THE SMART GRIDS MODEL REGION SALZBURG – KEY FINDINGS, CONCLUSIONS AND CLAIMS OF A DSO AFTER SEVERAL YEARS OF PROJECT WORK

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ABSTRACT

The goal of the Smart Grids Model Region Salzburg is, to describe and demonstrate the future "Smart Infrastructure Salzburg". The research activities deal with the integration of renewables, of electric cars, of residential customers, of buildings as well as load management. Within all these areas the possibilities of current and future ICT systems play an important role. This Paper gives an overview of the ongoing and finished projects as well as the key findings and conclusions out of these projects.

INTRODUCTION

The Energiewende has massive implications on the future energy system. As distributed resources are mainly connected to the distribution grid, the paradigms of how to plan and operate grids change fundamentally. New roles and markets evolve and a closer cooperation between generators, system operators and customers is necessary. In this new energy world, Smart Grids play an important part in enabling a successful transition to sustainable energy.

Salzburg is one of the pioneers in Europe in developing intelligent energy networks. This is why it was chosen to be the first Smart Grids Model Region in Austria. The European Electricity Grid Initiative (EEGI) core labeled Smart Grids Model Region Salzburg (SGMS) [1] shows how intelligent electricity networks can look in practice through comprehensive research activities and the implementation of demonstration sites for performance testing under daily routine. Up to now 25 projects were realized of which a majority have been funded by the Federal Ministry for Transport, Innovation and Technology and the Climate and Energy Fund, Austria. The goal of SGMS is to combine the findings of the individual projects into a systematic whole: Smart Infrastructure Salzburg.

SMART GRIDS MODEL REGION SALZBURG

The challenge in the future electricity supply is linked to the integration of decentralised renewable generation as well as additional loads like charging electric cars. Because of the fluctuation of renewable energy generation from wind or solar power as well as the decentralised grid integration, the behaviour is very different to conventional fossil generation units.

The transition to a renewable electricity supply is therefore much more than simply substitute fossil fuels by renewable generation. The task of balancing the supply and demand leads to a **total restructuring of the energy system** in future. The three main driving forces are:

- energy policy goals
- movements in society
- ICT revolution

The EU in particular set ambitious energy and climate targets. These targets extend from the well-known 20-20-20 targets [2] to the goal of reducing carbon emissions by at least 80 % of 1990 levels by the year 2050. [3]

These developments are strengthened by changes within society such as an increased environmental consciousness, individualisation and the desire for a larger degree of energy independence. More and more commercial and residential consumers are operating their own generation unit, thereby turning them from consumers to producers or "prosumers". [4]

The third driver is the new opportunities by the increasing digitalisation of information and communication technology (ICT). The next step of development will be the 'internet of things'. By allowing devices to communicate with each other, we will experience a new energy system, when revolutionary services for producer and consumer can be offered. [4]

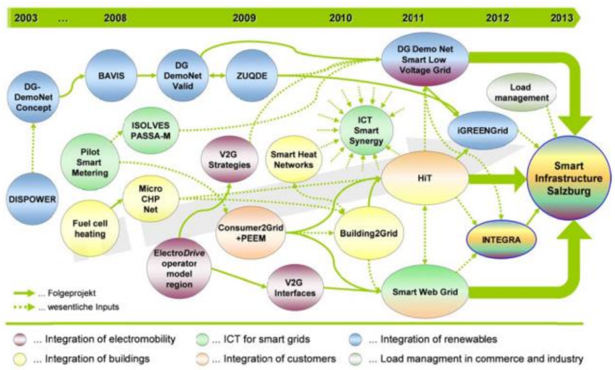

Figure 1: The "big picture" of SGMS projects [4]

"All these new challenges and opportunities affect not only the power grid but also other energy infrastructures such as the district heating and natural gas networks and will therefore require a paradigm change in the energy sector" [4]

