FROM SMART SUBSTATIONS TO SMART GRID
HOW IEC 61850 CAN HELP MAKING POWER SYSTEMS SMART

Marco C. JANSSEN
UTInnovation B.V. – The Netherlands
m.c.janssen@utinnovation.com

Peter OOMENS
Joulz B.V. – The Netherlands
peter.oomens@Joulz.nl

ABSTRACT

Smart Grid is the catch phrase of the electricity supply industry today. Embraced by governments around the world it creates an expectation of being the socially, politically and environmentally correct thing to do. But what is smart grid and what does it mean from the perspective of a utility with more than 25 year experience with substation automation to create smart power systems.

As electricity systems have become more closely connected, Wide Area systems are becoming increasingly important to monitor and model how the electricity system operates. The increasing use of distributed and intermittent generation imposes new demands on a system as does the regulatory requirements of a national energy market. How these requirements for flexibility, reliability and accountability are being met are discussed.

This paper focuses on the role of the distribution system operator in a smart grid environment and highlights the experiences of Joulz with using IEC 61850 to support this role and to evolve the grid to a smarter grid.

INTRODUCTION

The world today faces many challenges of which a large number are related to energy and its consumption. These challenges include global warming, the depletion of resources, the energy dependency of the economy, population growth and environmental awareness.

The recognition of these challenges has led and is leading to our modern day "Smart Grid" hype that has thousands of followers and has lead to hundreds of initiatives all over the world. One may think of a hype what they want, but every industry needs a hype to release funds and that is what is happening.

One of the cornerstones of Smart Grid is information or in other words communication. It is therefore not a surprise that IEC 61850 has been labelled as one of the key technologies for Smart Grid.

DEFINITION OF SMART GRID

Before elaborating about IEC 61850 and its role in Smart Grids, a definition of a "Smart Grid" should be given. Out of the many definitions this paper uses the definition of the European Technology Platform for the Electricity Networks of the Future [1]. According to this platform a Smart Grid comprises electricity networks that can intelligently integrate the behaviour and actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

This implies several things but the most important one is the free allocation of generation and load or in other words that the power grid will evolve from a hierarchical network to a truly meshed network [2]

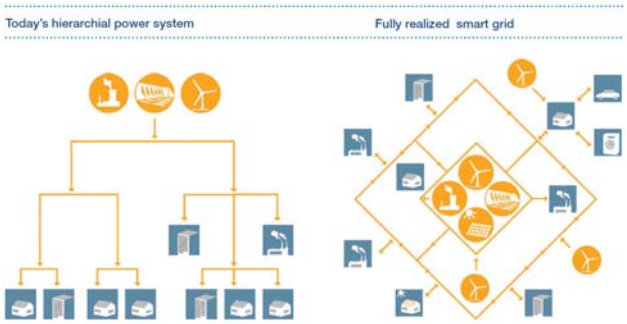

Figure 1: From Hierarchy to Mesh

But what does this mean? In order to connect users intelligently to the electricity network their behaviour should be known and predictable. This means that we need information about these users and this is where IEC 61850 appears. The international standard IEC 61850 for power utility automation allows for interoperable systems exchanging information between them freely and thus can form a good basis for open information exchange.

SMART GRID FROM THE SUBSTATION AUTOMATION PERSPECTIVE

The main building blocks of any power grid are its substations. Together with the lines that connect them they form the backbone of the grid. So a major question utilities are trying to answer is what it means for substations when introducing the Smart Grid?

From a substation perspective, a Smart Grid allows for the behaviour of all substation assets to be known and being able to influence them by means of intelligent applications. These applications can reside locally or remotely but in any case, they require information from the assets at various moments in time as well as the capability to interact with them in an active manner.

The automation of substations using a key technology such as IEC 61850 allows exactly that. Using a standardized approach furthermore allows for the re-use of developed solutions in different substations as well as the stepwise migration of existing substations.

