



by Dr. Wolfgang Wimmer, ABB, Switzerland

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IEC 61850

Engineering

Designing IEC 61850 systems for maintenance, retrofit and extension

The goal of IEC 61850 is to support arbitrary system configurations with centralized or decentralized architecture. The choice of a specific system architecture is beneath pure technical aspects determined by the existing products and proven solutions. As technology advances, other kinds of architectures may become usable and cost optimal, which lead to a different amount of IEDs and a different internal structure of them, which is reflected in the IED related identification of data. On the other hand, low effort long term maintenance needs identical names for identical objects. But even at the replacement of an IED by a functional equivalent IED from another manufacturer a different internal structuring and naming is most likely.

Usage of names

Names are used at system engineering time to establish relations between the different parts of the system: Relations between the switch yard (primary system) and the IED signals (secondary system), and data flow between IEDs for communication engineering respective online communication association establishment. A name change at a data source therefore leads to reengineering of all IEDs connected to the changed one respective replaced one. In former master slave architectures all data flowed between the bay level IEDs and one single central place, only the IED to be replaced and the central IED were concerned. For IEC 61850 however already for availability reasons several station level IEDs might be connected to the same bay level IEDs, and the new

communication services GOOSE and SMV (Sampled Values) allow new substation functionality or existing functionality with less engineering effort and higher reliability, however introduce multiple sinks for certain signals, which might be concerned by a change at the signal source, as illustrated in Figure 1.

IEC 61850 object types and data identification

IEC 61850-7 introduces IED and communication modelling concepts, and standardized data semantics by standardized names. However, the concrete instance names are additionally dependent on the physical and logical structuring of the data and therefore not a priori stable when replacing IEDs or changing the architecture. What is long term stable (as least as long as the switch yard itself), is the functional meaning of the data in relation to the switch yard respective the power delivery process. Further the substation automation functionality related to the switchyard is normally long term stable, although extensions are not excluded. Therefore IEC 61850-6 introduces a second way of identifying the same data, namely by functional designations as defined in IEC 61346.

IED related objects and their identifications

IEC 61850 as a communication standard in first line addresses data identification at communication level, i.e. at interface level between a server or publisher IED and the data receivers (clients, subscribers). To make this naming independent from the physical structure, the concept of a logical device (LD) is introduced as a management unit for functional parts. Figure 2 shows the resulting internal structure of an IED.

The communication function uses IED access points to connect clients with servers. In principle each logical node can be a client to other logical nodes on some server. IEDs which only receive data, like the OPC server AA1KA1 in Figure 1, can also be pure clients without a server.

To reach the goal of having standardized semantics, the DATA names as well as the names of DATA attributes are completely standardized. Also the semantic of the logical nodes is standardized by means of a logical node class, which is part of the logical node instance name. A real system needs instances of logical node classes, which are associated to different parts of the switch gear; therefore the LN instance

Wolfgang Wimmer works for ABB Switzerland in Baden. He is principle engineer in the development of substation automation systems. He has a M. Sc. degree as well as a Ph.D. in Computer Science from the University of Hamburg. After some years developing Computer networks at the German Electron Synchrotron DESY in Hamburg he changed to ABB (former BBC) for development of train control systems, later Network Control Systems. He has more than 20 years experience with development of substation automation systems. He is a member of IEC TC57 WG 19 and WG 10, and editor of IEC 61850-6.

identification has non standardized parts. The logical device name as a manufacturer / organisation related structuring is completely free within some syntactical limits. This is illustrated in table 1 with an example designation for a switch position value within the switch control function:
MyControl LD1/Q0CSWI3.Pos.stVal

A product manufacturer typically provides IEDs as products with some predefined functionality, however with no context to the project specific usage. Therefore the LD relative name and some parts of the LN instance identification need to be given by the manufacturer independent of the unknown project, and might be needed after project engineering to associate the project specific data to the project independent preconfiguration of the IED. Therefore it is manufacturer dependent, which parts of the LN instance identification can be adapted specifically for a project.

Although this designation is mainly used for communication establishment, we might call it a 'product related' designation in the sense of IEC 61346-1, especially if the IED designation is used as part of the LD name.

