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Smart grid automation using IEC 61850 and CIM standards

A. Naumann [a,*], I. Bielchev [b], N. Voropai [c], Z. Styczynski [b]

[a] Fraunhofer Institute for Factory Operation and Automation IFF Magdeburg, Germany
[b] Otto-von-Guericke-Universität-Magdeburg, Germany
[c] Irkutsk State Technical University, Russia

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ABSTRACT

An overview of basic IEC standards for smart grid applications is given and some examples of feasible information and communication technology for smart energy systems are shown. As ICT key standards for power grid automation, the two core standards IEC 61850 and IEC 61970 are presented in the paper. Protection automation relying on smart grid ICT technology is shown, and the hurdles to be overcome for the realization of smart grid automation are discussed. Practical examples for are demonstrated. One approach of making different standards work together is presented, which today is still not sufficiently solved and is a main hurdle on the way towards a seamless smart grid automation system.

1. Introduction

The expansion of the renewable energies that feed an ever-growing share of distributed generation in the medium and low voltage networks (MV and LV) increases the risk of an instable network operation and the risk of a critical situation occurring in the power supply. To handle these threats and ensure a stable power network operation, power system protection needs to be extended to work not only at the transmission system operator's (TSO) level, but also at the distribution level in an automatized way, so that protection configuration and protection execution can act immediately to prevent system failures (Han, Xu, Suonan, Lu, & Wu, 2013).

One burden for a broad application of automated protection today is the difficulty in handling the many new data arising from the necessary protection and automation devices, which cannot be managed and configured manually. Automatic data collection, concentration and calculation tools must be developed. The realization of these tools heavily depends on the application of open, uniform and standardized data formats for the data exchange (Lo & Ansari, 2013).

When talking about smart grid realization, the combination of protection mechanism and system automation is an important aspect (Falahati, Fu, & Mousavi, 2013). Conventional protection concepts alone may be suitable for ensuring that assets will not be damaged in case of failure, since they are configured to protect a special asset according to statically defined parameters. But they are not sufficient if a fast system restoration and failure fixing is necessary, especially in the distribution system. When using automated protection, protection devices for assets can be configured dynamically depending on the load flow situation enabling an improved efficiency and improved failure recognition accuracy. Here, data from multiple sources like the control center, other protection devices and measurement equipment is used to allow an automated online estimation of the state that the protection equipment is meant to protect.

Such adaptive protection algorithms have become necessary, since the load flow structure in the energy system changes as fast as the wind and sun feed-in changes, and accordingly, the load situations in the power network also change quickly. Additionally, automated protection allows for a fast system recovery by combining all available data to estimate the failure position as accurately as possible. An even higher degree of protection automation can be reached by installing appropriate remote control devices, so that failures can be automatically insulated very fast, and the supply of the unaffected network can be reestablished as soon as possible.

The installation of an appropriate monitoring and control infrastructure for the many decentralized devices in the smart grid is, of course, a prerequisite and will result in a huge amount of monitoring, control and protection devices. For all these devices an automated configuration and operation must be given, since a manual configuration for so many devices will inevitably result in errors. So, the realization of adaptive and automated network protection can only be done when data handling and communication mechanisms are used that are powerful enough, ensure interoperability between all devices and guarantee enough flexibility (Apostolov, 2011; Golmie et al., 2013).

The smart grid standards developed by several standardization groups, especially by the International Electrotechnical Commission

* Corresponding author. Tel.: +49 3914090784.
E-mail address: andre.naumann@iff.fraunhofer.de (A. Naumann).

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(IEC), are an important part of the data management and so make smart grid automation possible. They standardize the way data should be acquired, transmitted, forwarded and managed at all levels in the power system hierarchy. Some of them are shown in this paper. The existing standards are already able to describe many functions that are necessary for smart grid automation, but there are still some difficulties to overcome, as the authors will show in this paper. In particular, the harmonization between standards treating different levels of the smart grid is still a big challenge. Especially when trying to map data between the communication level (IEC 61850) and the energy management level (IEC 61970) for protection automation, no general algorithm is available for that today. By means of a simple case example from power system protection the application of smart grid standards is presented and one approach for a concept to realize a necessary data mapping is shown in this paper.

This paper starts with an overview of smart grid relevant standards and gives some more details on IEC 61850 and IEC 61970/61968. In the next part an example for protection in the power system is shown and typical parameters are listed. According to the identified parameters and functions, in the next part the relevant data models from IEC 61850 and IEC 61970 are identified and extended and a proposal for a mapping between them is shown, The paper finishes with a conclusion.

