701-OPE/INC 15-1135 will prevail.

The test has been carried out on one single specimen of the product as referred above and submitted to DNV GL by ABB Oy. The manufacturer's production process has not been assessed. This certificate does not imply that DNV GL has approved any product other than the specimen tested.

Arnhem, April 23, 2015

Issued by:

M. Adriaensen
Head of Department
Operational Excellence

DNV·GL
DNV·KEMA is now DNV GL

R. Schimmel
Certification Manager

[1] Level A - Independent test lab with certified ISO 9001 Quality System
[2] TPCL - Test procedures change list

UCA International Users Group

IEC 61850 Certificate Level A[1]

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No. 74101108-MOC/INC 11-3051

Issued to:
Siemens Protection Devices Limited
North Farm Road, Hebburn,
Tyne & Wear. NE31 1LX.
United Kingdom

For the product:
Reyrolle 7SR210
Non-Directional Overcurrent Protection
Firmware Version: 7a
EN100 V04.08

Issued by: KEMA

The product has not shown to be non-conforming to:

IEC 61850-6, 7-1, 7-2, 7-3, 7-4 and 8-1

Communication networks and systems in substations

The conformance test has been performed according to IEC 61850-10 with product's protocol, model and technical issue implementation conformance statements: "7SR210 & 7SR220 PICS (R7a-7a)", "7SR210 MICS (R7a-7a)", "7SR210 & 7SR220 TICS (R7a-7a)" and product's extra information for testing: "7SR210 & 7SR220 PIXIT (R7a-7a)".

The following IEC 61850 conformance blocks have been tested with a positive result (number of relevant and executed test cases / total number of test cases as defined in the UCA International Users Group Device Test procedures v2.2b):

1	Basic Exchange (20/24)	9a	GOOSE Publish (7/12)
2	Data Sets (3/6)	9b	GOOSE Subscribe (10/10)
2+	Data Set Definition (23/23)	12a	Direct Control (5/12)
4	Setting Group Selection (2/3)	12c	Enhanced Direct Control (5/13)
5	Unbuffered Reporting (15/18)	12d	Enhanced SBO Control (10/19)
6	Buffered Reporting (17/20)	13	Time Synchronization (4/5)
6+	Enhanced buffered reporting (10/12)	14	File Transfer (4/7)

This Certificate includes a summary of the test results as carried out at Siemens in United Kingdom with UniCAsim 61850 version 3.23.02 with test suite 3.23.00 and UniCA 61850 analyzer 4.24.02 The test is based on the UCA International Users Group Device Test Procedures version 2.2b. This document has been issued for information purposes only, and the original paper copy of the KEMA report No. 74101108-MOC/INC 11-3050 will prevail.

The test has been carried out on one single specimen of the product as referred above and submitted to KEMA by Siemens Protection Devices Limited. The manufacturer's production process has not been assessed. This Certificate does not imply that KEMA has certified or approved any product other than the specimen tested.

