SMART GRIDS ARE THE EFFICIENT BASE FOR FUTURE ENERGY APPLICATIONS

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ABSTRACT

"Smart grids" is a term often mixed with smart energy applications. By smart grids we mean an efficient solution to distribute energy according to customer needs. RWE is about to build up such a future-ready smart grid to get practical experience in a representative German region. To identify suitable economic grid concepts for the test grid and future energy supply, the demand has to be predicted. A bundle of about 60 parameters is sufficient to describe the required energy supply for each region. Characteristic regions for the future development of electricity production and consumption can be identified. On this basis the technical and economic advantages of conventional and innovative grid concepts are analysed. The result is a recommendation of what smart grids can look like.

INTRODUCTION

The reduction of oil, gas and coal resources force a careful use of primary energy. The world energy demand overall as well as the volatility of energy prices will rise in future. Thus, the increase of energy efficiency and the exploitation of all possible renewable generation is necessary. An efficient use of them will become a great economic factor for each country.

Alongside the challenge of a new electricity production structure for the supply system, the customer needs have changed as well. Forced by technological development and another lifestyle in combination with rising prosperity, energy consumption has changed and this process isn't at its end. As an example, the usage of electricity has developed from light and heat to communication applications and electric mobility.

In addition new technologies have a direct impact on grids, because they potentially allow a more economic grid realisation than conventional concepts.

The question is whether such revolutionary changes in the supply infrastructure impend in the future as we have seen in the telecommunication network. This leads to the central question of what a sufficient and economic smart grid will look like.

Today there are many national and international projects focussed on solutions to reduce energy consumption, to improve efficiency or to exploit renewable resources but mostly they don't consider the grid. Usually electricity distribution is associated with a copper plate but this isn't an economic solution in most cases. To analyse grid concepts and to demonstrate a smart grid the RWE Rheinland Westfalen Netz AG set up the project "grids for future electricity supply" which is partly funded by the German Federal Ministry of Economics and Technology. Additional aspects from equipment- and analysis-method development to science-based analysis are covered by the partners ABB AG, Consentec GmbH and the Technical University of Dortmund.

SMART ENERGY IS THE FRAME

We think that smart energy covers all activities around future energy concepts which involve production, wholesale, retail, distribution and customer applications (Figure 1). Grid customers can be consumers or producers or both.

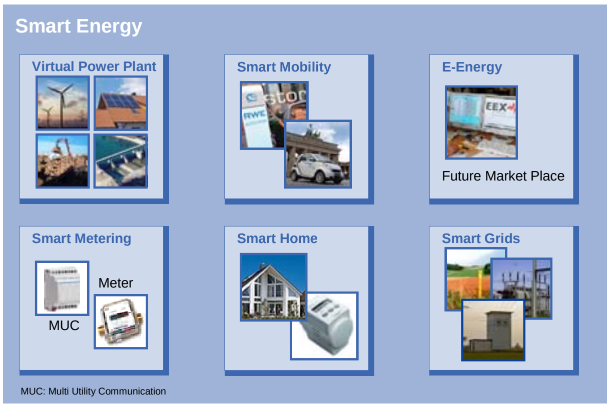

Figure 1: Diversity of smart applications

Virtual power plants combine small dispersed generation units to get entrance to market places. Smart metering activities are the technical base to allow flexible energy tariffs and to establish demand side management. Smart home applications realise control functions and customer advantages from energy control to ambient assisted living. Smart mobility allows CO_2- and respirable dust reduction of private transport. Most importantly smart grids have to provide a sufficient cross-section for electricity exchange between load and infeed. All efforts are needed to realise a sustainable energy supply and they have to work together in an overall concept.

In this understanding, an intelligently planned distribution grid is a smart grid. It will flexibly meet all current and future demands while using an economic amount of capital and operational expenditures. In this sense, the German association of energy and water industries (BDEW – Bundesverband der Energie- und Wasserwirtschaft) worked out the following definition of smart grids.

