***A**rbeits**K**reis **952.0.1**:*

Overview of the Results of the DKE Working group 952.0.1

Version 1.0

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1 Introduction

The IEC61850 system standard not only describes the communication technology for substation automation systems but also how such systems are engineered. It enables a standardized description of the information modelling and communication configuration of substation automation systems with the Substation Configuration Language (SCL) defined in part 6. Engineering with SCL is considered crucial for the interoperability and long-term profitability of projects.

Users and manufacturers have therefore teamed up to form two working groups of DKE committee 952 “Netzleittechnik” (power system management) on a national level to tackle the special issues arising from the IEC 61850 standard.

Working group 952.0.1 “IEC 61850-Engineering“ was founded in October 2005 with the goal to continue the work of the former working group GAK15 (modelling of a combined h.v. and m.v. switching station using the IEC 61850 standard, see [1], [2] und [3]) for engineering based on SCL.

The working group is composed of representatives of German power grid operators, manufacturers of substation control and protection systems and from one university.

The working group has worked on three subtasks whose results are documented in separate papers.

The following chapters give a summarized overview of these documents.

2 Description of the Engineering Process

In order to further benefit from the standard, it is necessary to formalize and automate the engineering process. The specifications for an efficient engineering process are depicted in [4].

2.1 Specification

The data model has to be specified at the beginning of the engineering process of the substation automation system (SAS) to be set up. In this context, the SSD file (Substation Specification Description) defines the functional view of the substation and of the secondary system and SCL provides a formalized description of the substation structure. The abstract logical node classes (LN classes) related to the corresponding structural levels of the system (substation, voltage level, bay level, equipment level, function level) can be assigned either manually or from libraries. The LN is selected according to the specification of the LN class via the linked LN type. The different LN types can be used to determine whether and which optional data types from the standard scope of the LN class are used. As the result, we obtain a specification that defines the data model (substation model) of the SAS with the correct topology and functions serving as the basis for the functional naming. This specification in the form of an SSD file can be used, for instance, as electronic requirement specifications for tendering.

2.2 Configuration

After the function naming the logical nodes are related to the product naming during the SAS configuration phase. The function-related abstract logical nodes are linked by reference to the product-related logical nodes of the device models (IED models). The result is a mapping of the device-independent substation specification to the physical devices. This enables users to use both the function-related and the product-related view in the subsequent engineering phases.

Should a flexible product structure be capable of exactly mapping the functional substation model, this model can be integrated directly into the product structure. Otherwise, an import of or comparison with the possible products is necessary. In practice, such IEDs are selected which best satisfy the specification. This is determined by comparing the LN types defined in the specification with the LN types in the description files of the IED capabilities (ICD - IED Capability Description). It is verified whether the LN types of the IEDs meet or exceed the specification, i.e. offer more objects than required.

Subsequently, the ICD files are taken over into the system description of the SAS and product naming and functional naming are linked with each other.

Especially this process step offers ample potential for optimization since the user can be supported by intelligent tools here. For instance, an automatic comparison of the specification and the IED capabilities could signal the user in how far the IEDs fulfil the specified functions. The tool could suggest suitable IEDs to the user, automatically adjust the identifications and establish the links between product naming and functional naming.

Subsequently, the communications relations inside the system are established. As the result, we obtain an SCD file that describes the data model and the communication model of the entire substation.

The device-related sections can be extracted from this file, passed on to the device configurators for transfer into the devices.

2.3 Creating templates and user-specific libraries

The typing of configuration data in the form of sample configurations (templates) greatly facilitates the engineering process for creating new substations or expanding old ones.

For instance, the following types of pre-configured templates are possible:

Type 1) Template of the complete device-independent specification of a bay (type 1a) or a substation type (type 1b)

Type 2) Template of a bay type consisting of a manufacturer-independent substation model and a manufacturer-specific device model including the links between product naming and functional naming

Type 3) Template of a bay type consisting of a manufacturer-independent substation model and several manufacturer-specific device models including the links between product naming and functional naming

Type 4) Template of the complete configuration of a voltage level of a substation type consisting of the associated substation model and manufacturer-specific device models including the links between product naming and functional naming

Organized in libraries, these templates can be used as models in the corresponding projects.

2.4 Roles and actors in the engineering process

The creation of a new substation encompasses certain roles which are defined by the tasks that have to be performed. These roles are filled basically by the actors called “Users” and “Service Providers”.

