Lecture #7
Substation Automation
with IEC 61850

Course map
Outline of the Lecture

- Recap of last lecture
  - Purpose and Scope of IEC 61850
  - Information models in IEC 61850
  - Logical Nodes
- Substation Configuration Language
- Communication Structures
- Communication Protocols in IEC61850
Recap
Purpose and Scope of IEC 61850

• The 61850 standard was developed to:
  - Address the need for a more structured approach to
design of Substation Automation Systems
  - Separate Data Model from method of communication
  - Utilise new technologies (Ethernet, TCP/IP)
  - Enable vendor independence
  - Simplify system configuration
  - Enable sharing of measurement among devices

Recap
Purpose and Scope of IEC 61850

• Model information about the real world
  - Status, measurements, settings
  - Configuration of system
  - Single-line diagram
  - Function related information
• Defines when to exchange values
  - Configuration of IED
• Defines how to exchange values
  - Configuration of IED
• Describe the recipient of the values
  - Configuration of IED
• Describe who to receive values from
  - Configuration of IED
Recap
Information Models in IEC61850

We would like to have some kind of standardized building-block for information
- Logical Node (LN) to Substation

https://www.flickr.com/photos/55631421@N03/8727559505/sizes/l/in/photostream/
Recap
Information Models in IEC61850

Recap
Logical Nodes

Relay1/XCBR1$ST$Loc$stVal

Logical Device

Logical Node

Data

Functional Constraint

Attribute
## Logical Nodes

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axxx</td>
<td>Automatic Control (4), ATCC (tap changer), AVCO (volt. ctrl.), etc.</td>
</tr>
<tr>
<td>Cxxx</td>
<td>Supervisory Control (5), CILO (interlocking), CSWI (switch ctrl.), etc.</td>
</tr>
<tr>
<td>Gxxx</td>
<td>Generic Functions (3), GOIO (generic I/O), etc.</td>
</tr>
<tr>
<td>Ixxx</td>
<td>Interfacing/Archiving (4), IARC (archive), BIMI (HMI), etc.</td>
</tr>
<tr>
<td>Lxxx</td>
<td>System Logical Nodes (2), LLN0 (common), LPHD (Physical Device)</td>
</tr>
<tr>
<td>Mxxx</td>
<td>Metering &amp; Measurement (8), MMXU (_meas.), MMTR (meter.), etc.</td>
</tr>
<tr>
<td>Pxxx</td>
<td>Protection (28), PDF, PIOC, PDIS, PTOV, PTOH, PTOC, etc.</td>
</tr>
<tr>
<td>Rxxx</td>
<td>Protection Related (10), REEC (auto reclosing), RDRE (disturbance)</td>
</tr>
<tr>
<td>Sxxx</td>
<td>Sensors, Monitoring (4), SARC (archs), SPDC (partial discharge), etc.</td>
</tr>
<tr>
<td>Txxx</td>
<td>Transformer (2), TCTR (current), TVTR (voltage)</td>
</tr>
<tr>
<td>Xxxx</td>
<td>Switchgear (2), XCBR (breaker), XCSW (switch)</td>
</tr>
<tr>
<td>Yxxx</td>
<td>Power Transformer (4), YPTR (transformer), YPSH (shunt), etc.</td>
</tr>
<tr>
<td>Zxxx</td>
<td>Other Equipment (15), ZCAP (cap ctrl), ZMOT (motor), etc.</td>
</tr>
<tr>
<td>Wxxx</td>
<td>Wind (Set aside for other standards)</td>
</tr>
<tr>
<td>Oxxx</td>
<td>Solar (Set aside for other standards)</td>
</tr>
<tr>
<td>Hxxx</td>
<td>Hydropower (Set aside for other standards)</td>
</tr>
<tr>
<td>Nxxx</td>
<td>Power Plant (Set aside for other standards)</td>
</tr>
<tr>
<td>Bxxx</td>
<td>Battery (Set aside for other standards)</td>
</tr>
<tr>
<td>Fxxx</td>
<td>Fuel Cells (Set aside for other standards)</td>
</tr>
</tbody>
</table>

### XCBR Class

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Attr. Type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNName</td>
<td></td>
<td>Shall be inherited from Logical-Node Class (see IEC 61850-7-2)</td>
</tr>
<tr>
<td>Lc</td>
<td>SPS</td>
<td>Local operation (local means without substation automation communication, hardwired direct control)</td>
</tr>
<tr>
<td>EfHealth</td>
<td>INS</td>
<td>External equipment health</td>
</tr>
<tr>
<td>EfName</td>
<td>DPL</td>
<td>External equipment name plate</td>
</tr>
<tr>
<td>OpCnt</td>
<td>INS</td>
<td>Operation counter</td>
</tr>
<tr>
<td>Pos</td>
<td>DPC</td>
<td>Switch position</td>
</tr>
<tr>
<td>BMOpn</td>
<td>SPC</td>
<td>Block opening</td>
</tr>
<tr>
<td>BMCls</td>
<td>SPC</td>
<td>Block closing</td>
</tr>
<tr>
<td>ChRтиров</td>
<td>SPC</td>
<td>Charger motor enabled</td>
</tr>
<tr>
<td>SumiAir Mats</td>
<td>BCR</td>
<td>Sum of Switched Amperes, resettable</td>
</tr>
<tr>
<td>BRCap</td>
<td>INS</td>
<td>Circuit breaker operating capability</td>
</tr>
<tr>
<td>POWCap</td>
<td>INS</td>
<td>Point On Switching capability</td>
</tr>
<tr>
<td>HaxCap</td>
<td>INS</td>
<td>Circuit breaker operating capability when fully charged</td>
</tr>
</tbody>
</table>

