Writing PACS specification towards a future-proof Digital Substation

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Contributions of Ricardo Cartaxo, André dos Santos, Wei Yang
AGENDA

1. Specification writing
2. Specification in IEC 61850 Engineering Process
3. Producing IEC 61850 Specifications
4. Substation PACS Specification
5. Conclusions and future developments
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1. Specification writing
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• How to describe functional requirements?
  – Natural Language:
    • Example\(^1\): "Transformer TR1 should be tripped during any overload greater than 120% of any of its coil nominal current that stays for at least 50ms in no more than 100ms"
    • Has been significantly used so far
    • Many easy-to-use tools are available: text and spreadsheet processors

[1] – Taken from CIGRE Task Force B5.02 Survey issued early 2017
• How to describe functional requirements?
  – IEC 61850 Substation Configuration Language (SCL):
    • Example\(^1\):
      – XCBR – Circuit Breaker; TCTR – Current Transformer; PTOC – Time Overcurrent; PTRC – Protection trip conditioning

<table>
<thead>
<tr>
<th>Data objects &amp; attributes</th>
<th>Type</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCTR.AmpSV.instMag.i</td>
<td>INT32</td>
<td>-</td>
<td>Current (sampled value), Output</td>
</tr>
<tr>
<td>TCTR.AmpSV.sVC.scaleFactor</td>
<td>FLOAT32</td>
<td>0.001</td>
<td>According to IEC61850-6-2LE</td>
</tr>
<tr>
<td>TCTR.AmpSV.units.SIUnit</td>
<td>ENUM</td>
<td>5</td>
<td>Represents the SI unit ampere</td>
</tr>
<tr>
<td>PTOC.InRef1.setSrcRef</td>
<td>ObjectRef</td>
<td>TCTR.AmpSV</td>
<td>Input to PTOC logical node</td>
</tr>
<tr>
<td>PTOC.StrVal.setMag.i</td>
<td>INT32</td>
<td>“1.2 x I_nom”</td>
<td>Pick up value for 1. stage of PTOC</td>
</tr>
<tr>
<td>PTOC.StrVal.units.SIUnit</td>
<td>ENUM</td>
<td>5</td>
<td>Represents the unit ampere</td>
</tr>
<tr>
<td>PTOC.OpDI.Tmms.setVal</td>
<td>INT32</td>
<td>50</td>
<td>Intentional time delay for 1. stage</td>
</tr>
<tr>
<td>PTOC.OpDI.Tmms.units.SIUnit</td>
<td>ENUM</td>
<td>4</td>
<td>Represents the SI unit second</td>
</tr>
<tr>
<td>PTOC.OpDI.Tmms.units.multiplier</td>
<td>ENUM</td>
<td>-3</td>
<td>Multiplier to obtain milliseconds</td>
</tr>
<tr>
<td>PTOC.Str.general</td>
<td>BOOL</td>
<td>[TRUE,FALSE]</td>
<td>Start of PTOC</td>
</tr>
<tr>
<td>PTOC.Op.general</td>
<td>BOOL</td>
<td>[TRUE,FALSE]</td>
<td>Operate of PTOC</td>
</tr>
<tr>
<td>PTOC.InRef1.setSrcRef</td>
<td>ObjectRef</td>
<td>PTOC.Op</td>
<td>Input to PTOC logical node</td>
</tr>
<tr>
<td>PTOC.Tr.general</td>
<td>BOOL</td>
<td>[TRUE,FALSE]</td>
<td>Trip signal for the XCBR</td>
</tr>
<tr>
<td>XCBR.InRef1.setSrcRef</td>
<td>ObjectRef</td>
<td>PTOC.Tr</td>
<td>Input for the trip signal from PTOC</td>
</tr>
</tbody>
</table>

\(^1\) – Taken from CIGRE Task Force B5.02 Survey issue early 2017
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• Bottom-up approach:
• **Bottom-up approach:**
  – Starts in IED Configuration Tool
  
