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REFLECTIONS ON SMART GRIDS

Summary. The discussions on the energy transition, the involvement of households as decentralized energy providers and the reduction of energy costs show an area of conflicts, in which they act as driving force on Smart Grids. In this regard Smart Grids are seen as a key element to address the former mentioned challenges. This paper continues the public discourse concerning Smart Grids and displays it from various perspectives such as technique, professionalism, and communication. It is striking to note that for a long time the discussion has been customer-focused, but in regard to the realization of the energy transition and the power line problem, the energy providers came to the fore. Altogether, there is a lack of a clearly defined target and its matching steps. Here, policy makers in particular are required to specify a legal environment, which considers national as well as international conditions and facilities on the internationally affected grid.
Keywords: Smart Grid, Smart Meter, Smart Market, Energy Transition, Grid Expansion, Load Management, CIM.

REFLEKSJE NA TEMAT INTELIGENTNYCH SIECI

Streszczenie. Dyskusje na temat przekazywania energii i zaangażowania gospodarstw domowych jako zdecentralizowanych dostawców energii i redukcji kosztów energii pokazują obszar konfliktów, w których bardzo istotne są inteligentne sieci. W związku z tym, inteligentne sieci energetyczne są postrzegane jako kluczowy element sprostania wyzwaniom rynku. Niniejszy artykuł jest kontynuacją dyskursu publicznego dotyczącego inteligentnych sieci i przedstawia problem z różnych perspektyw, takich jak technika, profesjonalizm i komunikacja. Uderzające jest to, aby pamiętać, że przez długi czas dyskusja koncentrowała się na kliencie, ale w odniesieniu do realizacji transformacji energii i problemy linii energetycznej i dostawców energii również są bardzo istotne. Bardzo ważne jest w tym zakresie prowadzenie spójnej polityki w zakresie środowiska.
Słowa kluczowe: inteligentne sieci, Inteligentny licznik, Inteligentny rynek, przekazywanie energii, rozbudowa sieci, zarządzanie obciążeniem, CIM.

1. Introduction

In German language presentations smart grids are commonly called *intelligent grids*. Due to the not often colloquially accurate interpretation of the word intelligence it is not always directly and entirely clear why these grids are really smart and what actually is meant. First of all, it is the combined use of energy and communication networks. That isdue to the possibility of direct information flows in terms of a feed back structure direct knowledge about the energy supply and use in the different grids emerges. Thus, this issue does not gain in importance for the customers, but for the network controlling in the context of renewable energies. A more efficient use and distribution of generated energy, the involvement of many decentralized power generators and power flows in both directions are vital issues that need a timely flow of information in order to achieve the energy transition to alternative energy resources [6].

Following the concept of intelligence, it is a process to receive information, to process it, to enable purposeful action [4]. With this knowledge it can be understood that existing grids are extended to include a communications net work to allow the involved parties to get a better decision support.

With an increased decentralized power generation, including wind, solar, combined heat and power (cogeneration), biomass, geothermal, and decentralized electricity storage, the requirements of the grid are changing dramatically. That is due to the fact that energy is no longer produced at the core of nuclear, coal or natural gas power plants. Instead, it is fed into the grid at different places and at different times [3]. This generates not predictable conditions for energy providers. Therefore, they are increasingly suggesting that an energy transition will only be achieved, if the network expansion will be operated not only in the scope but also in the appropriate communicative quality.

To get an overview, this paper deliberately brings the public discussions almost unfiltered together.So itcan show bundled the different perspectives in relation to smart grids from a practical, but well-founded theoretically point of view.

2. Perspectives of the smart grid

The above remarks lead to the consideration of three related perspectives: a technical view, which considers the equipment needed, a professional view, to be able to approach the object and purpose of the smart grid, and finally a communicative view to be able to adequately implement the relevant factor intelligence.

2.1. Technical Perspective

The entry of the intelligence in to the supply network is directly related to the construction and expansion of a powerful IT and communications infrastructure. The aim is a complete informational integration of all components in the supply networks. In order to realize a smart grid, e.g. smart metering plays an important. It is important for the energy measurement unit, the control unit, and the communication unit of measurement instruments of the customers, so called smart meters, to be able to offer a flexible and highly integrated technology that allows the manufacturers of intelligent meters to build economic systems.