- The distribution of the roles in the IEC 61850 engineering process begins with that of the **plant engineer for secondary equipment** who translates the guidelines into a specific planning. The outcome of his work is the requirement specification for the secondary equipment.
- The role of the **design engineer for secondary equipment** translates the system specifications into a solution comprising products, protocols etc. The result is the target specifications for secondary equipment.
- The role of the **supplier** who actually delivers the products does not have to be filled by the manufacturer as the actor at the same time.
- The **system integrator** interconnects the devices and routings of the bay-spanning functions logically and ensures the communications required to this end.
- The role of the **device programmer** carries out the parameterization for the individual devices, i.e. integrating functions into the devices.
- The role of the **construction engineer** has the task to translate specifications into wiring.
- After the role of the **assembly technician** has completed the assembly and wiring work, the role of the **system verification engineer** checks the entire system, performs fault diagnoses and ultimately releases the entire system.

2.5 Engineering tools

The standard defines various tools for the entire engineering process:

The **System Specification** tool is used to define the system structure, create the topology as single-line, create function-related abstract logical nodes (LN) according to IEC 61850 and generate the system specification file (SSD).

The **Device Configuration** tool is used to configure e.g. protection, control and automation functions, create the device model (ICD file), import the system configuration file (SCD), generate the device parameterization file and load the device parameterization file into the target device.

The **System Configuration** tool should be able to import the system specification description (SSD file), the device models (ICD files) and a system configuration file, configure communication settings and communication functions (reporting, GOOSE bay level-communication) and generate a system configuration description (SCD file).

The **Test/Diagnostics** tool allows process and communication signals to be simulated or stimulated, device and system functions to be verified and the desired behaviour to be tested. The diagnostics requires that device models (acc. to IEC 61850) can be called and visualized in order to listen in to and record the communication traffic.

3 Modelling guideline and sample modelling using SCL

From the very beginning, working group AK 952.0.1 has aimed to accomplish a sample modelling of the reference system proposed by GAK 952.0.15 based on the SCL description language. This approach served to verify the possibilities of the object model according to IEC 61850, to reproduce the engineering process using the associated SCL data and verify the consistency and practicability. For a better understanding of the information model of the reference system described in [6] we will provide an introduction to the application of the object model according to IEC 61850.

3.1 SCL object model

Parts IEC 61850-7-4 and IEC 61850-7-3 of the standard describe the class model as the entire scope of the possible equipment and functions. It is listed in both parts of the standard in tables containing mandatory objects and optional objects.

Standard part IEC 61850-6 defines an object model that is formally represented by SCL.

This SCL object model is composed of three sub-models and one part for the specification of data types (see Fig. 1) [7] :

The **substation model** serves to present the substation from a functional perspective. The object model provides a hierarchical structure for mapping the primary system. Within the substation structure thus mapped the primary equipment and their electrical connections among each other (topology) can be described. Secondary functions can be assigned to the system components, equipment and functions as logical nodes. In this manner, the relationship between primary and secondary system is described.

The **IED model** describes the secondary functions from the device perspective. The composition and structure of the functions is determined by concrete device-specific capabilities.

The **communication model** describes the communication configuration of the substation.

The secondary functions in the substation and IED model are represented by logical nodes. Standard part IEC 61850-7-4 defines corresponding LN classes for typical functions. These logical node classes differ in the naming and composition of mandatory and optional data objects and attributes. The actual composition of LN classes can be specified as LN types in the section *DataTypeTemplates.*

The use of LN objects and the possible relations between the model components are shown in Fig. 1 at the example of the distance protection function *PDIS* for a bay in a 110-kv-substation.

These components of the object model can be used to form the substation and product model for the different modelling tasks. These models can use different variants of the descriptions of the class model. All mandatory objects must be used while the optional data objects can be selected as desired.

The system model describes the structure of the switching station and is thus identical to the substation model.

The product model describes the product with its implementation-specific version of the class model.

