IEC 61850 interoperability and use of flexible object modeling and naming

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Abstract— In various discussions of international standardization and user groups, e.g. German DKE “IEC61850 Engineering” working group, use cases with dedicated focus on interoperability have been identified, e.g. especially in the case of bay extensions and device replacements.

A typical use case for transmission system operators is the replacement of an installed device by a device of a different vendor with a minimum of engineering efforts. This use case imposes the similar behavior on the network interface level of the devices.

A new concept for flexible object modeling and naming is introduced which enables efficient and seamless replacement of IEC 61850 devices. The concept features flexible data modeling and naming in the devices and the flexible use of communication services. Based on this concept, device interchangeability on communication level is possible. The paper discusses the consequences of this concept to the IEC 61850 engineering process in multi-vendor systems. Furthermore, it is shown how system operation can benefit through the approach of IEC 61850 interchangeability on communication level.

Index Terms—Engineering, IEC 61850, Interchangeability, Interoperability, Substation Automation

I. INTRODUCTION

The standard IEC61850 [1] is the world-wide basis for power utility automation. Currently there are practical experiences from over 1,000 substation automation systems (SAS) all over the world. Users expect reduced life-cycle costs from this new SAS technology. Particularly users associate interoperability as a major advance of IEC 61850. Naturally early implementations had some limitations regarding interoperability and consequently could not meet all user requirements. Today the advantages of IEC 61850 are most beneficial by using single-vendor configurations. Interoperability of Intelligent Electronic Devices (IEDs) of different vendors is possible by understanding the cooperation and co-functioning on communication telegram level. The interchangeability, required by some users, as the higher technological level is not achievable in practice by now.

II. SITUATION AND REQUIREMENTS

A. Current Situation and Challenges

Substations vary greatly in design according to application, historical evolution and operation philosophies. The same reasons apply for SAS. Substation automation functions are largely determined by application requirements (e.g. protection scheme), single line layout (e.g. interlocking concept), operation philosophies (e.g. control hierarchy) and SAS technology (e.g. serial or Ethernet communication).

Besides technical and historical constraints, cost efficiency has become the most important factor for users. That means that today the total costs of ownership have to be considered for the assessment of a SAS solution. The total costs of ownership include not only initial invest, but also costs for staff training, operation (comprises costs for maintenance, service, changes, extensions) and even for deconstruction of a SAS solution. In order to minimize the total costs of ownership, users expect an SAS technology which is long term stable and at best vendor independent.

The lack of SAS experts is another increasing factor, users and vendors have to cope with today. As a consequence the SAS shall be easy to handle, a variety of different SAS shall be avoided.

All these technical and economical goals are competing. For example long term stability and cost efficiency regarding staff training and spare-parts stocking can be achieved by exclusively relying on one SAS vendor. But this is in conflict with the common procurement strategy to consider at least two vendors.

Depending on the user profile different factors are the focus of attention. For municipalities it is for example important to have fast SAS deconstruction / commissioning phases and reliable SAS solutions. Transmission system operators attach particular importance to the migration from existing installations by reusing as much of engineering know-how and keeping up their operation and service concepts.

B. German User Requirements on IEC 61850

Today in Germany IEC 61850 based SAS solutions are well established in industry and distribution applications.
These users state, that technical and economic requirements are fully met by IEC 61850 [2, 3].

German transmission system operators have a different perspective. Particularly those transmission system operators, who carry out a large proportion of the engineering themselves and have systems and processes with a high level of standardization, require high standards with regard to engineering interoperability and implementation of IEC 61850. These users have developed their own secondary technical modules with interfaces that have a defined volume of information with respect to process connections and communications. With this user-type standardization, the secondary system modules are vendor-neutral and enable the user to exchange the modules during operation with virtually no reaction on the system. Modifications must be made to the traditional concepts in order to make full use of the value added offered by IEC 61850. One reason for this is that the signal-oriented communication protocols used in the IEC 60870-5 series are closely interlinked with the user-specific distribution of functions (e.g. protection, switch interlocking) [4].

III. INTEROPERABILITY / INTERCHANGEABILITY

Particularly users associate interoperability as a major advantage of IEC 61850. The understanding of the term “interoperability” is often not clear, sometimes it is mixed with the meaning of “interchangeability”. In the following sections shall explain these terms in general and in the IEC 61850 context.

