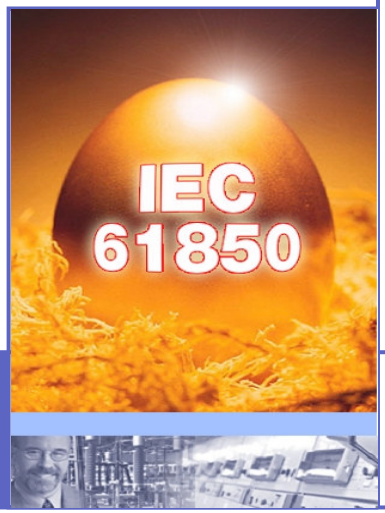
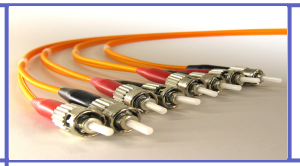
Introduction to IEC 61850 Industrial Ethernet in Distribution Automation

IEEE Switchgear Committee
Philadelphia, 18.10.2007



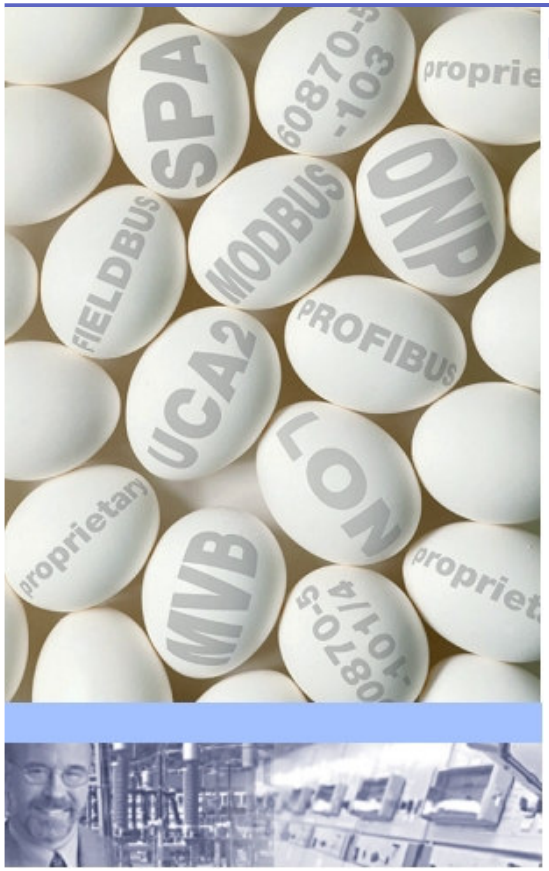
The „Future“ Outlook on how to build electrical systems more efficiently



Presentation Overview

- IEC 61850
  - **Background – Why IEC 61850?**
  - Goals and key thoughts of IEC 61850
  - Benefits of IEC 61850
  - IEC 61850 and impact to Switchgear business
  - Maintenance of the standard
  - Market outlook

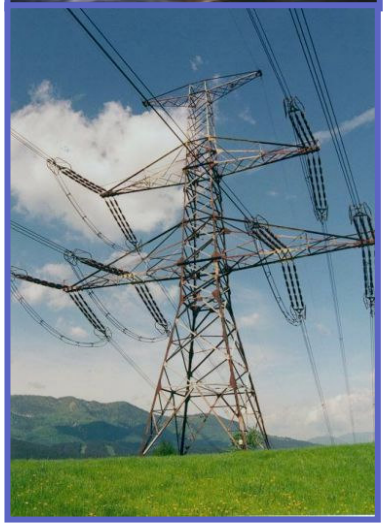
History…



- Standards/de facto standards for substation automation communication
  - IEC60870-5-103
    - Master slave serial protocol, SA semantics defined!, no controls (only with spec. extension), no horizontal communication, too restricted to give easy interoperability
    - Used in Europe and some far east countries
  - UCA2.0
    - Predecessor of IEC61850 by US vendors & utilities
    - Modeling & semantic ideas, horizontal communication
    - Never really accepted by customers
    - Officially and publicly to be replaced by IEC61850
  - Modbus
    - Well known but: no information semantics (signal engineering), no events, no time-synch
    - Used world-wide
    - Master slave serial and TCP version
  - DNP3.0…
  - …and the proprietary ones like SPABus, LONBus, ProfiBus

Reason & requirements for a communication standard?

- Global utility markets
  - Utilities becoming more and more international
  - Markets are growing together – global energy market
- Flexible communication structures, requirements for standard
  - Communication systems must be flexible to fulfill requirements of the one world not of one country
  - Rapid changes in communication state-of-the-art technology, but long life cycles of communication standards
- More information is needed for better utility performance
  - Modern secondary systems produce bulk amount of data
    - Data need to be converted into information
  - Communication networks provide access from anywhere
- The communication in substations has to support
  - Guaranteed and fast real time system responses
  - High resistance against harsh environmental conditions



The global standard common for IEC and ANSI ...

… was ready in 2004

… Products are already released!

… attracts a lot of attention from our customers

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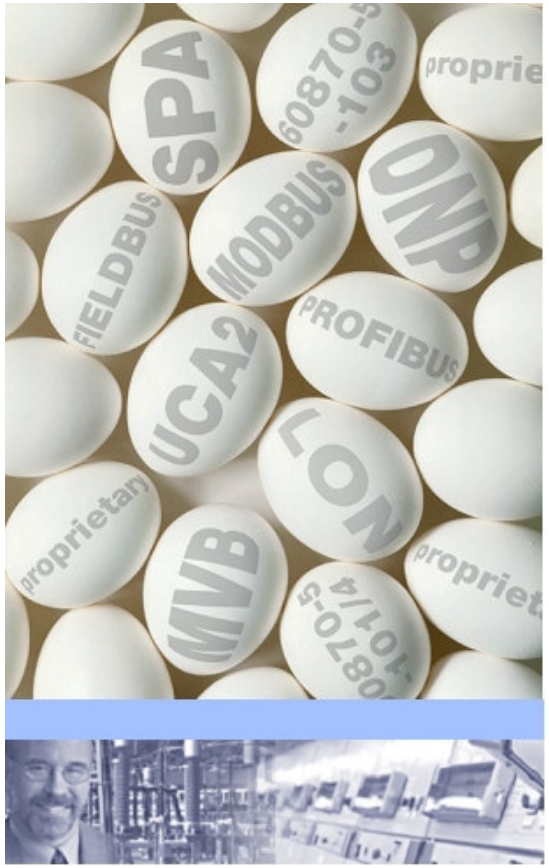
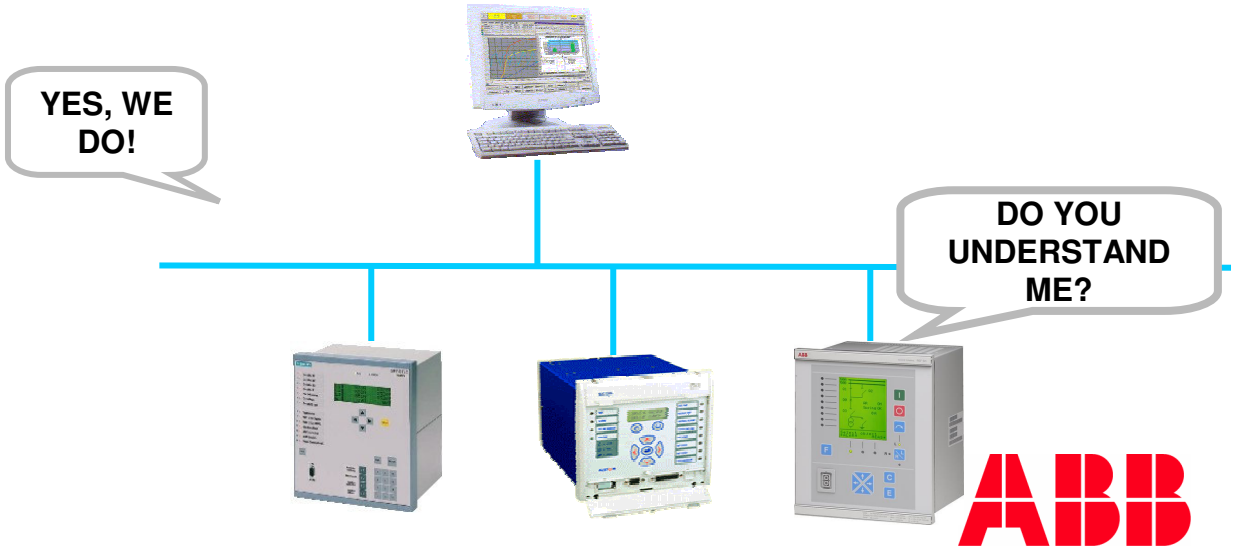
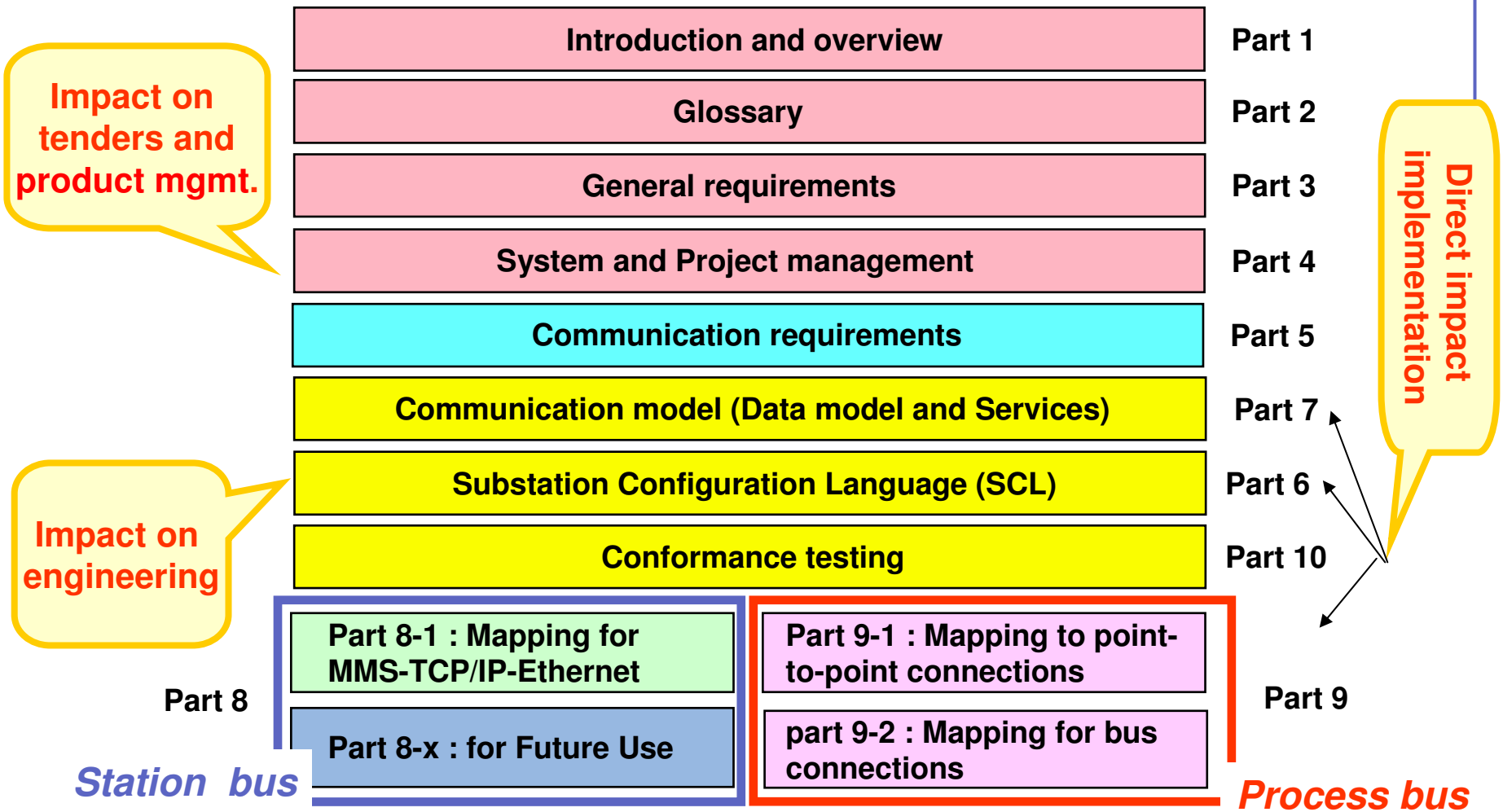
Background – What is IEC 61850?