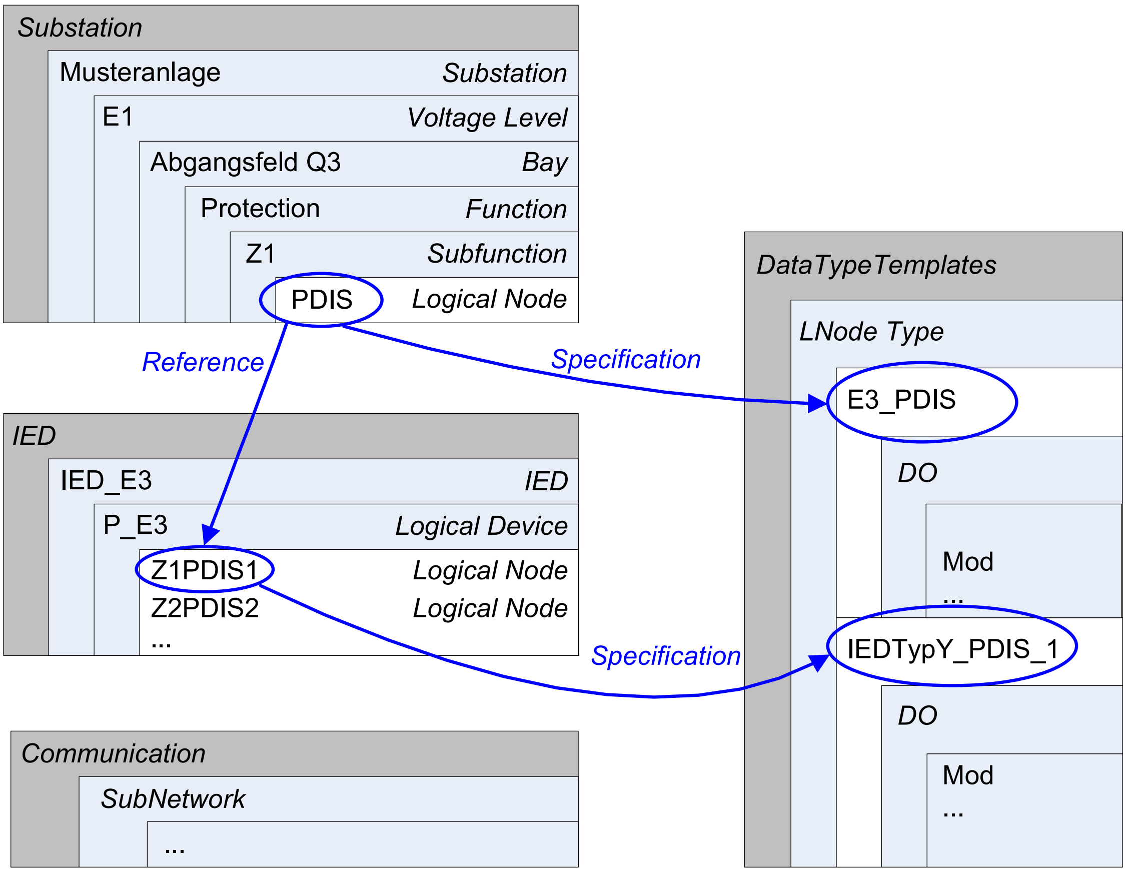

Figure 1:Components of the object model and relations between logical nodes

In the substation model the abstract LN object of LN class *PDIS* is arranged within the substation structure according to its application-specific use (distance protection function zone 1). For a detailed specification, the abstract LN object can be linked to an LN type (*E3_PDIS*) of the same LN class from the *DataTypeTemplates* section. The abstract LN object from the substation model can be linked by reference to the LN instance (*Z1PDIS1*) from the IED model. The LN instance (*Z1PDIS1*) itself is specified by the LN type (IEDTypY_PDIS_1).

3.2 Object addressing (naming)

3.2.1 Functional naming

A functionally structured data model established on the basis of SCL is manufacturer-independent and standardized. It enables users to transfer their own substation concepts in a consistent address space. The user-specific configuration thus achievable simplifies the engineering process because it is independent of the device technology of a SAS therefore becoming long-term stable and reusable. This function-related addressing schema is called “functional naming” in the IEC 61850 standard.

A substation model according to IEC 61850 is obtained by modelling the structure of the primary system with the logical nodes for the equipment, the distributed functions and the linked type classes of the logical nodes, data objects and attributes.

The working group 952.0.1 has completely modelled the GAK15 sample station and mapped it in SCL from a functional perspective. This is based exclusively on edition 1 of IEC 61850-6. The only exception is that the elements “Function” and “Subfunction” are also assigned to voltage levels and bays. This is not permissible in part six of edition 1 but was deemed necessary by working group 952.0.1 for the complete functional modelling of the substation. This expansion will also become normative in edition 2 of the IEC 61850-6.

