Infrastructure Portal to a more Reliable Energy Grid.

IEC 61850 Architecture and Applications

March 6th, 2023

Speaker #1

Francis Seifein, P.E., MSc

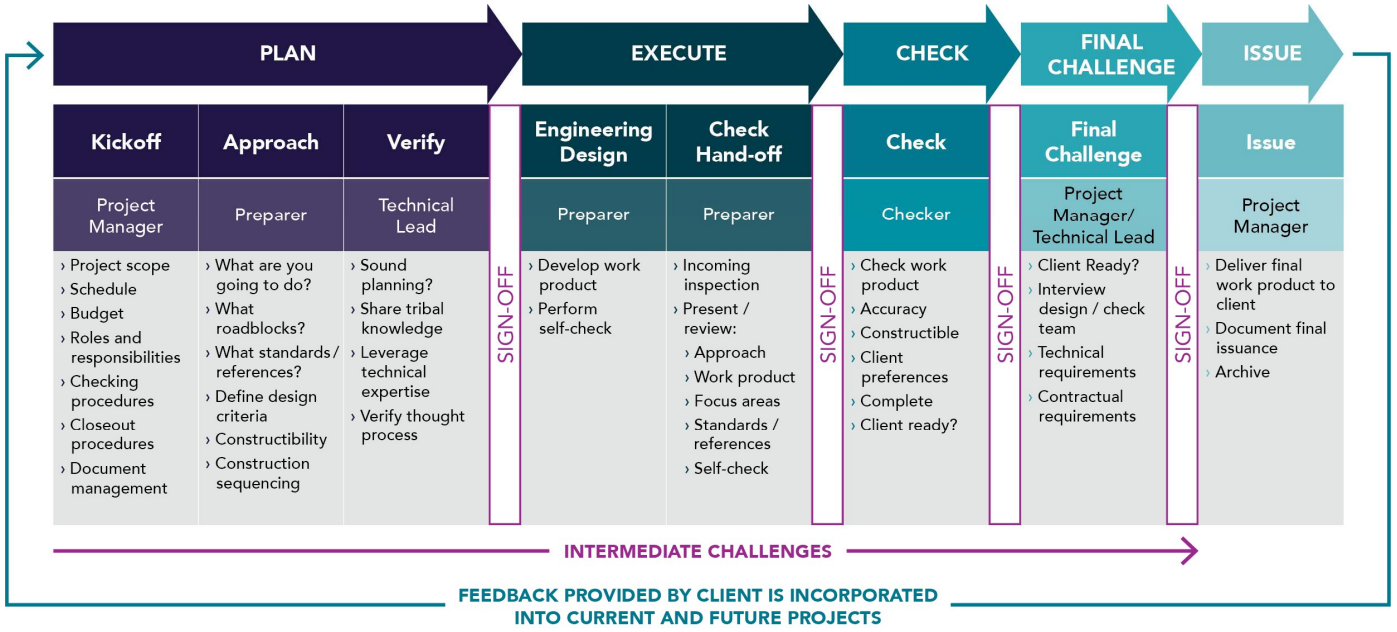
- Lead Protection and Control Engineer
- Phone: (689) 500-2136
- emad.f.e.seifein@leidos.com

20+ Years Experience in Power Systems Modelling, Design and Protection

- LV, MV, and HV Design Architecture
- Customized network solutions
- Engineering studies/ system Modeling (Aspen Oneliner, CYME, ETAP, Easypower, Ecodial, etc.)
- Development of relay protection Settings, schemes and programming
- Control Systems design & Programming
- Development and QC review of One-line, Schematic and Wiring diagrams
- Paralleling Switchgear Design and Implementation

Quality Management

Focus on Quality



Leidos' quality process focuses on:

- Forming a detailed, up-front approach prior to detailed design
- Establishing a defined design process
- A rigorous challenge before issuance of work products to our clients

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OUR MISSION

Leidos makes the world safer, healthier, and more efficient through technology, engineering, and science.

OUR VISION

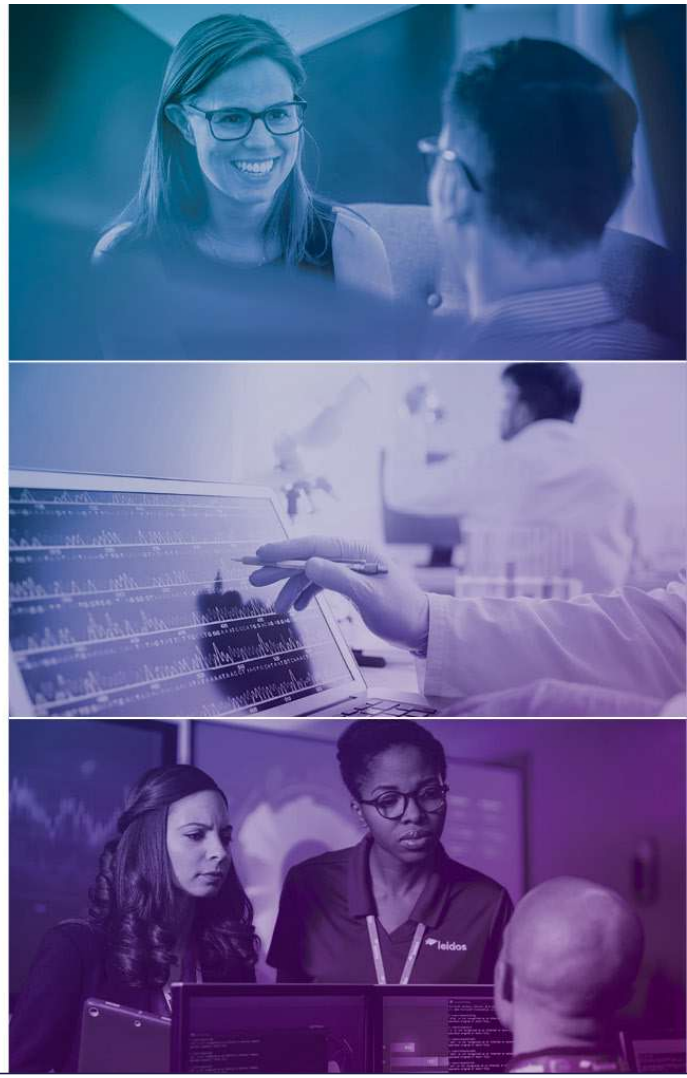
Become the global leader in the development and application of technology to solve our customers' most demanding challenges.

Engage, develop, and empower our diverse and valued people to foster a culture of creativity and growth.

Strengthen our communities through volunteerism, sustainable operations, and the advancement of equality.

OUR VALUES

- INTEGRITY
- INNOVATION
- INCLUSION
- AGILITY
- COLLABORATION
- COMMITMENT



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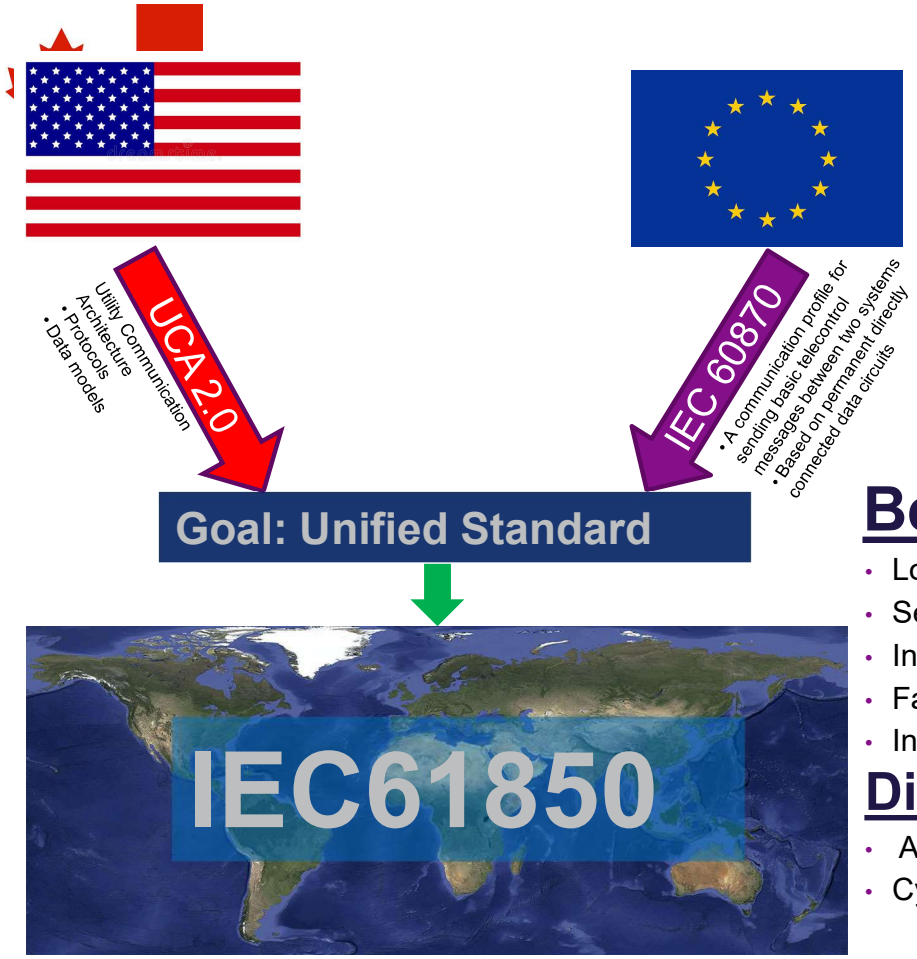
IEC 61850 Standard

Overview

IEC 61850 Standard Overview



- 2002-2005 Issued IEC 61850 Ed. 1
- 2009-2012 Issued IEC 61850 Ed. 2

Benefits & Advantages

- Lower cost for installation, configuration and maintenance
- Self Monitoring and Reliability improvement.
- Interoperability and Integration
- Fast communication
- Intuitive device and data modeling and naming

Disadvantages

- Additional burden on Network management
- Cyber security overheads: NERC CIP (CIP-002-1 through CIP-009-1)

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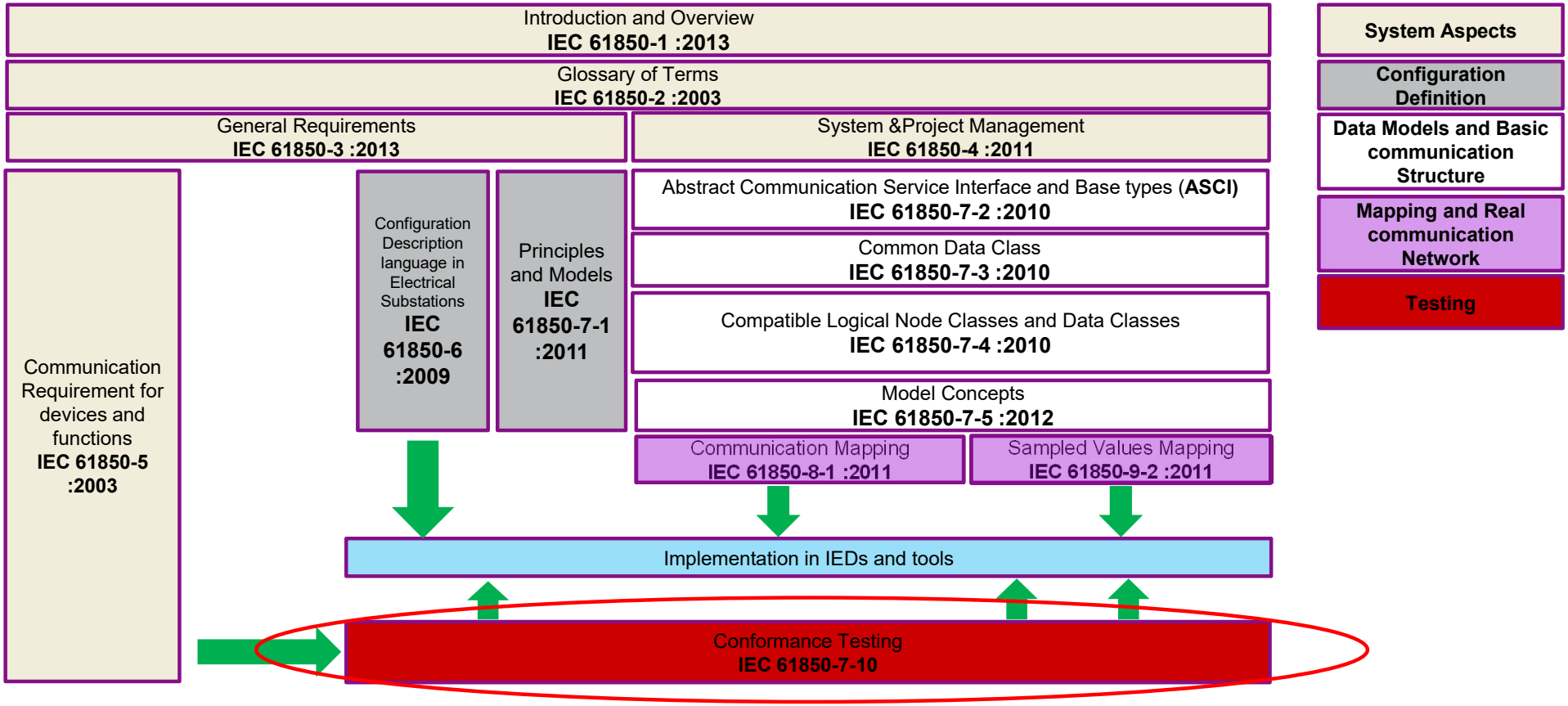
IEC 61850 Standard Overview



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IEC 61850 Standard

Development

IEC 61850 Development

Part	Edition 1	Edition 2	Main Changes
Part 1: Introduction and overview	2003 / 37 pp	2013 / 73 pp	Scope Extension of IEC61850 standard/ Quality Energy Properties/Statistics and Historic Data/Distribution, generation, monitoring and automation/Substation to Substation Communication/ Smart Grid Consideration.
Part 2: Glossary.	2003/42pp		
Part 3: General Requirements.	2002 / 33 pp	2013 / 136 pp	Requirements are in line with other equipment used in same environment (e.g., protection relays)/Addition product safety based on IEC 60255-27/EMC requirements one line and entire with IEC 60255 and IEC 61000-6-5
Part 4: System and Project Management.	2002 / 59 pp	2011 / 74 pp	This second edition constitutes a technical revision to unify document with other IEC 61850 standard parts, in addition extending scope of substation automation systems to all used automation systems.
Part 5: Communication requirements for functions and device models.	2003 / 131 pp	2013 / 306 pp	Extension of automation systems for substation to automation systems used/Interfaces inclusion for substations communication/Communication requirements beyond substation limit.
Part 6: Configuration language for communication in electrical substations related to IEDs.	2004 / 144 pp	2009 / 215 pp	Adding functional extensions based on other parts IEC 61850 changes, especially by IEC 61850-7-2 and IEC 61850-7-3/Adding functional extensions on engineering processes, especially for configuration data exchange between systems configuration tools

IEC 61850 Development

Part	Edition 1	Edition 2	Main Changes
Part 7.1: Basic communication structure – Principles and models	2003 / 110 pp	2011 / 289	Information models for specific substation on automatic systems power. •Device functions used on process automation. •Communication systems to provide interoperability within public energy service places compared to first edition, this second edition features: • Model for data and statistical historic. • Concept Proxies, gateways, hierarchies LD and inputs LN. • Time synchronization Models • Extension log function. It also clarifies certain items.
Part 7.2: Basic communication structure – Abstract communication service interface (ACSI).	2003 / 171 pp	2010 / 213 pp	Some types of data not required have been removed. •Added logging service for blocks of control. •Fixed IEC 62351 series safety.
Part 7.3: Basic communication structure – in electrical substations related to IEDs.	2003 / 64 pp	2010 / 182 pp	This second edition defines new common data classes used by new standards definition models objects based on IEC 61850 for statistical data representation and historical.
Part 7.4: Basic communication structure in electrical substations related to IEDs – Common Data Classes.	2003 / 104 pp	2010 / 179 pp	•Correction and clarification according to technical problems presented by users. •Extensions for model historical statistics data. •Extensions for new logical nodes for domain quality of energy. •Extensions for IEC 61850-90-1. •Extensions for new logical nodes for functions monitoring based on IEC 672271. •New logical nodes for IEC 61850-7-410 and IEC 61850-7-420 to general interest.