- **IEC 61850 is a global standard for "Communication Networks and Systems in Substations"**
- „How to make different devices AND tools from different vendors work together (=interoperability)"



Structure of the IEC 61850 standard



Impacts not only on communication !

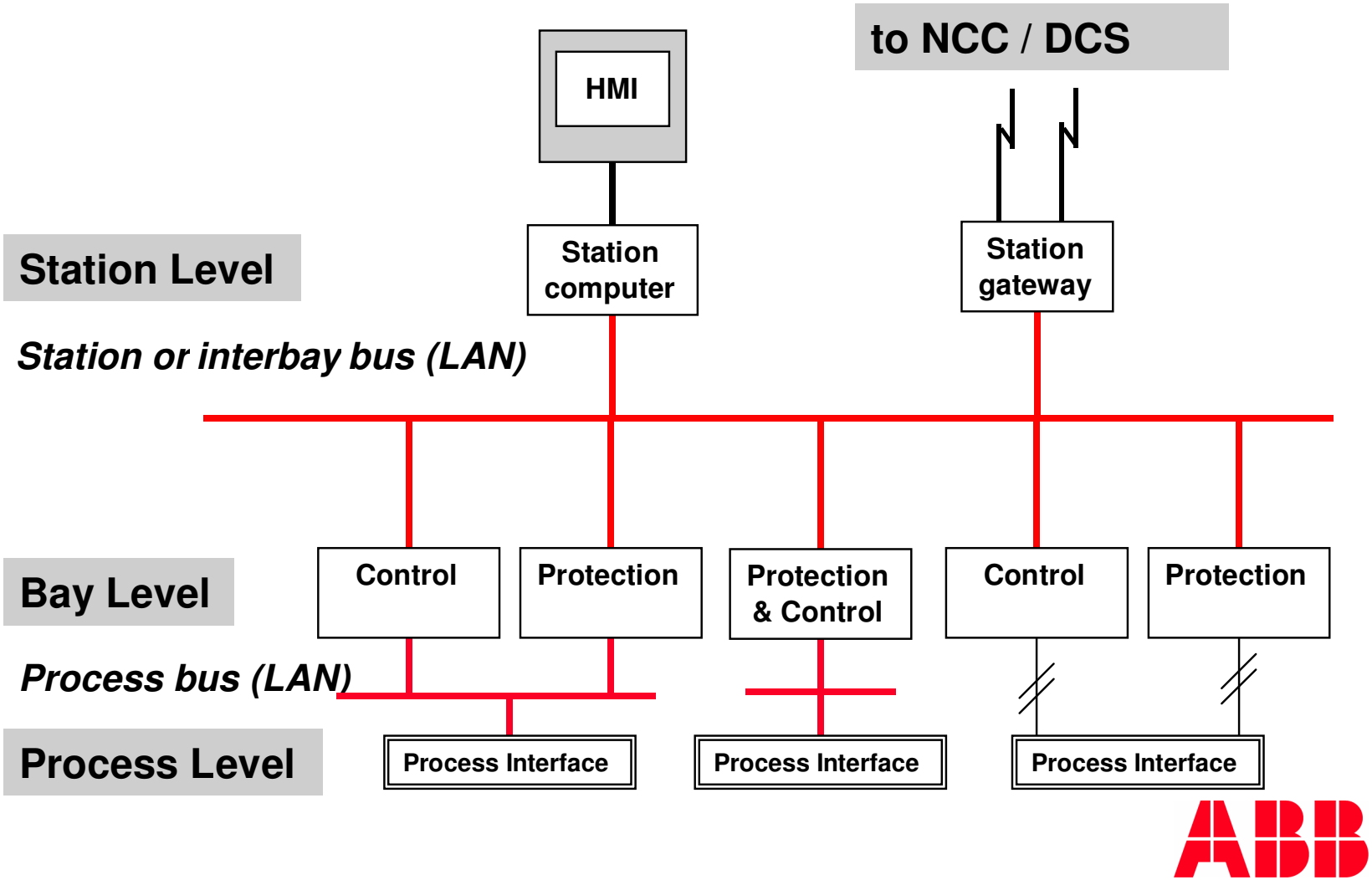
Goals and key thoughts of IEC 61850

- It specifies an expandable **data model and services for substation automation**
- It does not specify **protection or control functionality,** but it specifies how they will expose their information
- It supports free allocation of functions to devices
  - It is open for different system philosophies
- It defines a description language for substation automation systems
  - This facilitates efficient device integration
  - It supports comprehensive consistent system definition and engineering
  - This makes not only the devices, but also their tools & systems interoperable
- It uses Ethernet and TCP/IP for communication
  - Provides the broad range of features of mainstream communication
  - It is open for future new communication concepts