"Smart Grids Model Region Salzburg is supported by an interdisciplinary team from the energy sector (Salzburg AG, Salzburg Netz GmbH), a property developer (Salzburg Wohnbau), a technology vendor (Siemens), consulting services (Fichtner) and renowned research institutions (Austrian Institute of Technology, Vienna University of Technology, CURE). The goal is to create a holistic smart grid system called Smart Infrastructure Salzburg." [4]

The smart grid areas of application (which are shown in different colours in Figure 1), which were focused in SGMS projects, are:

- Integration of renewables
- Integration of electric cars
- Integration of residential customers
- Integration of buildings
- Load management in commercial & industrial enterprises

The next chapters focus on these five different areas. It should be noted that these areas cannot be viewed independently because they show overlaps.

INTEGRATION OF RENEWABLES

The challenge of fluctuating generation is the balance of generation and consumption. Currently there are two methods in use to solve this problem: first, price signals on the wholesale market; second, ancillary services in a control area. [4]

The described challenge is a 'global' problem, which is especially visible at the level of the transmission system. In contrast, in distribution networks the problems are 'local'. "In urban distribution networks the primary need is monitoring of network asset utilisation, and in rural networks it is maintaining the permissible voltage bands at each network node. These demands require different operation and control concepts which cannot exclusively be optimised by using just price signals. Since capacity utilisation and voltage band management are strongly driven by local network and load conditions, regional differences must be taken into account. In these critical areas of the network it is therefore necessary to strive for a reaction time of 30 seconds to one minute" [4]

"The DG Demo Net Validation, ZUQDE and DG Demo Net Smart Low Voltage Grid projects as well as V2G strategies offer ways to manage voltage bands and provide reactive power control in low- and medium voltage networks in different applications. The network control based on price signals will be enhanced with regional and timely differentiated approaches for voltage band and asset utilization management. Regulating reactive power locally and using on-load tap changing transformer at individual substations significantly improves voltage band management and utilisation of the exiting grid structure (see Figure 2)." [4]

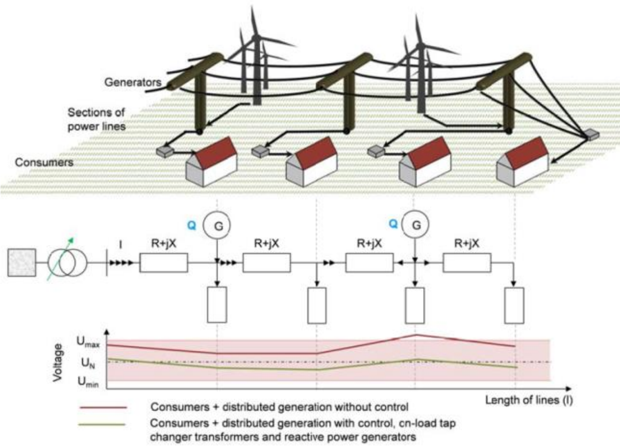

Figure 2: Improved voltage band utilisation through new network control [4]

Within the Project "ZUQDE" the question is covered, how the implementation of an automated, central-control-based voltage and reactive power control of transformers and small hydropower plants works.

In the 30 kV grid in Lungau, the ZUQDE system showed that an additional increase in generating capacity of around 20 % in critical network sections / branches is realistic. It is important that the decentralised generation as well as the flexible loads are distributed evenly in the network. So that the reactive power and thus the voltage can be controlled locally. [4]

Of course, the limits of physics will determine the boundaries to integrating decentralised generators. Once the maximum transmission capacity in the grid has been reached, investments to strengthen or to replace existing units will be unavoidable.

With regard to cost effectiveness, in particular to the question of whether this solution is cheaper than expanding the grid. It must be noted that these calculations are based on individual cases on which the following factors depend:

- Investments in reinforcing the grid cannot generally be avoided, but rather only deferred.