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IEC 61850 Development

Part	Edition 1	Edition 2	Main Changes
Part 8.1: Specific communication service mapping (SCSM) – Mappings to Manufacturing Message Specification MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3.	2004 / 133 pp	2011 / 386 pp	•Gigabit Ethernet support. •Link layer redundancy. •Extensions object reference length. •Following for mapping service. •Second object Reference mapping when is used on tracking or like link. •Message GOOSE simulation. •SCL erase on control block.
Part 9.1: Specific communication service mapping (SCSM) – Sampled values over serial unidirectional multidrop point to point link.	2003 / 29 pp	Replaced by: IEC 61850-9-2:2011	
Part 9.2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3.	2004 / 28 pp	2011 / 65 pp	Adding link layer redundancy •Redefinition “reserved” fields on link layer. •Components USVCB and MSVCB evolution. •Buffer sampled value transmission encoding evolution.
Part 10: Conformance Testing.	2005 / 43 pp	2012 / 170 pp	•Updates for devices server test procedures. •Addition of some test procedures (according to client device, sampled values devices, GOOSE performance).

IEC 61850 Development

- IEC-61850 is not just a communication protocol, it is a standard for Substation automation design.
- IEC-61850 Ed 2 issued in 2002-2005 improves and wide-ranging features of IEC-61850 Ed 1 issued in 2009-2012. These improvements include tests aspects, new functions inclusion and objects types used in modeling of electrical systems.
- The IEC 61850 Standard is mainly concerned with standardizing specifications so that different suppliers of stations can conform to a common set of provisions for a particular installation, to ensure interoperability.

IEC 61850 Standard

Protocol

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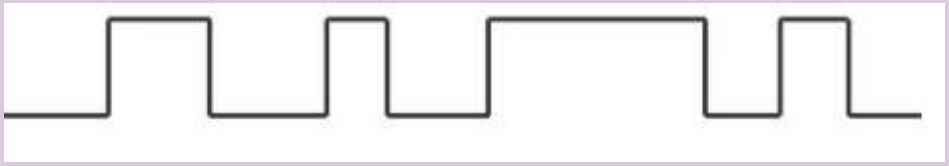
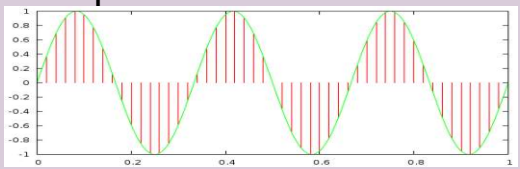
IEC 61850 Protocols

	61850-8-1 GOOSE	61850-9-2 SMV
Definitions	GOOSE (**Generic Object-Oriented Substation Event**) communication	SMV (**Sampled Measured Values**) communication.
Characteristic	• Specifies a method of exchanging time-critical and non-time-critical data through local-area networks • Event Driven (Circuit Breaker closed, Overcurrent protection operated, Trip Circuit supervision operated …etc.)	Streaming (Voltage Sin wave or Current Sin wave)
Information Transmitted	BOOLEAN 	Analog (Sine Wave) Time Stamped 
Update Rate	On Event Change	Continuous Sampling Rate

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IEC 61850 Standard

Network Topologies

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IEC 61850 Network Topologies

Ethernet communication features

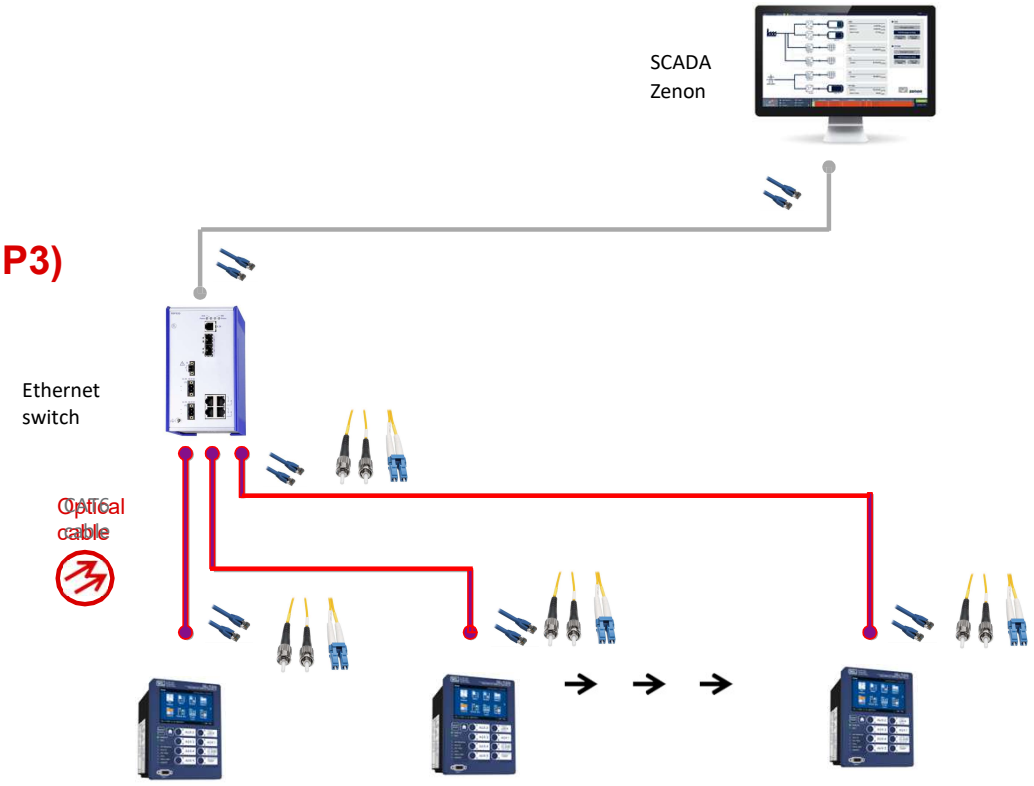
- Ethernet is the communication media for IEC 61850 and other protocols such as Modbus® and DNP3
- Media types: 10/100TX galvanic Ethernet cable with RJ-45 connectors or optical multimode 100FX with LC connectors
- Galvanic Ethernet cables must always be shielded (STP), minimum CAT5e Network topology - either star or ring

IEC 61850 Network Topologies

App (1): Ethernet star topology, galvanic connection (RJ-45) or optical connection (LC)

Ethernet station bus (IEC 61850, Modbus, DNP3)

- Control and events
- Measurements
- Settings and parameterization (IEC 61850)
- Disturbance record upload (IEC 61850, FTP)
- Fault records (IEC 61850, Modbus, DNP)



IEC 61850 Network Topologies

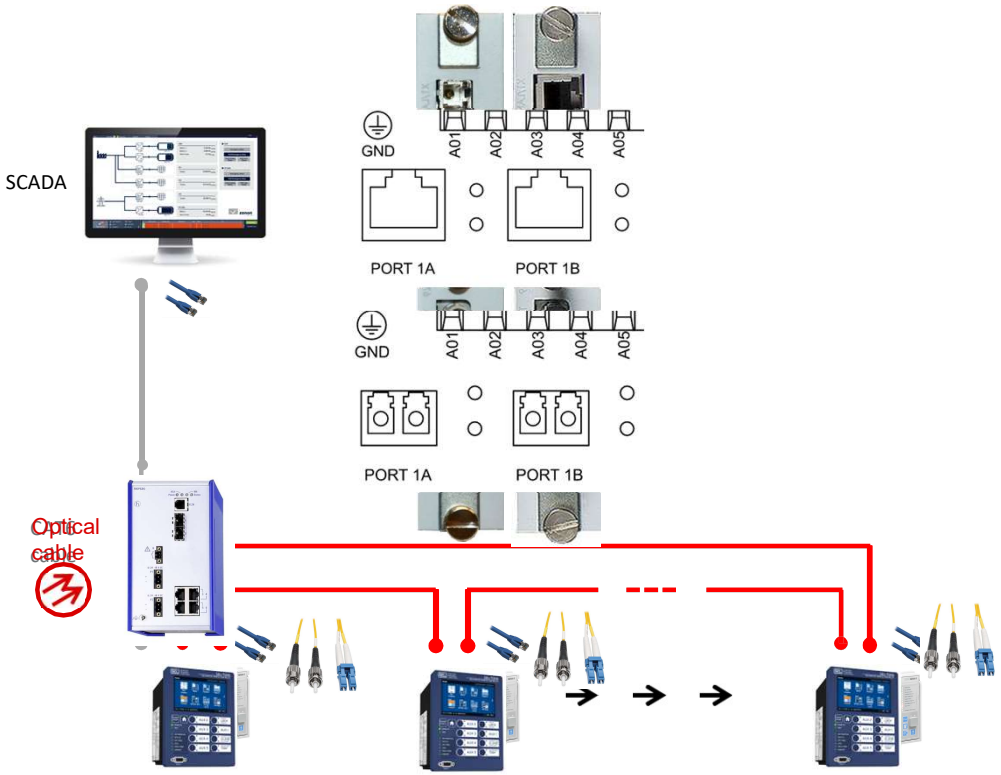
App (2): Ethernet daisy chain topology, galvanic connection (RJ-45) or optical connection (LC)

Ethernet station bus (IEC 61850, Modbus, DNP3)

- Control and events
- Measurements
- Settings and parameterization (IEC 61850)
- Disturbance record upload (IEC 61850, FTP)
- Fault records (IEC 61850, Modbus, DNP)

Note!

The topology can be built totally without switches as the relays have multiple Ethernet ports

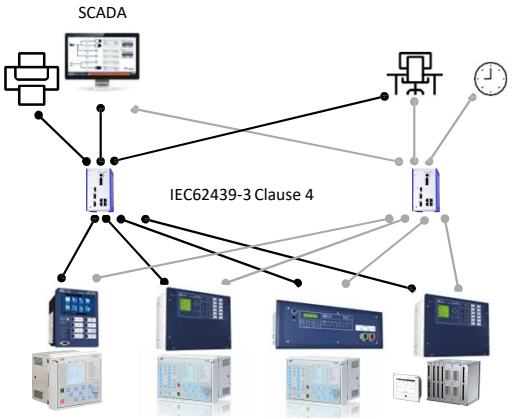


IEC 61850 Network Topologies

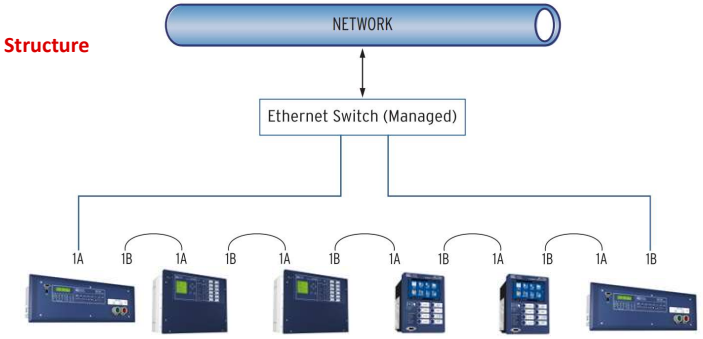
PRP and HSR redundancy protocols of the IEC62439-3

- Parallel redundancy protocol (PRP) is based on parallel redundant mesh networks (IEC62439-3 Clause 4).
- High availability seamless redundancy (HSR) protocol is based on ring topology with max number of relays 30 relay/ring (IEC62439-3 Clause 5).
- Ethernet Network Configuration With Ring Structure (Switched Mode)

