# USE CASE-DRIVEN INNOVATION FOR IEC 61850 MODELING

Julia MASURKEWITZ-MÖLLER
OFFIS.e.V
Julia.Masurkewitz-Moeller@offis.de

Michael SPECHT
OFFIS e.V.
Michael.Specht@ewetel.net

Wolfgang FRIEDRICH
Mauell GmbH
Wolfgang.Friedrich@mauell.com

## *ABSTRACT*

*Concerning the realization of innovative solutions for the distribution grid, it is not only essential that new system functions, business cases or methodologies, etc. are developed and proven useful, but also that communication standards can be extended to meet new requirements. Otherwise, advantages coming from standardization in contrast to proprietary solutions are omitted. Therefore, the BMWi-funded project "Green Access" has analyzed which new (control) functions could be adopted for extending the communication standard IEC 61850. In this paper, project-related use cases will be introduced and analyzed regarding their semantics, which currently cannot be properly modeled from the point of view of Green Access in IEC 61850.*

## INTRODUCTION

The future development of an intelligent distribution grid raises different expectations. On the one hand, the grid is expected to accept more and more fluctuating current from wind or solar. On the other hand, costs for the extension of the power grid should be reduced, respectively prevented from further increase. Regarding the investment in the needed communication infrastructure, intelligent solutions must provide cost-benefits in other domains. That could be, for example, automation systems, self-learning systems, etc., which could reduce the amount of necessary workforce deployment. Of course, automation systems also offer many benefits for technical management. But in order to realize those benefits, it is necessary that the new components work seamlessly without communication constraints. Using a standardized communication protocol between the different components of different vendors ensures a basic level of interoperability and minimizes the risk of vendor lock-ins. Hence, it is important to extend existing standards with new information objects which are needed for new functionalities. In the following, two aspects are highlighted: first the methodological approach of the project Green Access, that is the use case-driven process to raise communication requirements and communication information objects. Second, a consideration of new information objects, which could be suggested by our project to standardization.

## THE PROJECT GREEN ACCESS

The overarching aim of Green Access is to develop and test a concept for an automation of the distribution grid in terms of a plug and automate principle. The unique characteristic is the joint view of the medium and low voltage grids concerning adaptive monitoring and control functions. The whole project is based on the assumption that a high percentage of renewables must be integrated into the distribution grid and a stable / reliable control concept is to realize. The goals of the project are to optimize the use of the operating equipment, reduce the operation costs, provision of system services through inverter and ICT-infrastructure, and reducing the load on the power grid through an inverter. To realize this, among other, the following use cases are defined by our project:

- Adaptive plug and automate function for detecting unsupervised and unreported feeders and consumers in low voltage[1]
- Automatic integration of controllable components (IEDs)
- Automatic adjustment of topological grid data
- Automatic assessment of additional needed sensors and actors
- Single-phase control via inverter [2]

The other use cases of the project concern the compliance of a specific voltage range or limits of the operating equipment.

## USE CASE MODELING METHOD

To define and elaborate the applications and services of the project the use case method of IEC 62559 is applied. This standard and corresponding use case template were developed by domain experts to define and describe requirements for automation systems. Use cases describe the behavior of the system in order to perform a defined technical task, assuming specific influencing variables (environmental conditions or disturbances) [1].
The aforementioned method is applied in Green Access in order to break down the overall process of distribution grid automation into separate steps, which are formulated as single use cases. During the definition phase of the use case, in addition to a detailed description all relevant

[1] Further information can be found in: S. Fischer, et.al., 2016,"Self-detection of new photovoltaic power plants using a low voltage smart grid system", E-world energy & water.

