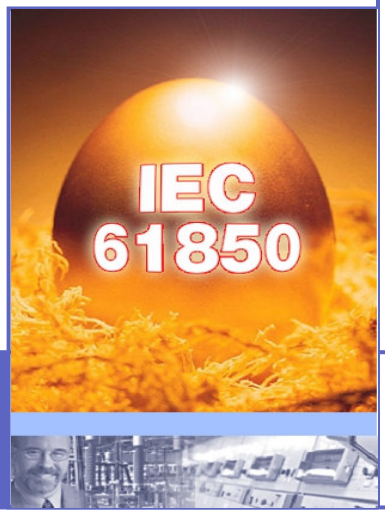
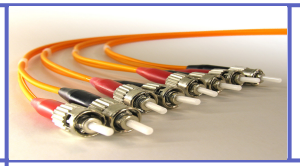
# Introduction to IEC 61850 Industrial Ethernet in Distribution Automation

*IEEE Switchgear Committee*
*Philadelphia, 18.10.2007*



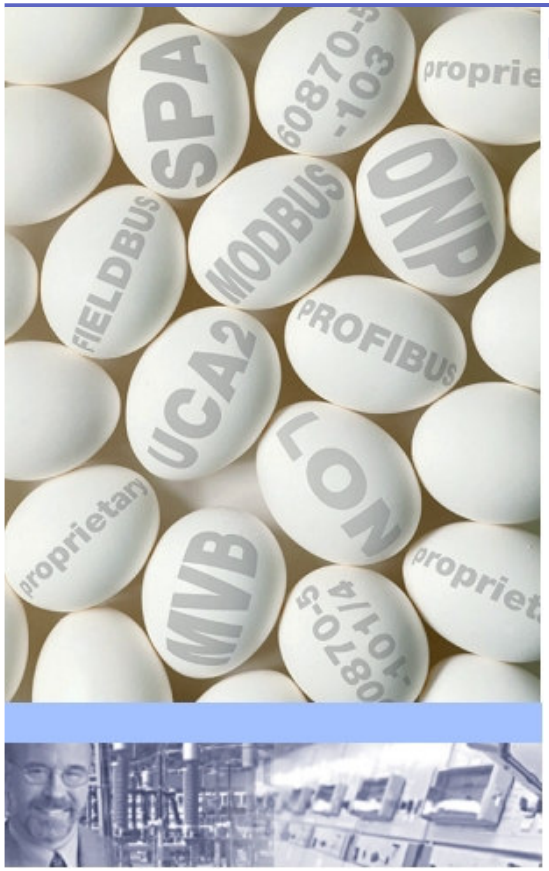

**The „Future“ Outlook on how to build electrical systems more efficiently**



# 