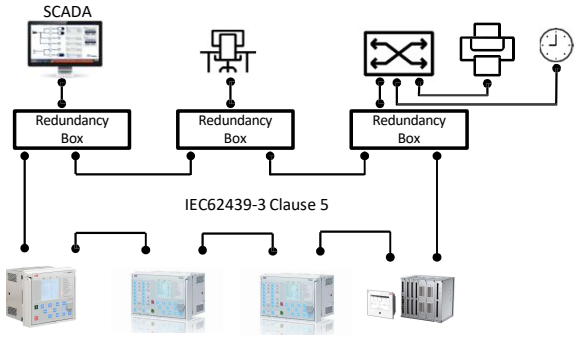
PRP



Ring Structure

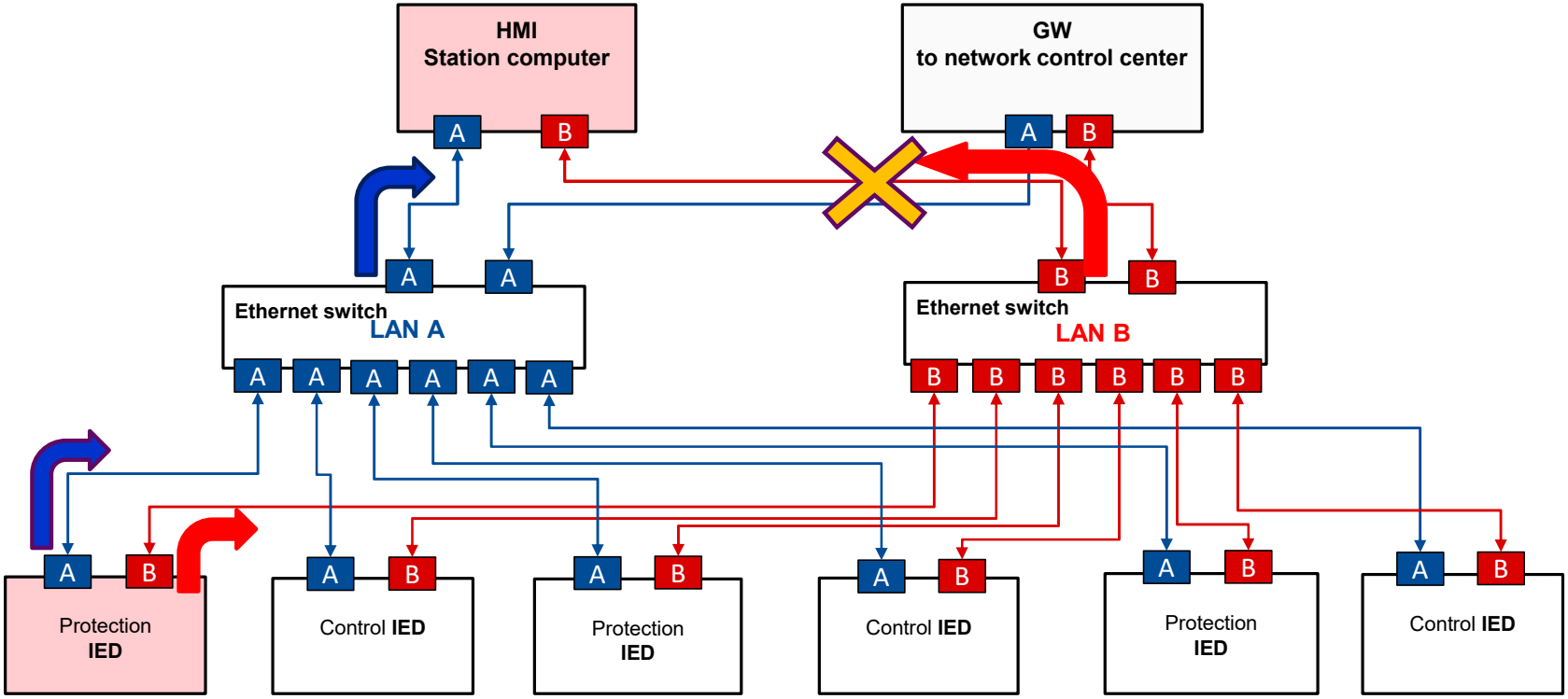


HSR



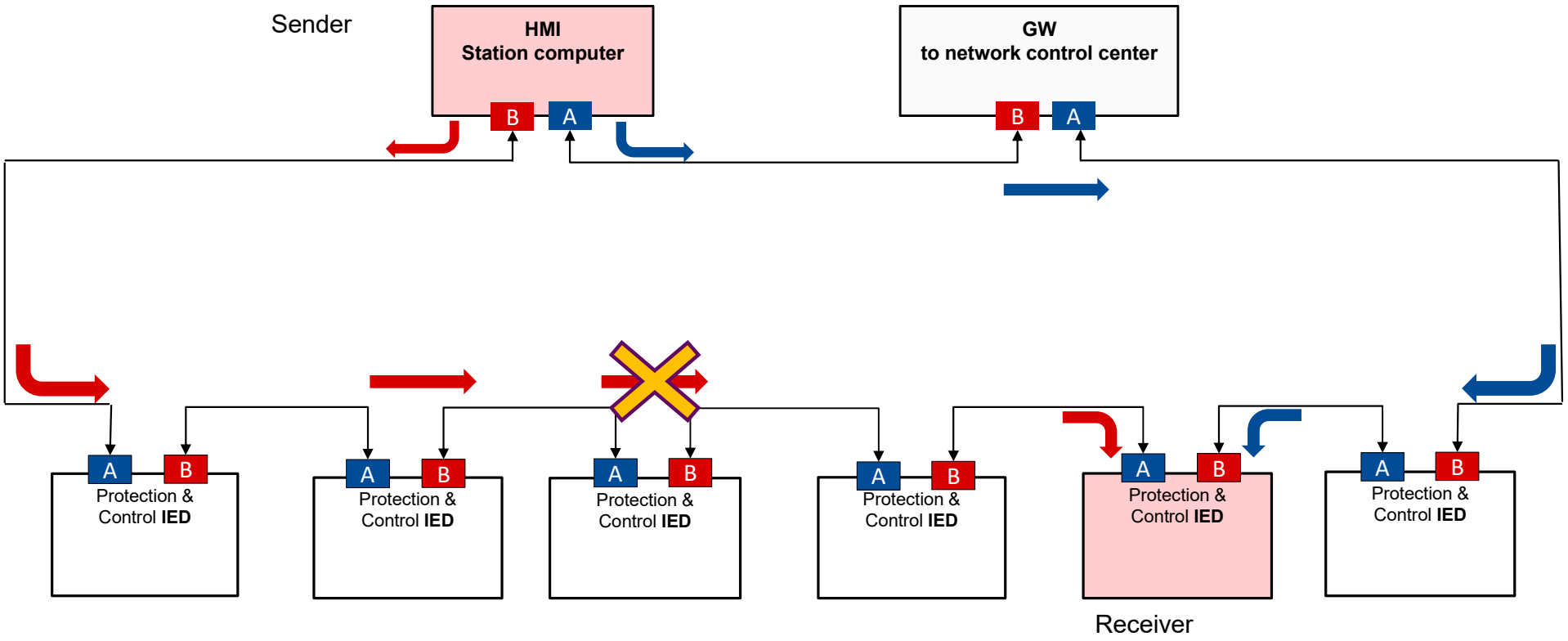
IEC 61850 Network Topologies

Parallel redundancy protocol (PRP) solutions for protective Relays (IEC62439-3 Clause 4)



IEC 61850 Network Topologies

High availability seamless redundancy (HSR) solutions for protective Relays



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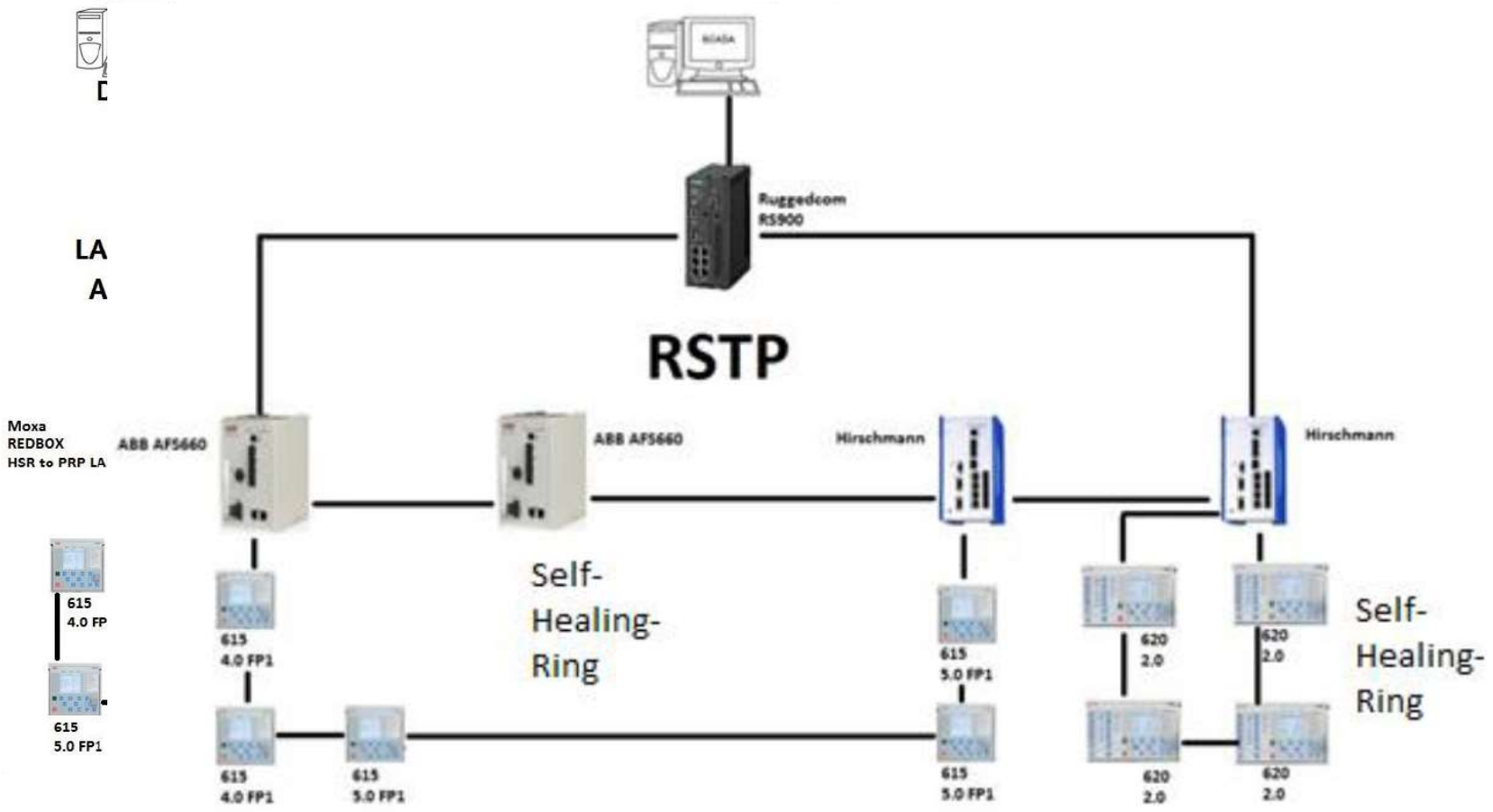
Station communication redundant solutions

HSR to PRP with ABB Protective Relays



IEC 61850

Conventional VS Digital

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IEC 61850 Network VS Conventional

Conventional Switchgear

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IEC 61850 Network VS Conventional

IEC 61850 Switchgear

IEC 61850 Network VS Conventional

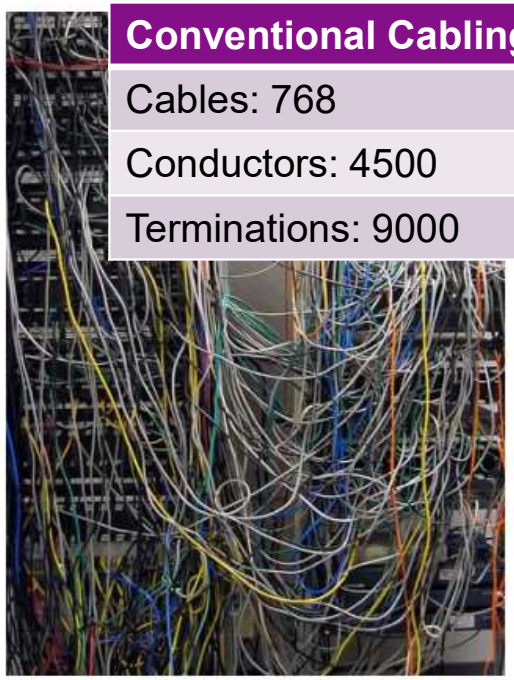
Conventional Cables

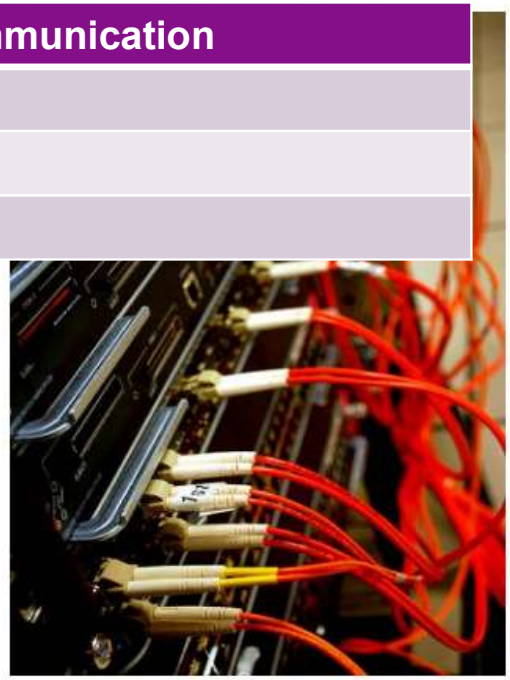
IEC 61850 Network VS Conventional

Traditional P&C System

IEC-61850 based P&C System

Conventional Cabling	Digital Communication
Cables: 768	256
Conductors: 4500	1500
Terminations: 9000	3000





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IEC 61850

Characteristics

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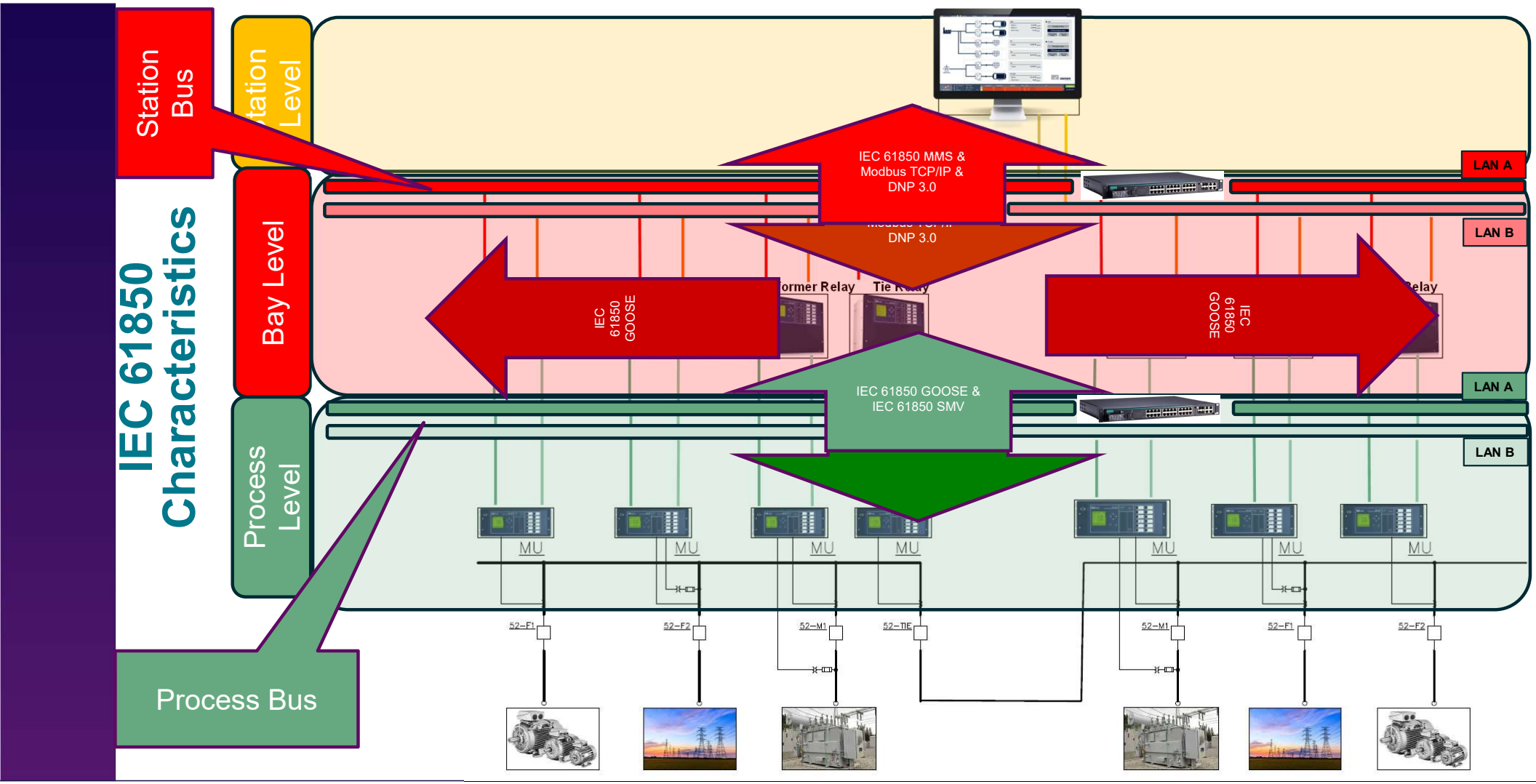
IEC 61850 Characteristics



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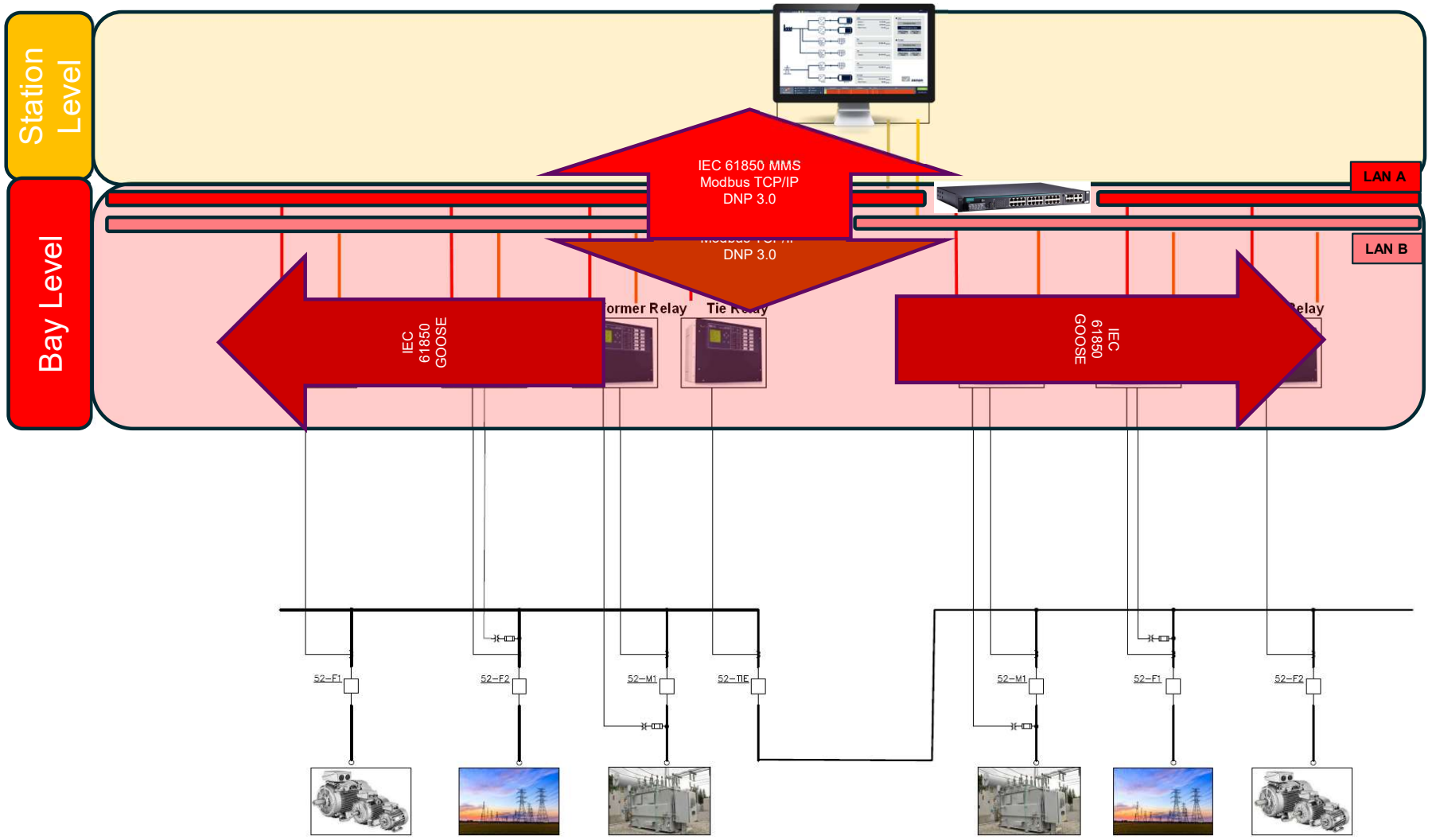
IEC 61850 Characteristics