- "How long" depends on the existing structure of the grid, the structure of consumers and generators and especially their development over time

In the project DG DemoNet Lungau it is shown, that the **additional costs** per installable decentralised feed-in power is about **50 % cheaper with Smart Grids solution** compared to classic line construction. [4]

The control concepts for medium voltage networks described here can in principle also be used in low voltage networks, as field tested in the flagship project DG Demo Net Smart Low Voltage Grid in Köstendorf. However, this method is much more complex in low voltage networks because of the greater number of electricity producers and consumers, which are also often prosumers, and the additional technical challenges (see Figure 3).

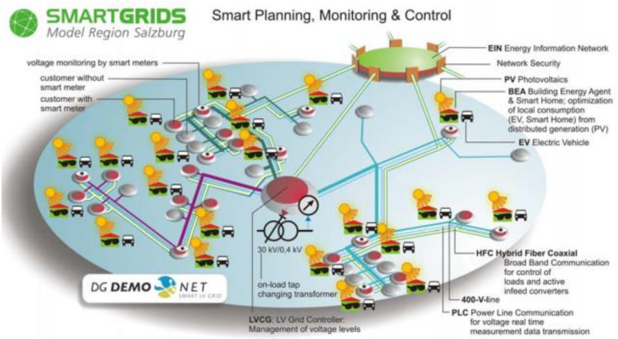

Figure 3: Schematic illustration of the control concept in the field test in the low voltage network Köstendorf [5]

The main question is, how specific or complex the control concepts need to be in order to ensure voltage band management in unbalanced 4-wire low voltage networks with strongly varying loads. Simulation based investigations have shown that the number of metering points necessary to characterise a low voltage network is extremely high in comparison to a medium voltage networks. Within only a few seconds, the voltage in the grid can change significantly. [4]

On the whole, there are promising solutions both in low- and medium voltage networks. The biggest difference is in the different stages of research. In the medium voltage network, the solutions which have been tested are practicable. For the further development of prototype products and solutions, there are concrete agreements with delivery companies. In workshops with grid operators in Austria and Germany, results and solutions have been presented and discussed. There is real interest in seeing them implemented. [4]

In low voltage networks, the first prototypes are currently being set up and being tested. For this reason, results are not as valid as in medium voltage networks. It can however be assumed that the solutions tested in the low voltage network will be similarly promising and will be able to be implemented as a purely network drive controller in the near future. [4]

Due to the numerous applications for residential customers, it will be necessary to bring the control of the power grid into line with the electricity market system. The optimisation of consumption in residential units, for example, has to be connected with generation from photovoltaic units and charging strategies for electric vehicles. In addition, everything has to be harmonised with the offers on the electricity market and correspond to the vicissitudes of time and region that will occur. For this reason, it is a greater necessity that the open questions at the system level be answered in order to design products for low voltage networks. [4]

INTEGRATION OF ELECTRIC CARS

“In the framework of SGMS, concepts for interaction portals, visualisations and user interfaces for electro mobility customers were established (V2G Interfaces project), and the technological and economic effects of grid-to-vehicle and vehicle-to-grid implementation on the electricity network were evaluated (V2G Strategies and ElectroDrive Model Region projects). These make it possible to better assess future options for the systems-level integration of electro mobility in urban and rural regions and to perform field tests (Model Community Köstendorf / DG Demo Net Smart Low Voltage Grid project).” [4]

One result from the Model Regions VLOTTE and ElectroDrive Salzburg is that charging is usually done at **home** and at work. These are the places where the car is typically parked. Because of the long parking times, a **charging power** in the range of **3.5 kW** (single phase) to 10.5 kW (three-phase) is **sufficient**. [4]

In the project, different charging strategies where covered. The term “uncontrolled charging” refers to the charging of electric cars immediately after parking at a station. Figure 4 shows the load profile of this charging strategy for 65 electric vehicles (EV) in sum. The peak is typically on weekdays in the evening after arriving home from work. [6]