  *specification is done before IEC61850*
  
  – Specification
    
  *mainly done in Natural Language*
  
  – Engineering Process
    
  *is based on manufacturer’s data model*
  
  – Utilities have
    
  *less control on IED data model*
  
  – Easier to kick-off IEC 61850 implementation
    
  *but is NOT FUTURE-PROOFED!*
• Top-down approach:
Specification in Engineering Process

• Top-down approach

– Engineering Process starts by utility SPECIFICATION!
– Specification of PACS functions through SCL files
– Manufactures shall implement specified data model
– Utilities have more control in their assets!
Going towards a **solid adoption** of IEC 61850 specification...

- Guarantee the **future replacement, expansion, efficient maintenance and good operation of PACS**

- Future-proofed substations must provide the same **availability, dependability and maintainability** as conventional ones, or **better**!

- IEC61850 **triggers** the need for **adaptation** of the specification for Protection, Automation and Control Systems (PACS)
  - Previous specifications can have **technical constraints** which do not exist anymore

- Utilities are the responsible entity

  so they play a crucial role!
Producing IEC 61850 specifications

Going towards a solid adoption of IEC 61850 specification...

1. Standardization is essential:

   – Identification of all different topologies existing in utility’s substations

   – For each topology, identification of:

     • Functions
     • Equipment (IED) aggregating functions
     • Signals for communication between equipment
     • Set of parameters to be specified for each function
Going towards a solid adoption of IEC 61850 specification...

2. Model each bay template functions and signals:

Signal List for Logical Node Q11XSWI1
Going towards a **solid adoption** of IEC 61850 specification...

3. Model each bay template Report, GOOSE and SV application:
Producing IEC 61850 specifications

Going towards a **solid adoption** of IEC 61850 specification...

4. Creation of libraries:

Specification Library – **Basic Application Profiles** (IEC TR 61850-7-6 is WIP)

- Functions Library
- Applications Library
- Bay Library

Now we can create substation specifications...
Producing IEC 61850 specifications

Going towards a **solid adoption** of IEC 61850 specification...

**Now we can create substation specifications...**

1. Bay instantiation from Library

![Diagram of substation components: Coupler Bay, Feeder Bays, Transformer Bay (HV side)]
Producing IEC 61850 specifications

Going towards a solid adoption of IEC 61850 specification...

Now we can create substation specifications...

2. Create IED SCL file from specification
Going towards a **solid adoption** of IEC 61850 specification...

**Now we can create substation specifications...**

3. Drawing substations communications network
Producing IEC 61850 specifications

Going towards a solid adoption of IEC 61850 specification...

Now we can create substation specifications...

4. Specifying parameter values in IED data model
Going towards a **solid adoption** of IEC 61850 specification...

Now we can create substation specifications...

5. Create IED CID file (what about ISD file?) and deliver it to vendors!

CID File:
- Specified IED services
- Specified data model
- Specified parameters
- Specified internal connections
Producing IEC 61850 specifications

Going towards a **solid adoption** of IEC 61850 specification...

And then?

• **IED is delivered**

• **IED’s ICD file is imported** in System Configuration Tool

• **Mapping** between specified and implemented Logical Nodes

• Applying **application configuration** → GOOSE, SV, report

• **IED configuration with CID file**: parameters, GOOSE, SV, and report configuration
Main advantages foreseen:

• **Less ambiguity** on understanding the requirements

• Great kick-off effort to create the libraries

But easier and faster future substation specifications

• Suppliers can still **improve their devices** – they just enable Logical Nodes **specified by utilities**
Main advantages foreseen:

• Modification in specifications means library modifications
  Done in template project

• Simple to update previous projects with updated specifications:
  – Easy upgrade to future IEC 61850 editions
  – Easier to specify and configure multi-edition systems

• Increase interoperability and data model similarity among vendors – towards interchangeability

• SCL has good applicability to power systems, implementability by tools and equipment, testability, modularity and modeling!
What is **blocking** effective specification writing?