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

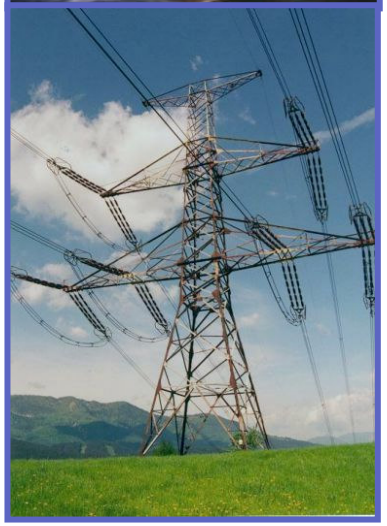
# History…




- 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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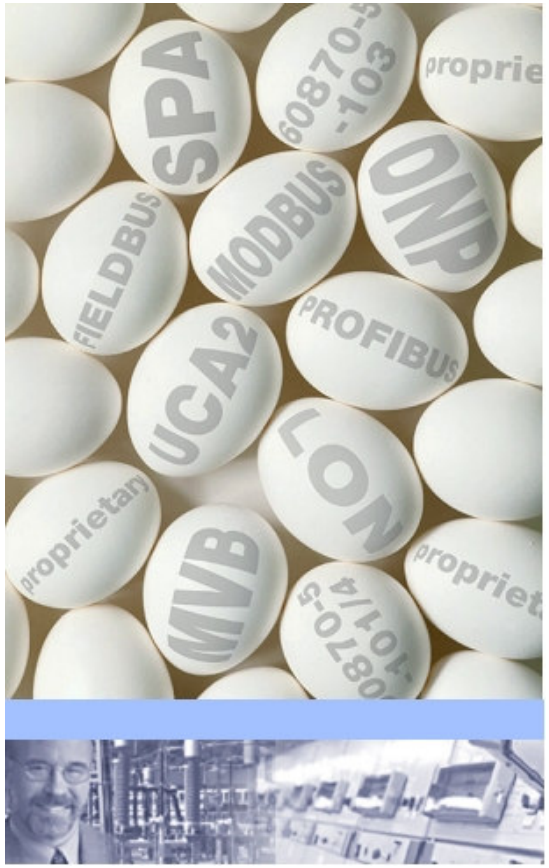
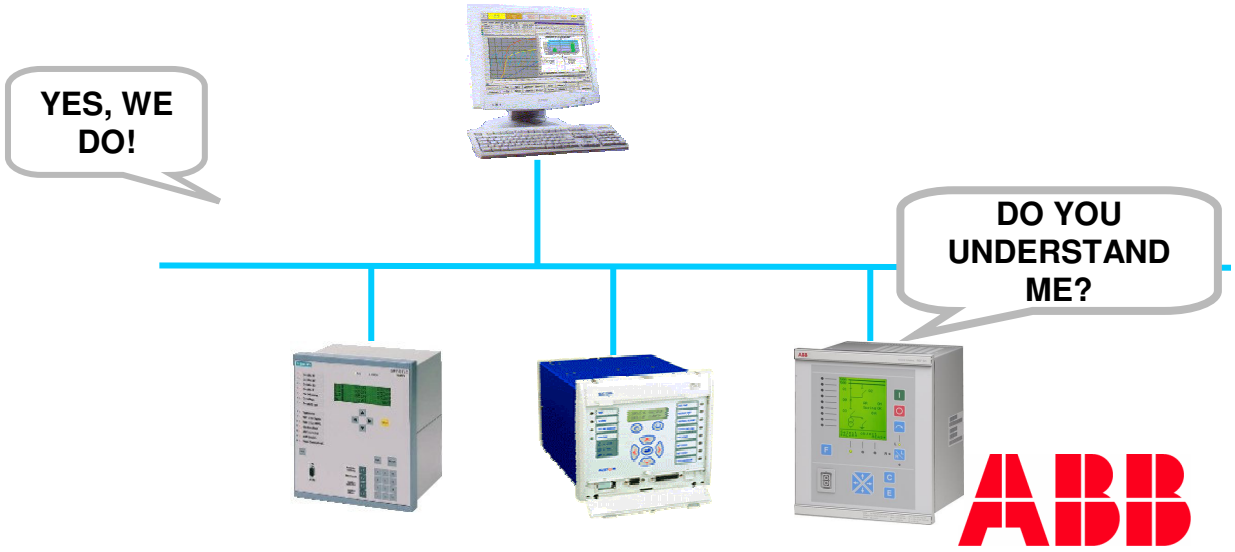
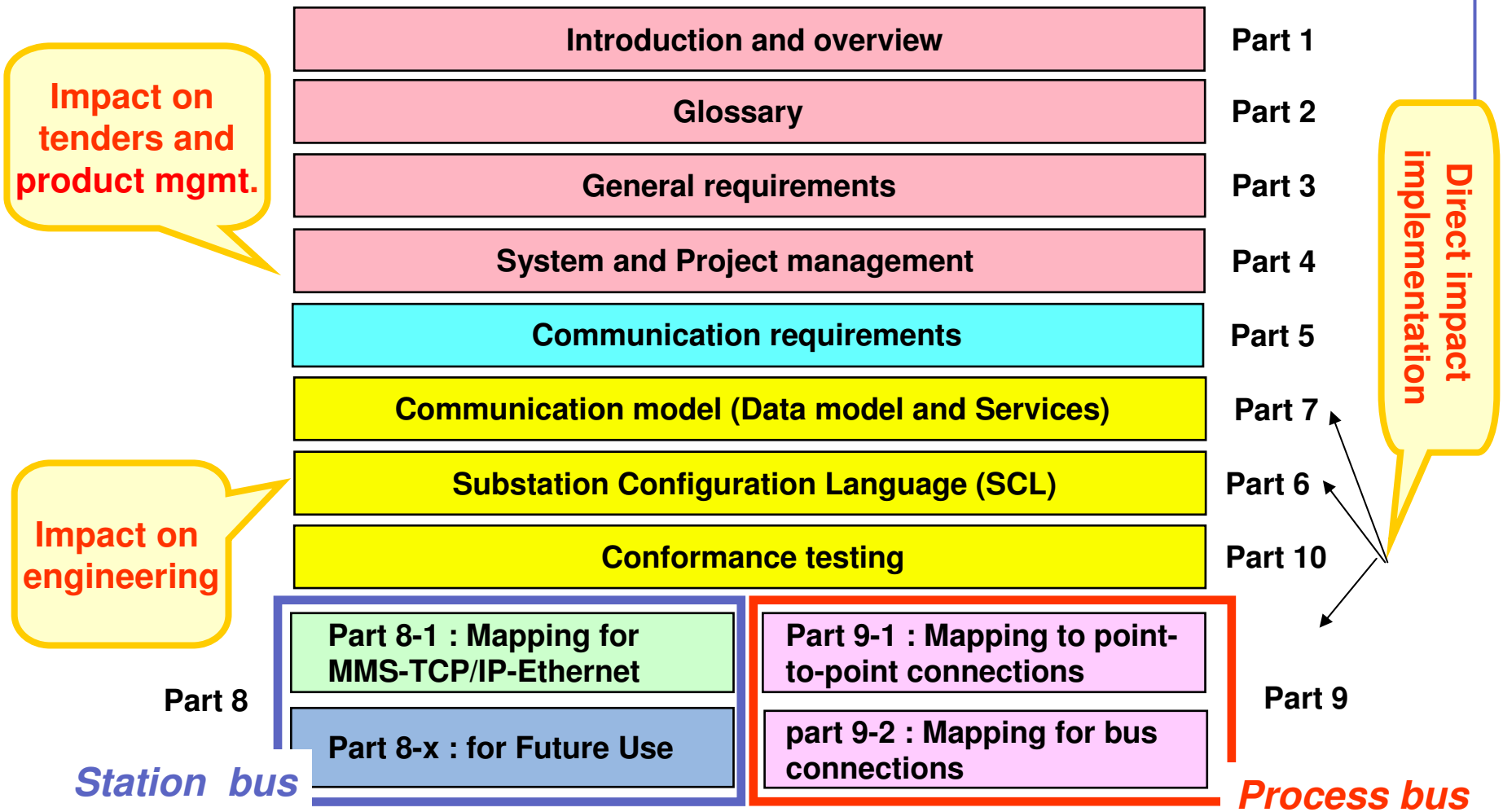
# Background – What is IEC 61850?