ABB

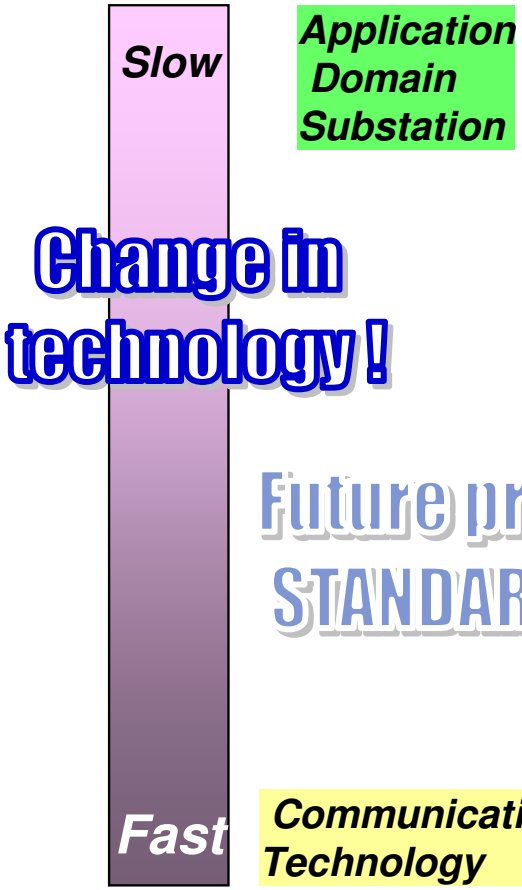
Application area of IEC 61850

- Electrical substations, also in industrial plants



Approach of IEC 61850

Problem for standardization approach

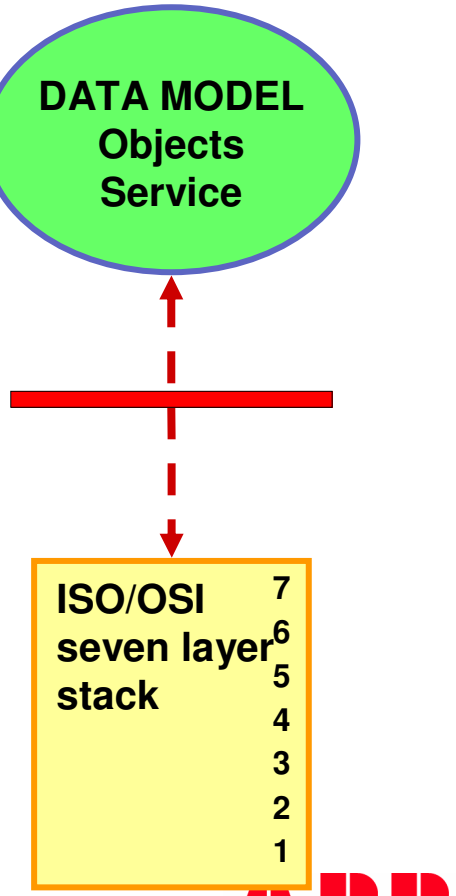


APPLICATION
switching devices
protection & control
commands, events,
alarms,
...

Split !

COMMUNICATION
messages,
telegrams, frames
on the wire
...

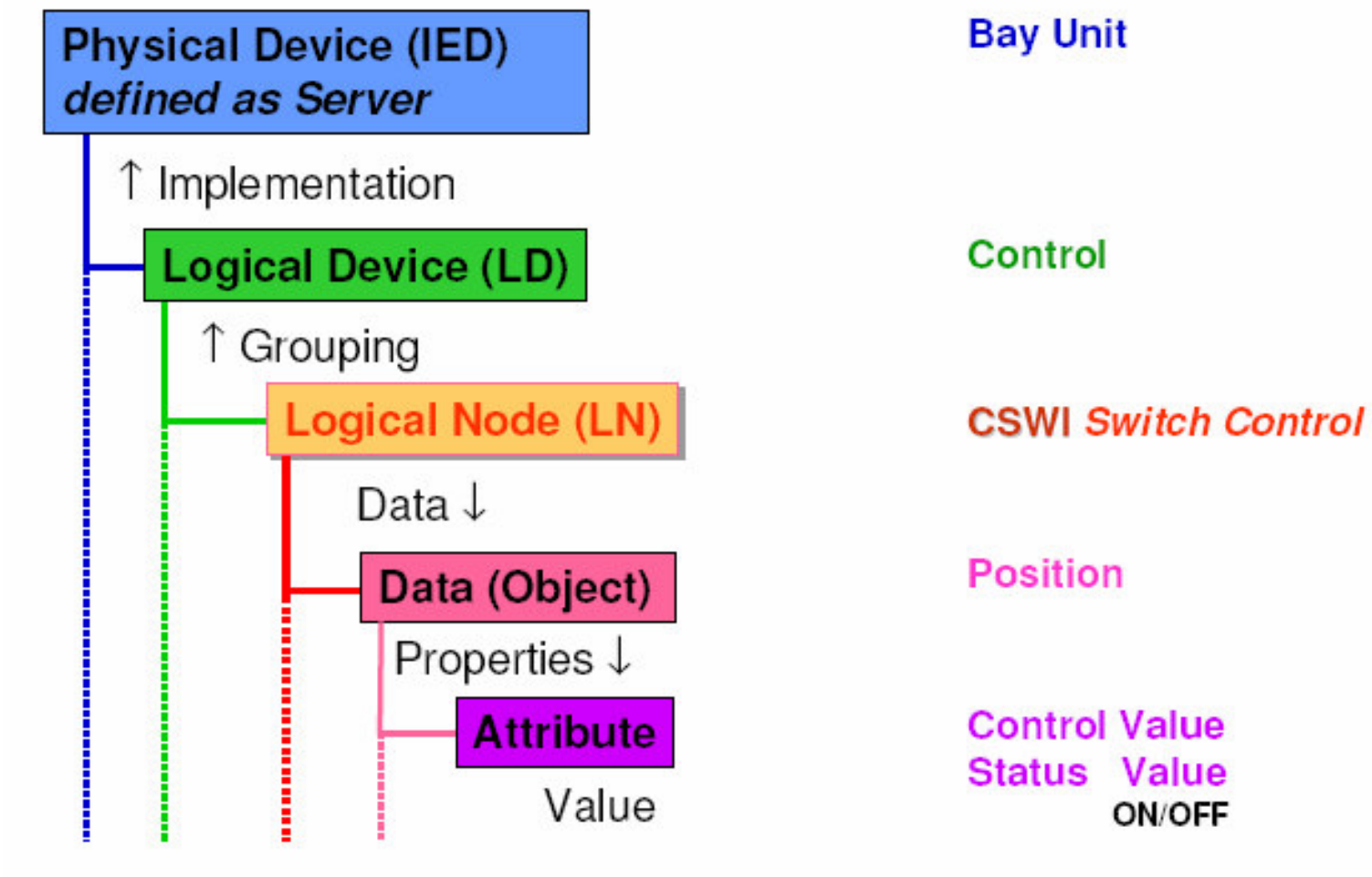
Solution for standardization approach



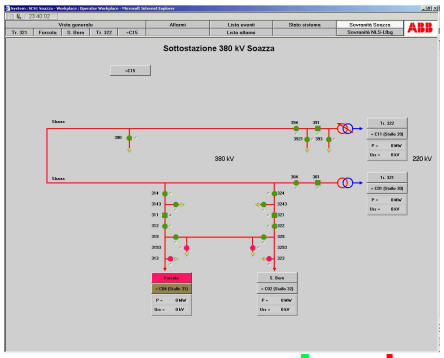
ABB

Data modeling hierarchy

IEC 61850-7



Example: Modbus and IEC 61850



Modbus

Position QA1	DA:12, 1x2347, latch reset 0x2454
Trip DistanceProt.	DA:42, 1x1827, CD bit 1x1828
Frequency	DA:12, 4x0488
Close CB	DA:12, select 0x4096, close 0x4098

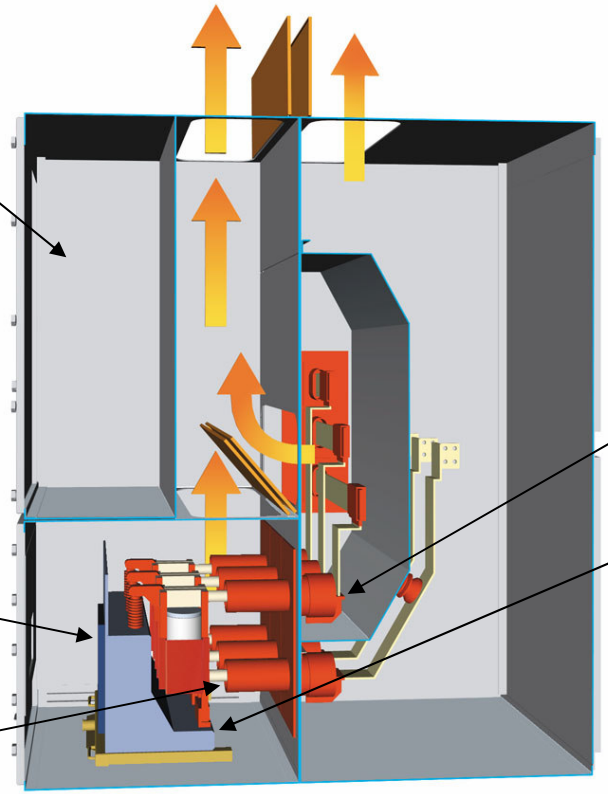
IEC 61850

Position QA1	E1Q1KA1.Ctrl/QA1CSWI1.Pos.stVal
Trip DistanceProt.	E1Q1FA1.Prot/PDIS1.Op.general
Frequency	E1Q1KA1.Ctrl/MMXU1.Hz.mag.f
Close CB	E1Q1KA1.Ctrl/QA1CSWI1.Pos.ctVal