From this discussion we see how the physical architecture influences the communication level naming. Table 2 illustrates this with two logical nodes for the control function: the CSWI handling control commands from the operators and the XCBR executing these commands at the circuit breaker. The architectures referenced in the table are illustrated in Figure 5.

Consequence: different physical architectures by grouping on IEDs as well as different organisational structures by means of logical devices lead to different names, even if an IED and its tool supports free naming for the non standardized parts. And the free naming is not mandatory according to IEC 61850, and naturally introduces additional engineering and testing effort – especially at LN instance level.

Function related objects and identifications

According to IEC 61346 the functional designation is at least as important for operation of a process as the product related naming for maintenance. IEC 61850-6 therefore introduces application related names of data by typically following the functions of the switch yard, however allowing additionally (with

Usage of application oriented functional names in parallel to maintenance related IED names with automatic translation via SCL files, enhances long term system maintainability

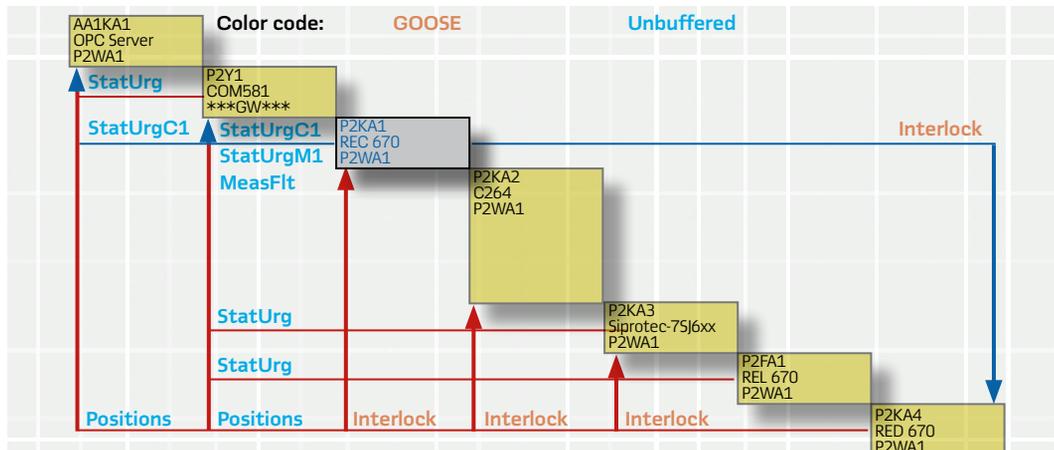
Edition 2 practically at all places) functions which are not directly switch yard related, like protection, control and automation functions, but also supervision functions outside the substation function itself like fire supervision, or functions belonging to power generation. The functional names are completely project / customer specific within the structural restrictions given by IEC 61346-1. The transition object, i.e. the place where product related name and function / application related name matches the same

Figure 1 an example of a small system

For interlocking reasons, the controllers exchange GOOSE messages. The replacement of IED P2KA1, influences 3 other IEDs. The four controllers in different bays are sending reports to the station level IEDs.

1 Data flow between IEDs in the substation

Example of a small system with an OPC server & a gateway as station level IEDs



object, is the logical node instance. From here on all DATA and attribute names are completely semantically defined in IEC 61850. If we look into the functional names of figure 3 for the same control function handled by the IED related names of table 2, these are:

AA1E1Q3QA1CSWLPos
AA1E1Q3QA1XCBR.Pos

The protection related name of the operation of distance protection for Zone 1 is:

AA1E1Q3F1Z1PDIS.Op

All these names are completely independent from the distribution of logical nodes and logical devices to IEDs, and also from the LD and LN instance names.

A complete SCL file for a substation automation system, called an SCD file, includes the functional name, the IED related name, the communication related (LD) name, and the relations between them – thus serving as a data base for translation between the different designations for the same LN respective DATA object. This is shown in Figure 4 for the above example, illustrating the independence of the functional name from the IED related name up to the point where IEC 61850 provides complete semantic standardization.