- **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 !

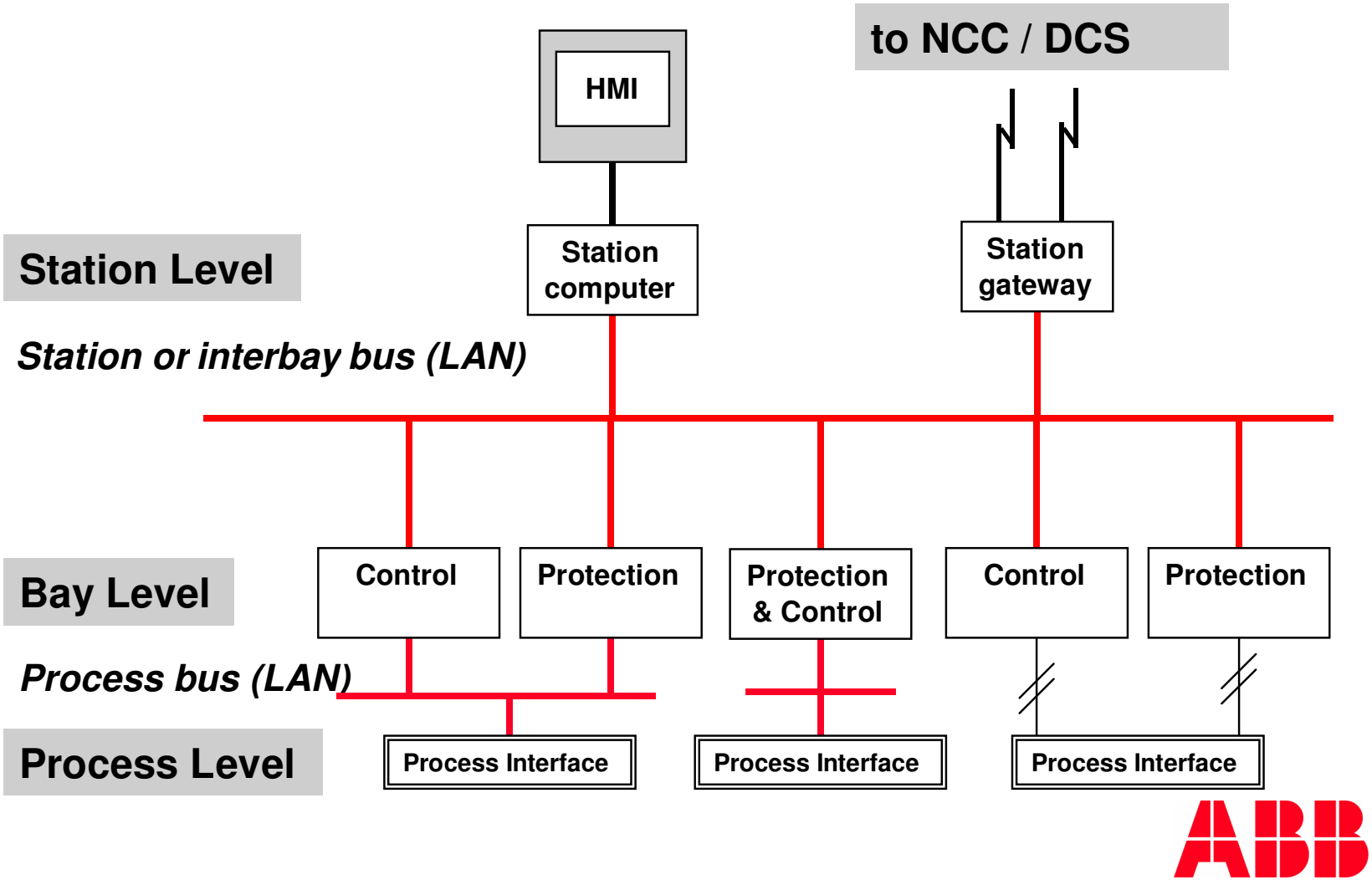
# Goals and key thoughts of IEC 61850


- 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

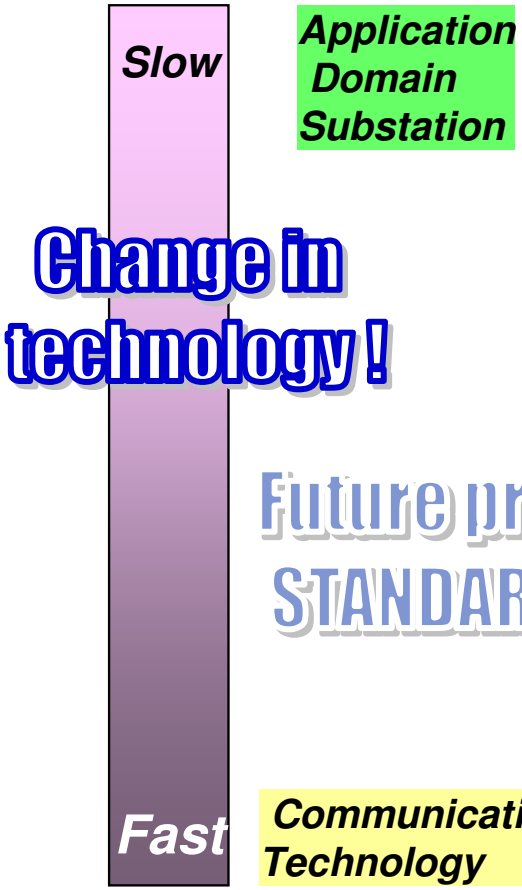
# Application area of IEC 61850

- Electrical substations, also in industrial plants



# Approach of IEC 61850

**Problem for standardization approach**

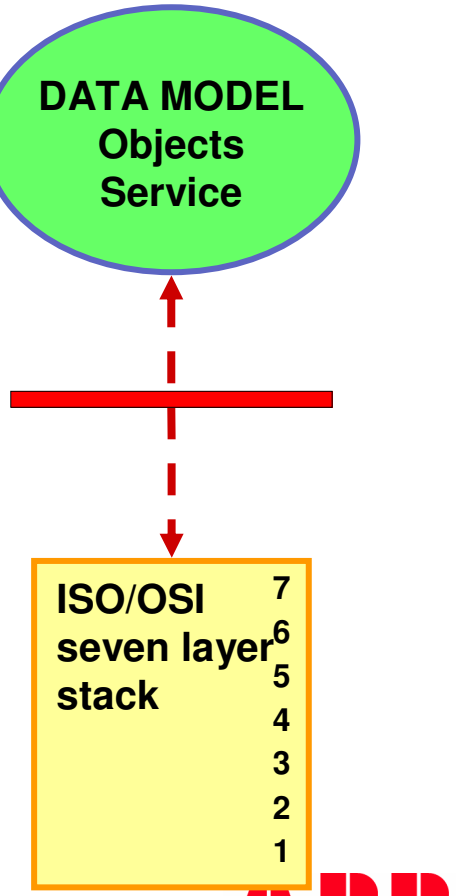



**APPLICATION**
switching devices
protection & control
commands, events,
alarms,
...

Split !

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

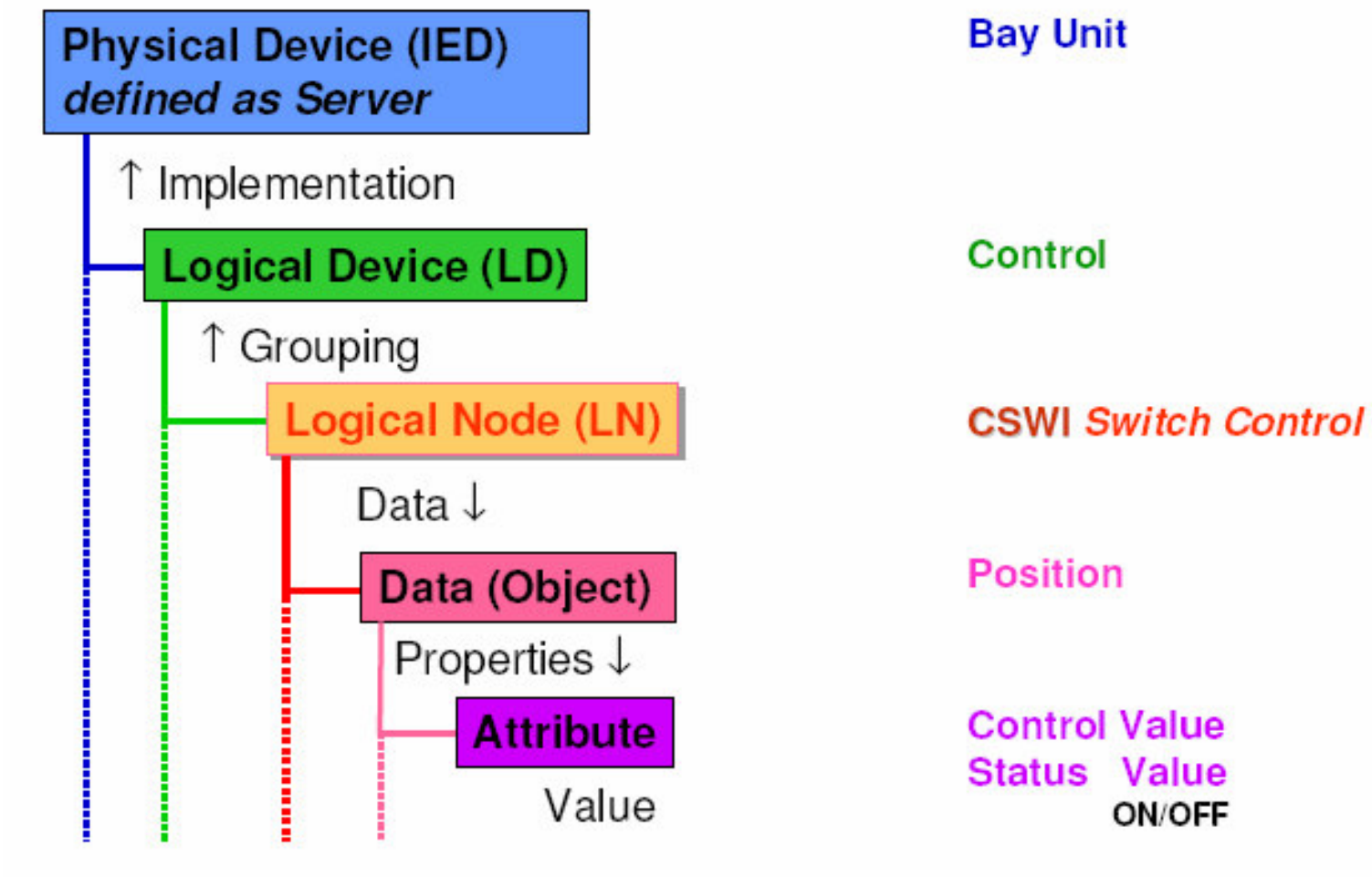
**Solution for standardization approach**



