Practical utilisation of the load shifting potentials in a rural Austrian municipality – evaluation and conclusions

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Abstract

The project GAVE (Großschönau as virtual energy storage) focuses on feasibility of technology for automated demand response (or demand side management, load management). This technology can be seen as one of the key instruments in future smart power grids. While control of generation units is still relatively straight forward as a reduction in power generation simply reduces the revenues, the situation on the demand side is much more complex. Therefore, GAVE aims to analyse the effectiveness and the user acceptance of automated demand response in an Austrian setting. The object under study is a municipality in Lower Austria. A part of the public energy customers in the municipality is equipped with sensors and actuators that allow conducting real load management. These consumers take part in a municipality-wide experiment. The operation of the specially equipped demand processes is measured and the data is fed into an evaluation process. Within the evaluation, the results of demand response measurements conducted at only a few sites due to cost restrictions is scaled up on the total municipality load in order to gain insights on the effectiveness of the demand response measures. It is aimed to determine the achievable load shift potential under the constraint that user comfort must not be affected.

Keywords: Demand response, rural municipality, load shifting, demand response potential

1   Motivation and central questions

Due to the rising share of renewable generation in the electricity grids, the controllability of the generation side of the electrical energy system can be expected to decline significantly in the coming years [1]. Apart from the approach of providing dedicated energy storages for intermittent renewables [2], one major effort to re-gain the lost controllability is to seek flexibilities on the demand side (see e.g. [3, 4, 5]). Unfortunately, although demand side management seems to play a major role in the operation paradigms of a future European

electricity system, actual implementations of demand side measurement are rare. While the theoretical basis for management algorithms is broad (see e.g. [5, 6, 7, 8]), experience in large practical realisations is yet to be made. As a step towards this direction, the Austrian research project "Großschönau as virtual energy storage" (GAVE) has analysed the practical utilisation of the load shifting potentials in a rural Austrian municipality. The key questions were how to practically utilise available potentials in the municipality and what effects can be achieved by this.

2   Methodology

In regard to the general challenge of gaining more practical experience with demand side management, the methodology of this approach is learning by doing. In order to answer the question regarding available potentials in the municipality and their practical utilisation, a detailed survey was conducted resulting in a precise image of the modalities of energy consumption in the municipality. From this data, an estimation of the theoretical load shifting potential was derived. At the same time, multiple representative shiftable loads were equipped with the necessary communication interfaces, automation components and measurement infrastructure in order to execute actual load shifts. A series of experiments resulted in data about the actual available potential of the representative loads. Figure 4 depicts exemplary results of such a load shifting experiment. From the experimental data, the total load shifting potential can be derived together with the required effort for utilising this potential.

3   Electricity supply and demand in the municipality

The municipality of Großschönau with its 1,264 inhabitants is situated in lower Austria in the district of Gmünd close the Czech border. It has an area of 42 km². The population density is 30/km², average size of households 2.7 people. About 37% of the area is covered by forest; approximately 58% of the area is in agricultural use [9].
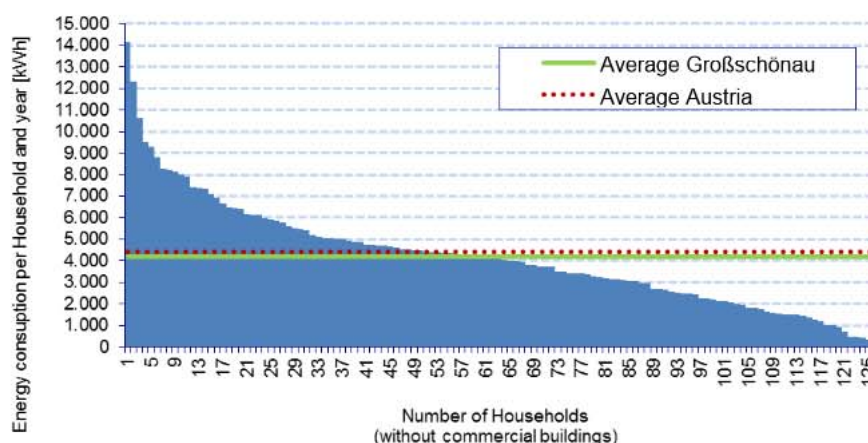

Figure 1: Average residential electricity consumption in Großschönau [9]

In cooperation with the municipality, a detailed energy consumption evaluation has been carried out. 70% of households did return a multi-item questionnaire about their energy

consumption, also including mobility and leisure. Data modelling the electric energy balance of the municipality is taken from this evaluation.

