RULES DRIVEN PROJECT SPECIFICATION IN THE CONTEXT OF IEC 61850 BASIC APPLICATION PROFILES

Camille BLOCH
Schneider Electric - France
camille.bloch@schneider-electric.com

Mayank SHARMA
Schneider Electric - India
mayank.sharma@schneider-electric.com

Michael HAECKER
Schneider Electric - Germany
michael.haecker@schneider-electric.com

Thomas RUDOLPH
Schneider Electric – Germany
thomas.rudolph@schneider-electric.com

ABSTRACT

The IEC 61850 series of standards has become the choice of standard to build power utility automation systems. With the use of standard file format exchange during the engineering process, the definition of information models, services and mapping them over a standard communication interface, the vision of a truly multi-vendor power utility automation solution has been made possible.

Interoperability is seen as a key enabler of smart grid. However, interoperability manifests itself into 8 different layers as per the GridWise Architecture Council framework [1] and is abstracted into 5 layers inside the Smart Grid Architecture Model (SGAM) [2]. From the perspective of application function(s) implementation in devices, information and communication interoperability layers are of importance. While the former concerns with the semantics of functions and services required for information exchange between functions, the latter describes the protocol, the syntactic interoperability to facilitate an information exchange. Addressing interoperability during the project engineering is yet another area that concerns stakeholders such as system integrators.

INTRODUCTION

Power utility automation applications implementations are strongly depending on user type, region and (operational) philosophies. This variety is reflected as well in IEC 61850 based automation systems which causes stakeholders to look for guidelines and tools to improve the interoperability in projects along the entire lifecycle (Figure 2) of a system. One example is the current work of the user association entso-e on an “Interoperability Specification Tool for IEC 61850” [3].

Due to increasing interactions between various systems on all levels in the domain of power utility automation like control centres, market participants, digital substations, distribution automation, DER, down to smart meters and EV charging points, interoperability is the key element to enable the power system transformation. Information exchange between different actors in the market like TSOs, DSOs, Aggregators, Energy markets, Power Generation, Prosumers and Energy Users demands a system-to-system approach with well-defined interfaces, roles and responsibilities.

In order to achieve interoperability on all types of application functions, a common understanding and interpretation of all necessary layers will be necessary which could be ensured by the use of profiles - a subset of elements from a standard required in a given environment. IEC Technical Committee 57 therefore decided to work on a guideline for building Basic Application Profiles (BAP) [4]. This guideline aims to provide a constrained framework to model typical and often used automation functions for substation automation systems in the context of IEC 61850 [5] in order to increase functional interoperability in practical applications and is following the approach of the framework document IEC TR 62361-103 [6] of IEC TC 57.

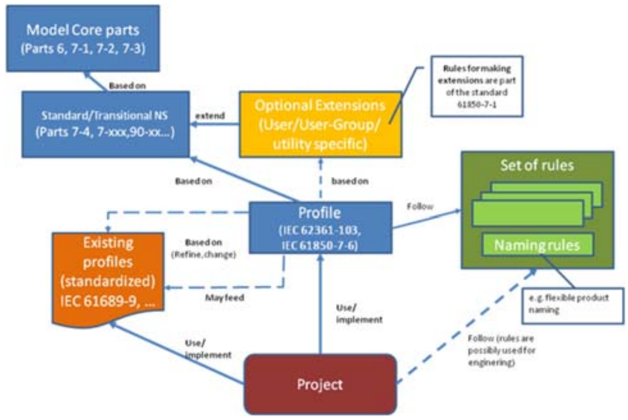

Figure 1 – Framework for Profiling IEC 61850 [6]

The upcoming guideline IEC TR 61850-7-6 [4] therefore focuses on the typical information exchange including the data and communication services and related engineering conventions to provide a common and generic way to describe the functional behaviour of a specific application function. The guideline itself does not describe the applications and the respective implementation. A BAP in accordance with the guideline shall provide a fully defined (no option) and autonomous description of an application function with all required data as an interface to the rest of the system and shall be independent from any implementation and any real IED.