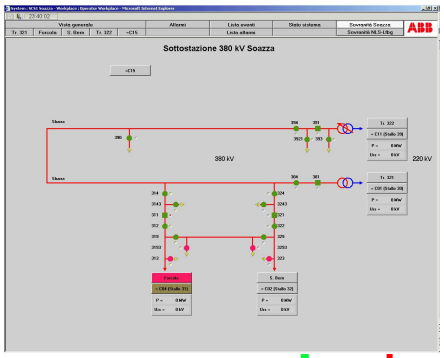

ABB

# 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 |

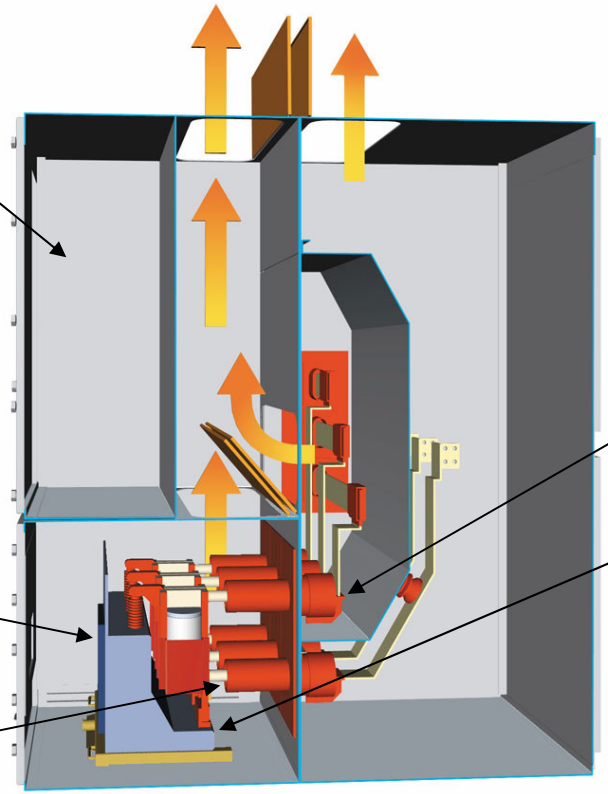
## IEC 61850

| | |
|---|---|
| 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

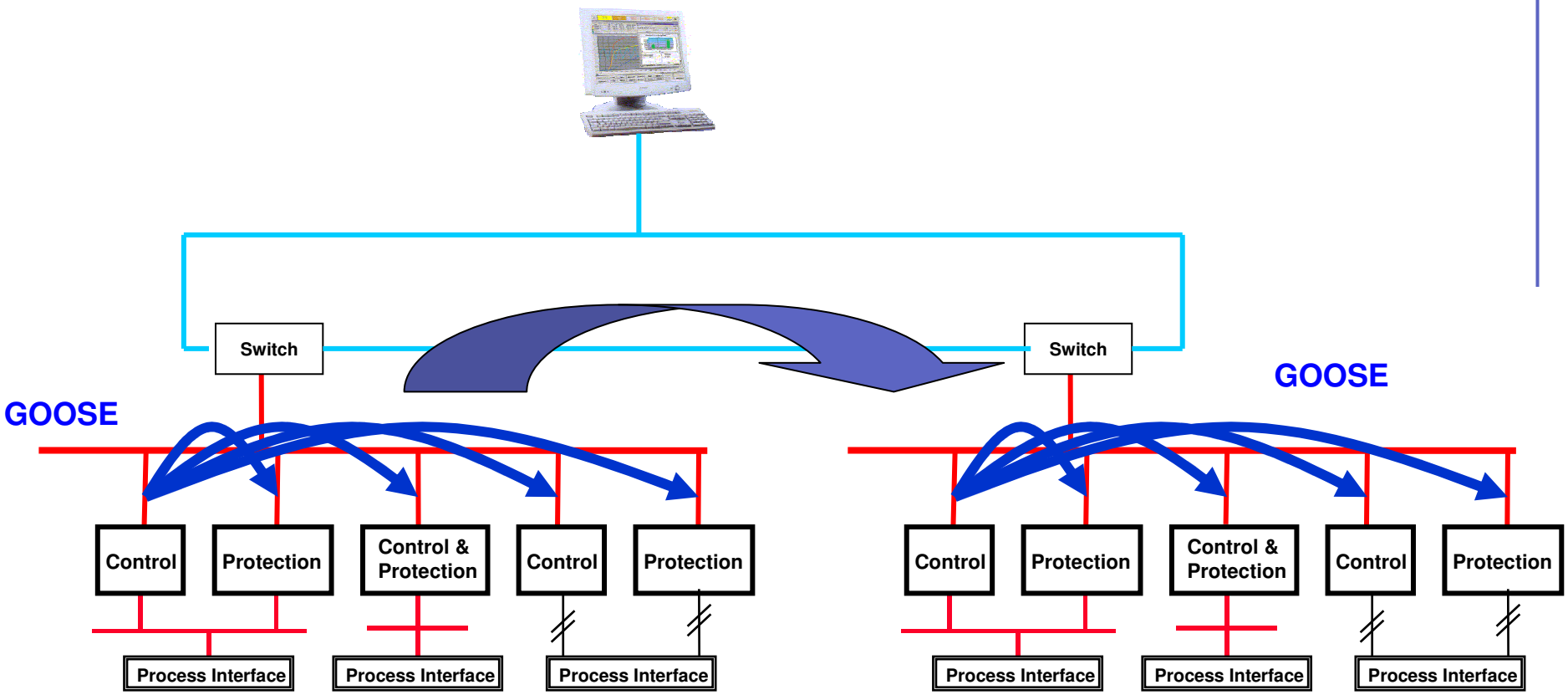
CBXCBR
- Circuit breaker

TRXSWI
- CB truck status

TCTR – current transformer

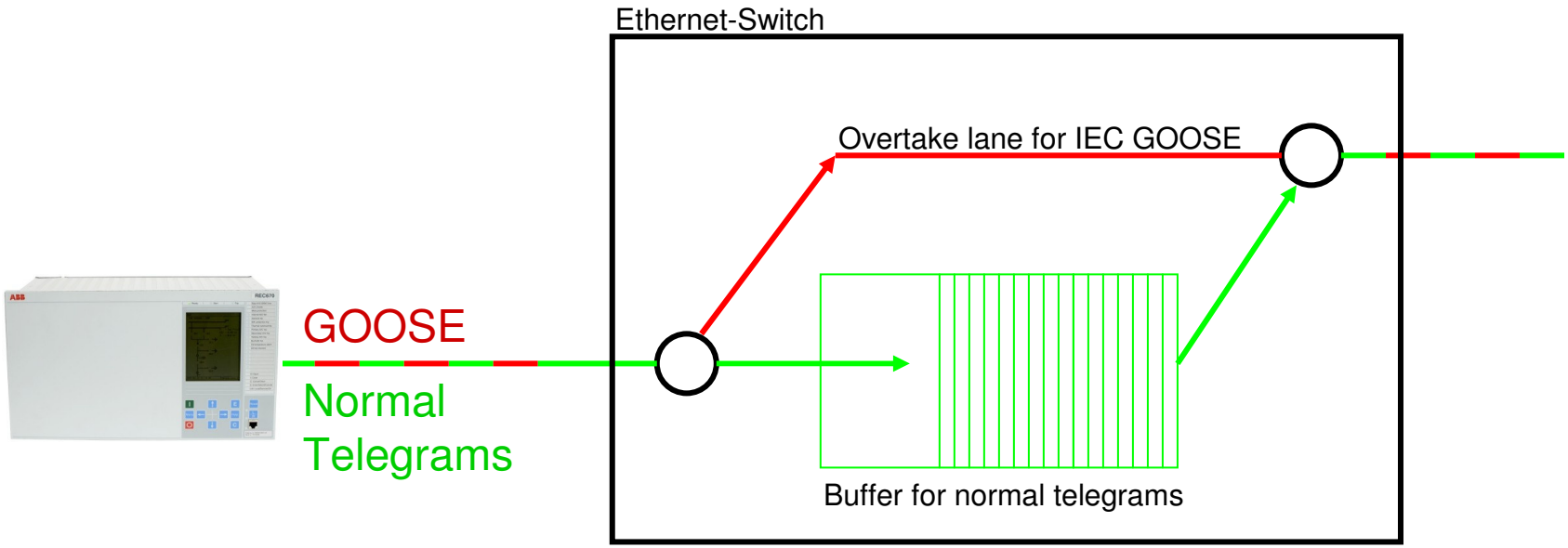
ESXSWI – earthing switch

# Horizontal communication: GOOSE




GOOSE: Generic Object Oriented Substation Event

# IEC 61850 GOOSE - Priority tagging



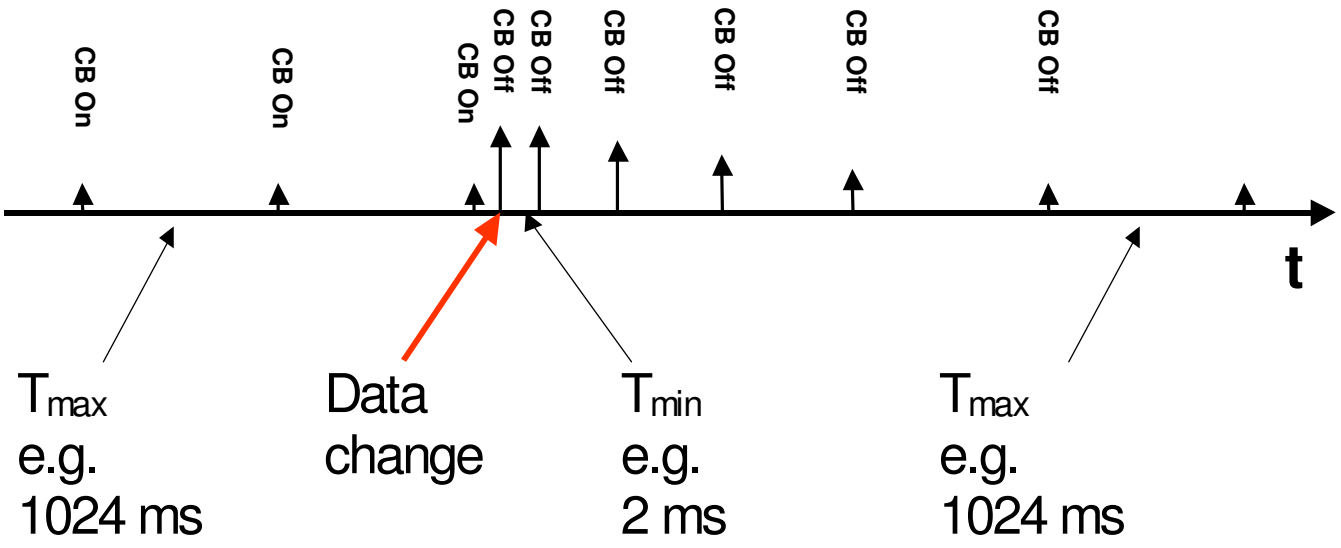