Communication engineering
IEC 61850 MMS based services allow an interactive browsing of the IED data model to retrieve all communication related names. Due to the unique LD name these can be translated into IED related names as well as functional names by means of the SCD file. However, normally operational traffic is based on preconfigured data flow for services allowing spontaneous sending. *These are typically:*

- Reporting service for status update and time stamped events to station level IEDs like HMI, or gateways to network control centres.

- GOOSE real time service for real time functions typically between bay level IEDs, or down to process level IEDs, e.g. interlocking related data or protection trips and blockings.

- SMV services, if analogue samples are needed directly from the process, e.g. for protection, synchrocheck and measurement functions.

To evaluate the importance of the DATA names for these services, we have to look a bit into their definition:

All services are configured by means of a data set, defining the

3 Example of a function hierarchy

Substation AA1

- Voltage level E1 at 110kV

- Bay Q3

- Equipment QB1 : DIS

- XSWI, Name /XSWI of Type m_XSWI
 - CSWI, Name /CSWI of Type E3_CSWI
 - CILO, Name /CILO of Type m_CILO

- Equipment QA1 : CBR

- XCBR, Name /XCBR of Type E_XCBR
 - CSWI, Name Q3QA1/CSWI of Type E3_CSWI
 - CILO, Name Q3QA1/CILO of Type m_CILO

- Equipment BE5 : VTR

- Function F1 : Protection

- PTRC, Name /PTRC of Type E3_PTRC
 - PSCH, Name /PSCH of Type E3_PSCH
 - PTEF, Name /PTEF of Type m_PTEF

- Subfunction Z1 : Distance zone 1
 - PDIS, Name /PDIS1 of Type E3_PDIS

- Subfunction Z2 : Distance zone 2
 - PDIS, Name /PDIS2 of Type E3_PDIS

- Subfunction Z3 : Distance zone 3
 - PDIS, Name /PDIS3 of Type E3_PDIS

- Subfunction Z1B :

- PDIS, Name /BPDIS1 of Type E3_PDIS

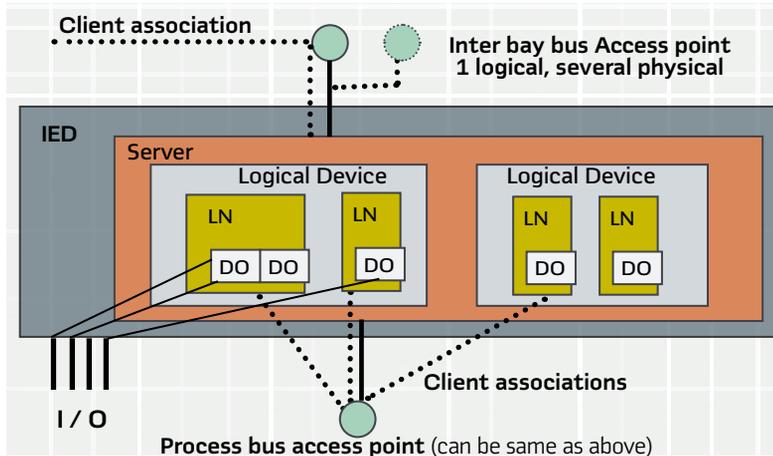
- Function R1 : ProtRelated

- RREC, Name /RREC of Type E3_RREC
 - RFLO, Name /RFLO of Type E_RFLO

- Function M1 : Measurement

- MMXU, Name /MMXU of Type E3_MMXU

2 IED related object model structure



The server access point allows access to data structured as follows: logical devices contain logical nodes (LN) containing DATA respective data objects (DO). Logical nodes on other IEDs can access the data as clients

IEC 61850 MMS based services allow interactive browsing of the IED data model.