2.1.1. Smart Meter

Basically, smart metering is the term used in the utility industry for transmission operations and associated processes and systems of using smart meters, which are equipped beyond measurement of energy consumption also with additional functions. A smart meter is a meter as defined in §21dEnWG that indicates connection users the actual energy consumption and actual time of use. Moreover, according to the *European Smart Metering Alliance* (ESMA), meters are called only as smart (intelligent), when they are at least controlled by one microprocessor. Such smart meters have been in use especially for large customers since the 1990s, but are also offered to private households since 2010. Depending on the model, collected smart meter data can be automatically transferred to the power supply company [10].

Beside the use of smart meters to measure the electricity consumption, it is also possible to collect the water, gas and heat consumption in a household intelligent. A so called *concentrator* is often inserted in order to allow for a Multi-category- functionality. This *concentrator* collectings data from all meters and relays the data to a superior collecting point. Usually that is called a multi utility communication controller or a multi utility gateway due to consumption data being captured collaboratively. Some manufacturers already integrate this function into the smart electricity meter, which is acting as an entry gate for other meters (not allowed in Germany). The direct service area communication from the meters to the concentrator is then usually processed via the standards RS485, RS232, or (Wireless) M-Bus [10].

2.1.2. Updating/Developing the Grid

The German energy agency (Dena) determines that there is still a high demand for development and investment within the area of the distribution networks throughout the years 2020 to 2030. With that the agency is also verifying the arguments of the BDEW. The integration of renewable energy is not just a big challenge for the power grid but even more so for the distribution network. Nearly all solar energy plants and more than 90 percent of the net output of the wind energy plants are connected to the distribution networks. Therefore, it is important to implement especially the high priority project for Upgrading and new development of those distribution networks. Furthermore it shows that with the use of already existing innovative technologies there is already potential for saving expenses and network investments [1].

Currently there is a surplus supply of power from wind energy in the north and east of Germany, whereas in the south there is the thread of a under supply during times of high demand of electricity, especially due to the during the Energy turn decided deactivation of numerous nuclear power plants. From this it follows that Germany is in need of more and highly productive power lines to transport the surplus of wind power energy from the north to the consume centers in the south of the country [8].

The extension of the power grid is also necessary, due to the necessity to connect the planned offshore windparks in the North and BalticSea to the power grid. The future energy supply will have to master this challenge. Regenerative power in the future is supposed to be generated where the best conditions are found. Thereby the ways the power has to travel could become longer and longer. For this reason there are plans to develop more long distance grids for example between Hamburg and Munich that are able to transport co current flow with high voltage. With this so called *High Voltage Co Current Transfers* significantly more energy can be transported compared to current conventional polyphase transfers.

Such power supply systems are also important for the pan European energy trade in which Germany is playing an important role due to its geographic position as a transit country between the markets in Western and Eastern Europe. Finally, the power grid operator/provider has the responsible duty the ensure system stability during highly fluctuating and supply dependent feed in.

2.1.3. IT Architecture and IT Security

In order to integrate the high number of energy generators an appropriate platform is necessary in which all players are speaking the same language. In this context especially the topic of IT security is coming into focus, especially due to possible attacks to critical infrastructure. Following general elements of IT, architectures are discussed and its application context arranged.

An adequate IT architecture is necessary in order to handle the demand based on load prognoses and running costs prognoses. Such prognoses under the already discussed basic parameters of a significant decentralized energy supply. Furthermore, adequate prognoses and with that demands to the control strategy (energy reserves in order to keep the balance in the power grid system) is of fundamental significance in order to design the performance strategy more precise. The flexible energy production creates from the date processing point of view demands for a faster up and downloading of energy demand. Architectures have to consider such systems in its structures in order to support a quick communication flow and response potential. Furthermore, it is uncertain how consumers interact with so called Demand-

Response applications and the technologies and incentives. Its effects still have to be understood in order to create a useful support through an adequate IT architecture [7].

IT architectures support the interaction of single software packages to achieve situation awareness, a system wide shaping, performance analysis far range surveillance and respective controls. Among the challenges in connection with the use of data intake is communication infrastructure, which is in need of the band width in order to transfer the produced data between single devices. It has to ensure a high level of dependability, if data for control decisions are supposed to be used directly and immediately. A second challenge is the lack of available applications that offer a significant and understandable visual demonstration of substantial data, which are produced from the smart devised up to the providers [7].