WIDE AREA SOLUTIONS

The introduction of IEC 61850 based systems in substations, in combination with access to these systems from various locations over a communication network, provides the means to develop wide area solutions. Examples of such solutions are the use of Phasor Measurement Units in combination with traditional SCADA, advanced remedial action schemes and power system protection to create wide area monitoring and protection schemes.

An example of the use of IEC 61850 in this area is the application of GOOSE messages over a wide area communication network to create advanced remedial action schemes. In such an application protection units exchange information regarding faults and automatically take decisions regarding the opening or closing of high voltage circuits.

The capability to exchange information of various kinds over a wide area in an interoperable way opens the door to many more advanced applications. This allows the utility to respond more accurate and faster to calamities, outages, to take informed decisions regarding the operation, maintenance and expansion of the power grid and to reduce power interruptions as much as possible.

DISTRIBUTED GENERATION

Since IEC 61850 Edition 2 covers Distributed Energy Resources (DERs), it supports that interoperable applications can be developed for distributed generation as an integrated part of a smart power system or Smart Grid [3].

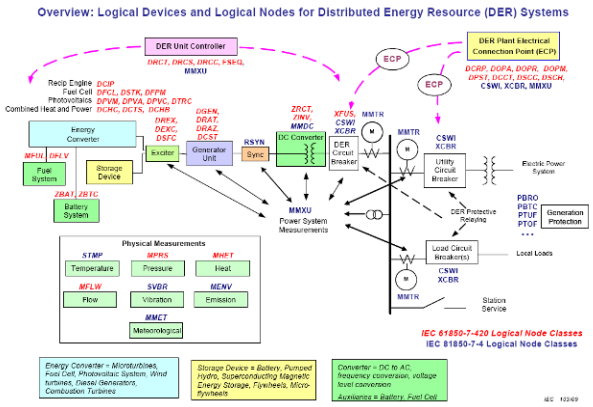

Figure 2: Overview of the use of IEC 61850 for DER

Access to operational, protection and maintenance information, such as set points, curves, parameters, controls, etc. allows for the integration of DERs in Automatic Generation Control (AGC) or for example, the creation of Virtual Power Plants that integrates various DERs in one virtual power plant that acts and behaves as a large power plant. This is actually being demonstrated in the Web2Energy project [4] in which the IEC 61850 and 61968 standards are being used as the backbone for the interoperable communication between all applications

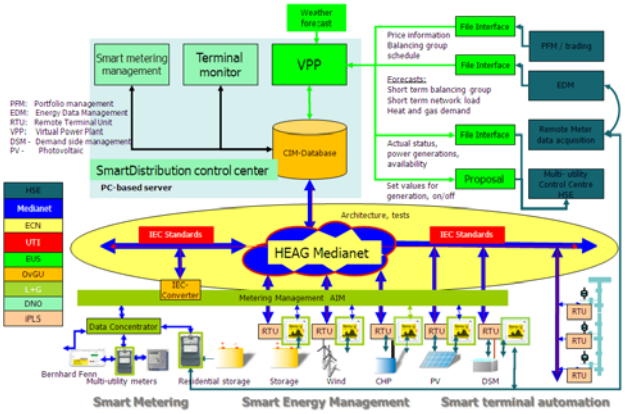

Figure 3: Overview Web2Energy applications

Under the current political environment, where carbon emission and renewables are high on the political agenda in combination with a public opinion that forces utilities to think "green" the inclusion of renewable distributed energy resources in the power system is a must.

The key to a smooth integration of these DERs is access to the information belonging to these units in real time. IEC 61850 in combination with the proper communication infrastructure supports that.

REGULATORY REQUIREMENTS FROM A NATIONAL ENERGY MARKET

The current regulation of Distribution System Operators or DSOs lacks mechanisms to promote network innovation, as there are no real incentives for a company to invest in innovation as the return on investment cannot be guaranteed. Also DSOs are cost (reduction) driven and therefore their behaviour is risk adverse with great reluctance to make investments involving new technologies.