From an application point of view a full system specification might be realized by aggregating different BAPs to answer to user requirements. But from an engineering process, the sum of all selected BAPs alone cannot guarantee the entire coverage of a project specification. A set of additional information is required – one component of which will be produced from the BAPs themselves and the other part from sources such as grid codes, other set of standards and specifications, manuals and engineering experiences. Moreover, ensuring interoperability between different BAPs and their implementations in real devices and their capabilities are going to be additional areas of investigation with this new specification and engineering paradigm. This additional information called "set of rules" (Figure 1) will be used to supplement the BAPs driven modelling of automation functions. This engineering approach could lead to the long term objective of achieving exchangeability in a given automation system.

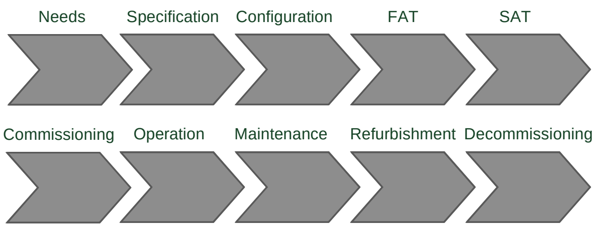

Figure 2 – Lifecycle of a System

ENGINEERING APPROACH

Engineering of a system can be a longer process **(**Figure 2**)** which starts from the gathering of user requirements to the commissioning of the system on site and as well in later phases maintenance and refurbishment. This engineering process is split into several steps which involves many stakeholders which exchange documents in different formats, which are produced by humans and which have to be processed by other humans. Therefore, the process may face several sources of errors due to:

- Data format
- Unit definition
- Human error
- Data interpretation

Standardization helps to reduce these risks. IEC 61850 defines a standardized data model with standardized files and an engineering process based on these files. Such a standardized data model helps to reduce data usage errors related to format, unit and interpretation. A standardized process based on file exchange helps to reduce human errors by defining roles for tools and a machine-to-machine data exchange without human data input. Today, IEC TC 57 enhances the process related to IEC 61850 system configuration engineering, the part in the middle of the full system engineering process.
IEC TR 61850-7-6 will provide the framework for Basic Application Profiles which will bring a new standardized description to express user application needs. This will help to reduce risks at early stages of the global process, for needs gathering and specification:

- Needs should be machine readable
- Needs are reusable
- Needs will be used as basics for specification
- Specification will be used as basics for configuration

In order to reduce risks for later stages of the global engineering process, rules will be used to help for a better configuration based on BAP creation. The configuration will then be composed of IEDs answering as much as possible the user needs, in a tested environment to reduce FAT and SAT issues.

RULES

As of today, the specification for an automation project is created manually even if it is partially making use of the System Specification Description (SSD) within the IEC 61850 engineering process framework. If consistency with existing projects is desired, the specification can also be based on a copy from the one of an existing project. In any case, it consists out of a number of parts, being general requirements and definitions common to all automation equipment, then system related requirements, requirements related to one or more bays and application related requirements. Since an automation system performs more than one application, the specification lists all required functions to cover all applications.

Further to the creation of a specification, BAPs can offer the opportunity of profiting from standardized definitions and thus reducing the personal effort while increasing the quality of the output. Having made the fundamental work which goes with every project, the user may identify BAPs representing the applications his project shall cover and, instead of re-inventing a solution by his own, take over the definitions associated with each application.

Assuming that BAP definitions will be laid down in a machine readable way, which is not defined yet, the definitions could be directly imported into the system configuration tool as project requirements. If the BAP content cannot be directly imported by the system configuration tool, at least the definitions can be used and fed into the specification manually. Depending on the delivery of the individual BAP, the data model and also the communication services may be defined there. The engineer then decides over the content of the import, whether to import the entire BAP or just selected parts of it. It will need some alignment between the imports and additional definitions to make the specification complete.