Arnhem, 5 December 2011

M. Adriaensen
Regional Director Management & Operations Consulting

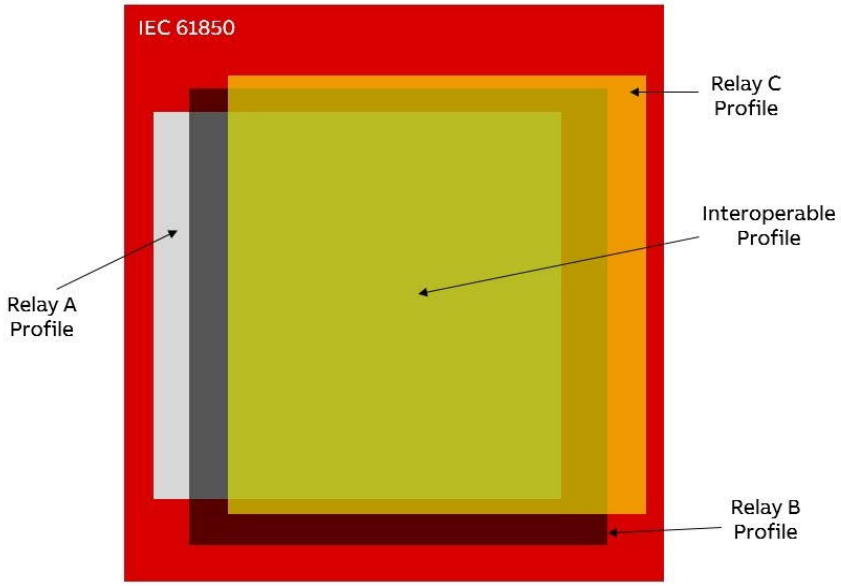
R.S. Massink
Test engineer

1 Level A - Independent Test lab with certified ISO 9000 or ISO 17025 Quality System

- Conformance Testing: For the success of multi-vendor substation automation system with IEC 61850 protocol, an effective process & set of procedures for verifying IEC 61850 products is needed. IEC 61850-10 describes the technical & documentation requirements for product conformance testing to the standard. Conformance testing of IEC 61850 based devices will provide the verification that the documentation, communication & data model specifications have been implemented correctly according to the IEC 61850 standard. The objective of conformance testing is to give confidence to users before actual system integration that certified devices from different manufacturers will inter-operate flawlessly under normal, stress & error situations. Conformance testing significantly reduces the risk of costly & time-consuming problems occurring during system integration & operation.

IEC 61850 and Ethernet Redundancy

Beyond conformance testing (Interoperability)



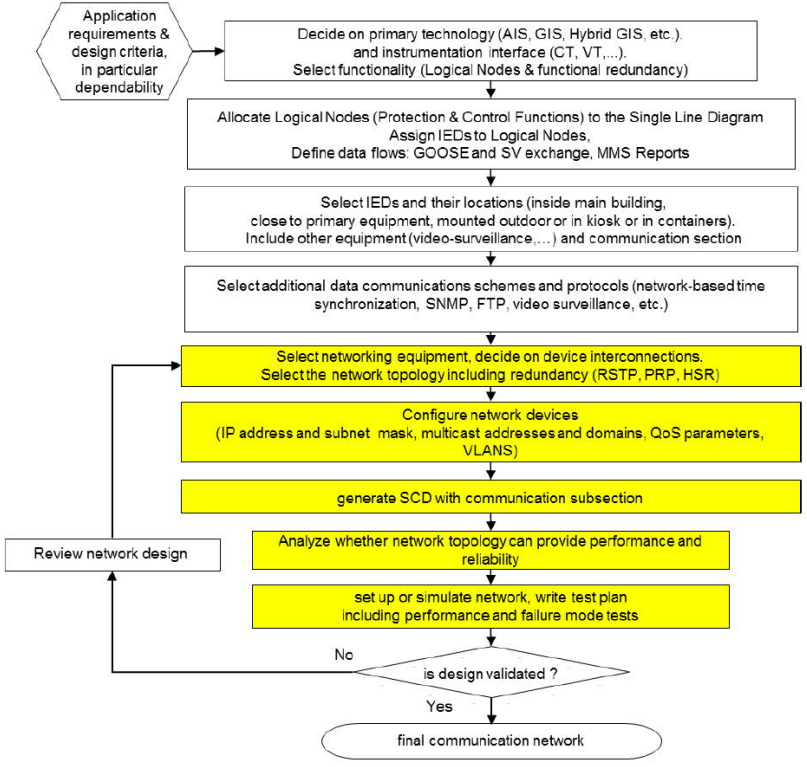
- Interoperability testing is not in the scope of the IEC standard or UCAIug accredited test labs & testing procedures. Standard conforming products from different suppliers or different products from the same supplier need not fulfill the same functional scope of supply.
- The interoperability test is testing the dynamic & inter-operable interaction of at least two IEDs in a Substation Automation System covering all potential configurations as far as possible. Also, the performance of services including delays caused by communication equipment like switches is verified. The interoperability testing in customer projects consists of project related tests, based on the customer specification for an ordered Substation Automation System.
- It is always recommended to carry out interoperability test before deciding the IEDs for the project to avoid any potential risk between specification or requirement against actual substation automation functionality. Always remember, Protection Relays can have conformance with IEC 61850 standards however still not be inter-operable in a system.