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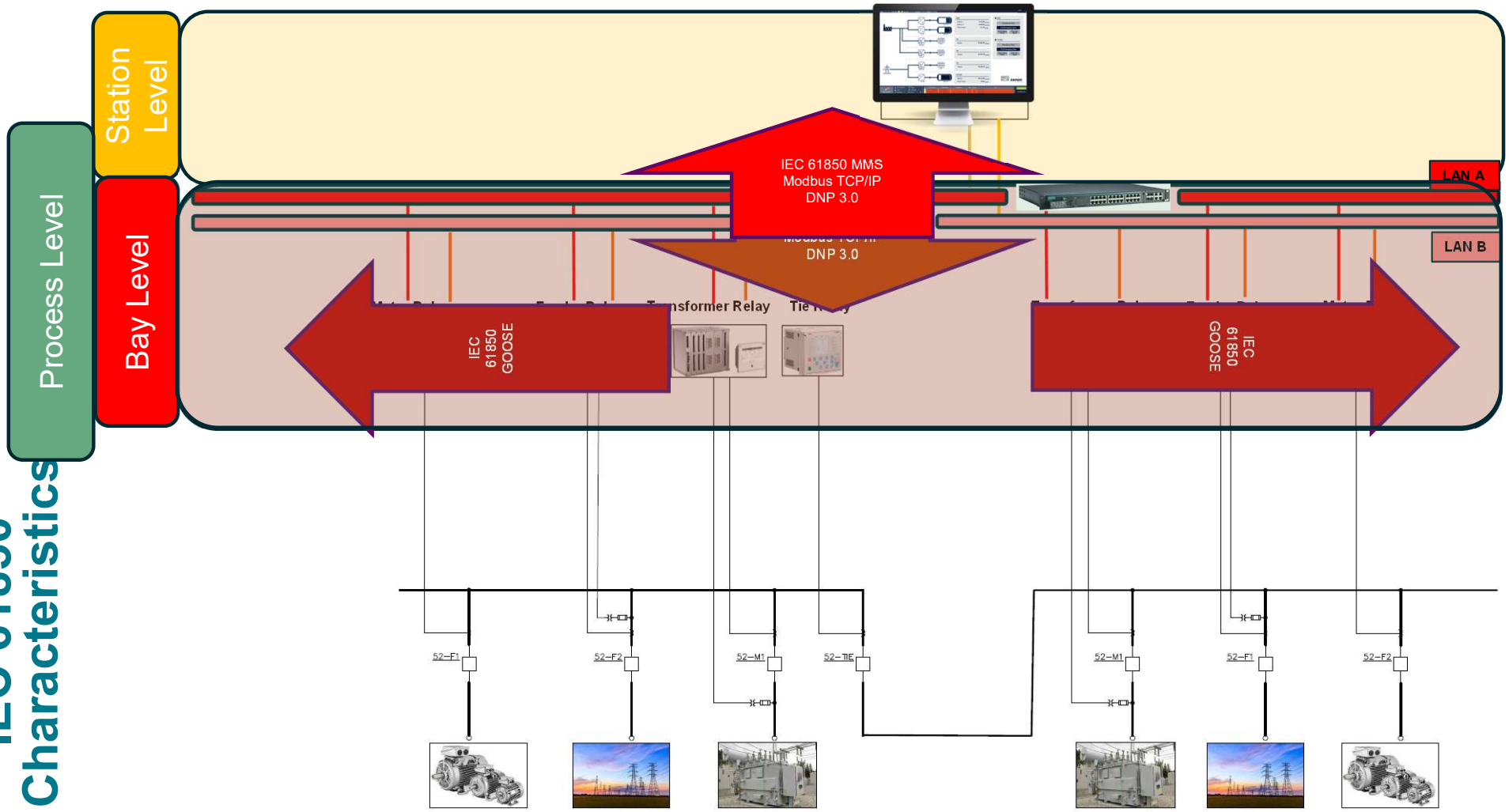
IEC 61850 Characteristics



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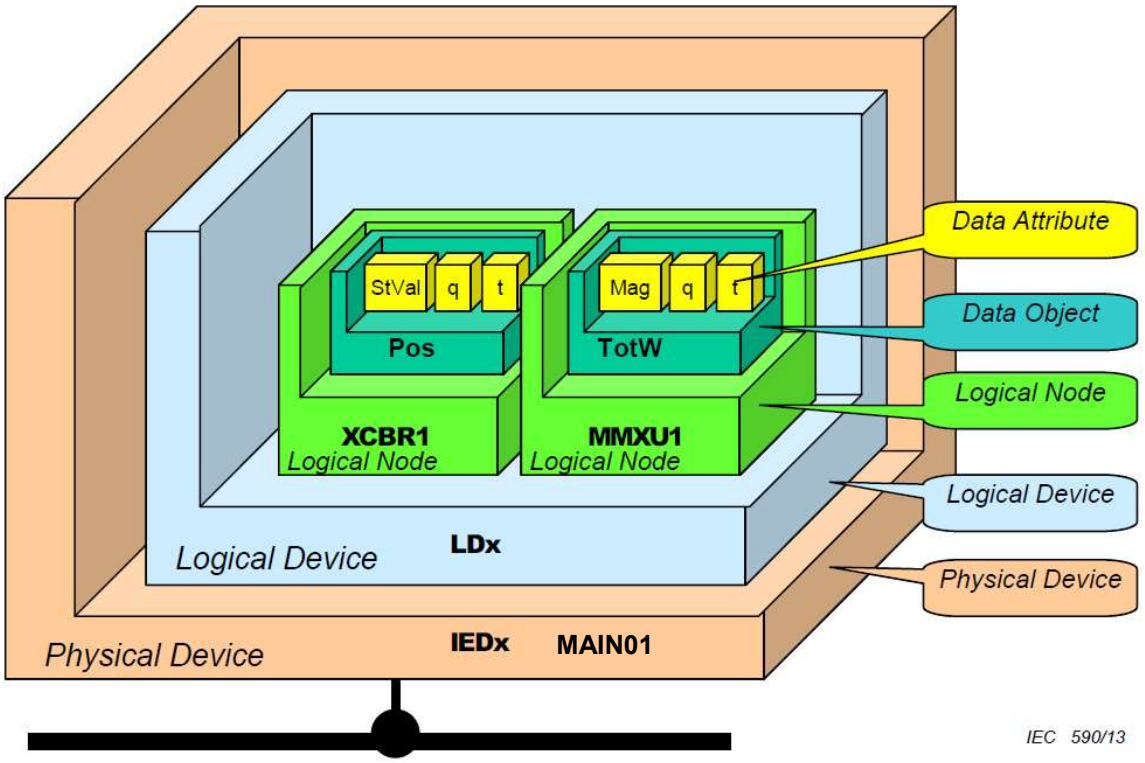
IEC 61850

IEC 61850-8-1 GOOSE Applications

IEC 61850-8-1 GOOSE Applications

Semantic Hierarchical Object Data Model



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IEC 61850-8-1 GOOSE Applications

Object Data Model

- IED is a container of three main **Logic Devices**
  - MAIN01.LD0
  - MAIN01.CTRL
  - MAIN01.DR

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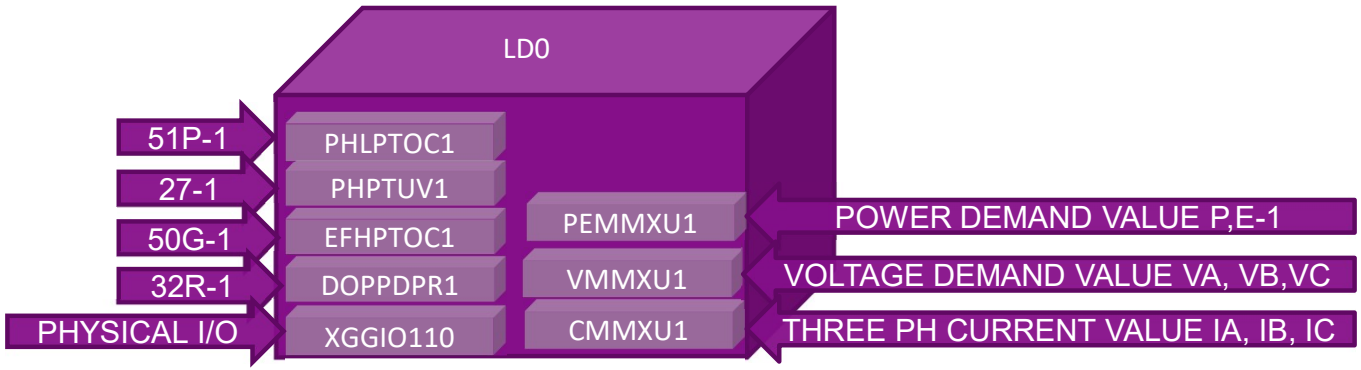
IEC 61850-8-1 GOOSE Applications

Object Data Model

- IED is a container of **Logic Devices**
  - MAIN01.LD0
  - MAIN01.CTRL
  - MAIN01.DR
- Logic Device is a container of **Logic Nodes**
  - MAIN01.LD0.PHLPTOC1
  - MAIN01.LD0.CMMXU1
  - MAIN01.LD0. PHPTUV1
  - MAIN01.LD0. EFHPTOC1



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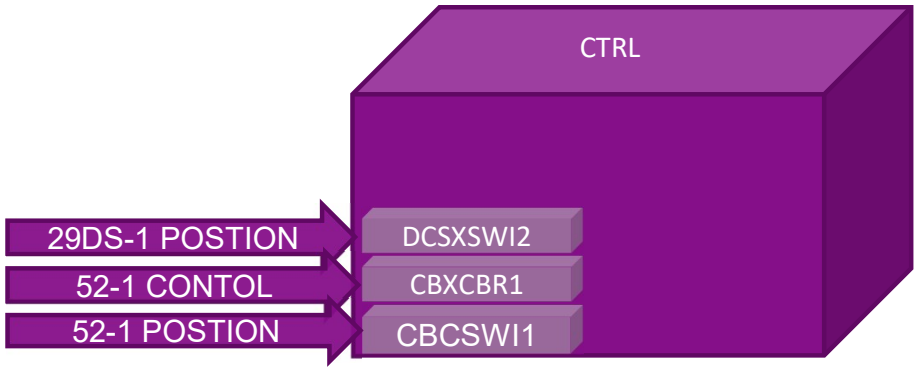
IEC 61850-8-1 GOOSE Applications

Object Data Model

- IED is a container of **Logic Devices**
  - MAIN01.LD0
  - MAIN01.CTRL
  - MAIN01.DR
- Logic Device is a container of **Logic Nodes**
  - MAIN01.CTRL.CBXCBR1
  - MAIN01.CTRL.CBCSWI1
  - MAIN01.CTRL.DCSXSWI2



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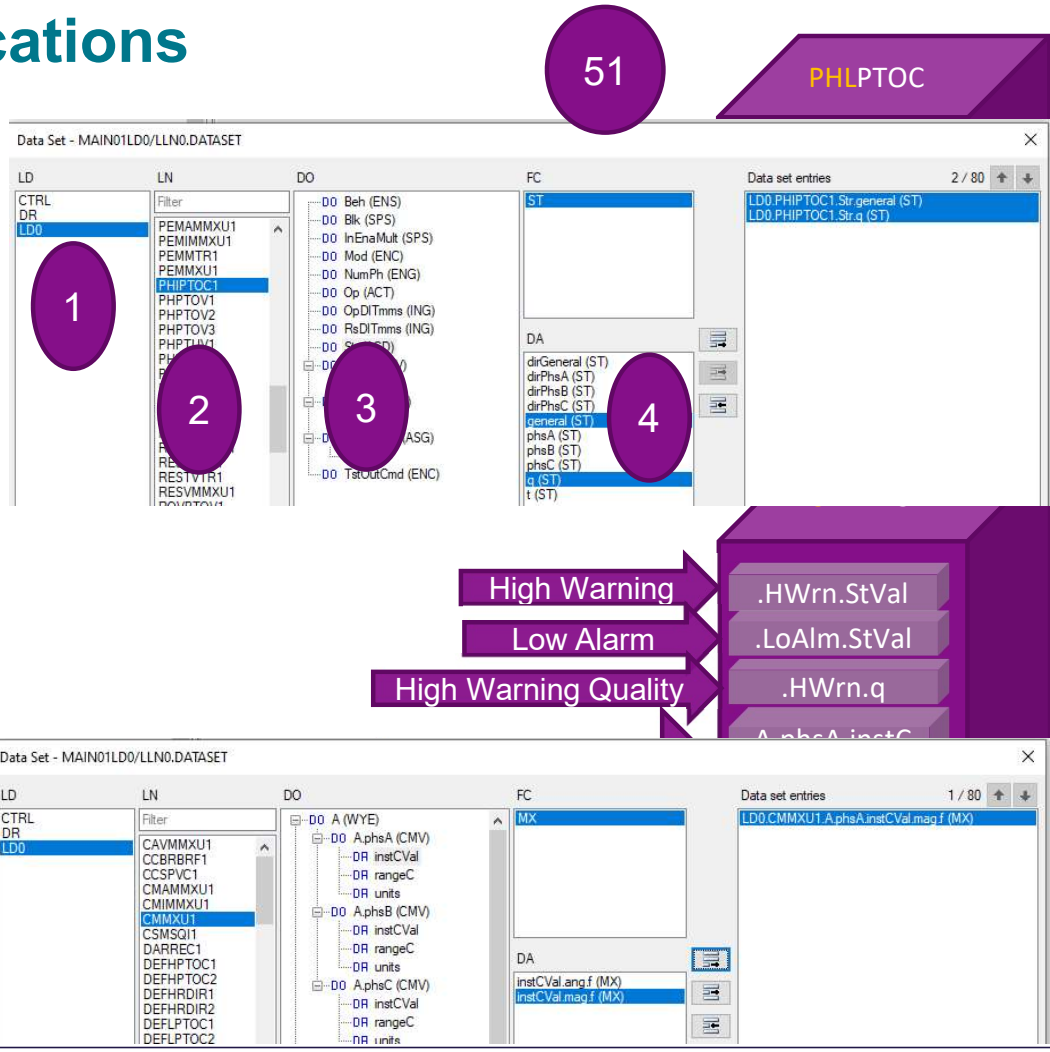
IEC 61850-8-1 GOOSE Applications

Object Data Model

- IED is a container of **Logic Devices**
  - MAIN01.LD0
  - MAIN01.CTRL
  - MAIN01.DR
- Logic Device is a container of **Logic Nodes**
  - MAIN01.LD0.PHLPTOC1
  - MAIN01.LD0.CMMXU1
- Logic Node is a container of **Data Objects**
  - MAIN01.LD0.PHL**PTOC**1.XX.XXX (51P-1)
  - MAIN01.LD0.CMMXU1.XX

  (THREE PH CURRENT VALUE IA, IB, IC)
- Data Objects is a container of **Data Attribut**



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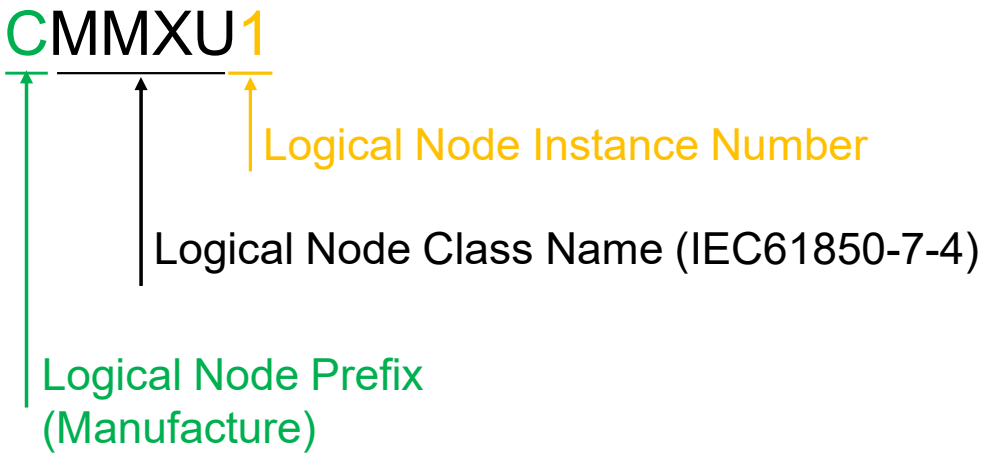
IEC 61850-8-1 GOOSE Applications