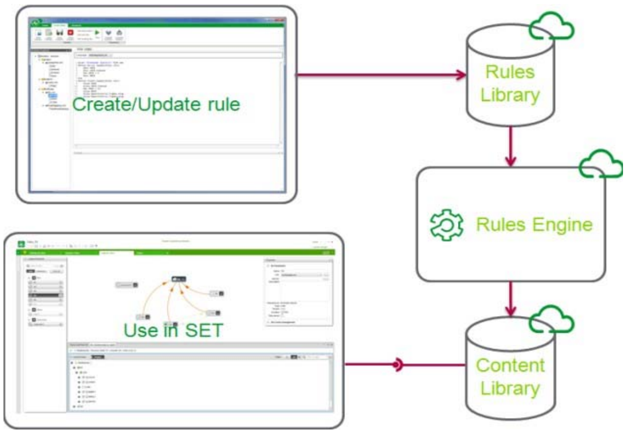

Figure 3 - Application of Rules in a System Engineering Environment

According to the profiling framework as described in the ongoing IEC TR 62361-103 document (Figure 1), the profiles provide a set of requirements which implies a set of rules to be followed. They play an important part during the overall end-to-end project lifecycle process including aspects of specification, engineering, commissioning and maintenance. Such set of rules could create a knowledge base inside an organization, leveraging past project experiences and challenges, collating non-standardized information on device capabilities – coming from standard machine readable formats like the System Configuration description Language (SCL) and documents such as MICS, PICS and PIXIT - and translating these demands for compliance into a rule based formalism. Such rule writing could be static or dynamically pushed into the project context where they could be held available for usage as and when required (Figure 3).

The complete set of requirements which makes up an application can be verified by rules. Rules can be used to detect whether an IED supports the functions required by a certain application. If so, it can be checked whether the information provided by the device is sufficient. Should customized names of the functions be required, rules can help to detect whether the IED allows the adaptation of names. Having verified data model related requirements for semantic interoperability, the syntactic interoperability is the next to be checked. The ways an IED offer to convey information can be evaluated by rules, falling into any level of detail.
Talking about the entire automation system, more than one IED will be involved, and the total requirements listed are to be distributed for support by a number of IEDs. On the other hand, more than one BAP may be supported by a single IED.

Rules can be of myriad types. Starting from a simple rule - e.g. of what optional fields are supported and what are not for a given report control block - going up to rules that may involve comparing several rules to generate a more complex one could be envisaged using a choice of language. Here are some rule examples for validating an IED against a given BAP with their possible impacts:

- A rule based upon the constraints on an IED "A" with respect to the string length of a subscribed GOOSE control block name published from an IED "B". If the string length exceeds a certain threshold, IED "A" cannot subscribe to a GOOSE message from IED "B". This results in a non-interoperable behaviour. A possible representation of such a rule could be:

  Given <Manufacturer> <IED A> <Version>
  Define
  MaxChar GSEControl.name = 10 //for SCL//

- A rule based upon the capabilities of an IED to support the control model as stipulated in the BAP

  Given <Manufacturer> <IED A> <Version>
  Define
  ctlModel = "sbo-with-enhanced-security"

- If an IED does not support the data quality "test" it cannot be used in test mode which could impact the entire test strategy.

  Given <Manufacturer> <IED A> <Version>
  Define
  LLN0.Beh = "test" && LLN0.Beh = "test/blocked"

The scope of IEC 61850 has transcended from pure substation perimeter to cover applications for domains like communication between substations and between substations and control centers - IEC TRs 61850-90-1 / 90-2 [13, 14] resp. - and DER integration. Interoperability aspects between these myriad application functions necessitate creation and usage of additional rules in order to build robust system specifications.

APPLICATION EXAMPLE

How rules for a project specification can be created out of the content of Basic Application Profiles is demonstrated on the example of a 'Reverse Blocking' (Figure 4) application. IEC TR 61850-7-6 includes 'Reverse Blocking' as an example, so the following exercise makes use of the technical requirements listed in that document as if it was a BAP.

'Reverse Blocking' can be reduced to an information exchange between two IEDs, where the one in the outflow bay signals to the one in the infeed bay to hold off starting. Among quite a few other requirements the IED in the infeed bay must be provided with an overcurrent function and this function must be modelled in its IEC 61850 data model. The BAP *requests* the data PTOC.Str, PTOC.Op and PTOC.Blk. While Str and Op are mandatory data objects for a PTOC implementation, Blk is optional in the standard, which makes the difference against the BAP. A rule can be set up to check for the provision of a *requested* data, and the publication in the dataflow by mean of a dataset and a report inclusion:

Given <Manufacturer> <IED B> <Version>
Define
PTOC.Blk
DSMemberRef[#] = PTOC.Blk
RCB.DatSet = DSName[reference]