3.2.2 Product naming and product model

While the functional data model is oriented at the primary system, the data models of the devices mirror the functions implemented in the actual bay units and protection devices of the individual manufacturers. Since the structure and scope of the device functions depends on the manufacturer-specific implementation, the individual data models of the devices and the resulting addressing schema can be different. This is referred to as “product naming” in IEC 61850.

The product model thus consists of the IED descriptions and the linked type classes of the logical nodes, data objects and attributes.

3.2.3 Linking

LN objects and the data objects and attributes they contain can be accessed through the hierarchical structure of the object models. By breaking down the structure we obtain a clear path to the target object.

If LN objects are linked via references in the substation model and in the IED model as shown in Figure 1, it is possible to access one object using two different paths - from the substation model and from the IED model. The object addressing via the substation model is accomplished via the *functional naming*; the identification via the IED model by the *product naming*. The data object *Mod.stVal* shown in figure 1 can thus be accessed in the following ways:

- *Functional Naming*: Musteranlage/E1/Abgangsfeld Q3/Protection/Z1/PDIS.Mod.stVal
- *Product Naming*: IED_E3/P_E3/Z1PDIS1.Mod.stVal

The data exchange during operation of a SAS on the communication level will always be accomplished the *product naming*. By linking the IED model and the substation model, each object can be presented in the functional view of the *functional naming*.

If the implementation of the IED model offers a certain degree of freedom for the product naming, e.g. a user-defined designation of IEDName, LDinst, Prefix and Suffix, the object addressing of the functional naming can be taken over into the product naming. This lays the technical foundation for the exchangeability of the devices on the substation bus.

In the sample modelling performed by working group 952.0.1 both variants are shown at the example of a bay.

3.3 Modelling guideline

This introductory section provides detailed specifications for modelling a reference substation in the form of a modelling guideline. These specifications complement the modelling guideline of GAK 952.0.15 and update them taking into consideration more recent events. In order to emphasize the continuity of the work, we will point out the expansions and modifications to the GAK 952.0.15 guidelines via cross-references to the guidelines modified by working group 952.0.1 in this document at the end of the modelling guideline [6].

3.4 Sample modelling using SCL

The middle part of the document presents the sample substation modelled in SCL according to the guidelines, and the basic procedure for modelling information in the engineering process according to IEC 61850 is depicted.

The layout of a SAS is determined by the requirements of the primary technology. Hence, the single-pole diagram of the primary system is the point of departure in the SAS engineering process. The circuit diagram reflects the electrical topology of the high-voltage equipment and their basic properties. The structures and the designations of the individual elements such as substation, voltage level, bay, equipment are largely standardized in the IEC 61346 and are an inherent part of the vocabulary of users. It is therefore a logical consequence to use the structure of the substation and the designations for the manufacturer-independent part of the engineering process of the SAS.

Using SCL, the specification of a SAS can be created in the form of a “system specification description” (SSD). A standardized notation is used for the various levels and pieces of equipment to create a hierarchical tree structure where the trunk represents the substation, the branches the voltage levels and bays and the twigs and leaves embodying both the primary and secondary system functions. The norm defines special object classes to assign unambiguous tasks and properties to equipment and functions. These object classes are called logical nodes. Their detailed structure is described with data and attributes by means of a LN class reference to a data type sample description (DataTypeTemplate).

The engineering of the sample substation was carried out by working group 952.0.1 using a manufacturer-independent tool and comprises the following steps:

I. Project planning of the primary system including a planned process link for the secondary equipment with assignment of the template classes “lnClass” which are not yet further specified. This step serves to determine the scope of the system and generate a first .ssd file.

II. Typed definition of the LNs, DOs and DAs. This is done when first defining types for the creation of the type library, unless it already exists and an existing library is used.

III. Assigning the typed information objects to the system and determining the entire scope of information. “lnType” is assigned here. The prefix and the instance numbers are not used since they are reserved for the product-related view. The hierarchical information modelling is instead accomplished in a function perspective (“functional naming”) using the elements “Equipment” and “Subequipment” for primary equipment and “Function” and “Subfunction” for the functions.

    The product-related structure of the control system is therefore still open in this phase of the engineering process so that this step results in a .ssd file including the information types (“data type templates”). It can be used for the solution-independent tendering phase.

IV. Complete information modelling including the system structure Here, .icd files are generated based on the functional specifications, or manufacturer-specific .icd files are imported and their product-related view (“product naming”) is adjusted or clearly assigned to the function-related view (“functional naming”). This step results in the .scd file from whose IED section the .icd files for each device which are tailored to the project are extracted. They represent the information modelling related to the project.