IEC 61850 and Ethernet Redundancy

Ethernet Redundancy

IEC 61850 and Ethernet Redundancy

Ethernet Redundancy



- High speed & highly reliable substation communication network is critical in any substation. IEC 61850-90-4: Communication networks & systems for power utility automation – Part 90-4: Network engineering guidelines can be handy to design such network.
- Substations operate round the clock & hardly shut down for maintenance, protection system involved must isolate the primary plant in the faulted zone immediately. Under such dynamic conditions, file & data transfer over Ethernet in a digital protection scheme, if experienced a mal-function, could spell disaster for the protection scheme.
- Utilities & industries have been striving to have reliable communications between substation assets like protection relays & substation automation systems (SAS) that can monitor, record & clear system disturbances within the least possible time.
- A usual requirement is the avoidance of any single point of failure, which implies the introduction of redundancy.

IEC 61850 and Ethernet Redundancy

Ethernet Redundancy

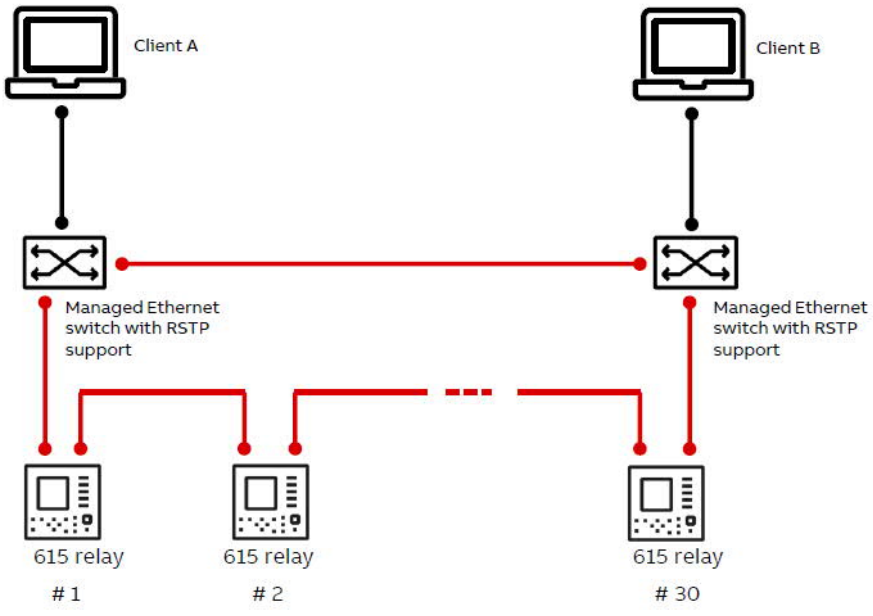
IEC 61850-5, Clause 11.4.4, Table 7

Communicating partners	Application recovery delay	Recovery delay of communication
SCADA to IED, client-server	800 ms	400 ms
IED to IED interlocking	12 ms	4 ms
IED to IED, reverse blocking		
Protection trip excluding Bus Bar protection	8 ms	4 ms
Bus Bar protection	< 1 ms	bumpless
Sampled values	Less than some few consecutive samples	bumpless

- A key parameter for redundancy network designed is how long a substation application tolerates an interruption of the communication due to recovery from a failure without consequences on the substation.
- IEC 61850-5 specifies in particular the different requirements on recovery time between station bus & process bus.
- If an IEC 61850 frame is not received in a timely manner, it loses its usefulness; & being late could be worse than being lost.
- A network should be designed from the start with full redundancy to utilize the full communication services as defined by IEC 61850.
- Numerous protocols provide partial or full network redundancy; the concepts are described in IEC 62439-1. However, we will focus on RSTP (Rapid Spanning Tree Protocol), PRP (Parallel Redundancy Protocol) & HSR (High-availability Seamless Redundancy) for IEC 61850 based substation.