Table 1 Degree of name standardization

IED structure level	Degree of standardization	Example designation	Standardized	Predefined name semantic
Logical device LD	Syntactical (61850-7-2)	MyControlLD1	---	---
100 Kb/S	Partly: LN class (61850-7-4)	Q0CSWI3	CSWI	Switch control
200 Kb/S	Full: DATA name (61850-7-4)	Pos	Pos	Switch position
Attribute	Full: Attribute name (61850-7-3)	stVal	stVal	Status value

For maintenance it is recommended to choose an IED related logical device name, structured as IED name - LD relative name

Use functional names as a key between old and new configurations

Table 2 Name differences caused by architecture

Architecture	LD Name	LN Name	DATA Name	Remark
Single bay controller	Ctrl19LD1 Ctrl19LD1	Q0CSWI1 Q0XCBR1	Pos Pos	LN's located in same LD
Process bus from bay controller to circuit breaker interface	Ctrl19LD1 SWg8LD1	Q0CSWI1 QA1XCBR4	Pos Pos	LD (IED) name at switch interface IED must be different to name in bay controller; LN instance names are manufacturer specific.
Central controller with process bus to circuit breaker interface	Ctrl11LD9 SWg8LD1	Q0CSWI1 QA1XCBR4	Pos Pos	Free LD naming would allow using centrally the same LD names as de-centrally – if the central LD structure is the same.

This means that the replacing IED has beneath the requirements on compatible semantics and data types to fulfil some engineering related requirements, which are not mandatory according to IEC 61850. Further it should be considered that errors at the reconfiguration of the data set when keeping the old revision number and data set identification can be safety critical, because the receivers do not demand to be newly configured. So, a good tool support or testing in a simulated environment is recommended.

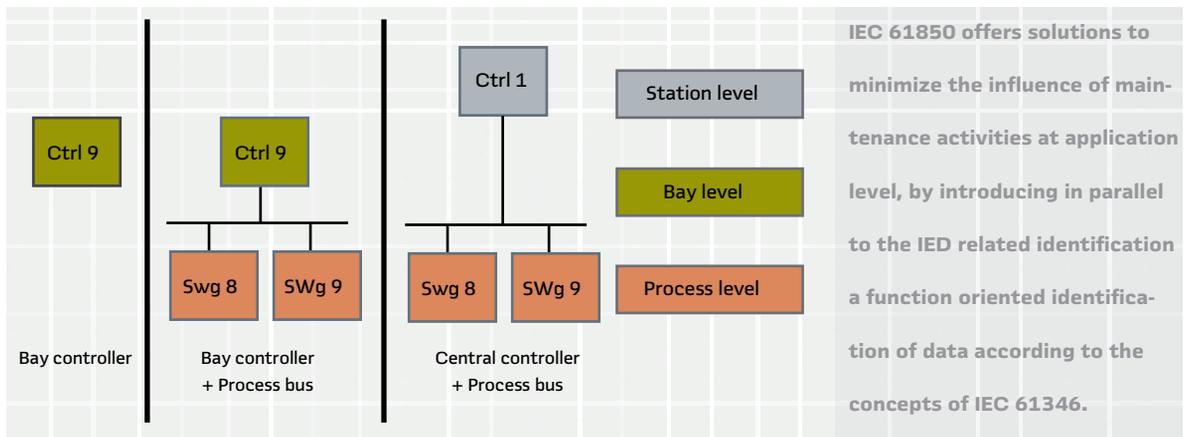
The problem of binding GOOSE or SMV receivers to the data set layout does not appear for reporting clients, because they can perform this binding dynamically. However, if the names have changed, the binding to the functional semantics, especially binding of LN instances to instances of switch yard equipment and functions, is still a problem. One means to solve this binding to the application function is to re-establishing the link between functional names and IED related names also for the new IED(s). This is

supported in IEC 61850 better than in other protocols in so far, as this binding is done on the level of logical nodes instead of signals, and will in all cases, where application specific LN's are used (e.g. no GAPC and no GGIO), reduce to a selection of LN instances with the same LN class, thus minimizing the amount of work as well as that of errors.

For good implementations of station level clients, which internally work with the functional names as defined above, it is then sufficient to reload them at driver level with the SCD file resulting from this re-mapping of LN instances.

Even better client implementations allow to do this reload per IED e.g. when communication with the (new) IED is (re-) established. In any case, the probability of errors is restricted to the remapped IED, and this

5 Different architectures



probability is quite low, because the remapping is performed on the relatively high level of LN instances, supported in most cases by the needed LN class. It should however be considered that the new IED should contain at least the same DATA per remapped LN instance as needed by the application.

Impact on engineering and used products

The following points are important to minimize the efforts in case of SA system retrofit:

- Use functional naming for system engineering and the IED related names, so that the SCD file provides a translation between them in a standardized format.