Object Data Model

Logic Node Name

- MAIN01.LD0.CMMXU1.A.phsA.cVal.mag.f



ABB= CMMXU1

.A.phsA.instCVal.mag

SEL= METMMXU1

.A.phsA.instCVal.mag.f

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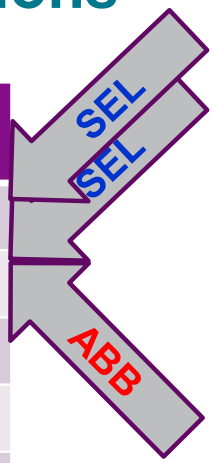
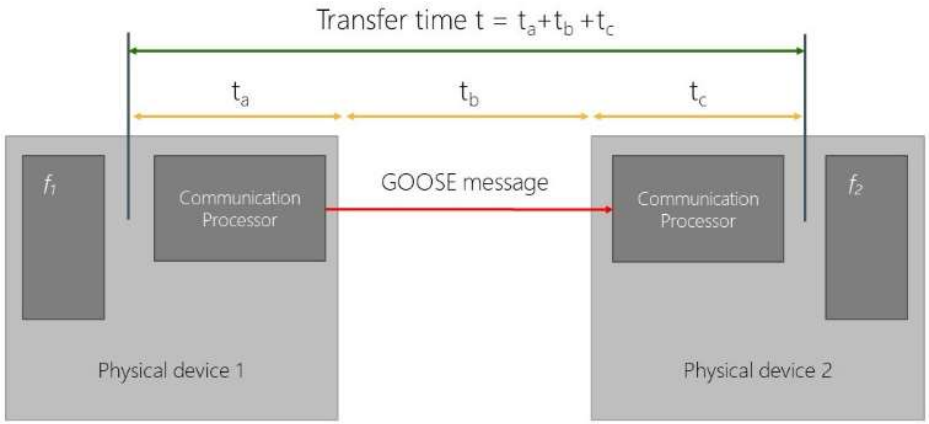
IEC 61850-8-1 GOOSE Applications

GOOSE Message delay

Type	App	Perf. Class	Transmission Time
1A	Fast Messages (Trip)	P1	10 mS
		P2/P3	3 mS
1B	Fast Messages (Other)	P1	100 mS
		P2/P3	20 mS
2	Medium Speed		
3	Low Speed		
4	Raw Data	P1	10 mS
		P2/P3	3 mS
5	File Transfer		>1000 ms
6	Time Synchronization	T1 (time)	± 1 (Accuracy)
		T2 (time)	± 0.1 (Accuracy)





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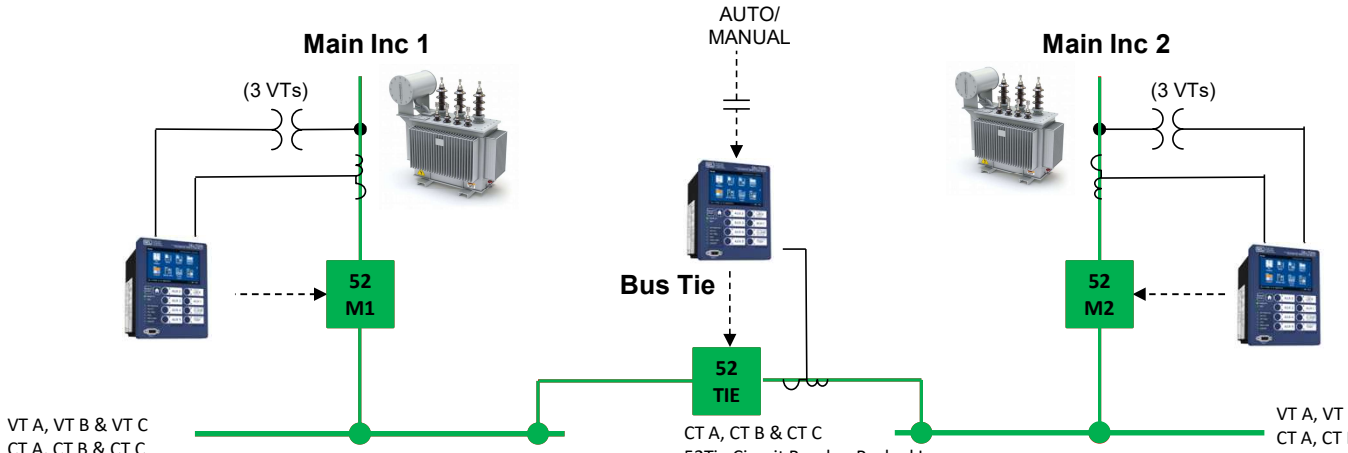
IEC 61850-8-1 GOOSE Applications

Conventional Automatic Transfer (ATS)



VT A, VT B & VT C
CT A, CT B & CT C
52M1 Circuit Breaker Racked In
52M1 Circuit Breaker test
On Delay Timer

52M1 NO Contact (52a) Position Open
52M1 NC Contact (52b) Position Closed
M1 Relay trip operated

52M2 NO Contact (52a) Position Open
52M2 NC Contact (52b) Position Closed
M2 Relay trip operated
52Tie Contact (52a) Position Open
52Tie Contact (52b) Position Closed
Tie Relay trip operated
Local Switch – Manual (Close operation)
Local Switch – Auto (Close operation)
Open Transition Enable (Close operation)

CT A, CT B & CT C
52Tie Circuit Breaker Racked In
52Tie Circuit Breaker Test
On Delay Timer

52Tie Contact (52a) Position Open
52Tie Contact (52b) Position Closed
Tie Relay trip operated
Local Switch – Manual (Close operation)
Local Switch – Auto (Close operation)
Open Transition Enable (Close operation)
52M1 NO Contact (52a) Position Open
52M1 NC Contact (52b) Position Closed
M1 Relay trip operated

52M2 NO Contact (52a) Position Open
52M2 NC Contact (52b) Position Closed
M2 Relay trip operated

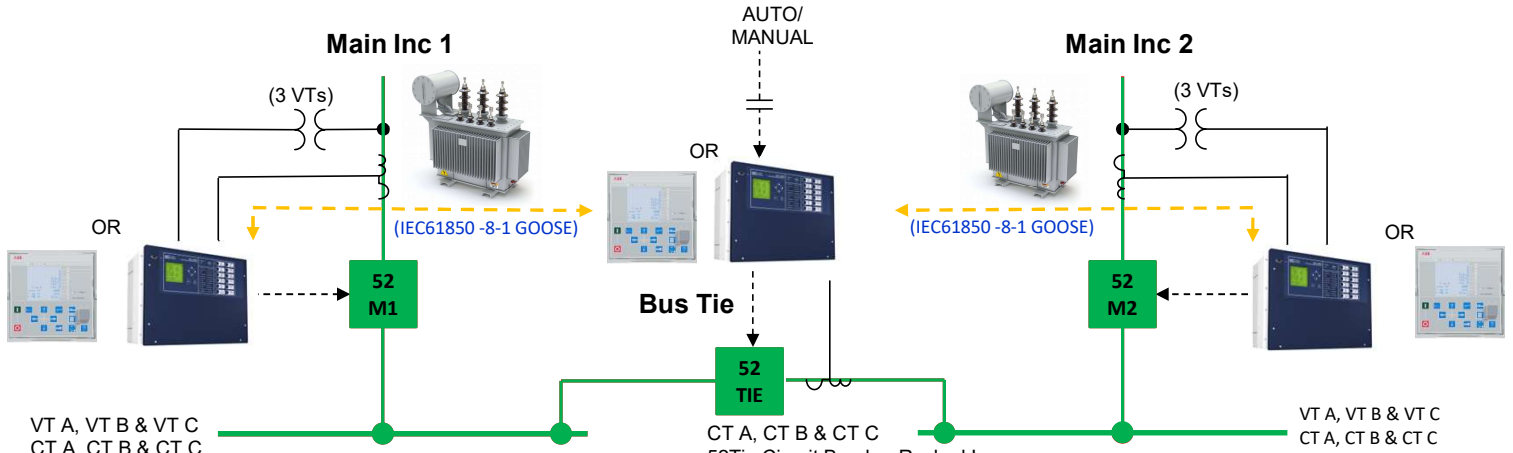
VT A, VT B & VT C
CT A, CT B & CT C
52M2 Circuit Breaker Racked In
On Delay Timer

52M2 NO Contact (52a) Position Open
52M2 NC Contact (52b) Position Closed
M2 Relay trip operated
52M1 NO Contact (52a) Position Open
52M1 NC Contact (52b) Position Closed
M1 Relay trip operated

52Tie Contact (52a) Position Open
52Tie Contact (52b) Position Closed
Tie Relay trip operated
Local Switch – Manual (Close operation)
Local Switch – Auto (Close operation)
Open Transition Enable (Close operation)

IEC 61850-8-1 GOOSE Applications

App (1): Automatic Transfer (ATS) using 61850 GOOSE



VT A, VT B & VT C
CT A, CT B & CT C
52M1 Circuit Breaker Racked In
52M1 Circuit Breaker test
On Delay Timer

52M1 NO Contact (52a) Position Open
52M1 NC Contact (52b) Position Closed
M1 Relay trip operated
~~52M2 NO Contact (52a) Position Open~~
~~52M2 NC Contact (52b) Position Closed~~
~~M2 Relay trip operated~~
~~52Tie Contact (52a) Position Open~~
~~52Tie Contact (52b) Position Closed~~
~~Tie Relay trip operated~~
~~Local Switch – Manual (Close operation)~~
~~Local Switch – Auto (Close operation)~~
~~Open Transition Enable (Close operation)~~

CT A, CT B & CT C
52Tie Circuit Breaker Racked In
52Tie Circuit Breaker Test
On Delay Timer
52Tie Contact (52a) Position Open
52Tie Contact (52b) Position Closed
Tie Relay trip operated
Local Switch – Manual (Close operation)
Local Switch – Auto (Close operation)
Open Transition Enable (Close operation)
~~52M1 NO Contact (52a) Position Open~~
~~52M1 NC Contact (52b) Position Closed~~
~~M1 Relay trip operated~~

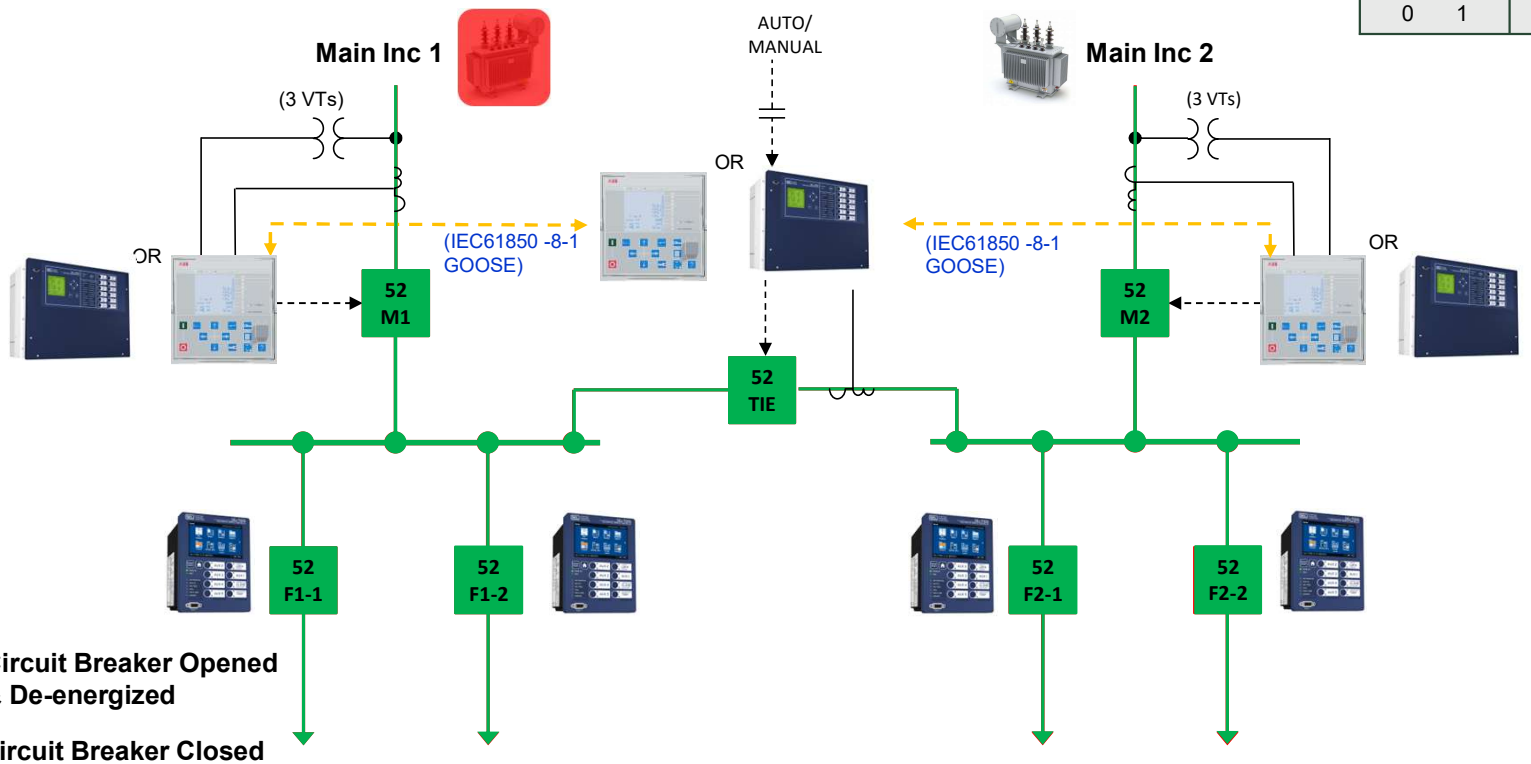
~~52M2 NO Contact (52a) Position Open~~
~~52M2 NC Contact (52b) Position Closed~~
~~M2 Relay trip operated~~

VT A, VT B & VT C
CT A, CT B & CT C
52M2 Circuit Breaker Racked In
On Delay Timer
52M2 NO Contact (52a) Position Open
52M2 NC Contact (52b) Position Closed
M2 Relay trip operated
~~52M1 NO Contact (52a) Position Open~~
~~52M1 NC Contact (52b) Position Closed~~
~~M1 Relay trip operated~~
~~52Tie Contact (52a) Position Open~~
~~52Tie Contact (52b) Position Closed~~
~~Tie Relay trip operated~~
~~Local Switch – Manual (Close operation)~~
~~Local Switch – Auto (Close operation)~~
~~Open Transition Enable (Close operation)~~

IEC 61850-8-1 GOOSE Applications

App (1A): Loss of Source 1 Open Transtion (Non-Std)

