MICRO GRIDS IN AUSTRIA? RESULTS OF ADRES CONCEPT

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ABSTRACT

The integrated concept ADRES shall point out the future of energy supply using intelligent, regenerative and efficient energy systems (Autonomous Decentralized Regenerative Energy Systems – ADRES).
Via combination of regenerative energy sources, intelligent grid management and highest efficiency in the entire energy chain, especially in innovative end use appliances, a regional low emission fully supply of all energy services (heat, electricity and local mobility) will be possible [1].
The intelligent appliances will have the autonomous and individual ability to change their demand on decentral indicators for power deficiencies or –surplus, without falling below their emergency supply. The efficient demand will be adapted to the stochastic supply at any time by an intelligent balance- and control algorithm. Connected to this, blackout situations may be prevented and the expenses for energy storage or backup systems can be minimized.

INTRODUCTION

Today the energy supply is faced to huge challenges. On the one hand Europe becomes more and more dependent on imports of fossil energy sources. On long term basis the delivery safety relating to price stability is not sure, caused through market power and the shortage of the resources themselves. On the other hand the energy consumption in combination with the yearly growth between 2 and 3% results in environment and climatic effects. Especially in Austria the problem leads to a divergence of the decrease target [1] and the actually CO_2 emissions (Kyoto goal for 2012: -13%, actually 2006: +23%).
Caused by this, all energy services (electricity, heat and mobility) have to be available at low emission in the future. The development of autonomous, regenerative energy regions where the local supply (wind, solar thermal, biomass, photovoltaic, water) meets the requirement, demands highest efficiency and is a central impact. This also can make a response to the question how much energy is needed for a full supply without a noticeable loss of comfort. Connected to this, new industries and crafts as well as new energy services including regional value creation and employment effects are expected.

Micro Grid vs. Smart Grid

The future of Power Systems can be summarized in two words: "Smart Grids". The European Technology Platform Smart Grids uses following definition: "A Smart Grid is an electricity network that can intelligently integrate the 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." There are also many other definitions through different national initiatives.

In contrast, a mini or micro grid is a system in which additionally the power autonomy, that is to say the operation in island mode, is aimed. However, a mini grid can be designed to interconnect with a centralized distribution grid and operate under normal conditions as part of the system. A disconnection occurs only if required to maintain power quality in case of a central grid failure. Nevertheless, a mini grid may be designed to operate autonomously because of its remote location.

MINI GRIDS IN THE INTERNATIONAL CONTEXT

The International Energy Agency (IEA) is working on this topic during "IEAPVPS Task 11 – PV Hybrids and Mini grids" [4]. For the IEA mini grids are systems in which energy generators, storage systems and loads are interconnected by a "stand alone" AC distribution grid with relative small related power and limited geographical area. In Task 11 systems from about 50kW (e.g. small settlements…) to about some MW were examined. The following figure shows different breakdowns by range of power, technology and type of users [5].

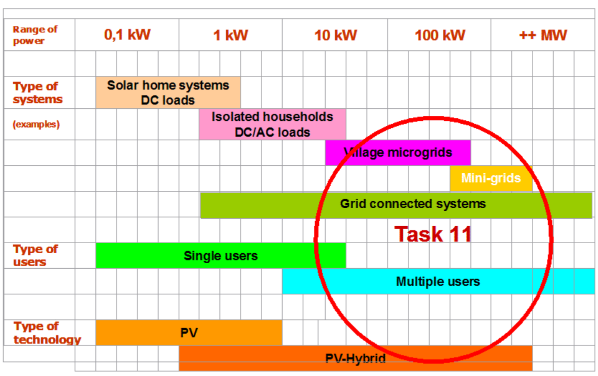

Figure 1: mini grid definition (IEA PVPS task11)

MOTIVATION FOR MICRO GRIDS IN AUSTRIA

Austria is situated in the heart of Europe and the ENTSO-E. The TSO and the DSOs provide electric energy services with one of the lowest failure rates in Europe. Why does research on mini grids should be done in Austria?

We believe that we will learn from them also very much for large systems. In this concept we create an "artificial shortage" with the goal to learn from the occurring problems. Derived from the results in the ADRES Concept we want to find solutions for the main drivers of Smart Grids. The different opportunities and goals can be summarized in four main topics:

1. To increase reliability, efficiency and safety of the power grid
2. To enable a huge amount of decentralized power generation, so that homes can be both, an energy consumer and an energy producer. Sometimes also named PROSUMER.
3. To increase the flexibility of power consumption of homes, industry and in future also electric mobility.
4. To increase the GDP by creating green jobs related to renewable energy at regional level.

ADRES CONCEPT

ADRES stands for "Autonomous Decentral Regenerative Energy Systems". That is to say not only mini grids should be examined, rather a holistic system approach is aimed [2].