[2] Further information can be found in: P. Steinbusch, , T. Bülo, W. Friedrich, "Automatic Integration of Photovoltaic Inverters in a Smart Grid System to establish Additional Power Grid Beneficial Functions", Solar Integration Workshop.

actors, their connection and the necessary information exchange for the use case were defined. Additionally, for every use case, different malfunctions are described and corresponding system solutions [2].
The advantages of the method are, that using the common method all use cases are documented and structured in the very same manner. This enables the project members to find information easier in comparison to every use case being described in a different manner. Also, the template enables us to control the quality / detail level of the use case and to a similar level overall. In general, this method is also used to support standardization processes through identification of standardization gaps [3].
The development process can be supported by a web-based application, which offers the advantage that the document exchange is superfluous and, for example, actors, requirements and functions have to be defined only once and can be reused in all use cases, which minimizes incoherences.
All project use cases were defined in the use case template [4] in the UCMR (Use Case Management Repository) from OFFIS. On this basis, the use cases were transferred into the Smart Grid (Reference) Architecture Model (SGAM) in order to foster the discussion about the selection of a communication protocol. The following figure shows the final communication concept. It should be noted that some already existing communication links will be used during the tests. In this respect, only communication links which will be created in the duration of the project are named in the figure.

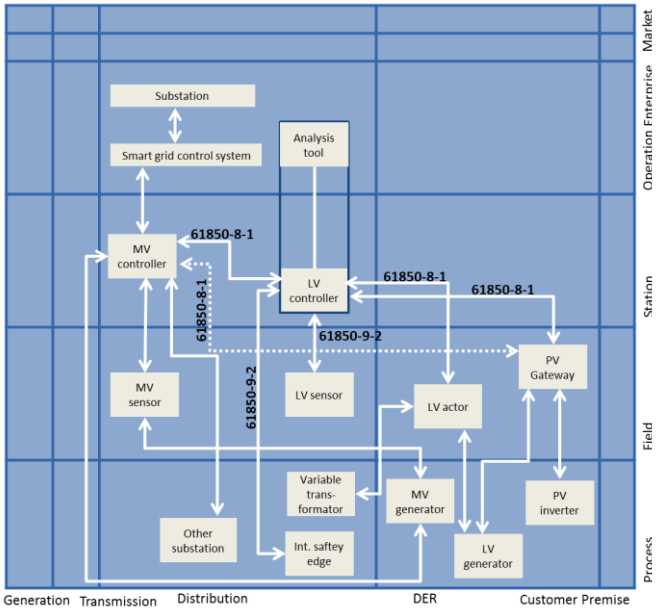


Figure 1: Communication concept of Green Access

## INTRODUCTION TO IEC 61850 AS USED IN GREEN ACCESS

IEC 61850 was originally developed for electrical substation automation systems, and has been extended to information exchange of electrical power systems and decentralized generators. The whole approach of IEC 61850 is not a signal-oriented approach, instead the components are represented as IEDs, thus following an object-orientated approach [5].
In our understanding the development of an IEC 61850 data model can be conducted in different ways. That means, generator-specific data models with a consistent communication can be realized, or type-specific data models, which already include some abstractions from the actual component. Another opportunity is, that one generic data model is developed. In Green Access, for each component a single data model was developed. Except for the photovoltaic (PV) gateway. Here, the challenge arises, that the gateway represents all PV systems, which have to be controlled separately by the medium voltage (MV) controller and the low voltage (LV) controllers. One option, which could be applied by our project, is that each PV system is addressed via one type-specific data model or that i.e. ten PV systems are summarized in one model. In our opinion, for the latter option the advantage is, that less IP addresses would be necessary, but the disadvantage is, that unneeded information blocks will be transferred.
Overall, IEC 61850 is a well-known and demonstrated standard for station automation. On a regular basis parts of the standard are updated and extended. Therefore, the standard can be regarded as future-proof.
Concerning the realization of the communication, the standards allows for a considerable degree of freedom in the practical application. The general scope is shown in the following figure:

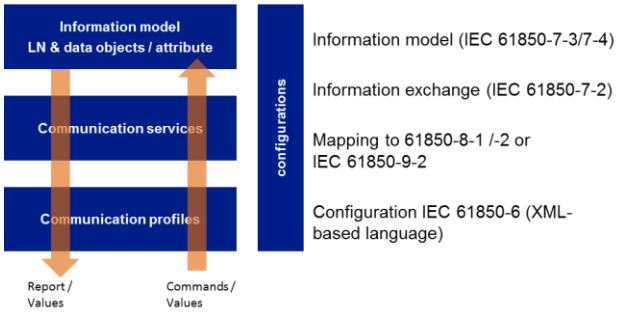


Figure 2: General scope of IEC 61850[3]

The structure is a hierarchical logical image of the real-life component. Each device is symbolized by a logical device which contains different Logical Nodes (LN). The LN - and the LN classes - represent different functions, i.e. the class `R` contains all protection related functions, whereas the class `Y` is specific for power transformers. For its specific function, every LN comprises all relevant data objects, which are further defined by data attributes.[4] All of them follow the same description logic, which

[3] Figure in accordance with IEC 61850.
[4] These were specified through sub data attributes, but for the aim of this paper they are not relevant.

supports the process of learning and understanding other data models. But to get an easy access to other data models it is necessary that all information objects are described in the correct LN, use the correct data object and so on.