At the same time the introduction of distributed generation poses new challenges for DSOs. Public pressure towards "green" development and reduction of carbon emissions as well as the need from a utility perspective to investigate the consequences of developments such as electrical vehicles, smart meters and distributed generation there are several (small) smart grid initiatives based on DSO ambition, DSO company image building and improvement of customer minutes lost.

REQUIREMENTS FOR FLEXIBILITY, RELIABILITY AND ACCOUNTABILITY WHEN MAKING POWER SYSTEMS SMARTER

When introducing smart systems, there are strong requirements for possibilities to adjust the systems to specific regional circumstances. Using products based on a standard like IEC61850 allows achieving maximum flexibility for these smart systems.

At the same time, there is a great need for reliability of

power systems as our society highly depends on electric energy. Interruptions or disturbances therefore have a great impact and reliability therefore also poses stringent requirements on the security aspects of smart systems.

Reliability not only refers to the smart power system itself. During the design phase of projects the maximum system reliability can be achieved by looking at requirements and costs.

Reliability also refers to the construction, test- and commissioning phases involved for instance in refurbishment- and upgrade programs. Reason is that during these phases no disturbances in power continuity are allowed. There are different ways to achieve this but in most cases this will put stringent requirements on organisations, techniques and employees.

One of the techniques to alleviate risks and obtain reliability is by having a standard interface between the "system intelligence" and the other equipment within smart power systems. A flexible and reliable IEC 61850 based process bus as a standardized interface between the intelligent part of the Smart Grid, the switchgear and the supporting secondary and auxiliary equipment is an important and logical next step.

For accountability, we have to take in account the DSOs drive for cost reduction and risk adverse behaviour. The present drive for DSOs regarding smart grid initiatives are their ambition, company image building and improvement of customer minutes lost. At this time these initiatives are often not backed by regulation and therefore lacking in a clear return of investment strategy.

THE ROLE OF THE DISTRIBUTION SYSTEM OPERATOR IN A SMART GRID ENVIRONMENT

Although the regulatory incentives to a large extend are still missing, the introduction of smart grids is ramping up. The question is at what speed the implementation will happen and what our intents are to manage them.

Each DSO needs to define their business requirements for Smart Grid and to have a common understanding on the definitions of Smart Grid, system intelligence and the ways to achieve this.

The basic requirement for a Smart Grid is communication and therefore a network. DSOs can develop initiatives to have such a communication network available and they can develop dedicated smart concepts and solutions for "system intelligence".

According to Joulz' own experiences over the years it makes sense to invest in small pilot projects involving smart grid functionality to gain experience within DSOs. Besides the possibility to gain technical experience with Smart Grid functionality it also enables rethinking of available technical requirements and to experience the effects on the organisation and its employees.

USING IEC 61850 TO SUPPORT THE DISTRIBUTION SYSTEM OPERATOR IN A SMART GRID ENVIRONMENT

On an average, systems specialists within Joulz have more than a decade of experience with projects involving Substation Automation. Joulz considers IEC61850 as the next step in Substation Automation and a way to make power systems smarter. Since 2007 specialists in Substation Automation have been involved in projects using IEC 61850. At this moment, they handle 10-12 projects per year, varying from refurbishments to upgrades and extensions.

From Joulz' experience IEC 61850 is a way to (force) standardization. In fact, to manage the introduction of Smart Grids and a large scale implementation of smart systems, standardization is a must. Common tools must be available to support customers (specific) standardization requirements. Such a customer framework is to the benefit of the distribution system operator but also to the suppliers, system integrators, system engineers and service engineers as it drives them towards standardized system components and software structures.

SYSTEM INTEGRATORS TO CREATE SMARTER SOLUTIONS

A key role in the Smart Grid implementation is that of the System Integrator. For a System integrator a number of roles are available as a:

1. Management Consultant to parties like Regulators
2. Technical Consultant to DSOs and TSOs
3. Contractor for smart grid programs/projects including service and maintenance

Many DSOs consider a System Integrator, who is also acting as a Service Provider for service & maintenance activities, not as a preferable solution. Reason is that for projects DSOs prefer multiple System Integrators and for service and maintenance, DSOs prefer a very limited number of Service Providers.