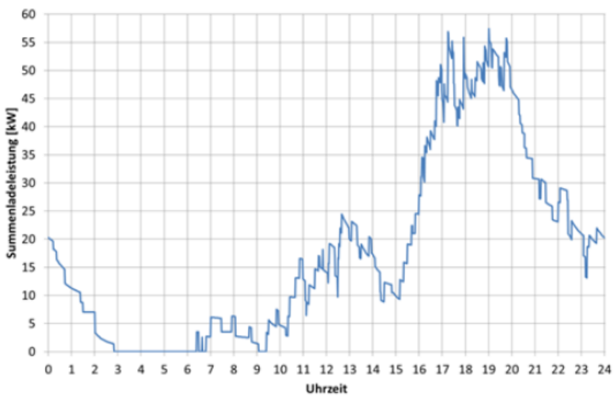

Figure 4: Load profile of 65 electric vehicles (EV) with 3.5 kW maximum charging power [6]

A second “**market driven strategy**” is based on flexible tariffs and price signals. This simulated scenario leads to a simultaneity factor of nearly 1, because all connected EV start charging at the same time. The occurring **load peaks** are more than **twice as high** as in the “uncontrolled charging” scenario and lead to problems in the LV grid. [6]

The goal of “smoothing the load curve” can be achieved by the approach of a random time delay of the availability of the charging power. In this simple solution there is no (bidirectional) communication needed. The results in Figure 5 show, that the peak value of charging power is reduced by 25 % compared to the uncontrolled charging strategy. [6]

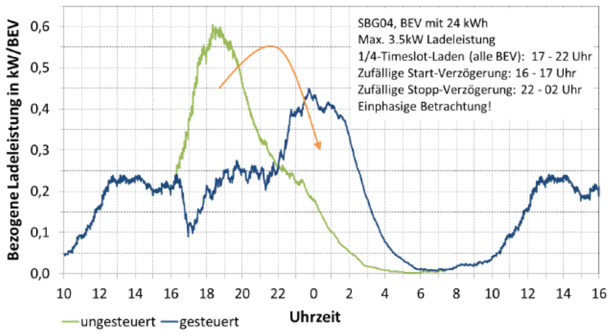

Figure 5: Load profiles for "uncontrolled charging" compared to random time delay [6]

With a further installation of bidirectional communication, a control loop can be implemented to achieve an optimum for the whole system with no reduction of the service level. [6]

INTEGRATION OF RESIDENTIAL CUSTOMERS

“In the framework of different projects (in particular C2G, PEEM and Smart Web Grid), the role of residential customers and their integration into the electric power system was examined. These projects focused on feedback on patterns of electricity use and on recommendations for ways to shift electricity use to times that are favourable for the system as a whole. The following findings and theses were derived from the projects.” [4]

“In the C2G project, different methods for providing feedback on electricity use were examined. Among these were the so called Wattson, the monthly electricity bill, home displays and a web portal and a control group with a yearly bill. In a year-long field trial, no significant differences in the reduction of electricity consumption could be discovered between the different feedback methods. ” [4]

The projects showed that Customers are concerned about the collection, storage and transmission of detailed energy data. It is necessary that the user has the possibility to control his own data. Furthermore, mechanisms to protect privacy must be taken into account in designing a smart-grid information and communication technology from the very beginning. In general, the benefit for consumers derived from providing their data must be clearly visible; otherwise, they will have difficulty accepting this technology. [4]

INTEGRATION OF BUILDINGS

“The optimisation of building operations to shift loads on the grid can be carried out using numerous flexible electrical aggregates and units assisted by different ICT solutions. Of particular importance are systems with thermal-electrical coupling such as heat pumps, chillers and co-generation power stations which use thermal inertia as virtual storage. In SGMS, two primary approaches were used: Optimised control of interruptible consumers using ripple-control units and the flexibility of buildings with the help of building automation systems. The latter are assisted by a Building Energy Agent, which acts as the communication interface to the electric power system (B2G approach). The power grid communicates using a smart grid controller.” [4]