- IEEE 802.1p CoS (Class of Service) extensions to Ethernet is specified to be used for GOOSE and SMV
  - To fully utilize these advantages, network infrastructure must support this

# 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

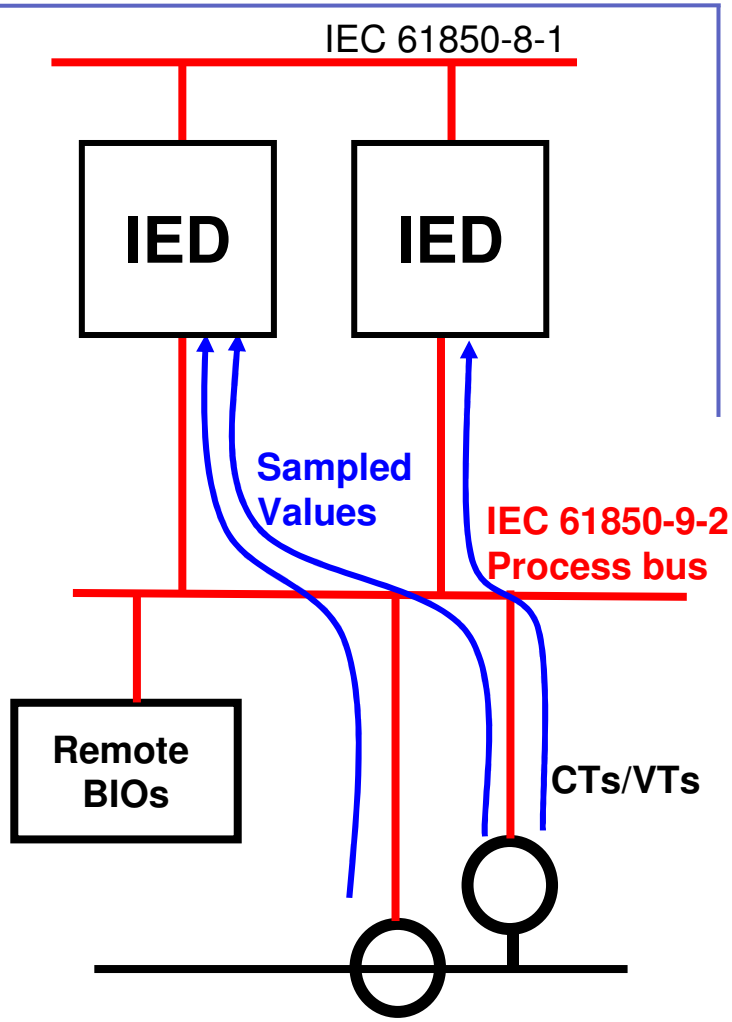
- GOOSE (Generic Object Oriented Substation Event)
  - System-wide data distribution
    - Device to device exchange of IED binary status information
  - Based on subscription/publisher mechanism
  - Mechanism:



# 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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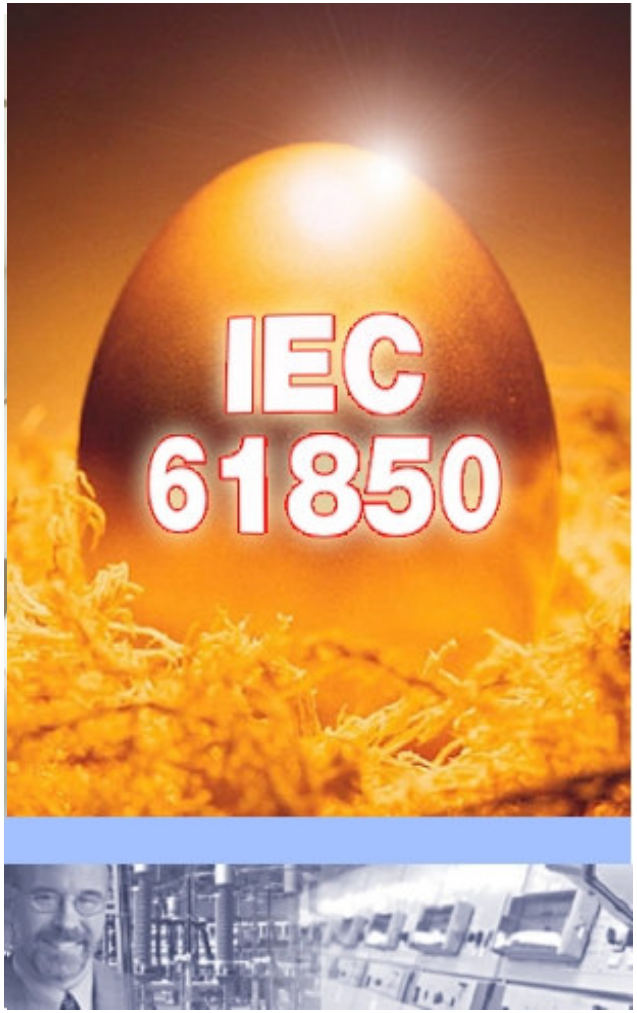
# Benefits of IEC 61850