Smart Grid

Intelligent realised distribution grids provide enhanced possibilities to adapt power generation, system management, storage and consumption to the ever-changing requirements of energy markets.

EXERCISE AND SOLUTION

To identify the most competitive infrastructure for electricity distribution, the present grid has to be left out of the analysis at first. Because of the huge capital expenditures and the long asset depreciation range, the existing grid would otherwise dominate the economic analysis. Thus, the exercise for a distribution grid, planned on a green-field basis, has to be defined. In the following chapter a method to describe the exercise – which we call energy-supply task – is explained.

The solution (Figure 2) in this case is a sufficient and not oversized grid. Aside from the identification of the optimal distribution grid in economic and technical respects, there are usually many grid structures which are similarly efficient in a green-field approach. As a second step, a solution has to be identified which is near the optimal one and which can be reached with minimal expenditures from the current state. That is, the existing grid is considered in this step of the analysis.

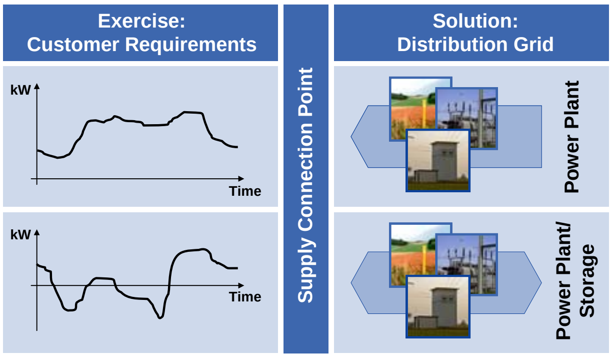

Figure 2: The future energy supply-task gives requirements to efficient distribution grids

To what extent communication technologies become a part of the efficient solution / the smart grid will in the end be an economic decision. Today three aims of communication applications can be differentiated:

1. Communication equipment to realise grid functions like system monitoring, remote metering and control. This equipment has been part of the grid asset for many years but consumer electronic products have the potential to replace equipment, to expand the features or simply to reduce costs.
2. Communication equipment to support workforce and failure management in case of grid operation.
3. Communication equipment to make customer applications with business models beyond the regulated distribution grid business available. E.g. smart home applications belong to this group.

From the asset management point of view, only the communication equipment mentioned in the first bullet belong to the regulated grid business.

ENERGY SUPPLY-TASK

The geographic coordinates of a customer and its requirement of energy exchange with a grid (consumption and infeed) define the energy supply-task. Thereby the amount of consumption and infeed depend on a lot of primary factors. For example the electricity demand depends on the kind of heating system, standard of thermal insulation, use of electric mobility, etc.. These primary factors can be combined to a secondary parameter which can be called electricity consumption. In our analysis we use three different kinds of customer groups but this is scaleable.

The secondary parameters are relevant for distribution grid optimization inside asset management. If the mathematics are clear, the secondary parameters can easily updated by better knowledge about primary factors. This is especially relevant for the forecast of the energy supply-task because only the affected parameters can be updated in a modular way. The needed parameters are always the same and it does not matter wether the current or a future supply-task should be described. This also allows an analysis of development of single parameters over the years.

To describe the supply-task for the whole of Germany we decided on using the German administrative structure as a base and determined the values of the parameters for all 413 administrative districts and over 12000 municipalities.

Roughly 60 parameters describe each of these energy supply-tasks and these can be broken down into the following categories:

- > Demographical and statistical data like number of inhabitants, houses, toal and populated area, etc.
- > Inhomogeneity of supplied area like unsupplied forests and lakes as well as populated areas with different population densities (Figure 3)
- > Energy consumption include number of supply connections simultaneity
- > Distributed (renewable) energy infeed described by kind of generator, annual power infeed, numer of connections, etc.