Voltage Level **Bay** **IED** **Log. Device** **Log. Node** **Data/Attribute**

IEC 61850-7 modeling example – real world

EFPTOC – earth fault protection
PHPTOC – 3phase over current protection
INPHAR – motor and trafo inrush detector
CBCSWI – breaker control
CBCILO – breaker interlocking
IMMXU – current measurement



IHMI
- Local display

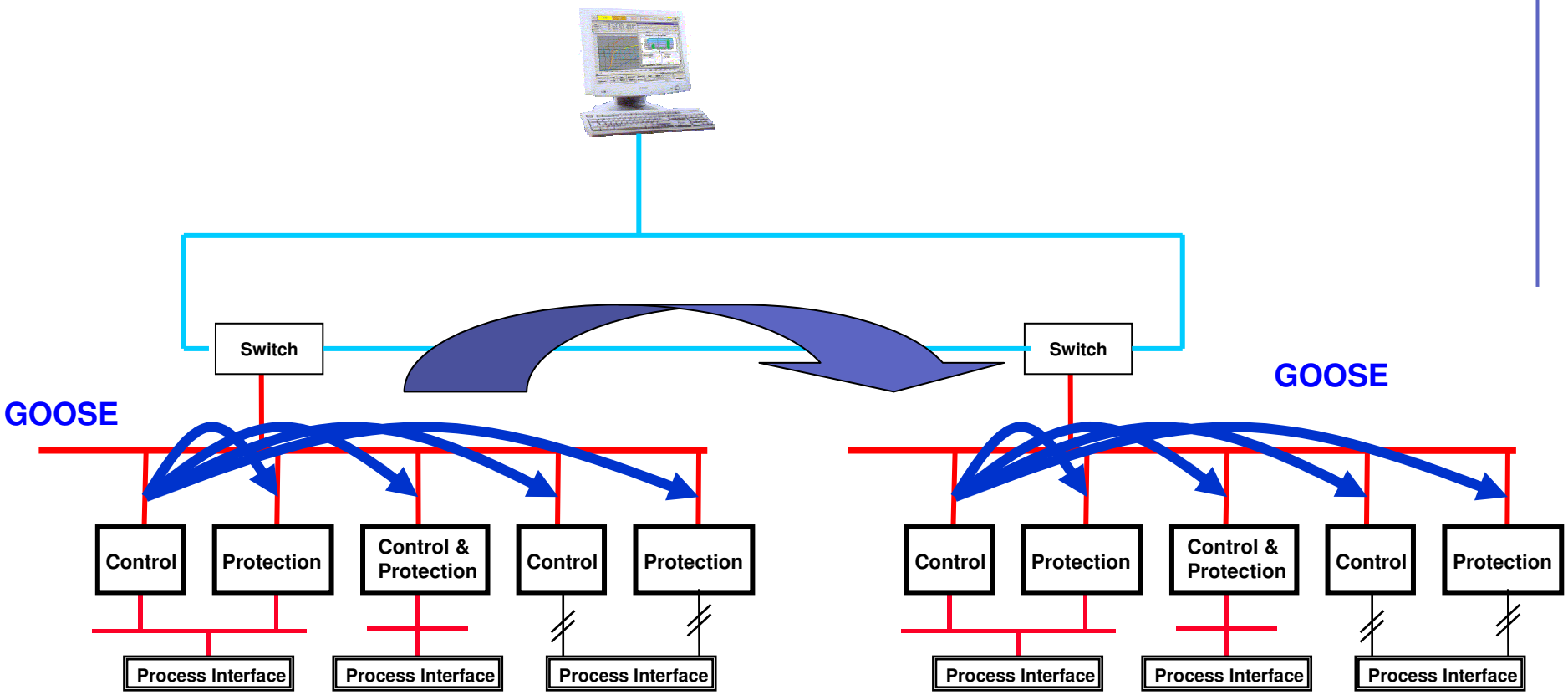
CBXCBR
- Circuit breaker

TRXSWI
- CB truck status

TCTR – current transformer

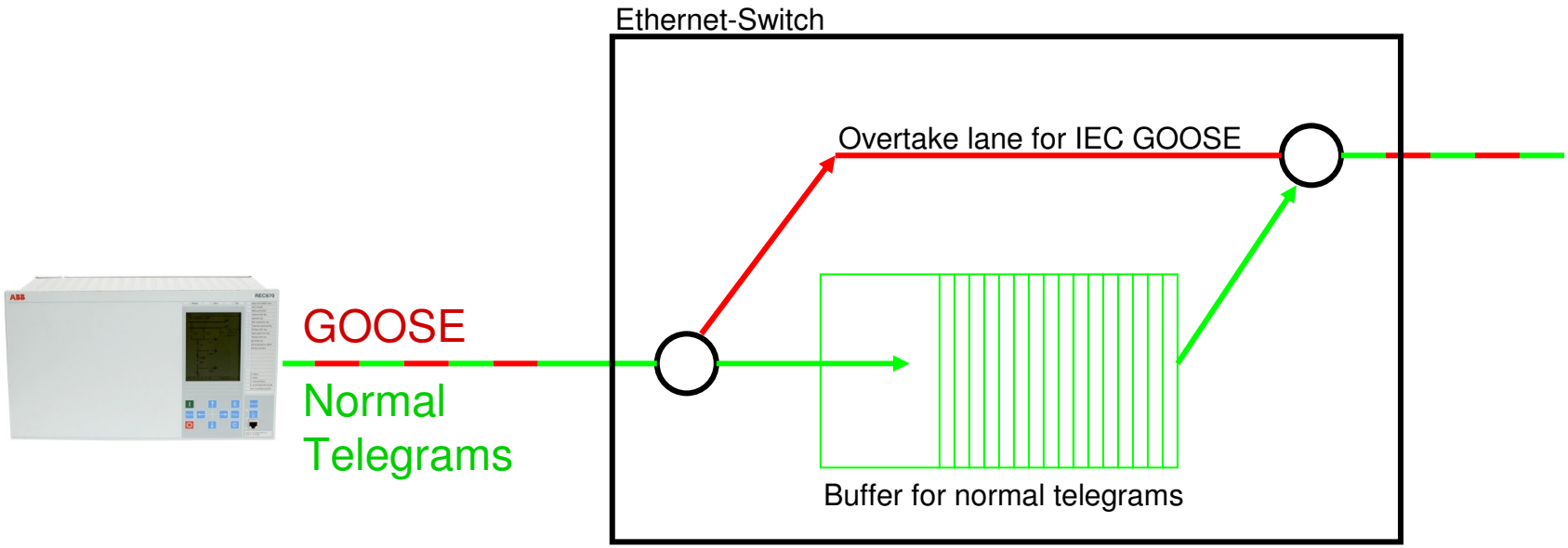
ESXSWI – earthing switch

Horizontal communication: GOOSE



GOOSE: Generic Object Oriented Substation Event

IEC 61850 GOOSE - Priority tagging



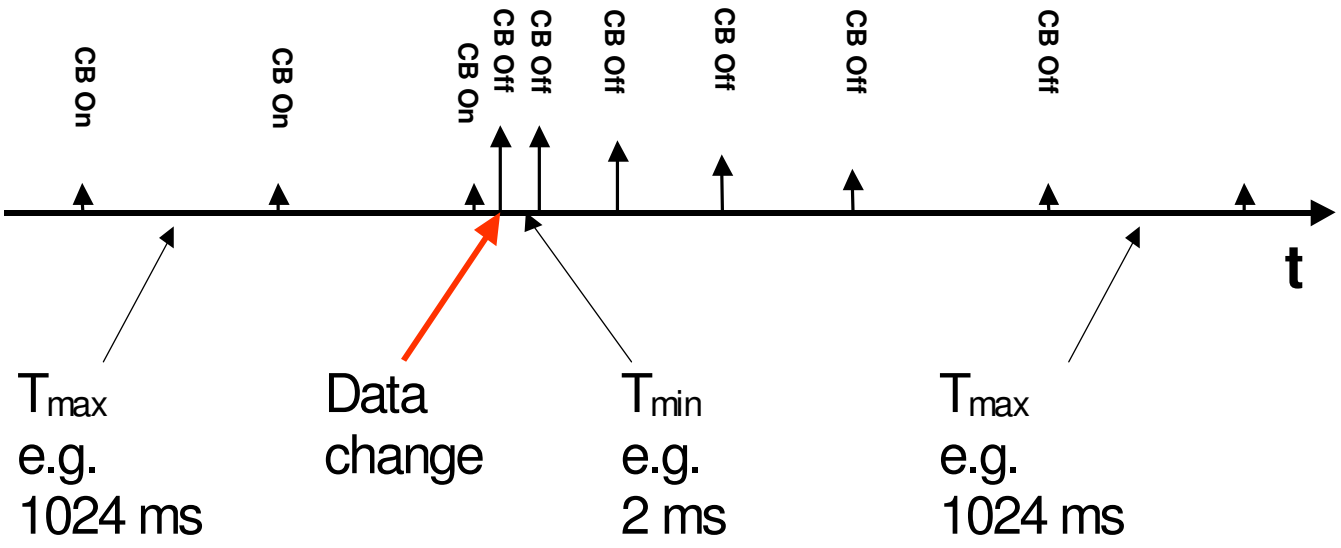
- IEEE 802.1p CoS (Class of Service) extensions to Ethernet is specified to be used for GOOSE and SMV
  - To fully utilize these advantages, network infrastructure must support this