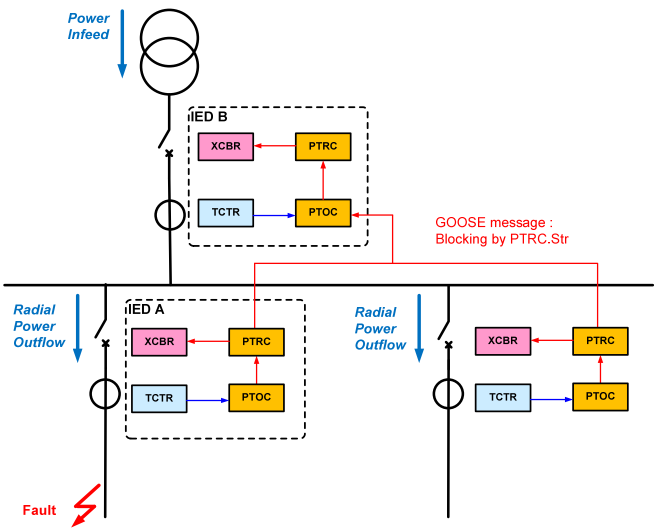

Figure 4 - Reverse blocking data flow with one infeed [4]

The information exchange between the IED of the outflow bay (blocking) and the IED of the infeed bay (blocked) is made via GOOSE. The information PTRC.Str in the GOOSE dataset must be provided on FCDA level (i.e. as data attributes). The rule to verify this capability is:

Given <Manufacturer> <IED A> <Version>
Define
DSMemberRef[#] = PTRC.Str.general &&
DSMemberRef[#+1] = PTRC.Str.q
GoCB.DatSet = DSName[reference]

Then, to complete the data exchange definition, the trip information shall be received by first IED. A rule to verify this usage is:

Given <Manufacturer> <IED B> <Version>
Exist
PTOC.Input.ExtRef with
DataRef = <IED A>.PTRC.Str
ServiceType = GOOSE
SrcCB = <IED A>.GoCB[reference]

Based on a library of IEDs (local or in the cloud), this set of rules will then be used during engineering process by an SCT to propose to the engineer the best candidate IEDs to answer the customer needs.

As a profile could also provide the functional tests of the described application, the testing procedure could be generated following these rules by identifying the sequence of calls between selected IEDs.

The application of rules could be extended to any other application like substation-to-substation communication use cases or any other system-to-system communication.

RECOMMENDATION TO THE ONGOING STANDARDIZATION WORK

Although the standard on BAPs has not been published yet and the work on it is ongoing, a few recommendations could already be made for the work on other standards:

The current draft does not yet propose a machine readable format of BAPs, nor the set of rules. To reach the expected level of benefits, a specific language has to be defined to cover all elements of a BAP including the rules definitions. The application of rules needs to become a part of the engineering environment.

Starting from the concept for substation automation as intended by IEC TR 61850-7-6, an extension to other domains using IEC 61850 needs to be targeted.

The processes to manage standardized profiles along their lifecycle and the hosting of them need to be discussed within IEC to make the concept work when the standard will be released. This should include the management of standardized profiles, the hosting, the access management and the related commercial agreements.

CONCLUSION

Interoperability of communication between the various elements inside substation automation systems and between several systems in the context of power utility automation is a must. The work started at IEC Technical committee 57 on Basic Application Profiles will lead to an improvement of the application level interoperability. Some other initiatives are addressing other levels of interoperability like the concept of “Flexible Product Naming” which could help to strengthen the BAP approach.

To facilitate the use of profiles the work on the set of rules will be important, a work which should not be underestimated. The quality and the content of the set of rules will have a direct impact onto interoperability aspects. Therefore the present processes for creating (project) specifications need to be enhanced for using as much as possible profiles.

Basic Application Profiles are at an early starting phase and first projects will provide feedback into the standardization process. The expected benefits like risk avoidance, shorter engineering times, faster commissioning and better lifecycle support will foster the application of profiles. Once validated for substation automation systems, the concept will expand quickly to cover interoperability aspects in other domains, specifically system-to-system aspects. New architectures integrating Operational Technologies (OT) and Information Technologies (IT) applications with a large number of communicating devices (IoT) and systems are going to benefit strongly by applying the profiling approach. New business models and services could be expected which will help users to create profiles, to maintain and to manage them.

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