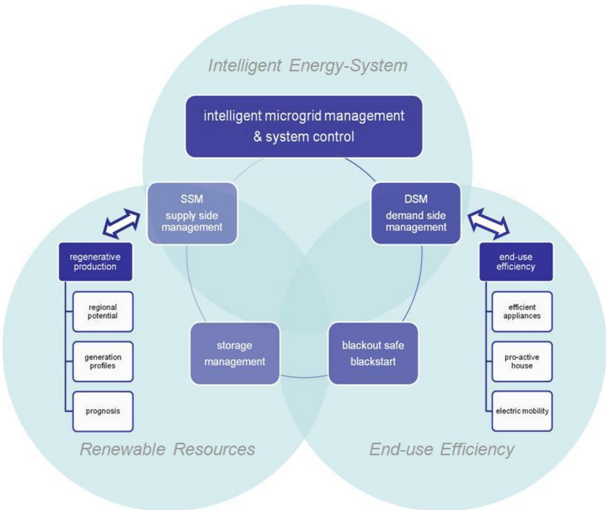

Figure 2: columns of ADRES

The figure above shows the three columns of ADRES. These are the supply side by using only renewable resources, the demand side with highest efficiency and an intelligent management of the system.

Flexible loads and DSM algorithm [3]

In ADRES it is necessary that the demand for electrical energy follows the fluctuating generation of wind power and PV. In order to answer the questions that arise especially in the household sector with an implementation of Demand Side Management (DSM), a simulation model was developed during a diploma thesis, which can reproduce the behaviour of household devices on the one hand and the effects of various DSM-systems on their power consumption on the other hand.

For this purpose, the different groups of consumers in a household were simulated in their behaviour. Each group of consumers is modelled by using so called device-classes. Care was taken that the simulated behaviour of these classes is as similar as possible to that of real devices.

The DSM systems to be examined should not require any additional communication between the consumers and have a simple structure. The information on the need for an intervention in the power consumption of the devices is to be determined from the line frequency. Thus, different algorithms a DSM system can be equipped with have been developed. These algorithms can be combined to form different DSM systems to examine the effects they may have.

With the help of already known load curves, through measurements and additional data, a first model of the devices of a household for an average daily load was established and verified.

This model was used subsequently as the basis for initial investigations of different DSM-systems. Using these results, initial demands for a realization of DSM can already be obtained.

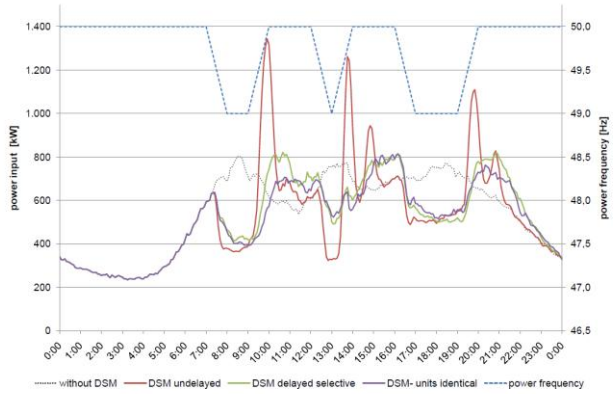

Figure 3: DSM system simulation [3]

The figure above shows an example how the cumulative consumption of the devices reacts on frequency changes. In this case three different types of DSM systems were examined, using the virtual devices of 5000 people.

Renewable Resources

Definitions

To understand the following figures some definitions are necessary.
In two figures (4, 6) you will see the annual duration curve of the power difference. The annual duration curve shows the backward sorted values from the difference of renewable generation and load.
The figures 5 and 7 show bar charts of up to 3 different comparative values.

The Cumulative Utilisation Ratio (CUR) is calculated as ratio annual renewable generation of all resources to the total electric load of settlement. A CUR of 100% implies the energy autonomy over a year.

$$CUR = \frac{\sum E_{renewabel}}{\sum E_{load}}$$

The Direct Utilisation Ratio (DUR) is calculated as ratio share of direct used renewable generation to annual renewable generation of all resources.

$$DUR = \frac{\sum E_{direct}}{\sum E_{renewable}}$$

The Non-Supply Ratio (NSR) is calculated as ratio non-supplied load to the total electric load of the settlement.

$$NSR = \frac{\sum E_{non-supply}}{\sum E_{load}}$$

Exemplary Analyses

The underlying scenarios are not the focus in this paper. Nevertheless, I want to give very briefly an explanation to understand the shown scenarios. The percentage of Wind, PV, etc. gives the share of energy related to the annual load of the settlement. The last value e.g. 4000kWh/a gives the average annual electric consumption of each household. In these scenarios 200 households are calculated.