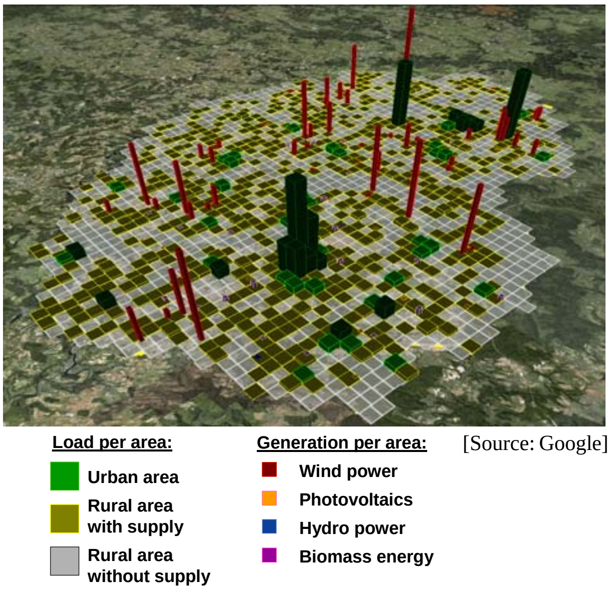

Figure 3: Inhomogeniety of energy supply-task

To determine the values of the parameters the grid business of the examined distribution system operator (DSO) has to be taken into account – e.g. the considered area, connected loads and applied power generators to the grid. In our case we consider the low and medium voltage level for the analysis and determined the supply-tasks for 2010 to 2030.

REPRESENTATIVE DISTRICTS

On the basis of the energy-supply task forecast up to 2030 we analysed typical developments of administrative districts. Alongside the relevant load density the density of renewable power infeed is similar important. For both parameters the inhomogeneity of energy amount and connection point distribution were evaluated.

Today there are districts in Germany which already had to undergo a strong development in the past and have almost implemented all changes expected up to 2030. This concerns the decline of carbon and steel industry as well as the upcoming renewable power generation. Thus, there are regions in Germany which nearly reached their supply task 2030 yet. Especially these regions are interesting for smart grid testing.

In Figure 4 the districts are pointed out which will have a representative development of one or more parameters up to 2030. All mentioned districts will also be caracteristic for the supply-task 2030. E.g. rural and urban, load and infeed dominated areas are covered. That is, with the combination of these districts future development of each German district can be evaluated.

The most dramatic changes will occur in rural areas. Even if renewable infeed or powerful consumption (like e-mobility) are existing in urban areas, the infeed per area/load or the needed capacity per load will be higher in rural grids. With an exception of photovoltaics the number and amount of renewable generation is because of the needed space also higher. Furthermore the provision of an adequate power quality is more difficult in extensive electricity grids with long lines.

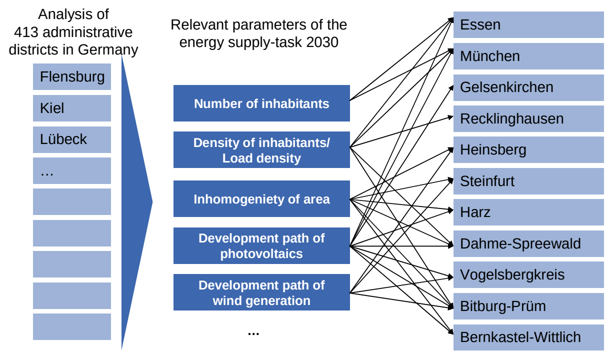

Figure 4: Representative districts of Germany are determined

Because of all these reasons the requirements and the potential for efficient solutions of distributed energy supply is much higher in rural than in urban areas. Therefore we focussed our analysis on solutions for rural grids and plan the erection of a smart grid in the Bitburg-Prüm district from the middle of 2010.

SMART GRIDS ARE AN EFFICIENT SOLUTION

To determine what smart grids can look like, different so-called grid concepts are defined and analysed. A task of future asset management is to choose the right concept in each supply case. Usually a mix of different concepts will provide the opmimal solution, but for purpose of analysis we focus the concepts on certain characteristics.