For a System Integrators however it is important to provide added value to its customers. This is possible when the System Integrator also has a role as a service provider during the life span of the system. In this way the System Integrator has a drive to create smarter solutions including playing a key role in asset management including all related software, spare parts, etc. This also means that DSOs do not need to focus on every part related to the introduction of Smart Grids.

At this moment Joulz focuses on being a System Integrator including service and maintenance activities. In this role Joulz has faced and is still facing a number of challenges, varying from setting-up standards related to specifications, hardware and software, integration of engineering processes (including servicing) and smart solutions for integrating

systems within live substations.

Present challenges for Joulz include creating smarter solutions for interchangebility, upgradability, expandability and interfacing of equipment, tools and documentation and service and maintenance. In all cases the intent is to make full use of IEC 61850.

ORGANIZATIONAL REQUIREMENTS FOR A SMART GRID ENVIRONMENT

Important when implementing Smart Grid is to re-think the organizational structure for a Smart Grid environment. DSOs will have to consider what level of expertise they want to include within their own organisation. Therefore it is important to have a good understanding of the role(s) of System Integrators and, depending on the DSOs definition of the System Integrator, the Service Provider.

A Smart Grid integrates a variety of techniques and thus requires expertise from many different areas to be combined. A modification of the organizational structure to match this development is important as this allows for the delivery of more integrated approaches. Focus is to have specialists work together in the fields of expertise related to Smart Grid. Training programs should therefore not only focus on the technical expertise, but also have a strong focus on a system wide way of thinking.

Joulz has a multidisciplinary team dealing with Substation Automation Projects. This team consists of high voltage engineers, system engineers, protection specialists and T&C engineers. When necessary, additional teams are available for assembly of IEDs in switchgear, including last “mile” testing and putting into service.

Smart systems require skilled staff for service and maintenance during the system life span. The larger the extent of Smart Grid, the more complex this becomes. To make this possible also training should have sufficient focus.

THE SMART GRID LIFE SPAN

The accepted life span of automation equipment in a substation environment at this time is 20 years. For switchgear this is 60 years. This means that during the life time of the switchgear, two upgrades of the smart equipment will be required as a minimum. Looking at the total cost of ownership and risks of the continuity of the energy supply during these upgrades this is currently, given the costs associated with these upgrades, not smart at all.

Smart in terms of life span can be achieved in different ways. For example by an extension of the life span of automation equipment to 30 years or more (in this way only one midlife update of automation equipment is required). Given the current technological developments this however is seen as unlikely. Therefore a solution is a substantial cost reduction of solutions and/or a significant simplification of solutions by using real standardized interfaces between the automation part and the switchgear part.

System extensions during the smart grid life span can be very complex. In all cases integration in the existing Smart Grid will be the challenge. Using the same technology and components is easier than integrating new technology. The complexity of system extensions has a direct relationship with engineering, testing, commissioning and service and maintenance and it will also influence the system life span.

CONCLUSIONS

DSOs play an important role in making grids smarter. Although still missing real financial incentives for innovation, there are smart grid initiatives based on DSOs ambition, company image building and improvement of customer minutes lost.

Using a standardized approach like IEC61850 allows for large scale issues for smart grid, like the re-use of developed solutions, as well as a step forward to standardisation, required for organisations like DSOs to manage implementation and servicing.

Besides the technical approach involving IEC61850 special attention is required for issues like the organisational approach and the specialist within this organisation were their skills should match the complexity.

REFERENCES

[1] European Technology Platform SmartGrids - Vision and Strategy for Europe’s Electricity Networks of the Future
[2] Toward a Smarter Grid ABB’s Vision for the Power System of the Future
[3] IEC 61850-7-420 - Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes
[4] www.web2energy.com