Coming back to the degree of freedom in modeling in accordance with IEC 61850, it should be noted that a generic LN is provided, which can be used for missing standardized information objects (LN GGIO). This can of course led to more and more single solutions and the opportunity of a shortcut for modeling. To maintain the advantages of an object-based modeling process a growing use of the generic LN should be avoided.

Regarding the actual communication in Green Access it was discussed, whether IEC 61850-8-1 (MMS) or IEC 61850-8-2 (XMPP), could be chosen for the relevant connection (see figure 1). Finally, IEC 61850-8-1 was chosen by the project partners. The reasons can be summarized as follows:5

- Market penetration: Cannot be stated for IEC 61850-8-2. Only one research project is known to us, where IEC 61850-8-2 have already been applied (In2VPP). For IEC 61850-8-1 are already components available. Hence, it can be assumed that the market penetration will increase during the next years.
- Release: IEC 61850-8-2 Ed. 1 have not been published yet, for this reason the scope of possible changes until released, could not be estimated.
- Plug and automate: The original idea for developing IEC 61850-8-2 was to introduce group communication into the IEC 61850 world. If it would have been applied as planned this new functionality would have had a huge contribution to the project aims.

Still, one of the main concerns during the discussion in the project was which of both protocols offers more benefits for connecting multiple PV through one PV gateway and if a self-registration of feeders is supported. Since the concept of a group addressing was not applied as suggested at an early stage in IEC 61850-8-2 IEC 61850-8-1 was chosen. Noteworthy is, that for an IEC 61850-8-2 conform communication IEC 61850-8-1 will also be necessary.

During an iterative process the project team defined the specific information objects, which are necessary for the different functions of the use cases. As described earlier, the use cases and its steps were specified. A step is to understand as one information exchange between actors of the use case. That means for every step the process / activity is named and described. Additionally, the implemented service is specified. The information producer (actor), the information receiver and the information, which is exchanged between them, was also defined. In our project we continued to address the exchanged information further in an interactive process. Afterwards, we began to map the exchanged information objects to IEC 61850.

Thereby, the generation of the Green Access data model is based on two guiding principles:

- The data objects should consist of a minimum of logical nodes.
- If possible, the data objects of a function should be included in the same logical node. Doing so it is easier to subscribe / unsubscribe to a specific function during the field test.

## NEW PROPOSED FUNCTIONS FOR IEC 61850

During the process of modeling the information objects to IEC 61850 data objects, it became obvious that not every information object, correspond to a specific data object [6] [7]. But this does only apply to certain information objects and not all of them.

In general, there were two different options available for Green Access if an exchanged information object could not be mapped to the data objects of IEC 61850:

- All data objects could be modeled in LN GGIO, which is the generic LN mentioned earlier. This LN is developed exactly for this purpose.
- Still, it can be tempting to express the data objects with nearly fitting already existing data objects. In our modeling tool we always added a description to clarify the object. The purpose was to maintain the general allocation of the standard (the allocation of the LN itself) and the further information like unities etc.

It is necessary to explain a little bit more about the functions (use cases) and the role of the specific data objects. Afterwards, the solution of the project concerning the mapping to IEC 61850 is presented in brief.

### Report of enhanced system conditions

Our project defined different status information of the system, which are reported from the LV controller to the MV controller and then to the control station (see figure 1). All of this status information is used to optimize the distribution grid automation through an increasing observability of the grid. Thus, a suitable actor can be chosen in a local environment for switching operation.