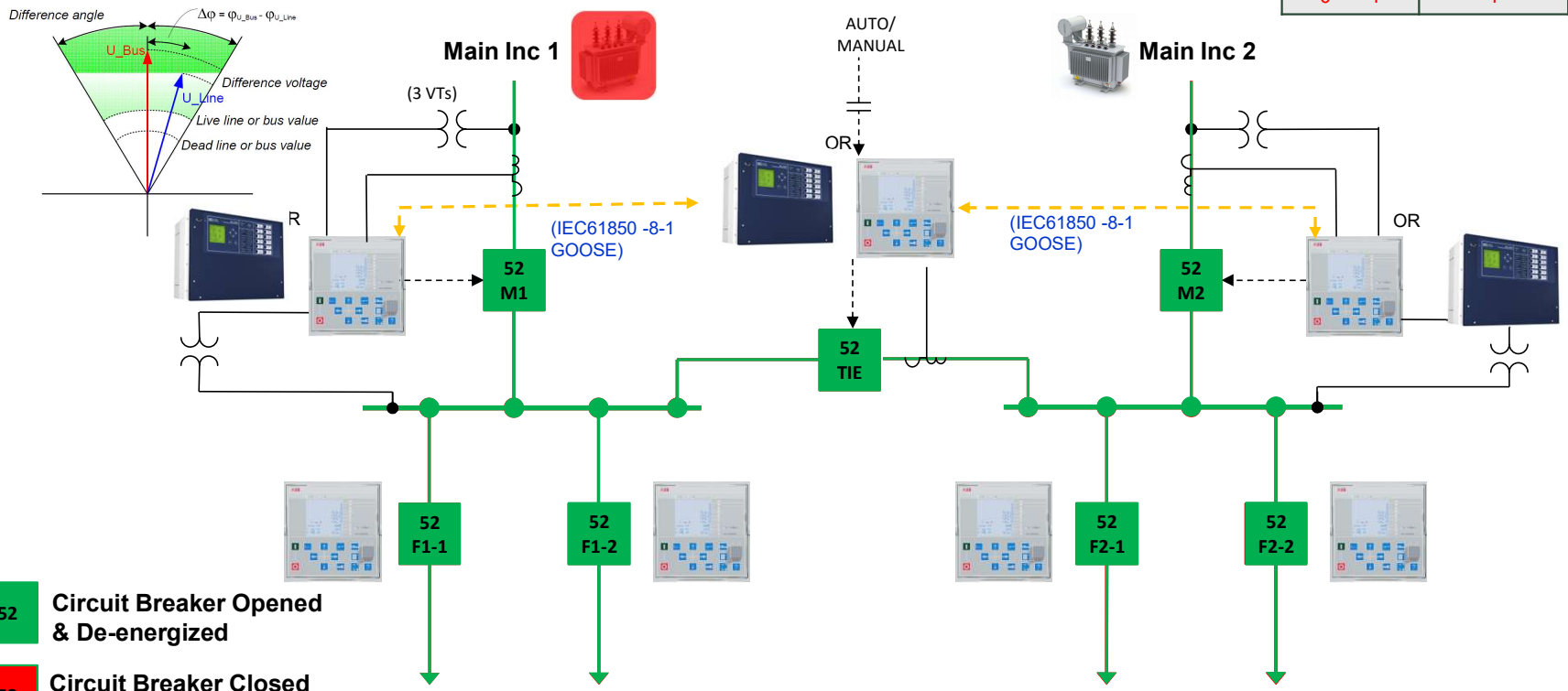
52M1	52TIE	52M2
0 → 1	0	0 → 1
1 → 0	0	1
0	0 → 1	1
0	1 → 0	1
0 1	0	1



IEC 61850-8-1 GOOSE Applications

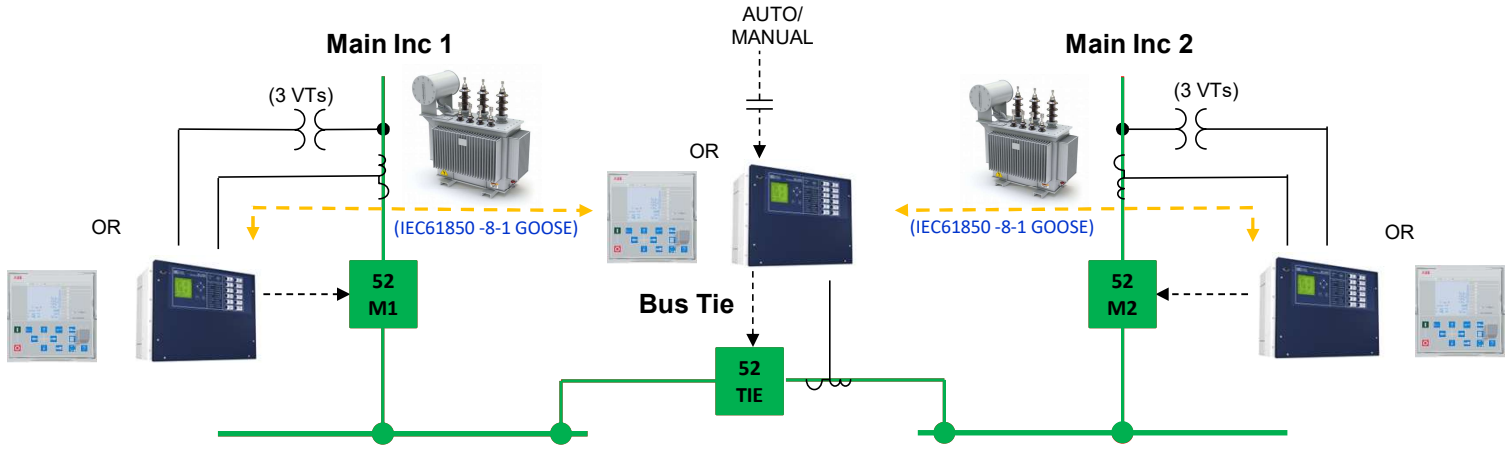
App (1B): Loss of Source 1 Closed Transtion (Non-Std)

52-M1	52-TIE	52-M2
0 → 1	0	0 → 1
1 → 0	0	1
0	0 → 1	1
Check Synchronizing 25 OK		
0 1	1	1



IEC 61850-8-1 GOOSE Applications

App (1): Summary



Open Transtion (Non-Std)

52M1	52TIE	52M2
0 → 1	0	0 → 1
1 → 0	0	1
0	0 → 1	1
0	1 → 0	1
0 1	0	1

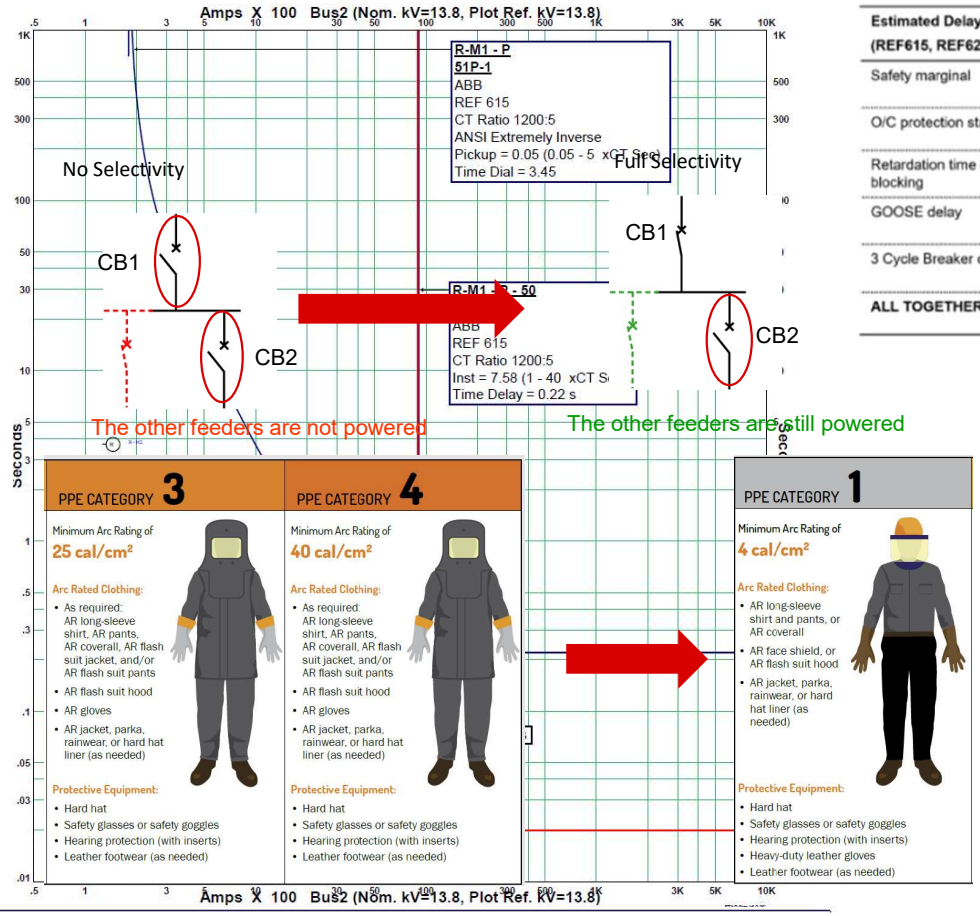
Keyed Selector Switch

Closed Transtion (Non-Std)

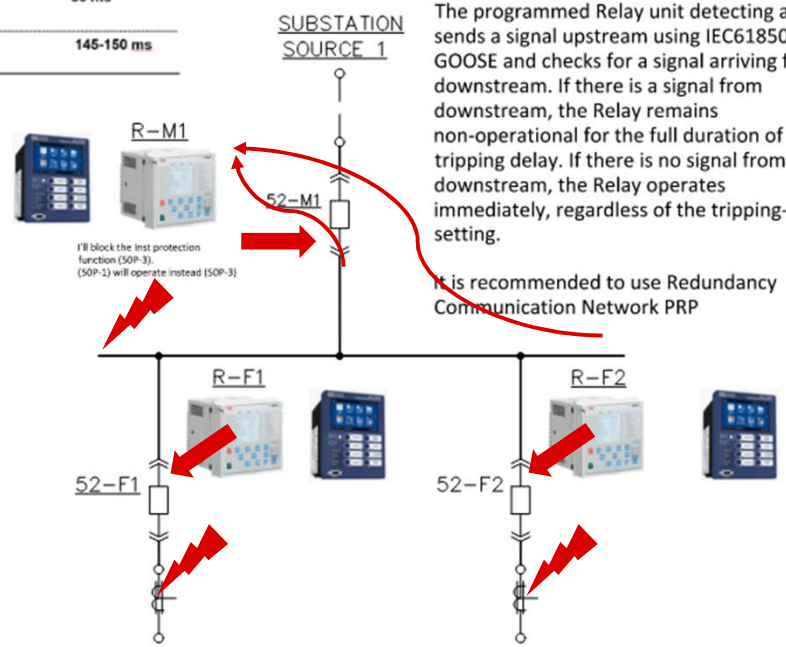
52-M1	52-TIE	52-M2
0 → 1	0	0 → 1
1 → 0	0	1
0	0 → 1	1
Check Synchronizing 25 OK		
0 1	1	1

IEC 61850-8-1 GOOSE Applications

App (2): Protection function Blocking using GOOSE 61850 (ZSI) to improve System Arc Flash



Estimated Delay setting with inst. O/C protection (REF615, REF620 & REX640 GOOSE approach)	
Safety marginal	60 ms
O/C protection start delay	20 ms
Retardation time of inst. O/C stage blocking	5 ms
GOOSE delay	<10 ms
3 Cycle Breaker operation	50 ms
ALL TOGETHER	145-150 ms



ZONE SELECTIVE INTERLOCKING (ZSI)

Zone-selective interlocking is used to reduce the short circuit duration on the installation by shortening the time required to clear faults, while maintaining time discrimination between the various devices.

IEC61850 GOOSE or Fiber optic network connects a number of protective relays, as illustrated in the diagram above.

The programmed Relay unit detecting a fault sends a signal upstream using IEC61850 GOOSE and checks for a signal arriving from downstream. If there is a signal from downstream, the Relay remains non-operational for the full duration of its tripping delay. If there is no signal from downstream, the Relay operates immediately, regardless of the tripping-delay setting.

It is recommended to use Redundancy Communication Network PRP

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IEC 61850-9-2 SMV Applications

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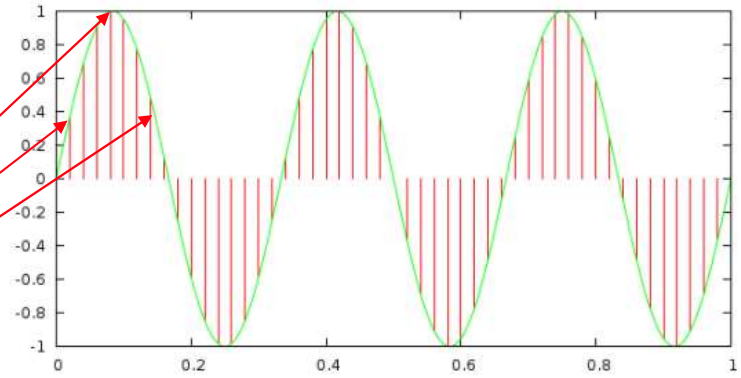
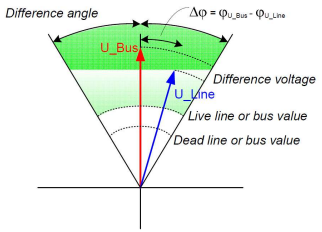
IEC 61850-9-2 SMV Applications

Time Stamped

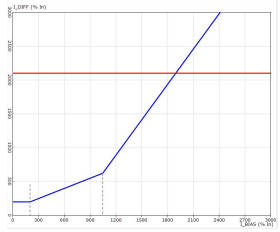


Number of hops in network (Ethernet Switches, Red Box …etc.)	Internal App Delay (µs) REX640		Theoretical max delay (µs)		Recommended Max Settings (mS)	
	50Hz	60Hz	50Hz	60Hz	50Hz	60Hz
2	1728	1450	2092	1814	2	2
5	1728	1450	2638	2360	3	3
10	1728	1450	3398	3120	5	4
15	1728	1450	4158	3880	5	4
20	1728	1450	4918	4640	5	5
25	1728	1450	5678	5400	6	6
30	1728	1450	6438	6160	7	6

25 Check Synch



87B Low Impedance BB



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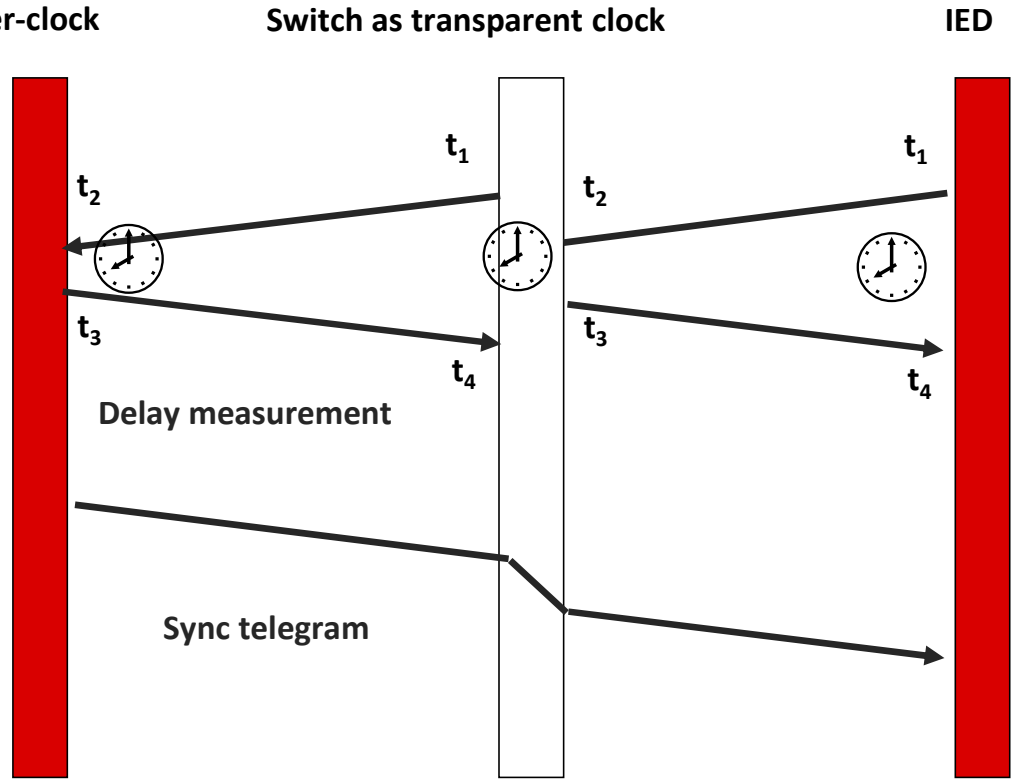
IEC 61850-9-2 SMV Applications