Flow measuring points detect the physical characteristics of voltage and electric current. This data can be used to judge and maintain the stability of the system after a destabilizing event within and outside of the energy balance. This ability reduced the probability of large grid instability, caused through an event. Data of flow measuring points are also useful for the calibration of models for energy production, energy sources, storage resources, and a system's utilization. This data is also used in planning programs and operation analysis like the rating of dynamic stability and voltage regulation [7].

Architecturally, the tendency is currently to a so called grid computing applications in order to monitor the grid conditions over control signals and to identify possible instabilities. Such information is to be used in economical models. Systems are to operate pro active and in real time in order to provide solutions immediately during possible incidences. This again requires anadequate communication infrastructure [7].

To the contents of IT architecture belong energy management systems, shaping tools, and status tools for the viewonto the grid and system event analysis, voltage examination as well as assessment of cost effectiveness of the used resources in relation to the market. Essentially extensive monitoring functionalities are to be integrated in order to provide an optimal usage of the grid and a prompt reaction to varying events. This qualifies a respective selection of secure systems and functioning algorithms to complete challenges. With that the circle closes to that effect that such systems and algorithms in turn are infrastructure drivers and the infrastructure forms in turn a driver for systems and algorithms. To such systems belong for example:

- Building Automating Systems – the software and hardware to monitor and control the mechanic, heat, cooling as well as lighting in a building.
- Home Area Networks – similar to smart building technology, in order to report energy usage and communicate emerging costs.

Both types of systems are supposed to support automated decisions in the medium term, so that the devices that react to certain indicators can be chronologically transferred or productivity can be cut even before market changes. This requires architectural components that allow timely reactions. That again also requires fitting basic parameters like:

- improvement of current market models,that are based on in plant characteristics und a conventional generation (Natural gas, nuclear energy, water energy);
- calculation of telecommunication requirements for the cost efficient participation of many small aggregated requests.
- utilization and extension of standards to integrate aspects of demands
- management of memory technologies, in order to integrate those efficiently and effectively into the energy delivery process. This under the stipulation of a correspondent cost effectiveness.

In this connection, research projects are especially in demand to deal with market theories and IT-architectures, which can live up to challenges of real time communication, real time support as well as confidentiality of data and network security. All parties are supposed to have access to the underlying infrastructure in order to reach an optimum of resource usage and distribution within the entire system [7].

For example, the *North American Energy Standards Board* and the *ISO/RTO Council* (IRC) are conducting development efforts for smart grid standards within the US energy whole sale. Furthermore, there are *demand response strategies* in the process, which are developed by the *California Energy Commission* and smart grid procedures which are designed by the *California Public Utilities Commission*. With this it is possible to, via developed pilot systems, better understand the system behavior and with that the demand reaction, the energy storage and distributed energy resources. Based on those findings and with utilization of existing standards, development efforts in direction of IT architectures in the area of smart grids can be drafted. This happens under adherence of risks and weak points along the entire chain of communication. With that, especially data security is coming to the fore [7].

A line of international forums is addressing the security concerns during data exchange. One of which is the National Institute of Standards and Technology, which recently published NISTIR 7628, a collection of guidelines for smart grid cyber security. Those are combined in a three part document and sees smart grids from an abstract functional point of view. Among the challenges in connection with cyber security, adapted guidelines exist for the power system monitoring and control applications, which are specific to complex single- and industry applications. Implementation, maintenance, monitoring and improvement of information security are hereby in accordance with existing organizational demands. The road map for cyber security concerns itself with evaluation and implementation of standard protocols and with that also with the question if they are implementable. It also demands the creation of standardized security management beyond all market player as well as auditing of encountered procedure packages [7].

Relating to the overall architecture, the goal is for single network services to exchange information and thereby to work together with service oriented architectures (a collection of services in terms of network systems). That makes the design of an IT-architecture sturdier, due to the fact that in the following years the priorities lie in designing of services and its connection to the infrastructure and not within the connection of it itself, closed software casings to many gateways. At the same time, it makes it easier to communicate with software systems that exist outside of the smart grid but are still taking or giving data to and from the system for variable reasons [7].

A centrally administered network model is an important architectural component. The *Enterprise Model Management System* (EMMS) is supposed to undertake the centralization of multiple current services. This model and the connected data management system reduce the connection time to the data flow. With that, resource monitoring and resource control is possible. Analogue to that, also an analysis of system events with the quickly changing network is possible. Customers are meant to be enabled to view current data and to react to them. All to costs that make design and sale of such devices interesting so that transparence within the system is noticeable [7].