V. Datasets, communication structure and services have not yet been determined since they depend on the actual IED structures. Guidelines and recommendations in this context will be given when the work has further progressed.

4 Applications with the services of IEC 61850

4.1 Need for application recommendations

The IEC 61850 communication standard was defined as an open standard, i.e. it was deliberately not tailored to the applications commonly used in substations. Rather, an option was included in the standard that allows the free data modelling of all object types customary today and a variety of possible communication services. This enables the standard to be developed further without limitations and to be extended to various fields of application. However, the drawback is that there is a certain ambiguity or lack of clear definitions when implementing an application. This is where IEC 61850 differs from other communication standards like e.g. IEC 60870-5-103 in the form of a fixed type/inf assignment. This is exactly the challenge when implementing applications in substations. To enable full “interoperability”, it becomes either necessary to implement the entire scope of services of the standard into all devices or to define certain restrictions or adjustments to determine which services are reasonable for implementing which application. This adjustment can be used by manufacturers as the basis for device implementation so that all important services will be made available in the future in all device types commonly used in substations today. For this reason, the working group has analysed this topic in detail and developed a corresponding application description that contains a recommendation of which services to select [5].

4.2 Selecting typical applications in substations

The selection comprises the applications frequently encountered in typical substations. The following applications were analysed in detail and a recommendation for choosing services was developed:

- Reverse interlocking
- Switching via Select-Before-Operate (SBO)
- Implementation of substation interlocking
- Switching with synchrocheck function / automatic synchronization
- Simulating the busbar voltage
- Commissioning and testing
- Remote/local operation
- Transmitting fault recordings to an archiving computer

4.3 The analysis procedure

The following steps were carried out for all selected applications to obtain a basis for recommending the preferred service according to IEC 61850.

- *Application* – step-by-step description of the application and highlighting conceptual differences. Advantages and disadvantages of the different concepts could be revealed simultaneously here.
- *Information and Communication Subscribers* – defines the individual process steps for the application, determines the affected communication subscribers and then the data content to be transmitted.
- *Required Object Information (LD/LN/DO/DA)* – tabular listing of the data modelling of the information to be transmitted according to IEC 61850 for all communication subscribers Examines the designations of the logical devices, the logical application nodes and the data objects to be transmitted.

- *Time Requirements* – Which general requirements exist for the individual process steps of the application (without prior knowledge of the possible services).
- *Evaluation of the Possible Services* – Which services can be selected for the individual process steps and how do they conform to the requirements.
- *Procedures* – Which single steps are running and how are the sequences according to the standard. Are there definite process steps or are additional recommendations required to enable a consistent implementation.
- *Marginal Conditions* – Which marginal conditions must be considered when putting the IEC 61850 into practice and what constraints or risks are involved in the transmission via Ethernet instead of the transmission method used so far.

4.4 Summary of the results

Following an in-depth analysis of the individual steps required for each application, the following services where selected to enable a best possible implementation based on what we know today.

Reverse Interlocking:
Transmission of the interlocking information: GOOSE

Switching via Select-Before-Operate:
Activation (central): Control via request/response
Supervision of the switching status (central/distributed): Unbuffered/Buffered Reporting

Implementation of central interlocking in substation unit:
Transmission of status information: Unbuffered Reporting
Transmission of release information to bay units: Control via request/response

Implementation of distributed system interlocking in dedicated bay unit:
Transmission of the status and release information: GOOSE

Implementation of distributed system interlocking in bay units:
Transmission of the status and release information: GOOSE

Switching with synchrocheck function / automatic synchronization:
Trigger synchrocheck function: Control via request/response
Feedback of the synchronism conditions: Unbuffered Reporting

Simulation of the busbar voltage:
Transmission of the status and measured value information: Unbuffered Reporting
Transmission of the command: Control via request/response

Commissioning and testing:
Activation/deactivation of the test mode: Control via request/response
Status report of the test mode: Buffered/Unbuffered Reporting

Remote/local switchover:

Activation/deactivation of the switchover: Control via request/response
Status report of the switchover: Buffered/Unbuffered Reporting

Transmission of fault recordings to an archiving computer:
Transmission of the status information: Buffered/Unbuffered Reporting
Transmission of the fault recordings: File transfer

5 Literature

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