Figure 4 shows three different scenarios. You can see the "inefficient" scenario with 4000kWh/a consumption in each household (blue continuous line). Because of low full load hours from wind and PV it is necessary to install high power capacities. In this scenario the installed power is about 500kW and peak load only about 220kW.
Through increase of efficiency and energy savings the installed capacity can be reduced as you can see in the "efficient" scenario with 2000kWh/a consumption in each household (violet dot dashed line).
Due to fluctuating generation and unavoidable prognosis deviations a high balance power requirement is resulting.
Predictable production units (e.g. biomass) can lower this balance power requirement as shown in third scenario (orange dashed line). However, a restriction of resources has to be noted.

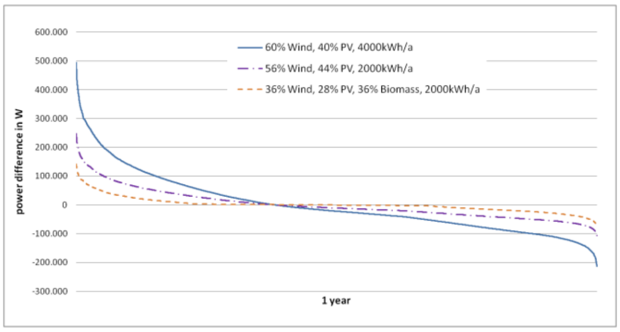

Figure 4: annual duration curve of the power difference, scenario 1-3

Figure 5 shows the corresponding analyses of CUR and DUR. The CUR of 100% in each scenario implies the energy autonomy. With additional use of predictable biomass plants the DUR can be obviously increased. By the way the NSR is, within scenarios of energy autonomy, equal 1 – DUR.

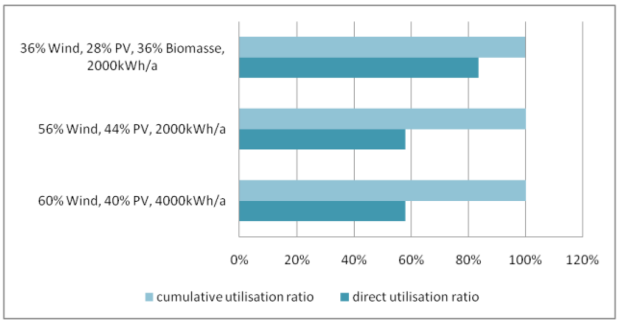

Figure 5: CUR and DUR analyses, scenario 1-3

In figure 6 the influence is shown using storage systems by the one hand and oversizing by the other hand. By comparison you will see the "efficient" scenario (violet dot dashed line) again. A coordinated storage management can enhance balanced operation as shown in the scenario with 2kWh (capacity of storage) in each household (green continuous line).

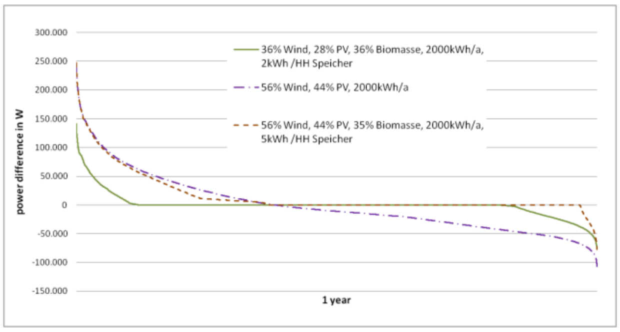

Figure 6: annual duration curve of the power difference, scenario 4-5

To increase the non-supply ratio as shown in figure 7 an oversizing is unavoidable and standard in stand-alone systems. You can see this in combination with 5kWh (capacity of storage) in each household in the last scenario (brown dashed line).

Figure 5 shows once more the corresponding analyses of CUR, DUR and additionally the NSR. Due to the use of storage systems the DUR can still be further increased. The oversizing (CUR > 100%) causes a decrease of the DUR but is necessary to decrease the NSR. This is again necessary to reach the power autonomy.

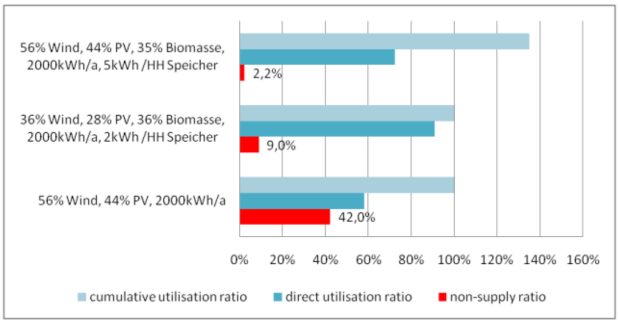

Figure 7: CUR, DUR and NSR analyses, scenario 4-5

CONCLUSION

- The autonomous full supply on the assumption of the today's consumption behavior is technically possible, however opposite existing central networks are not economical.
- That transfer to an energy system with highest penetration of renewable generation is possible only by simultaneous efficiency increase and energy saving.
- The synergy of sustainability and efficiency is essential.

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