2. Fundamental IEC standards for smart grids

2.1. ICT requirements of smart energy systems

The realization of the smart grid and thus of smart energy systems makes a broad implementation of an appropriate ICT system necessary. The expansion of the ICT system to the distribution level down to the low voltage level – including small stations, energy producers and consumers and even storages – is a necessary step to enable smart functionalities so that measurement and status values can be communicated between the different devices and control centers. The same holds true for commands and set point values (Li, Yang, & Ishchenko, 2012). According to these aspects the main requirements for the ICT system of the energy system can be named (Miao & Chen, 2012):

- Availability on all levels of the energy system.
- Standardized communication interfaces.
- Plug'n run capability for new components.
- Safe, reliable and secure data exchange (Wang & Lu, 2013).

When fulfilling these requirements an open architecture of the energy system can be built, independent of producer specific protocols, allowing a simple installation of new devices and the integration of all system participants. Fig. 1 illustrates this concept and compares the situation today with the target situation for smart grids. The left side shows the situation today, using different communication protocols between different parts of the system. At the lower level of the system, mainly connecting electrical loads to the energy system, no ICT is used. In the future, however, there will be more small generators and distributed storages (e.g. electric vehicles) at the low voltage level so the communication needs to be expanded to this level. The application of a common data exchange format for all participants ensures a working information interchange.

2.2. ICT protocol reference architecture

Several smart grid ICT standards mainly define communication protocols and interface specifications, but other aspects like cyber security (Hahn & Govindarasu, 2013; Miao & Chen, 2012) and function modeling are also described.

The IEC and its technical committee 57 (TC 57) is especially active in this field. The graphic shown in Fig. 2 shows the reference architecture developed by the TC 57 organizing the communication and interface related standards in a structure (IEC/TR 62357-1 ed1.0, 2012). At present more than 100 IEC Standards have been identified as relevant to the smart grid.

The following list shows only some of them:

- IEC 61850: communication networks and systems for power utility automation (IEC/TR 61850-1 ed2.0, 2013) (see Section 2.3)
- IEC 61970: energy management system application program interface including the common information model (IEC 61970-1 ed1.0, 2005) (see Section 2.4)
- IEC 61968: system interfaces for distribution management.
- IEC 61400-25: communications for monitoring and control of wind power plants (IEC 61400-25-1 ed1.0, 2006).
- IEC 62325: framework for energy market communication.
- IEC 62351: standard for the data transfer security (IEC/TS 62351-1 ed1.0, 2007).
- IEC 62056: data exchange for meter reading, tariff and load control (IEC 62056-21 ed1.0, 2002).
- IEC 61508: functional safety of electrical/electronic/programmable electronic safety-related systems (IEC 61508-1 ed2.0, 2010).
- IEC 61131: programmable controllers (IEC 61131-1 ed2.0, 2003).

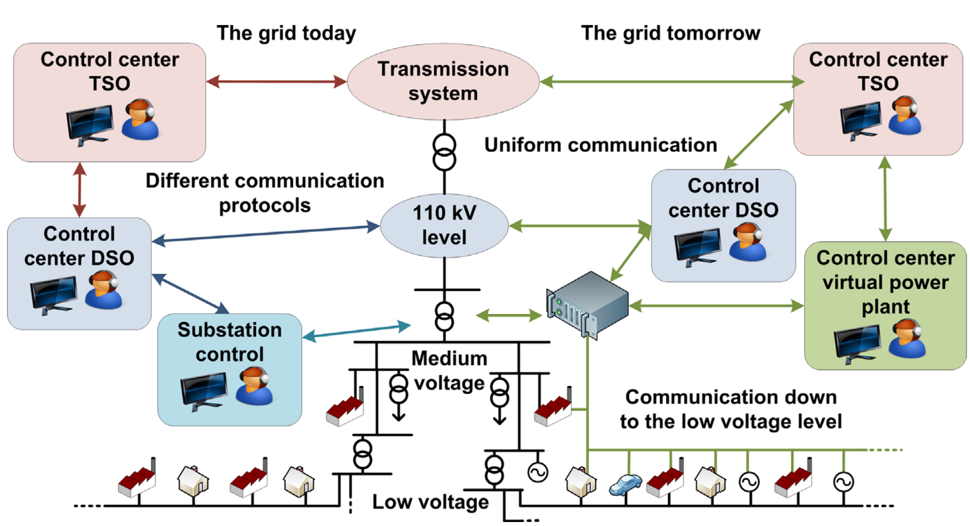

Fig. 1. The ICT structure of the power grid today and tomorrow (Naumann).