The status information consists either of two opposing conditions (red or green traffic light phase) or three conditions (corresponding to red, yellow, and green traffic light phase).[6] IEC 61850 does offer in LN GAPC (Generic Automatic Process Control) generic indications, warnings and alarms, which can be used for specific (non standardized) information objects. These data objects

5 These reasons are based on a analysis of communication protocols, which could habe been used in Green Access. This analysis was concuded by OFFIS.

[6] These are not corresponding with the BDEW traffic light phases.

have been used in the context of the project, but it could be considered to introduce some of these status information into IEC 61850, when the corresponding functions are applied in a wider range. The following status information is used in Green Access:

- LV controller can / cannot be used by the MV controller
- The controlling function of the LV controller is ok / disturbed
- Global status information of all single status information combined
- Communication with actors / sensors is ok / partly disturbed / down
- Compliance to voltage range
- Compliance to limits of operating equipment
- Function of status grid state identification
- Functioning of intelligent safety edge

We cannot recommend to map all of these information objects to IEC 61850. In the future, it might be useful to map a general status of the available communication and the compliance of voltage range and of the limits of operating equipment. Especially, if for both of the latter, a combined profile for asset management is realized as a separated LN. Further services could also be included in this LN.

## Automatic system integration of new actors or sensors

The Green Access use case *«automatic integration of new actors or sensor»* helps to accelerate the registration process through less effort, that means the configuration does not have to be conducted manually. Of particular importance is that the actor / sensor can register itself (actively) with the control center. Therefore, more specific parameters have to be transferred. In our project we defined the following objects:[7]

- Possible states of the control range
- Default parameter in the case of a communication failure
- Maximal nominal power
- Operation reserve
- Number / stages of control range
- Response time to control commands
- Upper and lower limit of the control range
- Location
- ID
- Type / name
- Etc.

It should be noted that some of these information objects do exist in IEC 61850 like the operated delay time in FXOT. This data object is used to describe time delay before operating once the operating conditions have been met. However, FXOT is used whenever a protection, control or alarm function is based on other physical measurements than primary electrical data. This does not fit to our defined information object *« (average) response time to control commands »* as a static parameter of the generator. Therefore, we would recommend to define a single LN for all information objects which have to be communicated if different generators should register themselves. Matching (already defined) data objects from IEC 61850 should be reused.

## Further processed, measured values for an automatized distribution grid

In addition to the parameters of self-registered actors and sensors, we think that it can be necessary to map further processed, measured values into IEC 61850 in order to improve the estimation of the grid. This information is to be provided to the MV controller by the LV controller or PV Gateway if it is a MV actor in order to optimize load factor of the distribution grid.

- Actual active power of all controllable actors in the range of the LV controller
- Maximal nominal capacity of all controllable actors in the range of the LV controller
- Actual exchange of reactive power and active power on the MV side of the substation
- Maximal reactive power (capacitive and inductive), which can be demanded by the MV controller
- Minimal actual power, which can be requested by the MV controller (underneath the substation)
- Actual power and reactive power which would be fed into the grid by the LV actors, if the MV controller would have not dropped the generation

All of these information objects could not be exactly mapped to IEC 61850, but can be expressed through the data objects by LN MMXU. If these specific information objects will be used frequently with this detailed semantic, we suggest that, they should be introduced into IEC 61850.

## Assessment of additional needed sensors / actors

The Green Access use case *«assessment of additional needed sensors / actors»* was defined to detect in which location of the grid additional actors and sensors would contribute to an area-wide monitoring of the distribution grid or disclose a new operating range.

For this use case, information about the position of the sensor / actor or the ID of the actor / sensor and the priority of the recommendation to deploy a further actor / sensor must be provided. The ID of the actor is just a second option in our project to get to know the (physical) position of the sensor. But this is only possible if the position (through a node number from the grid) is legible. The ID of the sensor / actor cannot be expressed through the physical name plate from LPHD, because in this data object the node number cannot be integrated due to its definition. That means, that for none of the three information objects a data object is already available and for the time being the three data objects were realized in

[7] This list is not exhaustive.

GGIO.
If this function will be applied frequently, we recommend an integration of these objects could be performed.

