Substation Automation with IEC 61850

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Trends in Substation Automation (SA)

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<th>Conventional</th>
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<td>Gateway</td>
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<td>bay cubicle</td>
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<tr>
<td>copper cables</td>
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<td>serial comm. (glass fiber)</td>
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**Functionality:** SA to control, operate, monitor, and protect the substation
“Today’s” Substation Automation

Device and Functional Structure (Example)

- Station Level
  - HMI
  - Network Control Center NCC

- Interbay bus

- Bay Level
  - Bay cubicle(s)

- Process Level
  - Q1, Q2, Q8, Q9

Functions Allocation

- Remote Communication
- Advanced Functions
- Monitoring
- Supervision & Control

- Protection
- Control
- Data Acquisition

- GIS or AIS Switchgear
- Instrument
- Transformers
- Power Transformers
- Surge Arresters

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Distributed Functionality

All those functions are implemented at the bay level for each bay individually:
- Synchrocheck per bay
- Interlocking
- Disturbance recorder
- Select before operate
- Runtime supervision
- Time tagging
- Event buffer
- Protection

When station level is lost the following functions are still available:
- Control, supervision, data acquisition, event buffering at the bay level
- Time synchronization and interlocking (ABB - depends on implementation)
- Protection

Distribution means Communication!
Market Requirements

- **The global market**
  - needs a global standard
  - means a standard supporting all design & operation philosophies

- **Mixing of devices**
  - at least like with copper cables

- **Cost reduction**
  - by competition
  - by more intelligent functions

- **Cost reduction**
  - for investments
  - operation and maintenance

- **Open, future-proof standard**
  - for safe-guarding of investments
  - regarding suppliers and improving technology
  - for future extensions by bays or functions
Requirements for Standard in SA

**Interoperability**

The ability for IED’s from one or several manufacturer to exchange information and use the information for their own functions.

**Free configuration**

The standard shall support different philosophies and allow a free allocation of functions e.g. it must work equally well for centralized (RTU like) or decentralized (SCS like) systems.

**Long term stability**

The standard shall be future proof, i.e. it must be able to follow the progress in communication technology as well as evolving system requirements.
The Approach of IEC 61850

- SA specific data model evolves slowly
- Communication technology changes quickly
- Splitting of SA specific data model from communication technology

**Abstract**

Communication Services Interface (ACSI)

- Model according to state-of-the-art SA technology

Data Model (Objects, Services)

- Client Server Communication
- GOOSE*
- Sampled Values

**Mapping**

- Stack selection according to the state-of-the-art Communication technology

- ISO/OSI – Stack
  - Hierarchical set of Rules how information is coded for transmission
  - According to state-of-the-art communication technology

- Ethernet Link Layer
  - Ethernet Physical Layer with Priority tagging (100 Mbit/s)

- Stack interface

* Generic Object Oriented Substation Event
Communication in Substation Automation Systems

- Information is exchanged between all devices which comprise the system.
- More precisely, data are exchanged between the functions and sub-functions residing in the devices.
- The smallest part of the function that exchanges data is called Logical Node (LN) in IEC 61850. The LN performs some operations for the overall function.
Example: LNs in GIS Substation

LN function-related in the substation:

- **Earthing Switch**
  - Q8_L1/XSWI
  - Gas density mon. Q8_L1/SIMG

- **Isolator**
  - Q9_L1/XSWI
  - Gas density mon. Q9_L1/SIMG

- **Circuit Breaker**
  - Q0_L1/XCBR
  - Gas density mon. Q0_L1/SIMG

**Primary technology**

**Secondary technology**

- **Control**
  - Q0/CSWI
  - Q8/CSWI
  - Q9/CSWI
  - Bay-HMI
  - IHMI

- **Distance Protection**
  - PDIS
The hierarchical Data Model

Physical Device (IED) *defined as Server*

↑ Implementation

Logical Device (LD)

↑ Grouping

Logical Node (LN)

Data ↓

Data (Object)

Properties ↓

Attribute

Value

Bay Unit

Control

CSWI *Switch Control*

Position

Control Value

Status Value

ON/OFF
Data access and transfer (Services)

- **read** a value / attribute
- **write** configuration attributes
- **control** a device (direct operate / select before operate)
- **event oriented** communication with reporting
- local storage of time-stamped events in a log
- get directory information
- **file transfer** for e.g.
  - parameter and software download
  - upload from monitoring information like travel curves or history of gas density values
- Transfer of **generic object oriented system events** (GOOSE)
- Transfer of **sampled (analog) values** (SV)
Tool Support by IEC 61850