IEC 61850 and Ethernet Redundancy

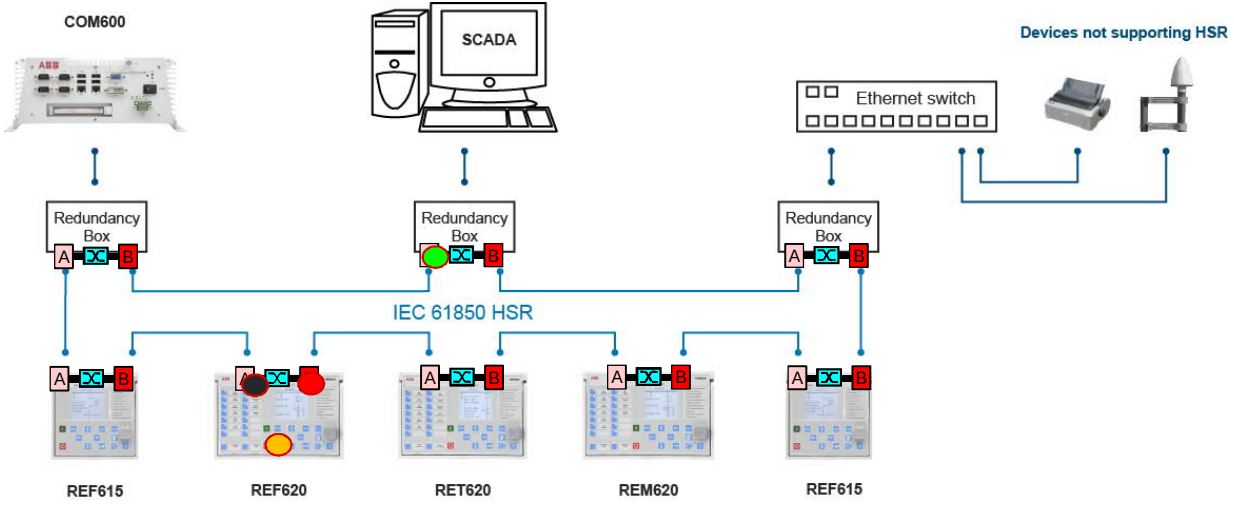
Ethernet self-healing ring topology



- RSTP is primarily intended for automatic LAN configuration & loop prevention, it provides redundancy against link & bridge failures.
- Although RSTP does not provide seamless recovery (0 msec loss of communication) however carefully engineered RSTP network with restrictions specified in IEC 62439-1:2010 can recovers fast enough (as per IEC 61850-90-4 standard, RSTP recovery time in best case scenario will be approx. 200 msec for 40 nodes) for most applications that use the station bus or non-critical IEC 61850 traffic.
- However, RSTP should not be used for traffic like time critical GOOSE messages (Type 1A, Class P1/P2) & Sample Values since as per IEC 61850-5 recovery time for such IEC 61850 services are either close to 4 msec or bumpless.
- IEC 62439 specifies in part 3 two seamless systems: PRP & HSR. The PRP & HSR protocols provide seamless recovery or zero communication frame loss & therefore can be used for demanding applications like time critical GOOSE messages and/or Sample Values.