Comparison traditional wiring vs. GOOSE

	Traditional way		IEC 61850 with GOOSE
-	Requires N*(N-1)/2 links for N relays.	+	Relays share common network making sophisticated protection schemes possible.
-	Requires filtering on links to prevent false trips.	+	Number of links for N relays is N.
-	Reprogramming can require rewiring.	+	Relays send their status to all other relays at once using GOOSE.
-	Don't know if links are working until you use them.	+	Status exchanged continuously.
+	Educated engineering, testing and commissioning personnel is not needed	+	Reduction of wiring costs
+	Accepted solution in every market	+	More flexible programming is independent of wiring
+	Wire will be always wire --> unlimited lifecycle	+	Reliability: Link status known before use.
		+	Higher performance with more data.
		-	Higher investment to network components is needed (not always true, since You often have the network anyway)
		-	Education of engineering, testing, and commissioning persons

Power of GOOSE services

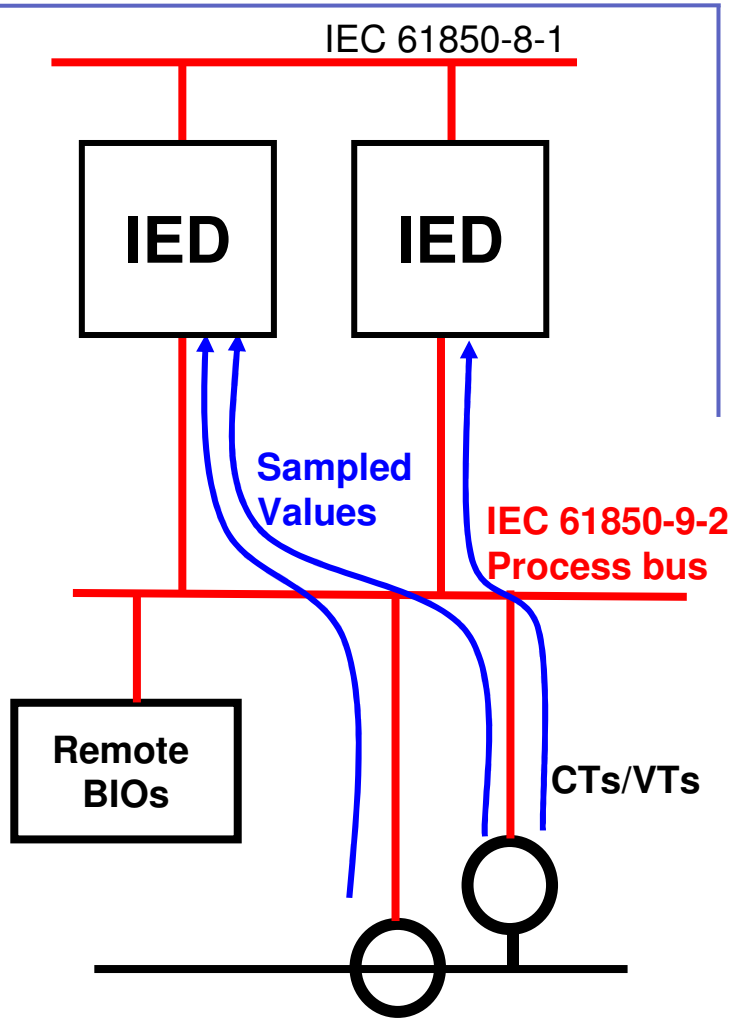
- GOOSE (Generic Object Oriented Substation Event)
  - System-wide data distribution
    - Device to device exchange of IED binary status information
  - Based on subscription/publisher mechanism
  - Mechanism:



Sampled measured values

IEC 61850–9-1, 9-2

- A method for transmitting sampled measurements from transducers
- Enables sharing of I/O signals among IEDs
- Supports 2 transmission methods:
  - Multidrop point-to-point service (USVC) over serial links
    - Predefined format and content
    - One direction (sensor – IED)
  - Multicast service (MSVC) over Ethernet IEC 61850-9-2
    - Information content is fully configurable
    - Status and configuration information can be accessed from IED



IEC61850-6, SCL - Goals within IEC61850

- *To be able to exchange the device descriptions and system parameters between tools of different manufacturers in a compatible way, IEC 61850-6 defines a substation configuration language (SCL)*
- Goal of IEC61850
  - Interoperability of IEDs from different manufacturers: process - bay, bay - station, MV bays - trafo - HV bays, Control - Protection
- An IED has to know about its environment: other IEDs, connection to the plant, communication capabilities

  => **SCL describes binding of IED to plant and communication system**
- Simple devices may be preconfigured, online configuration needs a kind of directory for ALL devices, engineering offline without IED manufactured

  => **SCL describes device capabilities**

IEC61850-6, SCL – file types

- .ICD file - IED Capability Description
  - For data exchange from the IED configuration tool to the system configuration tool
- .CID file - configured IED description
  - For data exchange from the IED configuration tool to the IED. It describes an instantiated IED within a project. The communication section contains the current address of the IED.
- .SSD file - system specification description
  - For data exchange from a system specification tool to the system configuration tool. Describes the single line diagram of the substation and the required logical nodes.
- .SCD file - Substation Configuration Description
  - For data exchange from the system configuration tool to IED configuration tools. This file contains all IEDs, a communication configuration section and a substation description section. Also for system products.

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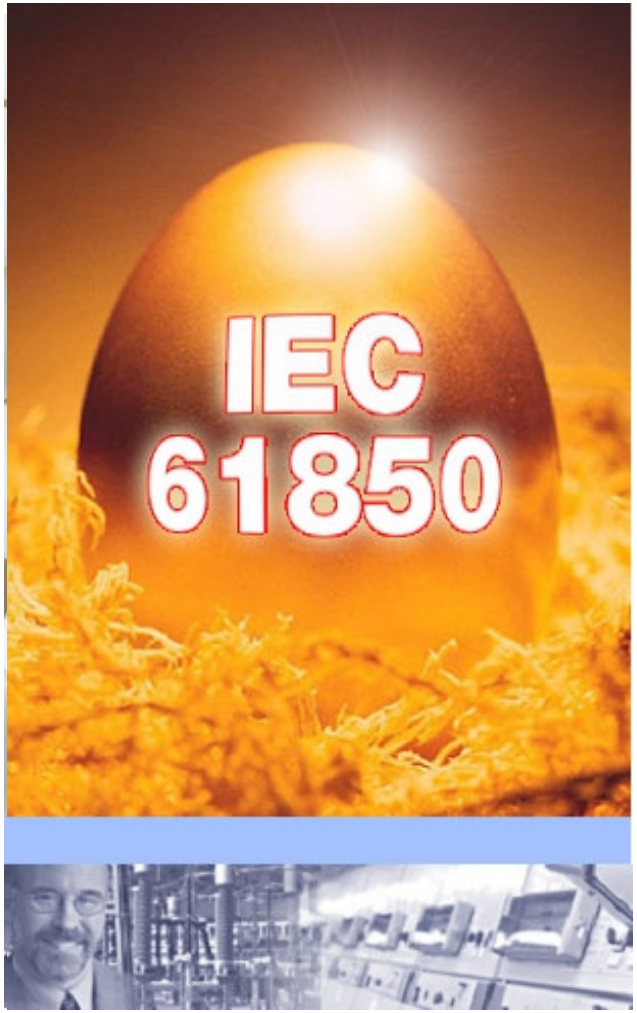
Benefits of IEC 61850



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

- Cost savings on substation automation system deliveries
  - Efficient device integration and system level engineering
  - Simpler wiring
- Support for new type of applications
  - Standardized high performance communication between bays
  - High performance process bus to connect intelligent sensors reducing system costs
- Future-proof applications
  - Application configuration withstands changes on communication systems
- Better connectivity and interoperability between devices and systems from different vendors
- Standardized, controlled way to define extensions to the system

Benefits of IEC 61850

- The tragedy of Automation:
  "There are no benefits without additional costs"
- It is not only account's view how to properly justify benefits of IEC 61850
- Keys to Successful Justification
  - Identify all the benefits (obvious).
- Identify ALL the costs:
  - Equipment purchase
  - Engineering
  - Installation
  - Commissioning
  - Utilization
  - Future upgradeability