The yearly total electric energy demand of approx. 5 GWh/a could in theory be fully covered by the existing PV potential (see Figure 2). In fact, only 4% of the electricity demand is currently covered by local production [9]. A small run-of-river power plant and some PV installations generated 167 MWh in 2010. The mentioned coverage does however only mean that on the average the yearly electricity demand would also be generated locally. Still, the power grid is required for matching demand and supply in any particular point in time. More details about the coverage of energy demand of the municipality by renewable sources can be found in [9].
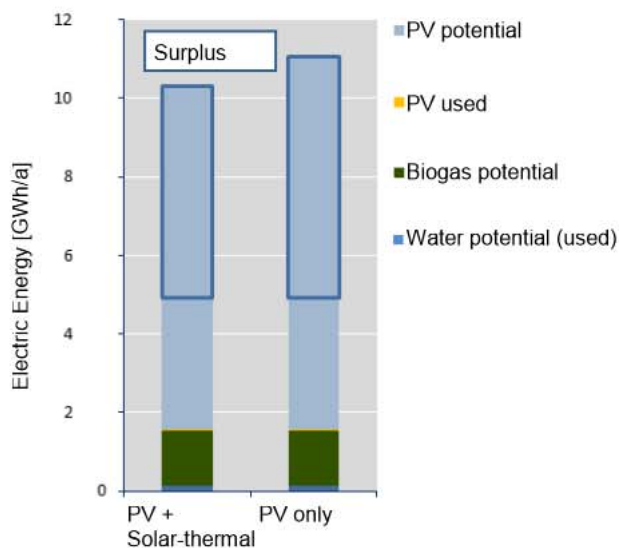

Figure 2: The potential for renewable electric energy supply in Großschönau is larger than the local demand [9].

4   Demand response resources

Assuming a higher amount of local and renewable energy supply, demand side measures would help to improve the on-site consumption. Potential devices for load shifting were identified within the project GAVE. Resources for demand response within GAVE were determined to be the fresh water supply system and the waste water disposal, because they consist of tanks, which can be used as storage for performing energy management. The theoretical approach behind is that energy which is needed to empty or fill the tanks is stored when the procedure will happen later in time or is consumed earlier when the process is scheduled earlier [10]. Additionally, heat pumps in public buildings and ventilation systems in the public school (gym) were considered. Figure 3 shows a map where the fourteen individual resources are located.

The potential demand response resources were equipped, as required, with additional sensors and actuators. Fortunately, the majority of the systems came already with a sufficient number of sensors. Also, most of the required acting devices were already in place.

In Figure 4, the general layout of a demand response resource is shown, valid for thermal, material, or any other kind of processes that can be used for electrical load management.

The central element is the storage. In case of the waste water treatment system for instance, this is a mud tank and the flows Q_1 and Q_2 are negative. This storage has a preferred level, usually achieved by some kind of control system that operates between the maximum and minimum level. The control system determines the electric power consumption of the system depending on Flow Q_2 in normal operation.
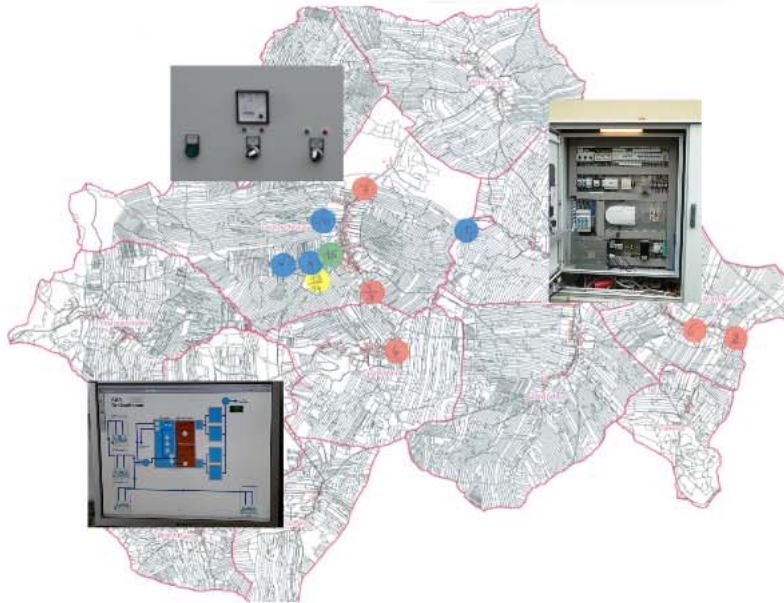