IEC 61850 and Ethernet Redundancy

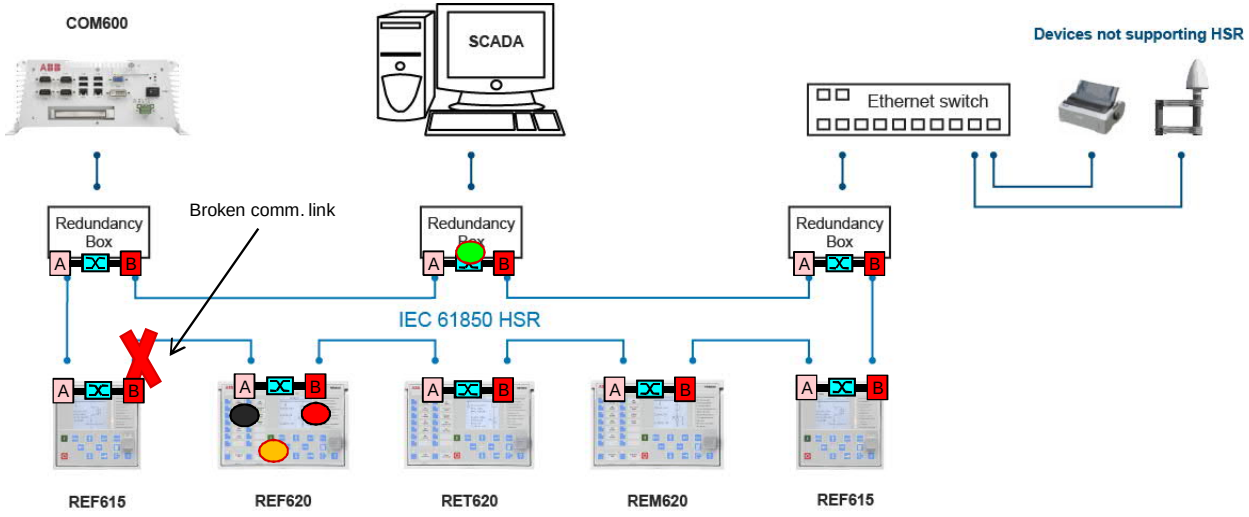
HSR - communication redundancy



- HSR (High-availability Seamless Redundancy) IEC 62439-3 Clause 5 If the ring is broken, messages will still arrive over the intact path. A broken ring is easily detected since duplicate messages are no longer received.
- Normal condition Message from IED is sent via both links (“A” & “B”) to the SCADA via HSR ring.

IEC 61850 and Ethernet Redundancy

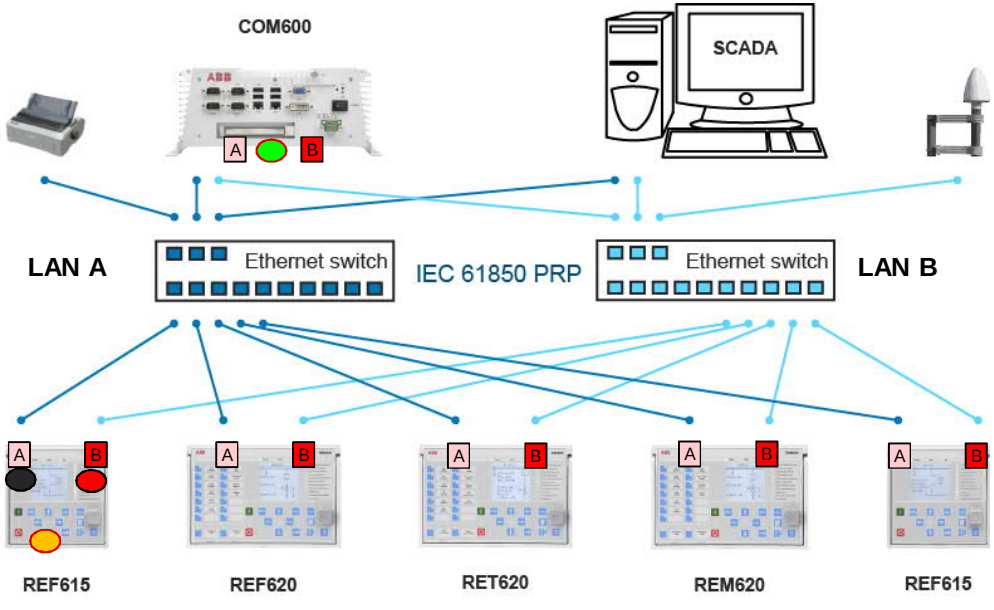
HSR - communication redundancy



- HSR (High-availability Seamless Redundancy) IEC 62439-3 Clause 5 If the ring is broken, messages will still arrive over the intact path. A broken ring is easily detected since duplicate messages are no longer received.
- Normal condition Message from IED is sent via both links (“A” & “B”) to the SCADA via HSR ring.
- Operation under failure condition Failure recognized in HSR ring (“A” link). Message is received by SCADA via healthy part of ring (“B” link)