- Use functional naming at application level, i.e. within application functions. Let the (MMS based) communication drivers translate the IED names into functional names by means of SCD file(s). In case of (station level) clients which do not support this, use a tool to create the new configuration from the SCD file, by using the functional name as common key between old and new configuration.

The safety of this approach can be supported by a system tool which supports the IED replacement at the functional structure on LN level, with a check of the same respective correct LN classes.

As we have seen, the replacement of GOOSE servers without having to reconfigure all GOOSE receivers needs some optional features from the IED respective its tool:

- Support free LD naming
- Support free data set naming, at least for GOOSE and SMV data sets
- Support free (guided) setting of GOOSE confRev

To make this procedure safer, the tool should support remapping the new IED to the functional names and, after this remapping, automatically (re-)create the GOOSE / SMV data sets with identical layout and name, set the LD name property identical and take over all 'old' addresses.

Unfortunately, all these features do not help for the GOOSE / SMV case, if a changed architecture leads to another logical device structure, so that the requirement on uniqueness of the LD name forbids the proposed LD renaming, or if due to a new physical structure the GOOSE messages have to be split onto different IEDs.

Some impact on system modelling principles

A relatively safe tool-supported binding of the LN instances of the new IED to the functional names by using the old IED's binding as template is only assured, if GGIO and GAPC LN classes are avoided as far as possible. This is also in the sense of IEC 61850, which demands using a fitting LN class wherever one is defined. Here also some improvements of manufacturer IED tools might help, which allow replacing a GGIO by a more appropriate LN class at IED (pre-) engineering time.

However, if the old structuring into logical devices does not fit to the new structuring, this does not help. Therefore, already at the initial system design, the logical device structure in relation to the used GOOSE and SMV messages should be set up to support the most distributed structure which is intended to be used during the switch yard life time. Further, GOOSE and SMV data sets should not reference data outside the LD in which they are defined – else these may later reside on different IEDs, and therefore force a redefinition of the data sets with appropriate re-engineering of the receivers.

The general concept of a maximal distributed system, even if it is implemented centrally, also helps in having a common behaviour of distributed and central systems concerning functionally connected logical nodes, because it makes the functional behaviour independent from the fact if internal functional connections between the LN implementation are used or external

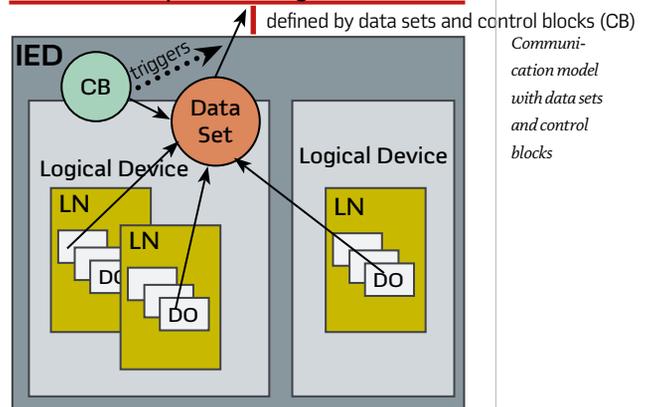
Designing systems for the maximal ever intended physical distribution, eases future retrofit

explicit communication connections. This has also been considered at the more detailed definitions of IEC 61850 Edition 2 for the influence of the test and block quality of incoming signals, and should also be used when implementing test and block modes on internally connected logical nodes.

If these additional system structuring rules are considered, then the consequent usage of functional naming for application related functions in parallel to the usage of product related naming for automation system maintenance, as foreseen in IEC61850-6, supports easy retrofit and system extension with minimum engineering, modification and (re-)testing effort even if the underlying physical architecture is changed or IEDs of a different type or a different manufacturer are used.

6 Communication model

GOOSE or Report messages



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ABB Switzerland Ltd
Power Systems
Brown Boveri Strasse 6
CH-5400 Baden/Switzerland

Phone +41 -58-585 77 44
Fax +41 -58-585 55 77
e.Mail substation.automation@ch.abb.com
www.abb.com/substationautomation