*"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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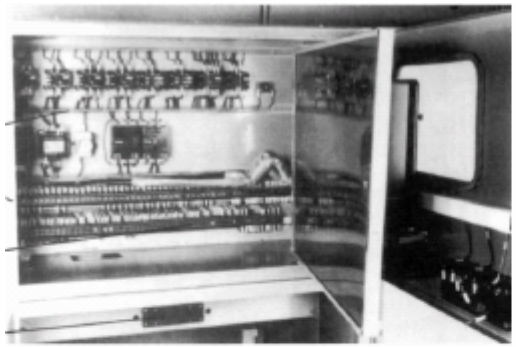
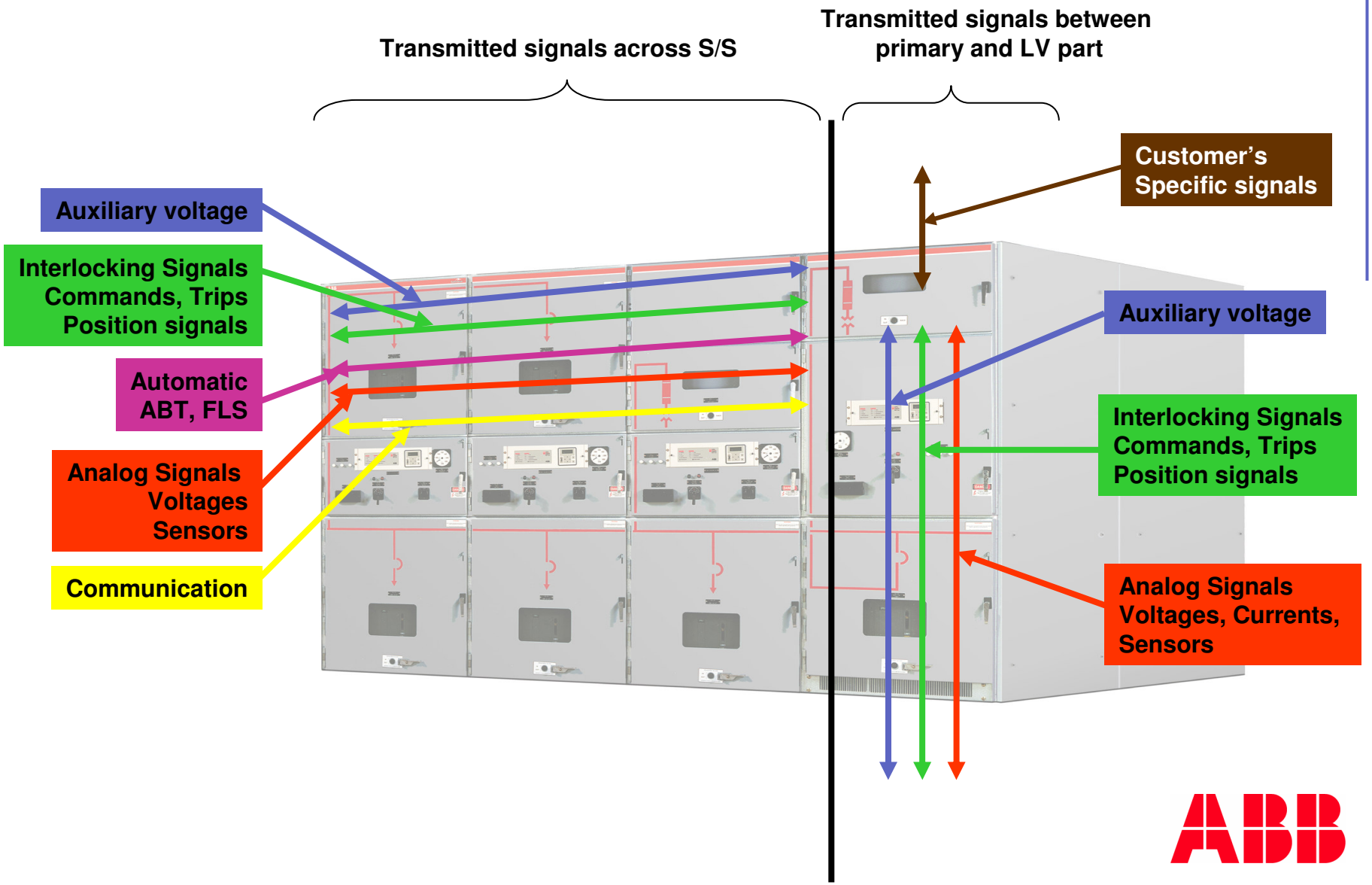
# Impact of IEC 61850 to Medium Voltage Switchgears