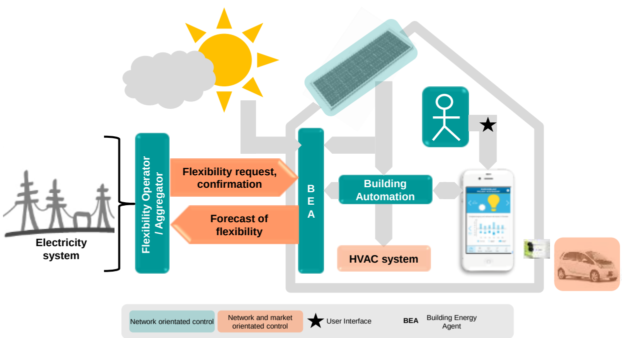

Figure 6: Basic working principle of the building to grid project [4]

In the Building to Grid project (B2G), building automation systems in ten existing buildings were installed (see Figure 6) which communicates with the power grid via a smart grid controller, fulfilling the following tasks: [4]

- Creating energy prognoses for the components used for the thermal conditioning of the building
- Dispensing the load-shifting potential, having taken into account warm-up or cool-down phases and compensation for the rebound effect within a defined period of time
- Optimising the utilisation of on-site generated energy from e.g. photovoltaic units using electro mobility and other flexible loads

LOAD MANAGEMENT IN COMMERCIAL & INDUSTRIAL ENTERPRISES

"Due to the great amount of electricity they use compared to residential customers, industrial customers have a high load-shifting potential, though the exact level must be determined by each individual company. The first cooperation with an industrial enterprise took place during SGMS with a company that can deal with up to 4.7 MW of flexible load by controlling the operation of mills. This corresponds to a potential that is much larger than the buildings examined in the Building to Grid project and can be put to use with comparably little investment." [4]

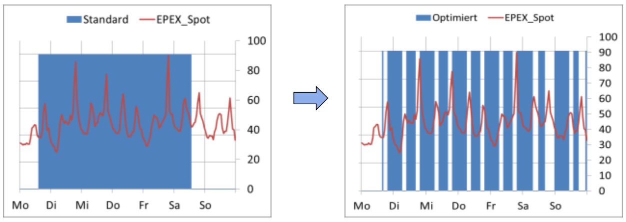

Figure 7: Optimisation of load management in the pilot project based on spot market prices [4]

The effort to install and program the control system was relatively low compared to the potential gains by load-shifting (see Figure 7). The problem in this project are additional costs for the industrial enterprise because of shifting production times and working hours. Thus, the financial benefit for industrial customers is the most important factor. [4]

KEY FINDINGS

The following list describes the key findings of the projects within the "Smart Grids Model Region Salzburg":

- The transition to a renewable energy supply is much more than substituting fossil fuels for renewables. Because of the decentralised generation the system is getting more complex and means a total **restructuring** of the **energy system**
- Information- and communication technology (**ICT**) is the **key element** of the future energy system. ICT-based energy system can increase the hosting capacity and help to avoid grid congestions by a local generation-load-balance.
- The use of ICT leads directly to the topic of **privacy & security** which is **essential** to guarantee. A secure technology and privacy protection is needed so that the customers have trust in ICT.
- **Smart Grids** lower costs and **contribute to** the **affordability of** the **energy transition.** The hosting capacity (e.g. decentralised generation, electric cars) of existing networks can be increased by using smart grid technologies. As the projects showed in the demonstrated examples, this was the cheaper solution compared to conventional line construction.
- The **distribution system operator (DSO)** has a **new task** in **managing** the complex **interaction** between grid, generation, prosumers and customers. At every voltage level a continuous monitoring of the grid status is needed.

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