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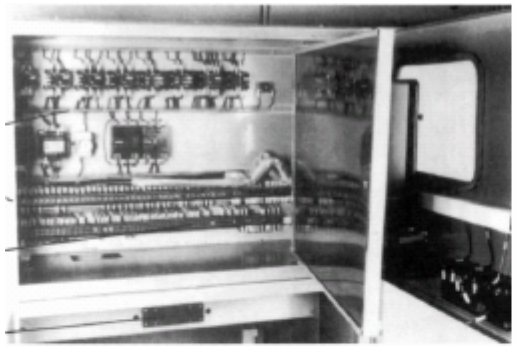
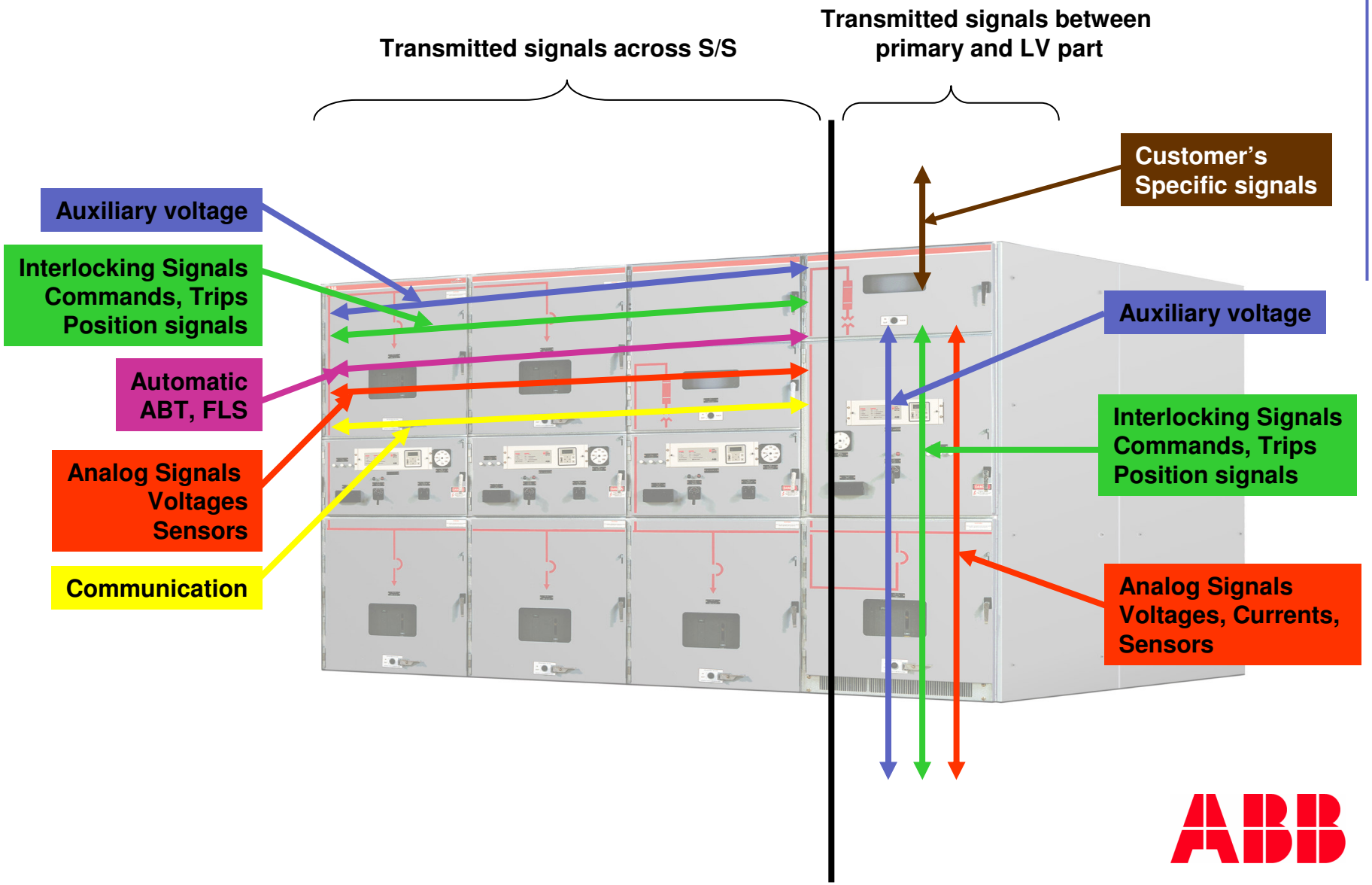
Impact of IEC 61850 to Medium Voltage Switchgears

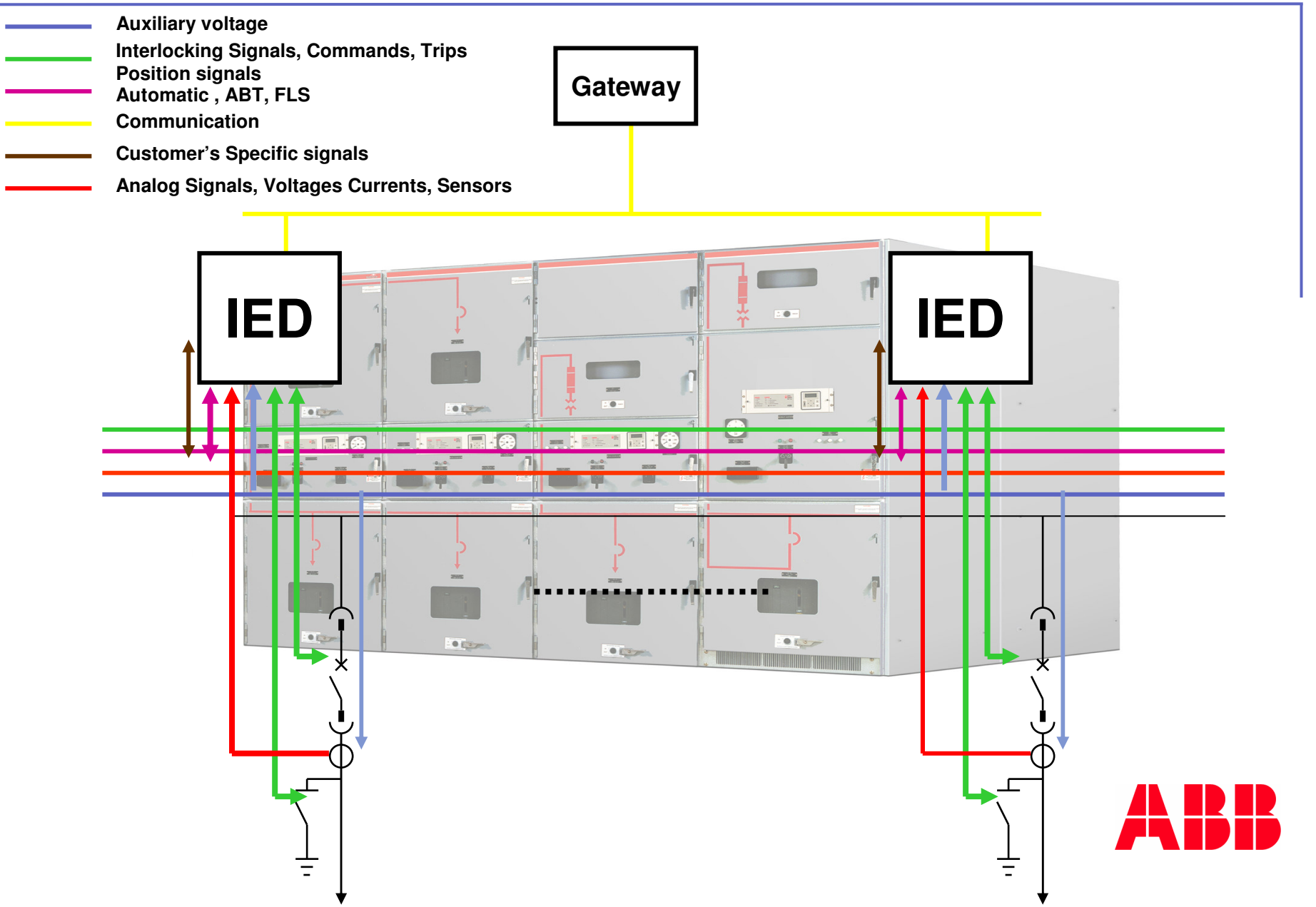


- Market pressure
  - Reduction of delivery time
  - Lower price
  - More functionality
  - …
- Slow changes in primary technology, fast changes in secondary technology
- IEC 61850 and Ethernet technology is a next step in Switchgear business
- IEC 62271-3 , Digital interfaces based on IEC 61850