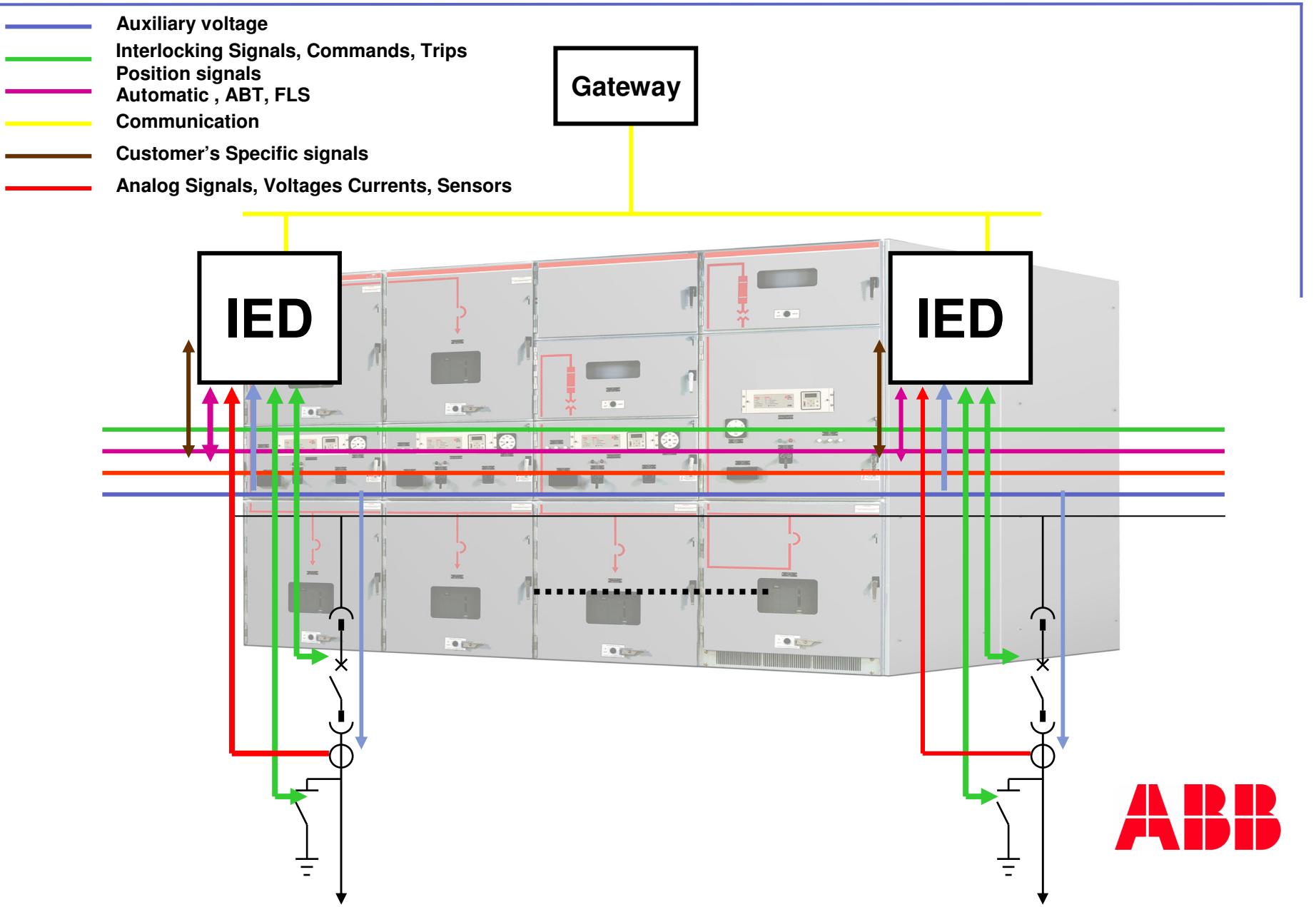


- Market pressure
  - Reduction of delivery time
  - Lower price
  - More functionality
  - …
- Slow changes in primary technology, fast changes in secondary technology
- IEC 61850 and Ethernet technology is a next step in Switchgear business
- IEC 62271-3 , Digital interfaces based on IEC 61850

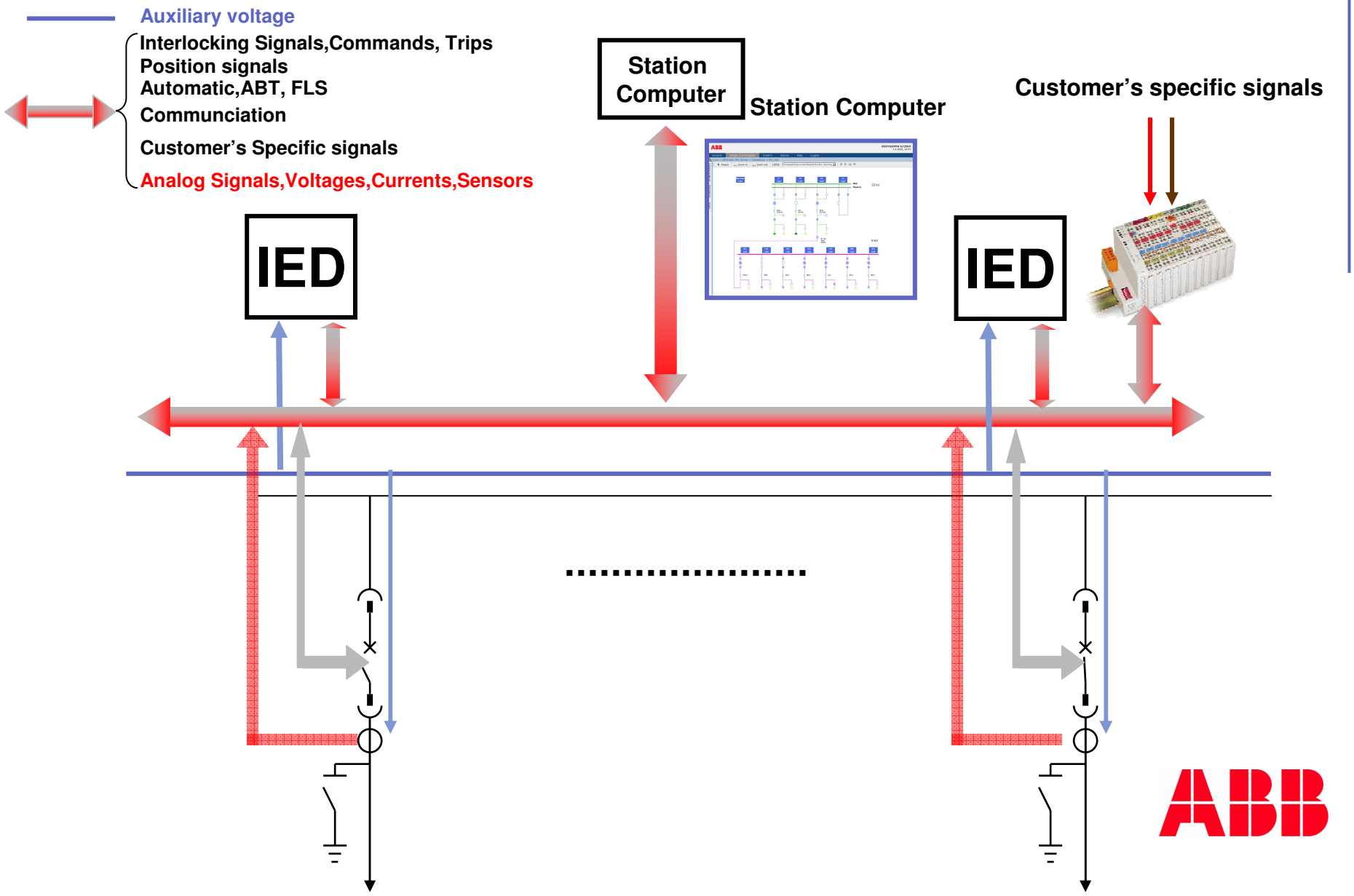
# Impact of IEC 61850 to Medium Voltage Switchgears



# 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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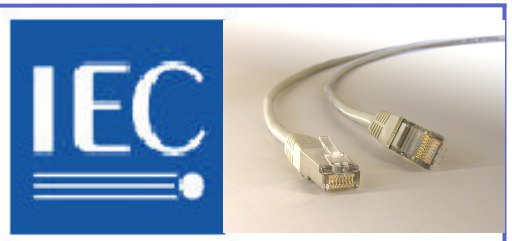
# Market update: IEC 61850 (1

- 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

# Presentation Overview




- 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, ...