Figure 3: For the municipality, 14 demand response resources were identified, ranging from fresh water supply systems to heat pumps in public buildings

When designing a practical electrical load management system, it is always preferable to place the actuators at the minimum and maximum levels rather than controlling the pump directly. By adding virtual inner limits in the safe area "before" the hard limits, influence on the pump operation can be realised without changing the existing control system, ensuring that the system state is always within the required limits. This however involves the disadvantage of more complex modelling of the transfer function between actuator signal and change in power consumption (see also [5] and [11]).
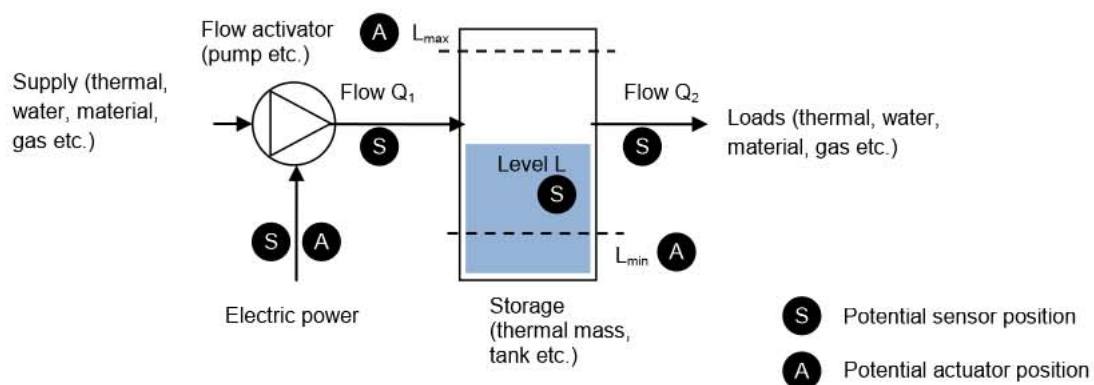

Figure 4: General layout of a demand response resource. For safe resource operation, it is preferable to place actuators at min/max levels rather than controlling the pump directly.

5   Load Shifting Potential

Within the field test, the parameters of the systems are measured over one year during normal operation and conditions. The measured values are stored in a database for long term evaluation. For each device, a specific control strategy was defined in order to be able to analyse the load shift potential. Time series data for the total municipality demand was estimated through the combination of the standard demand profiles for households and the mentioned energy survey. Consequently, typical peaks can be expected happen during early morning, midday and a third peak in the evening.

Table 1: Calculated load shedding potential for three different waste water stations in Großschönau