Supports come in form of in itself closed and secured gateways as well as web services and orchestrated business processes which are developing and communicating with each other permanently. In some cases in which the amount of data is to large, File Transfer Protocol (FTP) Server are to be used. Secure FTP will also be used for the exchange of network models with other businesses. Such secure FTP activities can be supervised with Web services. Such flexible service oriented architecture makes it possible for businesses to inform themselves about rates, systems and other information via new services. Hereby offers the *Common Information Model* (CIM), as an international standard, support, which is addressed in a different place. It remains the mission to always check if and which standards already exist, in order to not complicate the desperately needed market entry of many participants through unnecessary barriers and with that put the development in the smart grid system on a wide and promising base [7].

Network structures, IT architectures and also smart meters however do not develop a value without a degree of specialization that justifies a demand based regulation.

2.2. Professionalism Perspective

The competition amongst the public utility companies is increasing. That means that the margins are decreasing at the same time. That means for the utility companies that they have to create new sales potential that can coexist with other traditional business models. There are new options beyond the controlled area that can be associated with smart home, building management systems, energy management, energy efficiency, contractual obligations, and gas electricity generation on the one hand side, and by the marketing of offers related to the IT sector and other communication services. The amount of data that are produced by the utility companies will increase by smart grid, smart meter, smart home and other energy management systems. Due to this fact, there will be an increase of demand in spreads and real-time communication.

2.2.1. Demand of Smart Meter

The objective of an intelligent meter is consumer orientated. That means that the meter has the ability to provide the consumer with effective data about their energy consumption and time of use in their private households. And this is certainly important in the field of electricity, natural gas, long-distance heating, and hot water as there is a lot of competition in that range regarding prices. Based on these options, the utility companies want to offer energy costs depending on the time of the day and, if applicable, lower than the ones the consumers are already paying. That allows the utility companies to take better advantage of the existing infrastructure of the power plant and provides the opportunity to avoid or delay the investment for an expansion of the peak load [10].

With the idea of an intelligent power grid it involves various expectations of service/power. These expectations are as follows: a better control of decentralized plants for electricity generation of renewable energy sources. These energy sources are subject to major variation. In 2009 they only covered 16 percent of the entire electricity consumption of Germany. Remarkable is also the integration of new electromobil cars as energy storage device, the intrusions in energy delivery on the side of the customer as well as the supply of statistics about power usage in real time for private households. The first step in fulfilling those expectations is the implementation of smart meters. Smart meters could also communicate power usage of a private household overall as well as the usage of each single device to its provider as well as illustrate it to household members. As meaningful as smart meters may seem in order to improve the organization of power grids, it would be naïve to think that energy providers will be for forced to install such devices area wide due to a high demand. Besides scoring points in society concerning the ecology, private customers do not want to spend money on a smart meter. The motivation is also low for most people to sit in front of the household energy cockpit, in order to reduce the personal energy costs by switching on and off of energy consumers. It is way too cumbersome and the achievable reduction of the energy bill is small. Therefore, the installation of smart meters alone will not lead to a reduction of power usage in a private household. The spread of energy efficient household devices, entertainment electronics and computers is far more important. In the past it was not enough to just promote the feed of green energy sources or thermal insulation of buildings. So now it is also not enough to count on free market sources and unfolding demandwhen promoting discussion of smart power grids/meters. Without concrete legal guidelines those innovations will not become accepted in the mass market in the coming years [5].

2.2.2. Smart Meter

Intelligent control and automation functions help to ensure the balance between electricity supply and demand and to operate the grid safely. Also several ways of storing electricity are increasingly integrated. A power supply is provided that is based on renewable energies [11].

Hereby, the smart market is also in focus that primarily refers to energy amounts. The connecting element is the information and telecommunication technology (IKT), because without it a complexitytrap threatens, which will result in failure of the energy transition. The IKT plays a key role in the design of such an energy transition, due to it connecting smart grid and smart markets [2].

The IKT includes all products and services that are offered on the market under consideration of energy legal expectation and restriction. However, this market is tough to access, even though outsources activities especially in the area of measuring and communication services are increasing. For a successful energy transition, smart systems and smart architectures are essential in connection with an incentive system. A basic rule for a new regulation approach should be that in case of a market failure the responsible party, meaning currently the provider, holds the control potential.