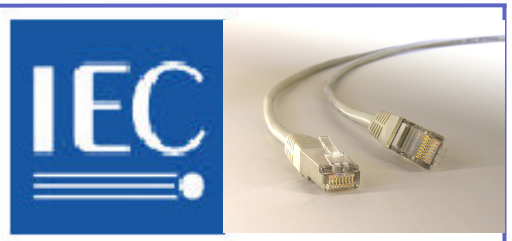
# Ethernet challenges in Distribution Automation

- 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

# Presentation Overview




- Industrial Ethernet
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  - Ethernet architecture aspects

# 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

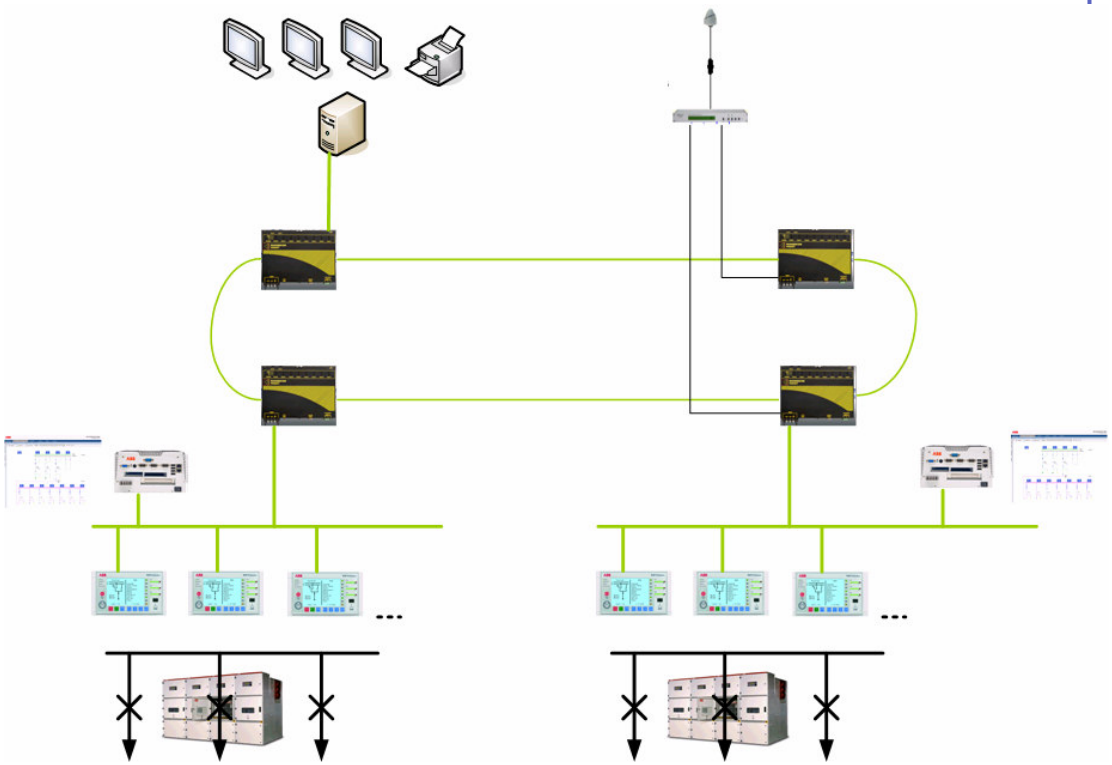
# Comparison of *tree* and *ring* architectures

| 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

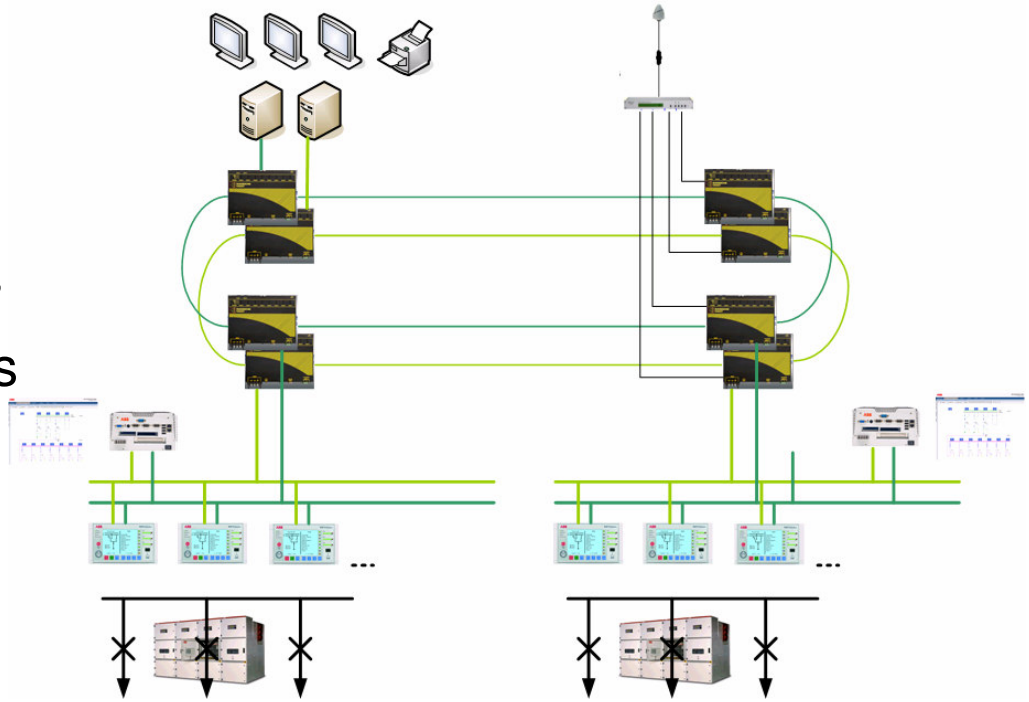
- Single ring backbone
  - Network redundancy is given by selection of proper switch, RSTP
  - Lower cost
  - High reliability than star configuration
  - Optical/Galvanic – both are possible
  - Projects with few 100s of IEDs



# Examples, large systems

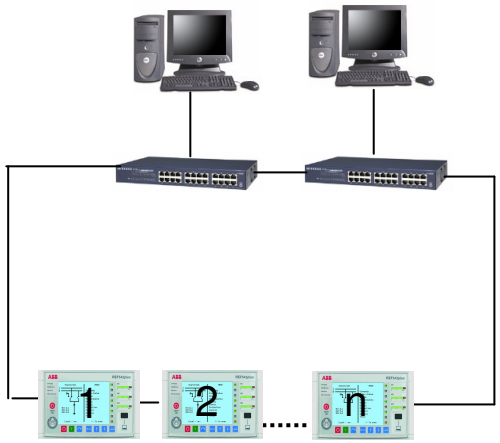
When redundancy **required:**

- 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

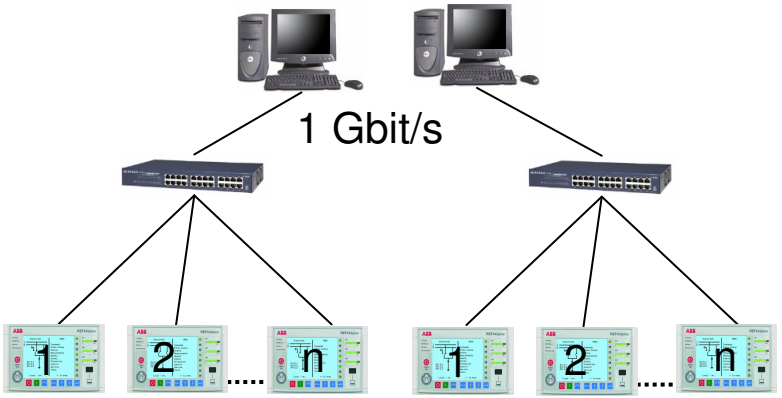


# Examples: smaller systems

- 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

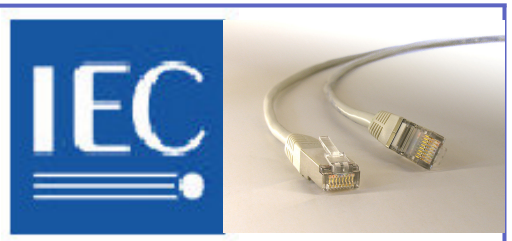



100 Mbit/s available for whole network




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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