**Report of unsupervised feeders / consumer**

The combined Green Access use case of *«reporting unsupervised feeders and consumers»* to the control center is designed to detect new installed unsupervised and not reported feeders and consumers. It is to say, that the use case of the detection of unsupervised consumers is more relevant, because feeders have to be reported in accordance with regulations in Germany. Detecting new consumers can support estimating the grid status, controlling the distribution grid and integrating them into the topology database. To realize this function, it is necessary that measured values are provided. The only new information object which has to be transferred to the distribution grid operator is, if and where a new feeder or consumer is detected.
In our project the report to the distribution grid operator (DSO) will not be conducted with IEC 61850. That means we have not mapped this information object. In Green Access, the DSO could get this information from our analysis tool. If this information is communicated differently, we suggest that it should then be mapped.

## CONCLUSION AND LESSONS-LEARNED

This paper has tried to give further recommendations for standardizing new functions and data objects in IEC 61850. Summarizing, the following figure shows an overview of Green Access the IEC low voltage controller and its LN. The black ones are used as described in the standard. The gray ones contain data objects, which have not been found or are expressed in generic data objectives.

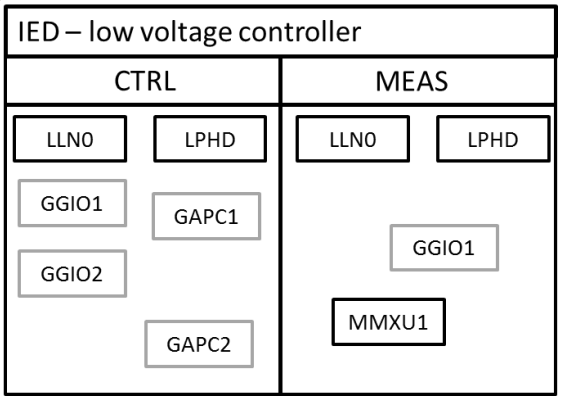


**Figure 3: LN`s of the LV controller**

In our opinion, two common problems can be highlighted when new functions are modelled in IEC 61850. Either no data object could be found and a generic data object has to be used or a data object could be found, but the corresponding LN does not fully fit the purpose of the function or positioning of the new function. This will lead to the decision whether more and more special solutions are realized through the use of generic objects; or if matching data objects in non matching LN are used, as a result the structural logic of the standard is messed up. Still, in both cases different advantages of the standardization are being ignored.
In general, this causes problems of applicability for users and is one of the main challenges for IEC 61850. On the one hand the standardization body should follow its current way and continue to integrate new LN for new functions in order to be able to address the challenges of a distributed grid. But on the other hand, this makes the standard even more complex than it already is in real world installation. It could slow down the practical implementation.
Altogether, as a feedback from Green Access it is necessary to update the standard and to introduce new information objects, but these have to be perfectly grouped into relevant (new) LN in order to sustain the practicability.

## ACKNOWLEDGMENT

This research has been supported by the BMWi and BMBF, under "Zukunftsfähige Stromnetze" project Green Access (grant no: 03ET7534A) Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the BMWi or BMBF.

## REFERENCES

[1] R. Santodomingo, M. Uslar, A. Goering, M. Gottschalk, L. Nordstrom, A. Saleem, M. Chenine, 2014, "SGAM-based methodology to analyse Smart Grid solutions", *Energy Conference (ENERGYCON)*, 751-758

[2] M. Gottschalk, M.Uslar, C. Delfs, 2017, *The Use Case and Smart Grid Architecture Model Approach - The IEC 62559-2 Use Case Template and the SGAM applied in various domains*, Springer International Publishing

[3] M. Gottschalk, J. Sauer, 2016, „Ein Ansatz zur Unterstützung des Normungsprozesses für Smart Domains", *VDE Kongress 2016*

[4] IEC 62559-2:2015: Use case methodology – Part 2: Definition of the templates for use cases, actor list and requirements list

[5] M. Uslar, and R. Bleiker, 2013, "Automation for the Smart Grid: IEC 61850 - Substation Automation and DER Communication", Springer Berlin Heidelberg

[6] IEC 61850-7-4 Ed.2: Communication networks and systems for power utility automation – Basic communication structure – Compatible logical node classes and data object classes

[7] IEC 61850-7-420 Ed. 1: Communication Network and Systems for Power Utility Automation for Distributed Energy Resources (DER)