2.2.3. Load Management

The flexible load and generative management are a main point of the smart grid regarding the inter connection. An intelligent load management can be used for synchronizing a volatile generating with the consumption as well as the automation of the distribution grids are necessary for the purposes of smart grid. Across the distribution grids, which involve 98 percent of the 1.7 million km of the grid and 99.9 percent of the 45 million meter points in the current range, there are 97 percent of renewable energies that are fed into the grids. In addition, the consumers will contribute to the compensation of generating and consumption by load impact. Many of the functions that are needed for this process are known for a long time. Load impact are, for major industrial consumers and for instance at night storage heating, a current practice. Even the required coordination of interests between the generating sector and the grid at the consumption motivation in addition with a high offer of renewable energies has also been know for many years in the work of system operators. New is only the quantity at a smart grid in the future. All solution for few bigger applications had been driven by qualified staff so far but now and in the future that must be implemented for millions of smaller applications with a high level of self organization and automation. The image of a performance of electrical power supply systems at the very end of the ongoing process of change are relatively stable, even though there might be need for clarification regarding the technical conducting of essential functions. That applies especially to the management of systems coupled with a multitude of small and smallest players that need to be included [11].

To get the load management going, to establish a market, and to use a smart meter meaningful, there is a need for a communication structure that allows every competitor in the market to participate.

2.3. Communication Perspective

Because there is more and more electricity coming from renewable source, we need to prepare the transmission network and the grid for the decentralized in feed and at the same time we need to make it intelligent.

The *Common Information Model* (CIM) meets the essential requirements of the utility companies regarding the data and IT model. These requirements are applicable within an architecture based on news as a direct and technical standard for the integration of the application. By supporting the extensive tools and using the methods of a model-driven development it is possible that one can directly produce many relevant code objects within the Enterprise Application Integration (EAI) layer without being in need of extensive additional work or manual adjustment. The XML-news provided by CIM can be replaced by Web Services within a so called *Simple Object Access Protocol* (SOAP) [Uslar and Grüning 2007].

In addition to the XML-schemes that can be used for news in the field of integration there are also RDF schemes for the CIM, which can be used especially for the representation of grid topologies. The RDFs offer more advantages in their print options. There are tools for graphical modeling of grid topologies and for the development of diffgrams, also there are standards for the representation of the CIM/XML technology data by use of Scalable Vector Graphics (SVG) and Geography Markup Language (GML) as early as in the first state of standardization. RDFs enable a flexible saving of data of a company because they do not need an adjustment of the data schemes in case of saving data that are unknown by the time of construction. The IEC works on an alignment of the CIM with other standards in energy supply (i.e. field level communication on the basis of IEC 61850 standards). In the course of this alignment the CIM acts as basis for semantic integration. There are further initiatives that refer to the usage of CIM as a main element of the *UN/CEFACT Modeling Methodology* (UMM) introduction and the CIM are also used to adjust the existing standards of commercial data saving used by the utility companies. These standards overlap the CIM in a semantic way, so that it would be a meaningful support and use to integrate one into the other [Uslar and Grüning 2007].

3. Conclusion

Smart grid unites more individual topics than initially assumed. These topics are intelligent grid expansion, the management of grid capacities and grid conditions, as well as an appropriate grid control. We need to consider that queries regarding the grid capacity are primarily connected to a necessity of regulation that will include the consumer. Smart market is the keyword in this context. With smart market one can achieve a different user behavior by prices and stimuli at the exchange of amounts of energy. In this case we need to consider that we can transform traditional markets into smart markets by smart meter, but we cannot transform grids into smart grids by only using smart meter. That is why we ought to use the information provided by the traditional grid. It is obvious that there is no master plan or component for the smart grids available at the moment. And we definitely need this component for safety reasons when converting the traditional grid into the smart grid. Despite the high costs for research and the high amount of money for initial investments we need to stress that smart grids are more and more essential for a resource orientated society. The data of usage need to be covered and protected by data protection and strict legal obligation. By implementing intelligence as such into an economical system and at the same time taking advantage of its efficient and effective usage is a vital request that is important for all who are involved into the process and who will make this challenge work.

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Omówienie

W artykule zajęto się problemami pojawiającymi się przy wdrażaniu gospodarstw domowych w rolę zdecentralizowanych dostawców energii pod kątem redukcji kosztów energii i minimalizacji wpływów środowiskowych. Praca jest kontynuacją dyskusji dotyczących inteligentnych sieci i przedstawia problem z punktu widzenia techniki, profesjonalizmu i komunikacji.