A. Interoperability Requirements

Basically “interoperability” of two technical systems means that these systems offer the ability to cooperate. Depending on the specification of the systems’ interfaces, different levels of integration efforts may be necessary to achieve a correct cooperation. Fig. 1 illustrates various levels of interoperability due to different interface compatibilities. The level of compatibility of the two systems’ interfaces is denoted as “integration” distance. If the interfaces share basic connectivity, syntactic and semantic understanding, the efforts for integration should be lower than without common interface features. In the case that no standards are available a custom integration is required to achieve interoperability. If the interfaces can be mapped by the use of a gateway (e.g. from IEC 61850 to IEC 60870-5-104 protocol) the integration effort can be reduced. In case the interfaces share a common data model and services models a further reduction of integration efforts is possible. At best a plug-and-play interoperability (by profiling data models, services and application semantics) can be reached.

Fig. 1. Integration distance

B. Interoperability in IEC 61850

Here the standard gives a clear definition: “Interoperability is the ability of two or more IEDs (Intelligent Electronic Devices) from the same vendor, or different vendors to exchange information and uses that information for correct co-operation” [1].

In enlargement to that: “Interchangeability is the ability to replace a device supplied by one manufacturer with a device supplied by another manufacturer, without making changes to the other elements in the system” [1].

When IEDs are interoperable, in practice this means the IED provide a comparable functionality. The user can expect a compatible interface allowing the user to adapt the behavior of the IEDs to the specific application with a limited engineering effort.

As a difference, interchangeability means identical process and communication interfaces and in addition identical functionality with same function and system parameters. This implies identical algorithms for protection and automation functions. So interchangeability is achievable today only with IEDs of the same type from the same vendor.

As a consequence in the standard IEC 61850 is stated: “Interchangeability is beyond this communication standard” [1].

But one of the future goals is that interchangeability is possible on the communication level, what means by configuration of the interface the communication addresses of the same information is the same from IEDs of vendor A or of vendor B independent on the implemented IED functionality.

IV. APPROACH FOR INTERCHANGEABILITY ON COMMUNICATION LEVEL

A. Basic Scenario

The basic scenario describes the system and communication configuration of a substation automation system (SAS) and the fundamental issues for the exchange of an IED regarding IEC 61850. A typical SAS consists of a station and a bay level (Fig. 2): IEDs at the bay level, for example protection relays, bay or transformer controller, and station units and local HMIs at the station level. The interbay-communication with IEDs at
the same bay level is executed typically with an IEC61850 GOOSE service. The communication of IEDs to one or several station units and local HMI is executed in a client-server mode. From the different IEC61850 services the reporting service is often used.

![Diagram of Control Center, Local HMI, Protection & Bay Control IEDs, and Process Station Unit](image)

**Fig. 2. Basic scenario, including the IED, which shall be replaced**

GOOSE is a multicast communication service. A publisher sends multicast telegrams and the configured subscriber read, decode and process the information in these telegrams. The configuration for the GOOSE communication will be carried out with the help of the system configuration description language (SCL). The configured data objects are provided by the publisher IED to all participants in data sets and so called GOOSE control blocks (GoCB) in a SCL-description (SCD).

The reporting communication will also be configured in the SCD. The instances of the data objects will be selected within the data model and the references will be collected in data sets. By report control blocks (RCB) the detailed behavior of the client-server communication will be described in the service the report.

**B. Use Case “IED Exchange”**

According to the current cost pressure and the high power system utilization regarding capacity, out-of-service times of substation equipment and therefore the duration of service in case of equipment failure shall be minimized. A typical example is the failure of an IED which has to be replaced by spare IED (see Fig. 2).

The goal of this use case “IED Exchange” is to replace an existing IED “A” in a bay through another IED “B”. The following requirements shall be taken into account:

- IEDs “A” and “B” fulfill the same functions (e.g. protection and control)
- IEDs “A” and “B” are of different type (vendor or product version)
- Reengineering and testing of other IEDs in the system environment shall be avoided.

This means that the IEDs in the system environment do not detect any changes in respect to IEC 61850 communications. As a consequence the IED “B” must provide the exact behavior of IED “A” at the communication interface. This includes the aspects of IEC 61850 data model and services.