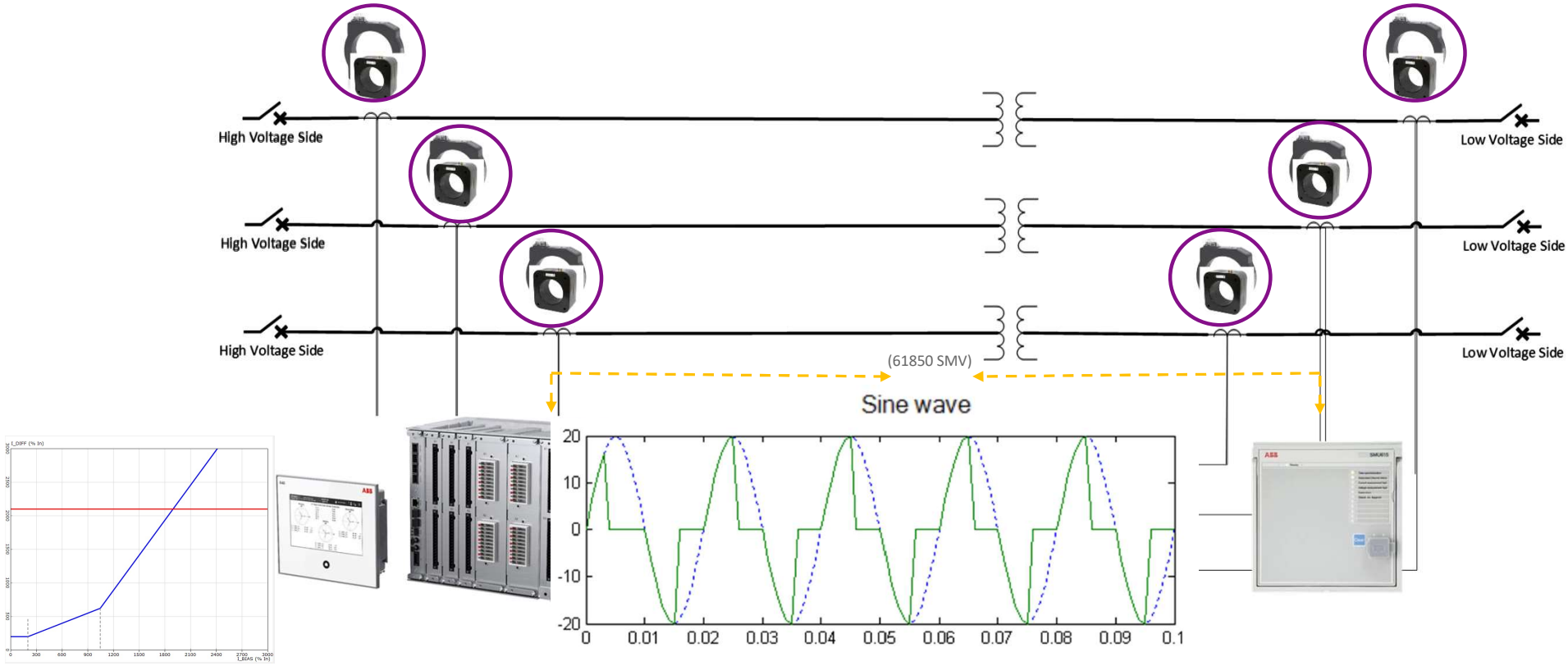
SMV Message delay

- IEC 61850 has five time performance
- categories – most severe requires +/- 1 µs
- Timestamp requires microsecond resolution
- IEEE 1588 (Precision Time Protocol – PTP) version 2 with Power Profile time synchronization method enabling 1 µs high accuracy time synchronization



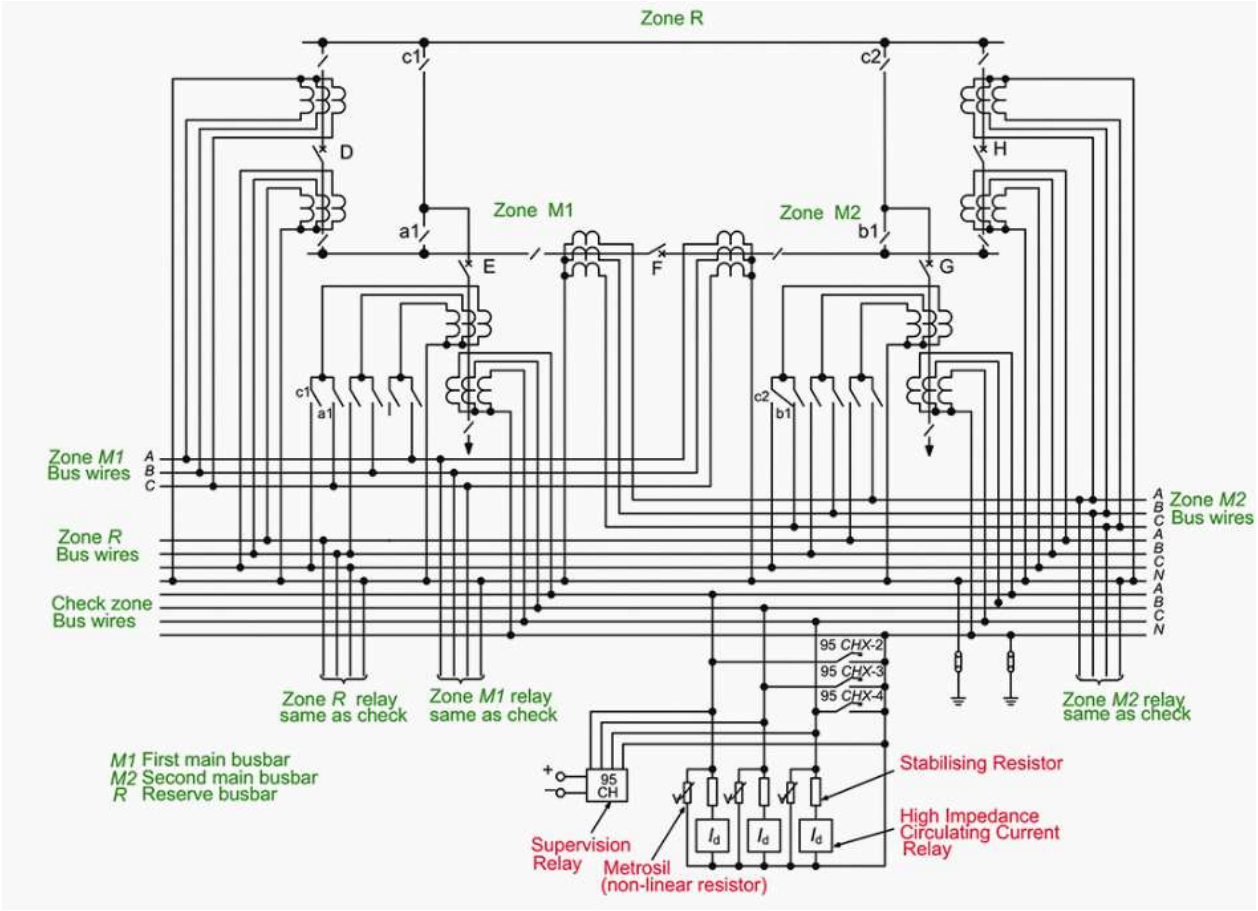
IEC 61850-9-2 SMV Applications

App (4): Bus Bar Protection Sytem Low impedance using IEC61850 (ABB Relays)



IEC 61850-9-2 SMV Applications

App (5): Bus Bar Protection Sytem High impedance



High Impedance
BB Differential

Op. time >20 mS

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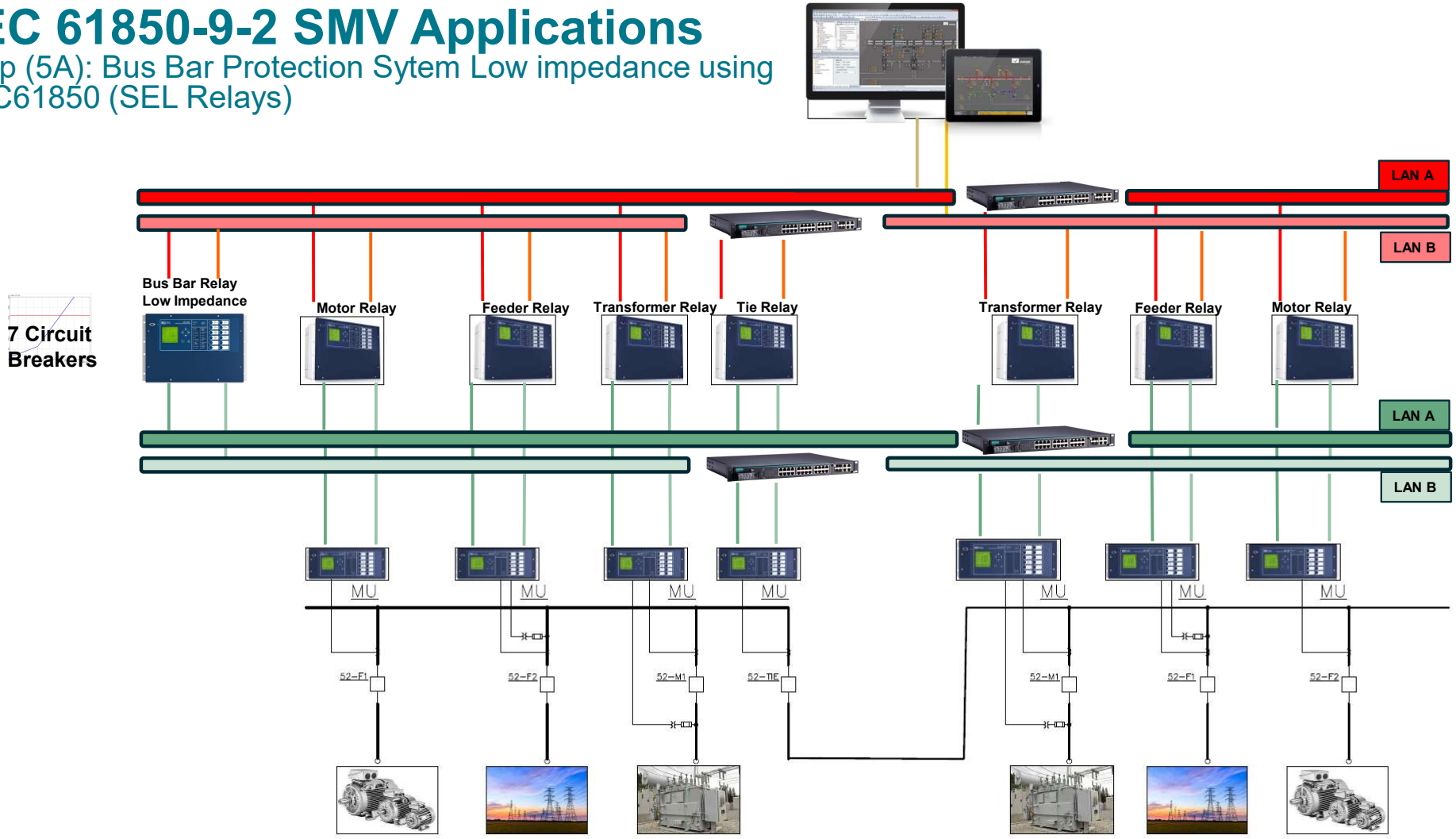
IEC 61850-9-2 SMV Applications

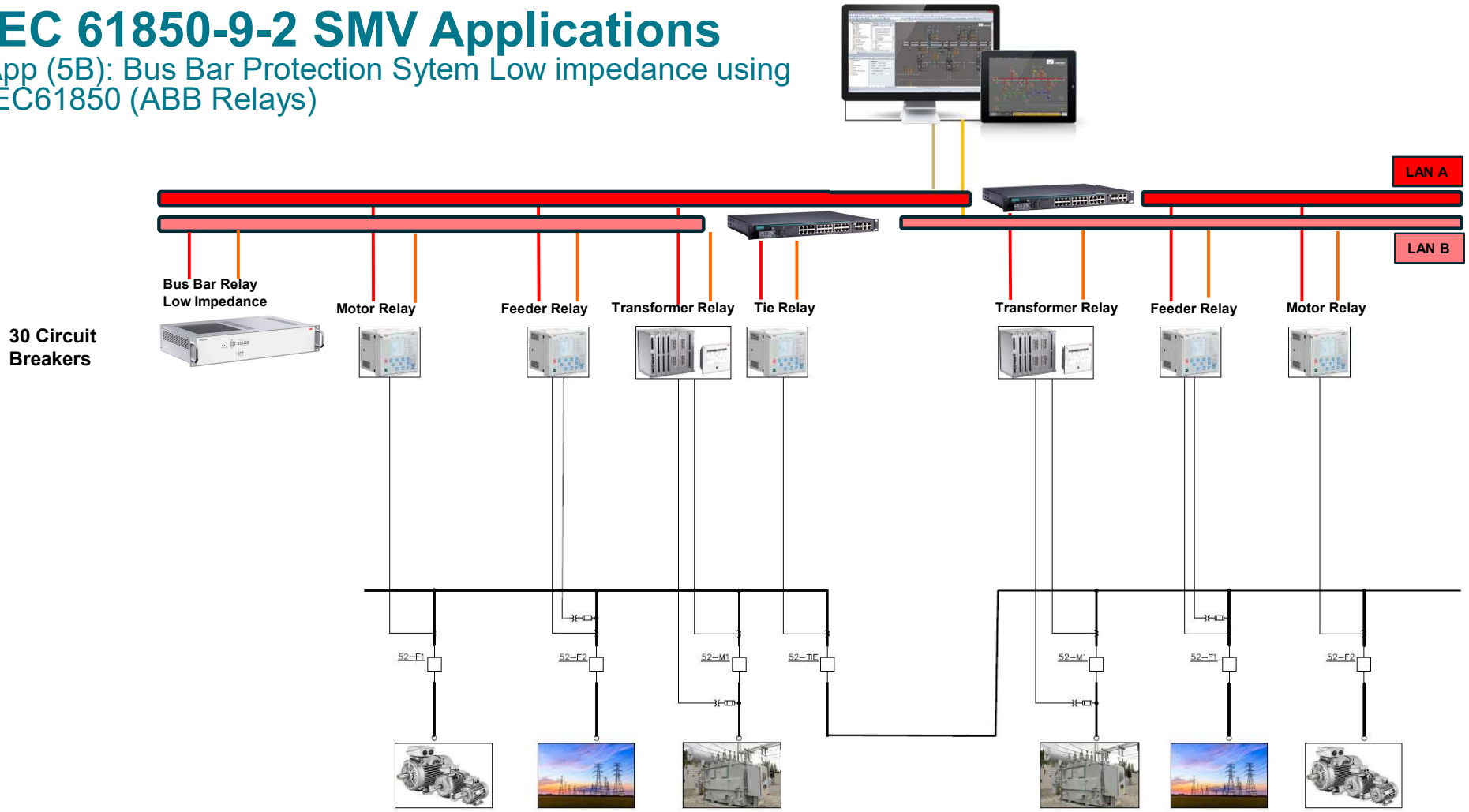
App (5A): Bus Bar Protection Sytem Low impedance using IEC61850 (SEL Relays)



7 Circuit Breakers

IEC 61850-9-2 SMV Applications

App (5B): Bus Bar Protection Sytem Low impedance using IEC61850 (ABB Relays)