Hierarchical Data Tree defined and implemented in ABB tools

SCL based on XML as defined by the standard IEC 61850

For Substation Engineers

For "machines" like Engineering Tools
Support by UCA®International

- The UCA2.0 standard is frozen on the level of a technical report is frozen and will not further supported.
- The UCA users group was transformed into UCA®International User Group.
- The UCA®International is a joint user’s group both for utilities and suppliers.
- UCA®International is not dealing with UCA2.0 but focusing on the promotion of the three IEC standards:
  - IEC 61850 (SA)
  - CIM (IEC 61970)
  - TASE.2. (IEC 60870-6)
- The main focus for the time being is IEC 61850.
- The UCA®International will be present at the CIGRE 2004 exhibition in Paris.
Steps forwards compared to other protocols (1)

- **IEC 60870-5-103**
  - Standard for the informative information exchange for protection devices in SA
  - Limited standardized data (numbered sequence) mainly for line protection
  - Mainly incompatible private extensions instead of generic part used
  - Low speed master-slave protocol (9.6 – 19.2 kBit/s)

- **IEC 60870-5-101, DNP3**
  - Low speed master-slave protocol (1.2 kBit/s or more)
  - No object model but numbered sequence of data points only
  - Developed for NCC-RTU connections

- **IEC 60870-5-104, DNP3 over LAN**
  - Network and transport layer added for use in network
  - Increased speed (64 kBit/s or more)
  - Peer-to-peer communication not supported at least by DNP3
  - No object model and engineering approach support
Step forwards compared to other protocols (2)

- **LON**
  - Ethernet based protocol but dedicated version of Echelon
  - Support of peer-to-peer communication
  - Powerful but proprietary use for SA by ABB
  - Slow speed (1.25 Mbit/s)

- **UCA 2.0**
  - Ethernet based protocol
  - Support of peer-to-peer communication
  - High speed 10…100 Mbit/s
  - First Object Model for SA but very dedicated regarding data and attributes
  - Modeling approach not flexible enough for global needs
  - No sampled values supported
  - No engineering support like SCL in IEC 61850
Trend in protocol evolution

Evolution of Communication in SA Systems

- Open exchange
- Limited exchange
- Isolated

Interoperability vs Functionality

Signals only
Data only
Data including context

IEC60870-5-103
DNP 3.0
101/104
IEC61850
UCA
LON
Global experience

IEC 61850

- Experience from the past not lost
- The best of many existing protocols used
- A big step beyond the past and existing protocols

IEC 60870-5
IEC 60870-6
experience

EPRI-Project UCA™ 2

The international agreed goal

one world
one technology
one standard
IEC 61850
Some features of IEC61850 (1)

- **Provision of process bus**
  - In future none conventional ct’s and vt’s will be available on the market. To provide a standardized interface the IEC 61850 provides a clear definition for the process bus (IEC 61850-9)
  - Sampled analogue values

- **IEC 61850 defines conformance tests**
  - against which devices can be tested and certified for conformance to the specification.
  - This ensures a high level of compatibility between different suppliers products used within a IEC 61850 based solution

- **IEC 61850 defines general device requirements**
  - E.g. temperature range devices need to adhere to, etc.
  - To ensure that the used equipment is also suitable for environments present in substations.
Some features of IEC61850 (2)

- **IEC 61850 defines communication requirements that devices have to comply with like required behavior after communications are interrupted, etc.**
  - Issues that have an impact to be able to provide a full working system solution using the benefit of selecting devices from different suppliers.

- **IEC 61850 defines an interoperable exchange of engineering data**
  - between IEDs of different manufacturers in the same system
  - between different IED versions during long time system maintenance
  - based in the ICD (IED configuration description) file request for each IED
  - based on formal SSD (Substation System Description) file
  - Providing a reusable formal system description

- **IEC 61850 defines strong extension rules**
  - to guarantee interoperability also in case of extension needed

- **IEC 61850**
  - will be used for wind power plants, hydro power plants, dispersed generation
All benefits of IEC 61850 by ABB

Scalable SA functionality satisfying even the highest customer requirements

Optimized solutions open for the integration of compliant devices and subsystems according to your needs

Support of future extensions and upgrades with the benefit of safeguarding your investment from the beginning

Comprehensive product portfolio
Benefits of ABB SA with IEC 61850

- System **according to your needs** can be provided by the fast growing portfolio of IEC 61850 compatible devices and systems with **direct implementation** of IEC 61850 **fully exploiting for you the benefits of the standard** including
  - HMI and NCC gateway
  - protection and control control

- **Conversion means** available provide you **backward compatibility** if needed

- Powerful **engineering tool set** fully **based on the IEC 61850** but tested already with LON SA systems in the backward compatibility mode empowers **system engineering** and facilitates **documentation** and **maintenance**

- High **effort in developing** the standard from the beginning provide you **high expertise**

- The **participation of ABB** from the beginning in **interoperability tests** from feasibility studies to implementation tests provides you **reliable interoperable interfaces** according to IEC 61850 and **reliable system integration**