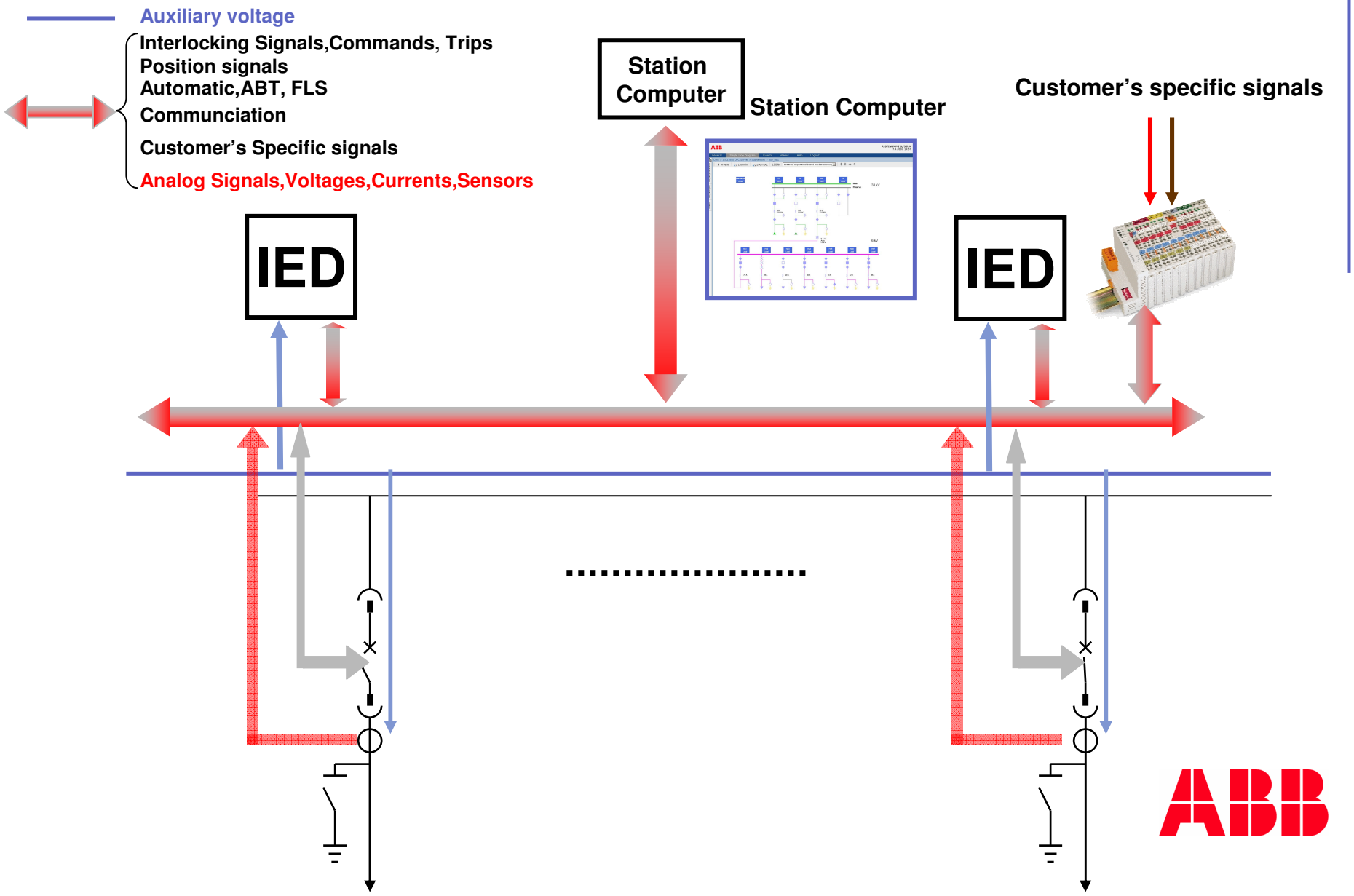
Impact of IEC 61850 to Medium Voltage Switchgears



Conventional MV Architecture



State of ART


Auxiliary voltage
Interlocking Signals,Commands, Trips
Position signals
Automatic,ABT, FLS
Communciation
Customer's Specific signals
Analog Signals,Voltages,Currents,Sensors
Station Computer
Station Computer
Customer's specific signals
IED
IED

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IEC Working groups TC 57

Working groups of the technical committee 57 in the IEC

IEC TC57 is responsible for communication in “Power Systems”

- **WG 3**: Telecontrol protocols
- **WG 10: Communication standards for substations: Functional architecture and general requirements**
- **WG 11: Communication standards for substations: Communications within and between unit and station levels**
- **WG 12: Communication standards for substations: Communications within and between process and unit level**
- **WG 13**: Energy management system application program interface (EMS - API)
- **WG 14**: System interfaces for distribution management (SIDM)
- **WG 15:** Data and communication security
- **WG 16:** Deregulated energy market communications
- **WG 17:** Communications Systems for Distributed Energy Resources (DER)
- **WG 18:** Hydroelectric power plants - Communication for monitoring and control

Commonly responsible for the IEC 61850

Only WG10 is active at the moment,since standardization work is ready for most of the parts

Oct ’05: WG10,11,12 have merged to one WG10

UCA User's Group International

- UCA International Users Group = non profitable / non-IEC organization to:
  - Maintain the standard
    - GoE (Group of Experts) analyzing the input = "Tissues"
    - Voting procedure for "Tissues"
    - Collect input/resolve and feed to IEC -> Amendments, new editions
  - Develop testing procedures
    - UCA UG Conformance Test Procedures
  - Accredit test centers
    - KEMA in Netherlands is a accredited test center (see certificate of SPA-ZC400) – class A certification
    - ABB SVC centre Baden – class B certification
    - AEP – class B certification
  - Develop implementation guidelines
    - "9-2 light"
  - Anybody can participate!

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Market update: IEC 61850 (1

- All major SA vendors promote new standard actively
- Hundreds IEC 61850 based SA systems are already commissioned
  - ABB – more then 250 projects from Utility customers and more then 50 projects for Industrial customers
- Interest on the electrical utilities varies – conservative business
  - Some wants to try, some wants to wait, some require today
- Extension of IEC 61850 Models for
  - Hydro Power plants IEC 61850-7-410
  - Power Generation
  - Wind Power IEC 61400-25
- Next extensions already proposed e.g. Low voltage switchgears

Market update: IEC 61850 (2

- Larger industrial customers require IEC 61850 already today, e.g. O&G, Pulp&Paper
- Standard is not that easy and unambiguous
  - Expectations and interpretations vary
- Topics not settled – at least on a standard way
  - Redundant communication, redundant Ethernet – IEC 62439
  - How to verify interoperability – conformance can be verified e.g. by KEMA – class A certificates, ABB and AEP – class B certificates
  - Physical media (electrical, optical, connectors)
  - Information security

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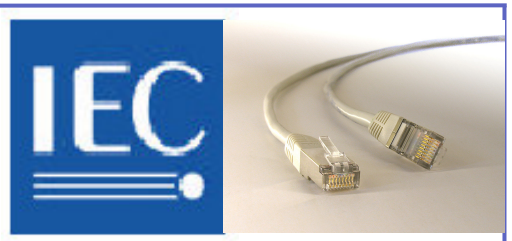

- Industrial Ethernet
  - Why Ethernet in Distribution Automation and our challenges
  - Ethernet architecture aspects

Why Ethernet in Distribution Automation?

- Ethernet is the prevalent communication technology
  - Most of the competing technologies, even technically better have failed to enter market
- A lot of applications, a lot of protocols, a lot of components available on the free market
  - Cost savings and better functionality and performance than proprietary communication solutions for automation
- Unlike the traditional serial communications, the Ethernet link can be shared
  - Most of the applications can run on same Ethernet backbone of the plant
- Whole automation community is going for Ethernet based solutions
  - E.g. DA: Modbus/TCP, DNP 3.0 over LAN/WAN, IEC 61850, ...

Ethernet challenges in Distribution Automation

- Environmental
  - Even the components meant for industrial use, will not fullfill “by default”, requirements for DA
  - EMC, ambient temperature, power supplies
- Availability
  - Some applications require high availability
- Time synchronization
  - Some, especially emerging applications require very high accuracy time synchronization
- Cyber Security
  - Common technologies are more open for attacks and other vulnerabilities of this kind

Communication trends in DA

- All trends showing success of Ethernet!
- IEC 61850 – the communication standard for DA
  - Standardization ready not until 2005
  - Booming globally in Utility sector
    - Several major utilities standardized use of IEC 61850
  - High interest on Industrial Electrification
    - Petrochemical, Pulp&Paper, …
- DNP over LAN/WAN
  - Mostly asked by old DNP 3.0 users in ANSI markets
- Modbus/TCP
  - The common nominator for all types of systems – but only a fallback solution

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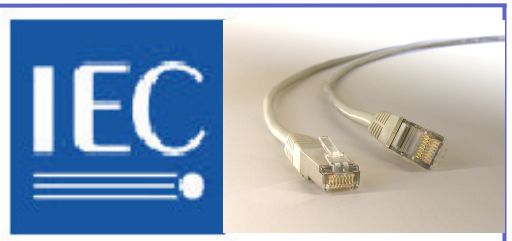

- Industrial Ethernet
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Ethernet setups for IEC 61850 based systems