IEC 61850

IEC 61850 Working Designs

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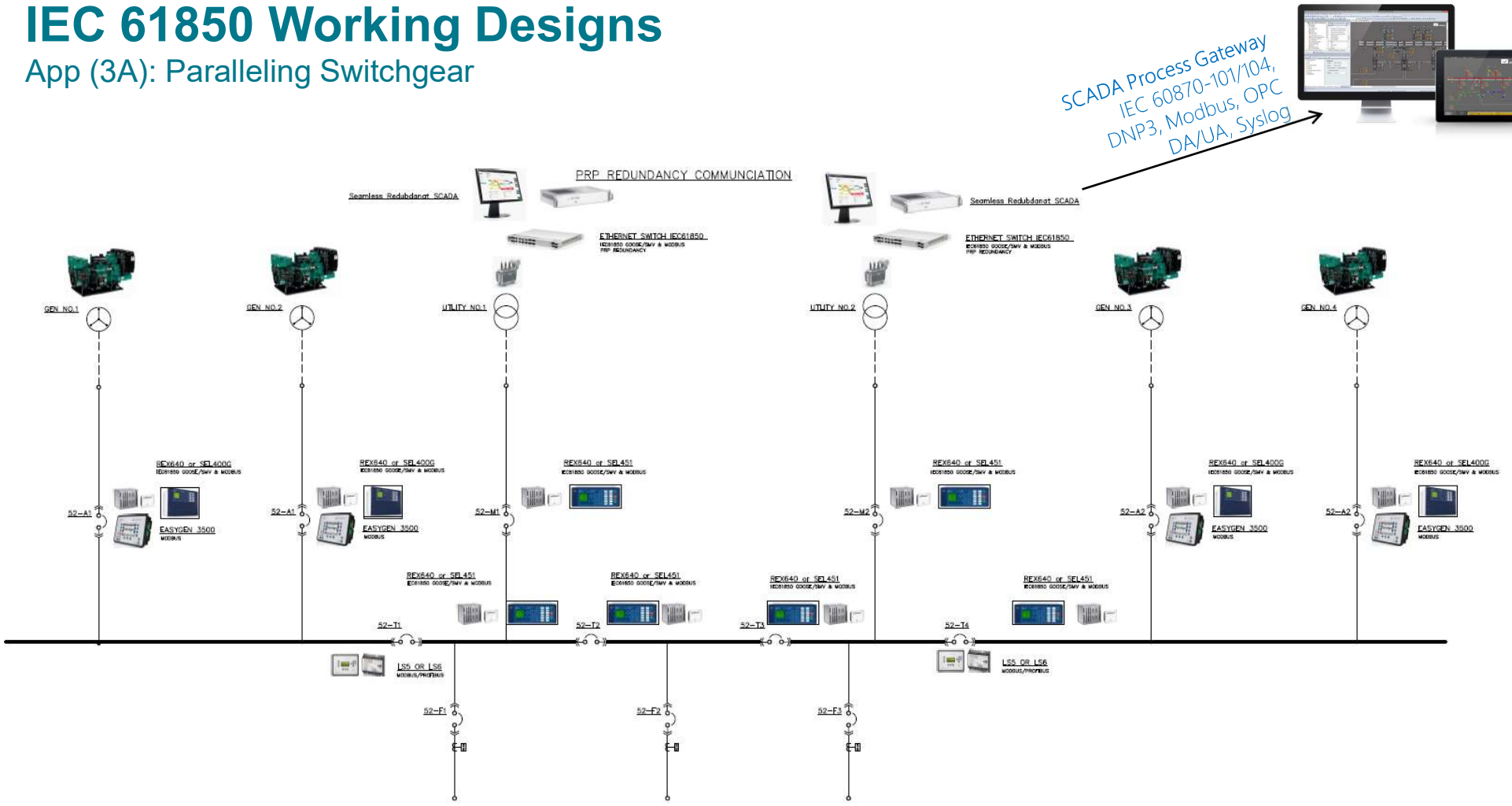
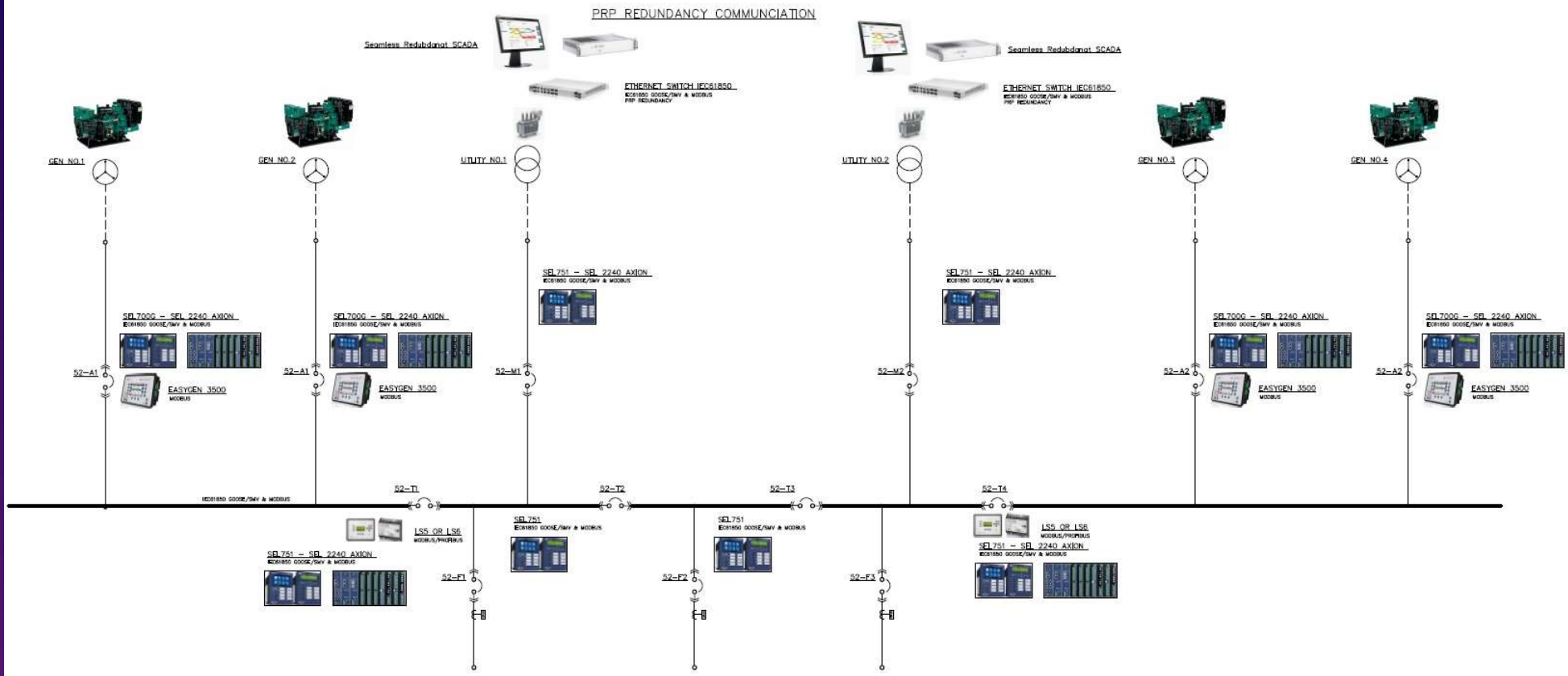
IEC 61850 Working Designs

App (3A): Paralleling Switchgear



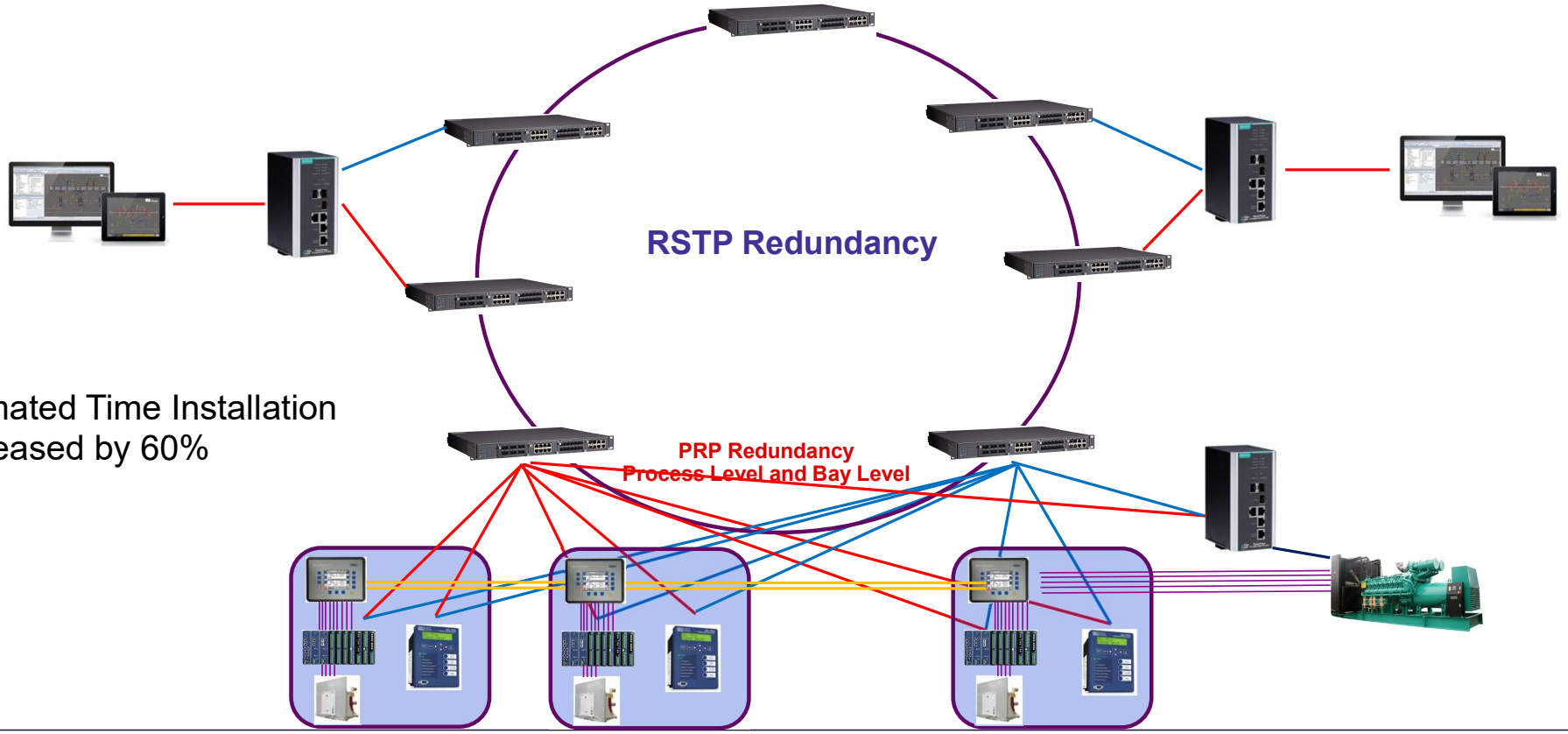
IEC 61850 Working Designs

App (3B): Paralleling Switchgear



IEC 61850 GOOSE Applications

App (3C): Paralleling Switchgear



Estimated Time Installation decreased by 60%

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IEC 61850-8-1 GOOSE Applications

App (3C): Paralleling Switchgear

Easy Gen Inputs	Easy Gen Outputs	Relay Inputs	Relay Outputs
Analogue Input from relay Voltage Control (Relay/Axion)	Analogue Output to Generator Voltage Control	Voltage Inputs GEN Side from PT	Analogue output To Easy Gen Voltage Control (Relay/Axion)
Analogue Input from relay Speed Control from SCADA/Relay/Axion	Analogue Output to Generator Speed Control	Current Inputs BUS Side from CT	Analogue output To Easy Gen Voltage Control (Relay/Axion)
Can bus Communication RS485	Can bus Communication RS485	Currents Inputs GEN Side from CT	Circuit breaker open
Voltage Inputs GEN Side from Relay/	Engine Start Stop	52a	Circuit breaker Close Command
Voltage Inputs BUS Side from Relay	Circuit breaker open Command	52b	Circuit breaker Inhibit Close Command
Currents Inputs GEN Side from Relay	Circuit breaker Close Command through the protection relay	Truck in service	52a
Digital Input from PB Voltage Control (Raise Lower)	Easy Gen Healthy to SCADA	Truck in test	52b
Digital Input from PB Speed Control (Raise Lower)	Ready for operation to SCADA		Voltage Inputs GEN Side from Relay/
Circuit Breaker Position Indication from Relay			Voltage Inputs BUS Side from Relay
Gen Start Stop			Currents Inputs GEN Side from Relay

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IEC 61850-8-1 GOOSE Applications

App (3C): Paralleling Switchgear

Easy Gen Inputs	Easy Gen Outputs	Relay Inputs	Relay Outputs
GEN Oil Level Alarm			
GEN Oil Level Trip			
24V DC supply Healthy			
Digital Input from PB Voltage Control (Raise Lower)			
Digital Input from PB Speed Control (Raise Lower)			
Circuit Breaker Position Indication from Relay			
Gen Start Stop			
Engine Running			
Engine Start			
Engine stop			

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IEC 61850-8-1 GOOSE Applications

App (3C): Paralleling Switchgear

Easy Gen Inputs	Easy Gen Outputs	Relay Inputs	Relay Outputs
Manual Mode			
Auto/STBY Mode			
Transfer to Emergency Mode			
Load Management Mode			
No Load Test Mode			
Utility test Mode			
Gen Alarm			

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IEC 61850

Evolution and Conclusion

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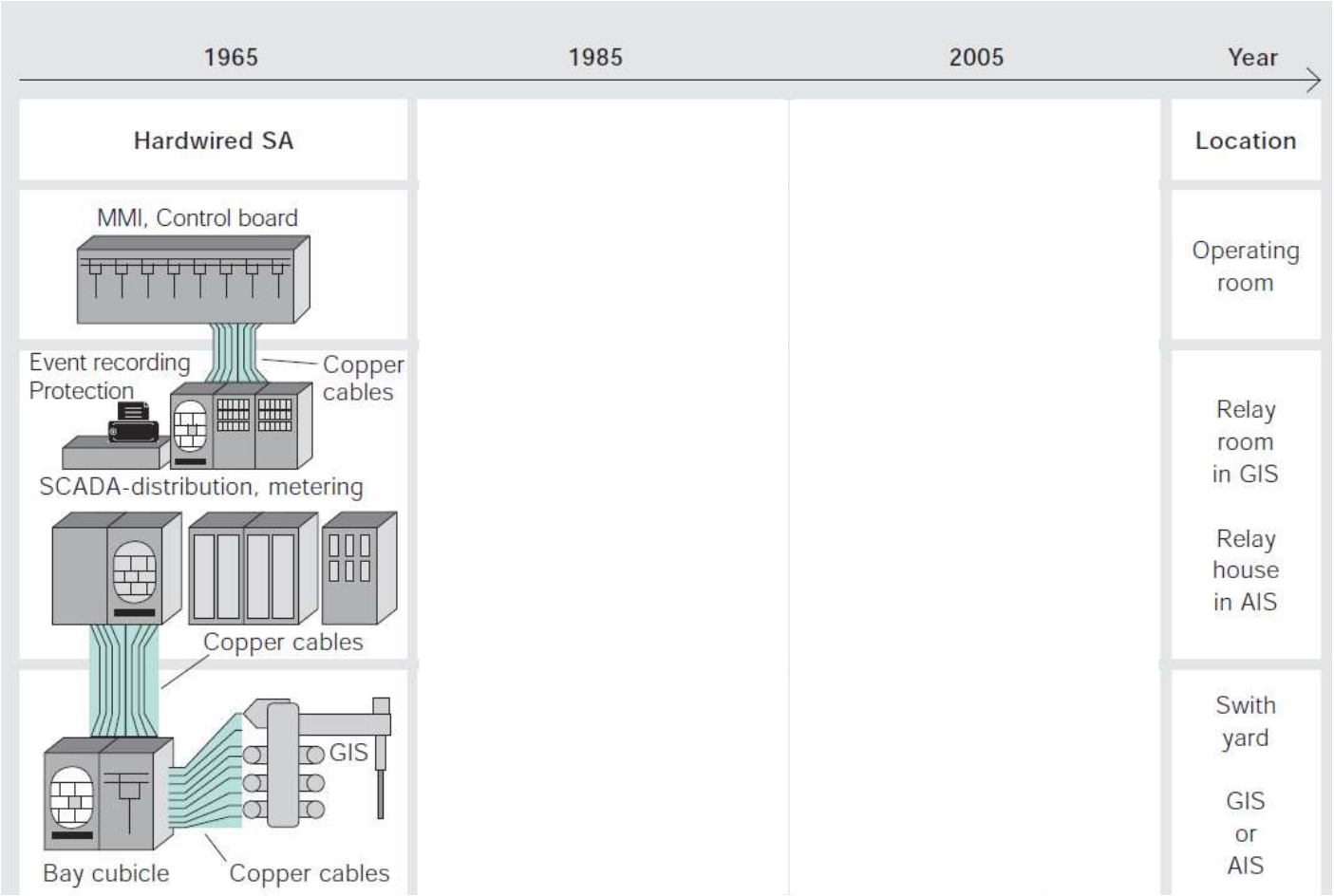
IEC 61850 Standard Overview



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Q&A

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