IEC 61850 and Ethernet Redundancy

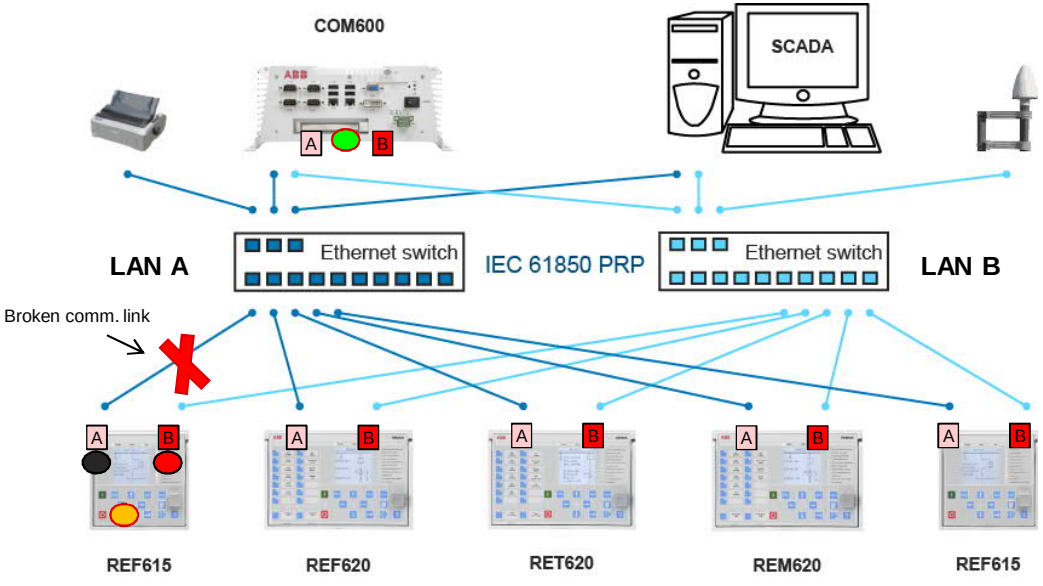
PRP- communication redundancy



- PRP (Parallel Redundancy Protocol) IEC 62439-3 Clause 4
- The communication network is fully duplicated.
- If only one packet is received, the receiver knows the other path is broken.
- Normal condition Message is received in COM600 via both parallel links (LAN “A” & LAN “B”)

IEC 61850 and Ethernet Redundancy

PRP- communication redundancy



- PRP (Parallel Redundancy Protocol) IEC 62439-3 Clause 4
- The communication network is fully duplicated.
- If only one packet is received, the receiver knows the other path is broken.
- Operation under failure condition
- Failure recognized in PRP network (LAN “A”)
- Message is received in COM600 via healthy link (LAN “B”)

IEC 61850 and Ethernet Redundancy

Summary

IEC 61850 and Ethernet Redundancy

Summary

- The features & characteristics of IEC 61850 that enable unique advantages are so numerous that they cannot practically be listed here.
- IEC 61850 enables devices to quickly exchange data & status using GOOSE & GSSE over the station LAN without having to wire separate links for each relay. This significantly reduces wiring costs by more fully utilizing the station LAN bandwidth for these signals & construction costs by reducing the need for trenching, ducts, conduit, etc.
- Thanks for Sample Values support by IEC 61850 standard, it is possible to transfer of analog information, high frequency consolidated raw voltage & current measurement packets from conventional instrument transformer or sensors between relays and/or CPC (centralized protection & control) units which offers very high level of flexibility & easy deployment of protection & control functionality in ever changing distribution gird scenarios.
- Conformance testing of IEC 61850 based devices will provide the verification that the documentation, communication & data model specifications have been implemented correctly according to the IEC 61850 standard.
- IEC 61850 standard support inter-operable & future proof substation automation & it is highly important to choose redundancy strategy from the beginning. It will be challenging to change over from one network redundancy to other i.e. RSTP to either HSR/PRP during normal day to day substation operation.

IEC 61850 and Ethernet Redundancy

Questions & Answers

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