1	Use of information and communication technology (ICT) for different purposes:
	> ICT to prevent load and/or generation peaks
	> ICT for optimal capacity utilisation of primary equipment
	> ICT for grid monitoring
2	Home energy-management to increase grid capacity
3	Storage positioning to avoid grid expansion
4	Voltage regulation by distribution transformers (Medium-/Low voltage level)
5	Voltage regulation at supply service
6	Layers of hierarchy in medium voltage level

Figure 5: Innovative grid concepts

The main categories of innovative grid concepts are given in Figure 5. The first concept summarises the advantages of common information and communication technology (ICT) for asset management. The advantages for distribution grids are:

- homogeneous load by dynamic adapted load profiles,
- improved short circuit power by meshed grids,
- optimised step-voltage regulation by using grid-measured voltages as setpoint values,
- reactive power control of renewable generators and storage and
- grid monitoring in normal and failure operation as well as equipment control. The provided detailed data enhance power system planning and failure management.

The second concept describes the possibility to increase grid capacity by a reduction of supply service capacity at households with photovoltaics. Prepared with a battery, for example, houses with generation can achieve a load generation balance. The grid then is almost standby and provides predominantly system services.

Another concept (3) is to avoid grid expansion by using solutions ranging from storage devices, to block-unit heating power plants and up to interstage transformers. The background is to provide mainly active power to enhance or reduce the voltage level far away from the substation.

Voltage regulation by distribution transformers (4) considers the decreasing ICT costs and split the voltage control between low- and medium voltage level. Thus, additional grid capacity can be provided, especially in rural areas with voltage restrictions, for connection of renewable generation at existing distribution grids.

Concept number 5 has the same backround because the power quality should be improved to the EN 50160 standard at supply service. Two technical possibilities are in competition with each other. On one hand an autotransformer driven by power electronics can be used. On the other hand a serial converter provide the same functionality. The last one can be split into rectifier and inverter. Then they need not be placed together and DC-grids are possible.

The 6th concept comprises a bundle of solutions around hierarchy structures inside the medium- and low voltage levels. A simple example is the question of whether a 20-kV- or a 30/10-kV-grid is efficient and which structure characteristics are important for the selection. Thereby both hierarchical levels can be operated at the same voltage level.

IMPACT ON REGULATION

Additional grid functions like load flows in different directions or total exploitation of renewables will enhance grid cost. Asset management will use every possibility to limit the increase of costs, but smart grids will not come true if increase of revenues are prohibited.

Smart grids will use different concepts with a variety of equipment. Today, not all innovative grid equipment belongs to the market role of a DSO – e.g. small storage devices like batteries or biomass storage belong to the market role of power producers, which is a different company. This is a strong entry barrier for smart grid concepts.

The complexity of used solutions for economic power supply will rise and to guarantee a fair comparison more benchmark parameters are required. Furthermore, the use of DSM by DSOs will strengthen deviations in the balancing of supply and demand. Therefore the balancing-mathematics has to be adapted, because the energy will only be time shifted.

CONCLUSION

The analyses are ongoing and they will be finished middle of 2010. The first results confirm the relevance of intelligent solutions for efficient supply of rural areas to allow total exploitation of renewable generation. The use of exercise-adapted grid concepts is essential as well as an economic use of open standard communication structures which can be built up for other purposes (e.g. the internet).

The use of regulated distribution transformers are efficient in cases of voltage problems and low load requirements. In some specific cases at the end of long lines the use of voltage regulation at suppy service is economic, but usually not in the German residential structure. Because of the still expensive power electronics, the autotransformer solution is mostly more efficient than serial power electronic solutions.

The use of storage devices in low- and medium voltage levels also seems to be inefficient because the grid capacity is usually sufficient to allow statistical load and generation balancing, which is free of charge. Thus the load and generation balance has to be done on higher voltage levels. An exception is the use of storage capacities which are bought for other purpose like batteries in electric cars and demand side management (DSM).

It has to be taken into account that the flexibility of distribution grids can only sold once: to allow any user-defined load or infeed, or to reduce grid cost by reduction of reserves. In practice smart grids will not provide any distribution capacity to allow any load or infeed at any time but they will provide an economic optimum.