- IEC 61850 does not mandate system topology or even physical layer – it says just *Ethernet*
  - Topology and cabling can be freely chosen
  - High availability redundant solutions are not yet standardized
- Aspects to consider
  - Geographical layout
  - EMC requirements
  - Amount of devices
  - Availability of the system – Ethernet Redundancy
  - Connectivity of existing non-IEC 61850 devices

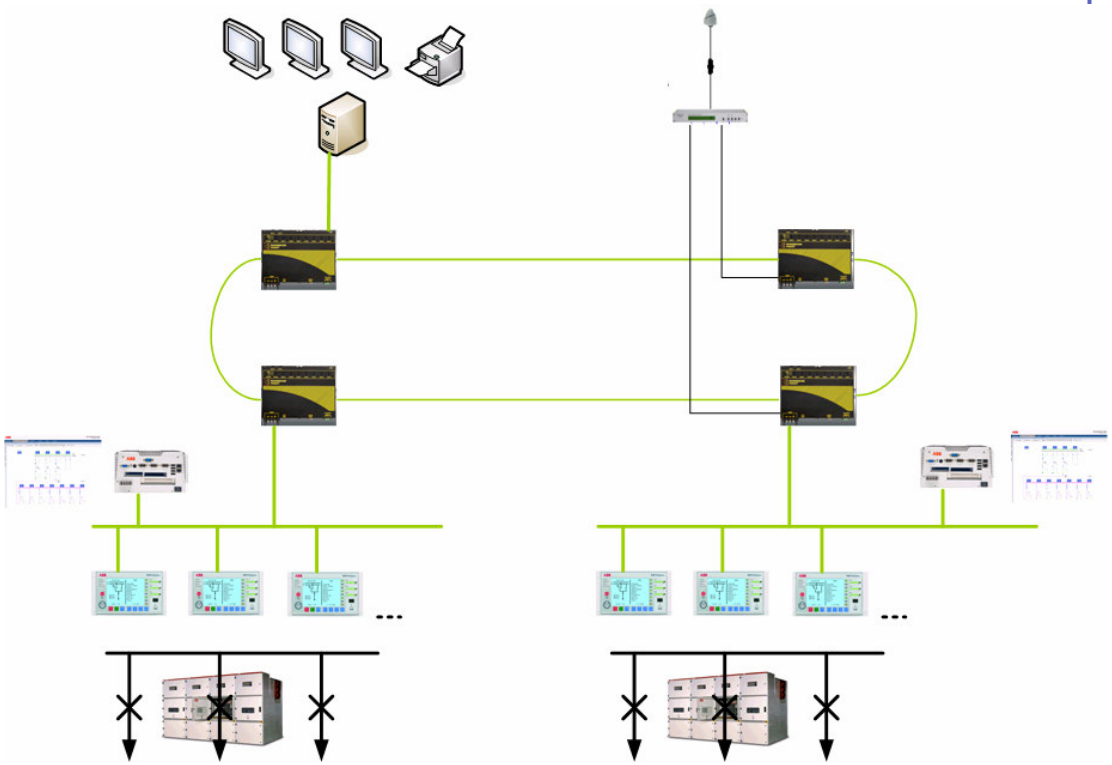
Comparison of *tree* and *ring* architectures

Criteria	Tree	Ring	Remark
Cost	Higher -	Lower +	Depends on geographical layout
Availability	Lower --	Higher ++	Applies backbone only
Worst case load	Lower +	Higher -	Load can be controller by report buffering, E.g. GOOSE can be run with priority
Response time for real-time applications	Higher +	Lower -	E.g. GOOSE has to pass all switches in ring, adds n*100 µs

- Most often the optimal topology is combination of stars and rings

Examples, large systems interconnected

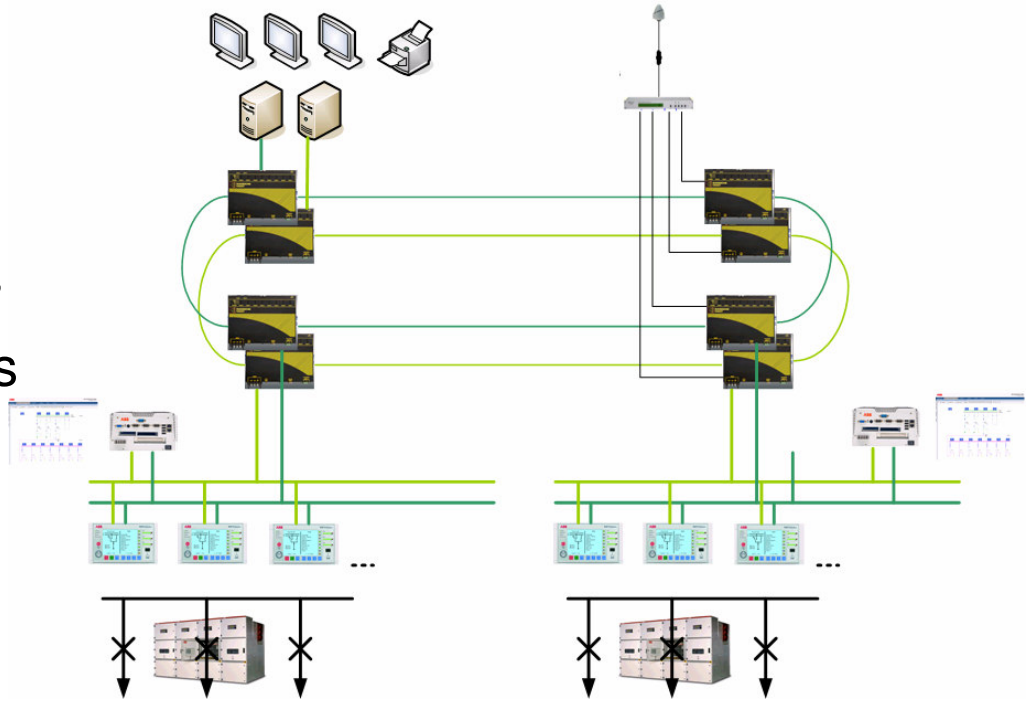
- Single ring backbone
  - Network redundancy is given by selection of proper switch, RSTP
  - Lower cost
  - High reliability than star configuration
  - Optical/Galvanic – both are possible
  - Projects with few 100s of IEDs



Examples, large systems

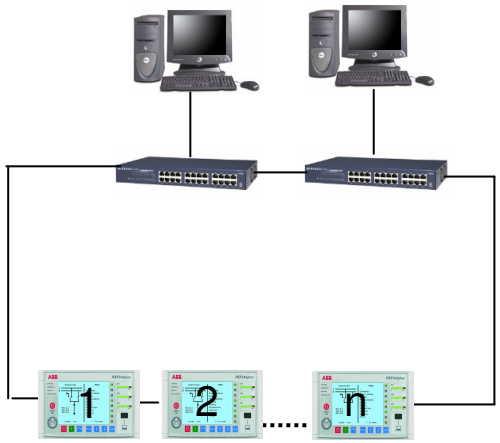
When redundancy **required:**

- Redundant ring topology
  - Network backbone redundancy is given by selection of proper switches
  - High reliability – but requires specific features from IEDs
  - Optical/Galvanic – both are possible
  - Projects with few 100s of IEDs

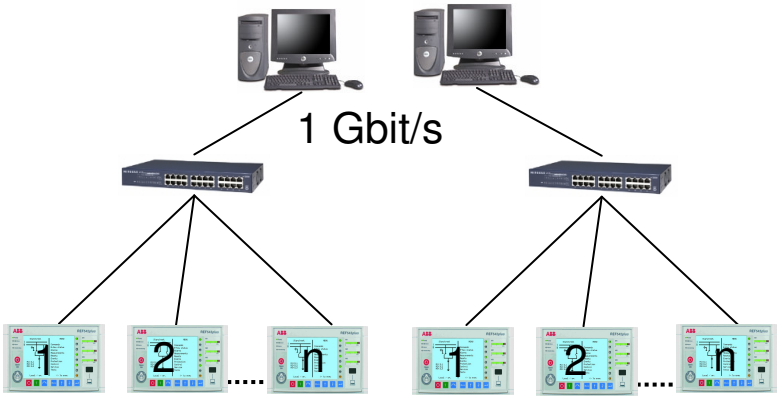


Examples: smaller systems

- Ethernet loop, devices having integrated switches
  - Cost efficient – in best case no external switches needed
  - Loop concept is suitable for low-end IEDs due to the worst case load capacity
  - One node in maintenance + one node failure = complete system failure

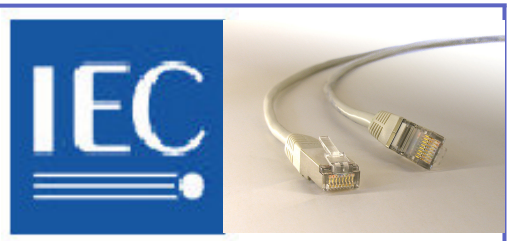


100 Mbit/s available for whole network



100 Mbit/s available for each IED

Presentation Overview



- Industrial Ethernet
  - Why Ethernet in Distribution Automation and our challenges
  - Ethernet architecture aspects

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