### Data Name, Common Data Class, Mandatory/Optional
Recap
Logical Nodes

- A common data class is a generic type of information that can be found in a substation automation system

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Substation Configuration Language

- XML based document
- Different types of files
  - ICD, CID, SCD, SSD,
- Purposes
  - Documentation
  - Interoperability
- Content
  - Depend on the type of the file
  - SCD file
    - Substation, Communication, IEDs, ...

Substation Configuration Language

- Different SCL file in engineering process

- System specification (.ssd file)
- Substation Configuration Description (.scd file)
- IED Capability Description (.icd file)
- Configured IED Description (.cid file)
- Vendor’s configuration tool
Substation Configuration Language

• Example

```xml
<substation>
  <content/>
</substation>
```
Substation Configuration Language

- Example

```xml
<Configuration>
  <Address>
    <IP>192.168.1.100</IP>
  </Address>
  <Device>
    <Name>SW1</Name>
    <Type>Switch</Type>
    <Description>First Switch in the Network</Description>
  </Device>
  <Connection>
    <Source>SW1</Source>
    <Target>SW2</Target>
    <Type>Ethernet</Type>
    <Media>UTP Cat 5e</Media>
  </Connection>
</Configuration>
```

Substation Configuration Language

- Example

```xml
<Substation
  <Version>1.5</Version>
  <Name>Substation</Name>
  <Connection>
    <Device>
      <Name>SW1</Name>
      <Type>Switch</Type>
      <Description>First Switch in the Network</Description>
    </Device>
    <Source>SW1</Source>
    <Target>SW2</Target>
    <Type>Ethernet</Type>
    <Media>UTP Cat 5e</Media>
  </Connection>
</Substation>
```
Substation Configuration Language

- Example

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Communication Structure

• Three levels
  - Station
  - Bay
  - Process

• Two buses
  - Station bus
  - Process bus

• Horizontal vs. Vertical communication
Communication Structure

Horizontal Communication

Vertical Communication

Figure 11 – Station bus, process bus and traffic example
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Communication protocols in IEC61850

- Generic Object Oriented System Event (GOOSE)
- Manufacturing Message Specification (MMS)
- Sampled Value (SV)
- Configuration in SCL
Communication protocols in IEC61850

- **GOOSE** – Horizontal communication
  - Publish subscribe model
  - Multicast
  - No confirmation
  - Messages sent repeatedly

Figure 8 – GOOSE protocol timing-diagram chart
Communication protocols in IEC61850

- GOOSE – Horizontal communication

![GOOSE protocol time chart]

- MMS – vertical communication
  - Server Client model
  - Reporting model

![MMS protocol diagram]
Communication protocols in IEC61850

- **MMS** – vertical communication

  MMS specifies a set of messages which allow an MMS client to control an MMS server.
  MMS does not specify the application interface.
  MMS specifies the class of objects that an MMS server is expected to hold.
  MMS specifies how messages are encoded for transmission.

  ![MMS Diagram](image)

  Source: Prof. Dr. H. Kirrmann, ABB Research Center, Baden, Switzerland

Communication protocols in IEC61850

- **SV** – Process level

  ![SV Diagram](image)

  Source: Prof. Dr. H. Kirrmann, ABB Research Center, Baden, Switzerland
Communication protocols in IEC61850

- **SV** – Process level
  - Sampled Values are transmitted cyclically
  - Carries analog measurements
  - Sending frequency of 4-5000 values/second.

**Figure 10 – Example of SV traffic (4800 Hz)**

Communication protocols in IEC61850

- **Configuration** – GOOSE
  - GOOSE control block
  - Data set
Communication protocols in IEC61850

Figure 9 – GOOSE protocol time chart

Communication protocols in IEC61850

* Configuration – GOOSE
Communication protocols in IEC61850

- Configuration – MMS
  - Report Mode: report control block

- Server-client: based on the request

Communication protocols in IEC61850

- Configuration – SV
Communication protocols in IEC61850

- Example - GOOSE

- Example - MMS
Communication protocols in IEC61850

• Example - SV

In summary

And we will get back to how these protocol stacks work in detail in Part#2 of the course
The End