- SCL files not suitable to be readable/writable **directly by humans**
  - Need for **specific tools**:
    - Tools are not mature – **need constant fixes**
- Frequent bugs due to the **highly IED firmware change rhythm**
- **Incompatibilities** among different IED, specification and configuration tools
- Some manufactures are **not willing to deliver** IED with client-defined data model
  - Many IED with **fixed** or **poorly flexible** data models
What is **blocking** effective specification writing?

- **Qualified personnel** dominating IEC 61850 standard is needed to specify, design and commission
  - Not easy for a new user to quickly learn the concepts and techniques
- **Great initial effort** from utility
- Not easy to **prove** that the specification **attends the requirements**
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### What needs to be specified?

<table>
<thead>
<tr>
<th>What</th>
<th>How</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection and automation devices</td>
<td>IEC 61850 SCL files</td>
</tr>
<tr>
<td>Interlocking</td>
<td>.doc</td>
</tr>
<tr>
<td>HMI: data acquisition, data storage, log management, access control</td>
<td>.doc, .xls</td>
</tr>
<tr>
<td>Oscillography recording</td>
<td>IEC 61850 SCL files</td>
</tr>
<tr>
<td>Time synchronization system</td>
<td>.doc</td>
</tr>
<tr>
<td>Communication infrastructure (links, switches, routers)</td>
<td>.doc, .xls</td>
</tr>
<tr>
<td>Metering devices</td>
<td>IEC 61850 SCL files</td>
</tr>
<tr>
<td>Gateways</td>
<td>IEC 61850 SCL files</td>
</tr>
<tr>
<td>Monitoring devices</td>
<td>IEC 61850 SCL files</td>
</tr>
<tr>
<td>Wiring and cubicle works</td>
<td>.dwg, .doc, .xls</td>
</tr>
<tr>
<td>Substation Redundancy schemes</td>
<td>.doc</td>
</tr>
</tbody>
</table>
• What needs to be specified?
  – Examples of non-IEC 61850 SCL specifications:
    • Wiring and cubicle works
What needs to be specified?

Examples of non-IEC 61850 SCL specifications:

- Interlocking

<table>
<thead>
<tr>
<th>Category</th>
<th>Safety, avoid damage of equipment and hazard for people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Rule 11</td>
</tr>
<tr>
<td>Device</td>
<td>Circuit breaker, isolator, earthing switch</td>
</tr>
<tr>
<td>Operation</td>
<td>Close</td>
</tr>
<tr>
<td>Topology change</td>
<td>Connection of active and earthed sections</td>
</tr>
<tr>
<td>Reason for interlocking</td>
<td>Earth fault yields damage</td>
</tr>
</tbody>
</table>

Graphic representation:

(similar rules for isolators and earthing switches)
• What needs to be specified?
  – Examples of non-IEC 61850 SCL specifications:
    • Substation Redundancy schemes

The clients are the local SCADA units and the gateway and the servers are all IEDs that send information to the station level. In this case, there is not a preferred server (in a pair of redundant IEDs), that is, there is not an ‘active’ and a ‘stand-by’ server. This principle is depicted in Figure 9.
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Conclusions and future developments

To conclude...

• Specification shall consider replacements, future expansions and refurbishments. **Live together with legacy systems!**

• **Recommendations:**
  – Avoid GGIos – an important IEC61850 feature is the standardized data model
  – Standardization of system engineering
  – Adoption of future-proofed procedures for specification, FAT, SAT and maintenance tests using IEC61850
  – Cyber-security: need to plan the system, access rules, configuration procedures, maintenance procedures
  – How to start? Pilot projects...

For the future...

• Manufacturers could be more willing to cooperate on having a efficient specification process...
• Tools have to reach a steady development state
• Future work:
  – Fully implement and improve specification while IEC 61850 experience growths
  – Interchangeability
  – Semi-automatic methods to speed-up repetitive tasks
Thanks for your attention!

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