**C. Current limitations regarding exchange of IEDs**

The following limitations may complicate the exchange of IEDs:

- The internal data structures (LD-/ LN structures, see Fig. 3) of the devices are not flexible. It is not possible for the user to configure these data structures according to the structures of the previous IED.
- The data classes (LN, DO, DA) that are required by the users are not supported the IED.
- The optional features of the IEC 61850 communication services are implemented in a different way by vendors.

**Fig. 3. Example: IED “A” and IED “B” with different data model**

As result the behavior of the replaced IED is different to the previous IED. This makes reengineering and testing of the IEDs of the system environment necessary in order to achieve a consistent and operating substation automation configuration. Therefore the requirements of the use case “IED exchange cannot completely be fulfilled.

**D. Requirements for exchange without additional IEC 61850 configuration changes**

In order to overcome the limitations of the current implementations the concept of “Flexible Object Modeling and Naming” was developed. This approach covers the use case “IED exchange” completely by fulfilling the following requirements.

- Flexibility of the implemented data model of the equipment. Possibility of the users determining the logical device structures (LD). Creating and using the possibility of the user LD with that.
- Free creating LN in conformity with the standard. Possibility of the complete use of all essential data classes the IEC 61850 (LN, DO)
- Free name of IEDname, LDinst, Prefix and suffix.
- Complete mapping of the service features. The possibility carrying out the settings of the reporting and GOOSE communication identically being able to do. The elements of the data sets must particularly be absolutely identical with respect to contents and order.
- The information which shall be transmitted about GOOSE is used only from the FCDA level (Functional constraint data attribute). The telegrams of the reporting
between server to the client shall contain only FCD elements (functional constraint data).

- Controllable data objects must be the same. This indicates that the location must be identical in the data model. The mapping specific structure of these objects also must be the same. The control model shall be the same. also the behavior during the control sequence shall be equal e.g. use of the addCauses.

- Configuration revision values (configRev) for the supervision of a solid GOOSE communication must be taken into account.

At the flexible configuration of the data structures and communication settings it must be taken mandatorily into account that there are limits and dependences between the application software and the data modeling. It has to be considered that in most cases the use of the data objects “mode/behavior” is not or only restrictedly possible on “Logical Device”-level. This has effects on testing concepts. The setting groups also must be on the top level of the LD. If settings of setting groups will be separated by the modification of the LD structure, than they can not edit by communication services any more.

V. USE OF CONCEPT

The beneficial use of the replacement concept comprises planning, preparation and implementation. During planning of substation automation systems the user has to select the IEDs capable for replacement according the following rules:

- Ensure that the set of IEDs, which are selected for replacement, provides a comparable functionality (e.g. protection and control) and physical compatibility (terminals, auxiliary voltage level).

- Ensure that the set of IEDs supports a common set of data classes and communication services. This includes the ability for “Flexible Object Modeling and Naming”.

In order to allow a fast replacement in case of IED failure, the IED configuration shall be prepared. This includes the pre-configuration of functions, data model and communication services. This pre-configuration can be carried out on tool-level. It is recommended to test the replacement in an offline system test bed and ensure the correct behavior prior to real application.

In case of a real IED failure, the IEDs are physically replaced. The pre-configuration of the spare IED is adapted to the specific application and uploaded. With a final verification of functions and communications the replacement is completed.

VI. CONCLUSION

IEC 61850 offers a complete framework for substation automation which allows the industry to develop modern and powerful products and solutions. The interoperable use of such product and solutions is the major user expectation. The degree of interoperability depends on vendor implementations. It has been shown that with flexibility in regards of IEC 61850 data modeling and naming, as well with support of various communication services, interchangeability on communication level can be met. This approach allows the implementation of the use case “IED exchange” which reduces out-of-service times in case of IED failures.

VII. REFERENCES


VIII. BIOGRAPHIES

Henry Dawidczak studied in Moscow at the Moscow Institute of Management. His employment experience includes software engineering in energy automation. He has been working for Siemens since 1991 in different departments in energy automation. He is member of the working group 10 and 17 of the IEC TC57 and of the national committee DKE K952 of Germany. He is editor of part 7-4 the IEC 61850 and convener of the German working group AK952.0.1 “Engineering”.

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