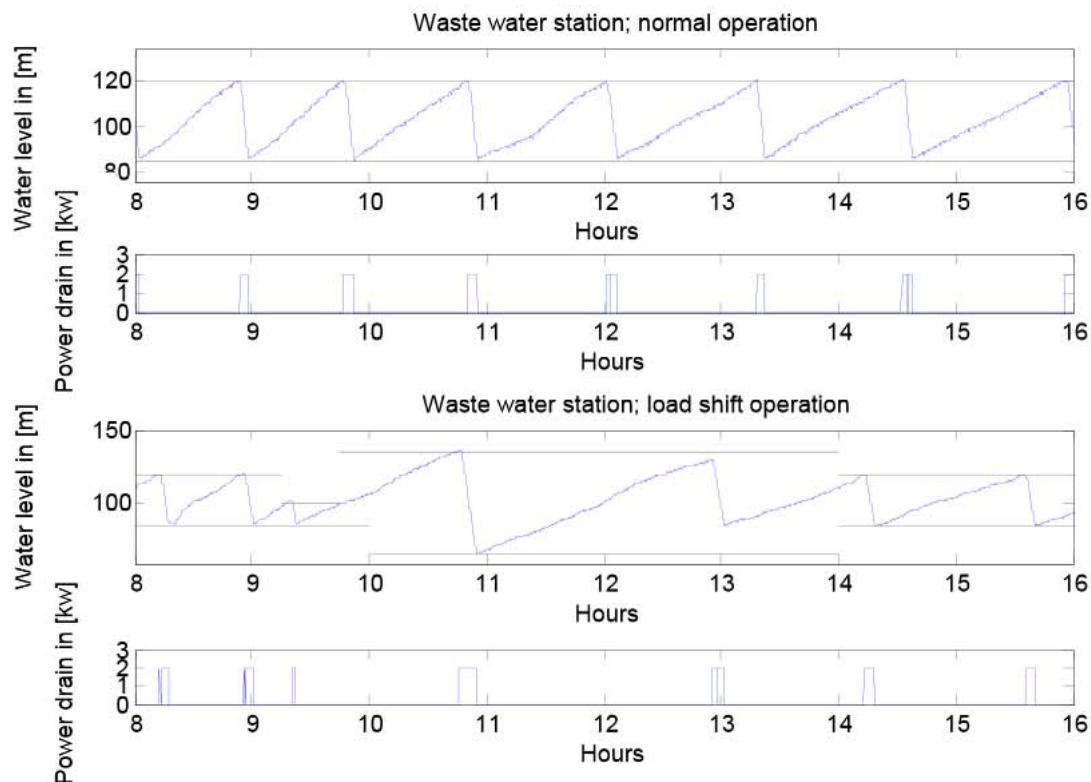| Name	minutes per cycle	power rating in kWh	number of cycle	kWh per cycle	load shedding potential per day in kWh
Mistelbach	11	11	4,29	2,02	4,33
Rothfarn	5	2	10,86	0,17	0,91
Großschönau	4,7	7,4	27	0,58	7,83

Figure 5: Experimental results for load shifts with a freshwater reservoir pump. The water level in the storage tank has to be kept within certain limits. Above: normal operation of the pump, below: load shifts induced by a change of threshold levels

Each control strategy consists of three different states that the device has to run through. First, the device must be pre-conditioned to maximize the time period for the shedding process. In the second step the device will be shed, but there will still be emergency thresholds i.e. to prevent overfilling of the waste water tanks. Finally, there will be a rebound phase. The whole process can be defined as a cycle. Through the short pumping times, each second cycle can be shed.

Taking into account the total daily energy consumption of roughly 12 MWh (winter) or 8 MWh (summer) in Großschönau, the shifting potential of the waste water stations account for only 0.1% of the municipality demand. Even when adding fresh water supply, ventilation of public buildings and other loads that are part of public infrastructure, the shiftable part of energy consumption will not exceed the 1% range.

6   Conclusions

The results of the project and its experiments can be categorized into four areas:

1. **Utilisable shifting potentials** were found in public infrastructure. In the project, pumps of the fresh water supply and waste water treatment system, ventilation system of the local school gym and heat pumps in public and private buildings were selected as representative loads. In total, only 10% of the energy consumed by the selected representative consumers is shiftable in time. However, the total amount of shifable energy demand of public infrastructure is estimated with 1% compared to the total municipality demand. Therefore, privately operated loads such as heat pumps would also have to be involved for achieving significant load shift potentials.
2. **Interfacing the loads** was less complicated than expected. Especially for the systems belonging to public infrastructure, existing remotely operable management systems had to be extended with few additional sensors and actuators. However, for (privately owned) heat pumps, a special device had to be developed that allows to simulate arbitrary values of an outside temperature sensor.
3. **Appropriate modelling of the resource behaviour** is a prerequisite for demand side management [5]. However, still significant individual engineering effort is required to gain these models. Together with the interface costs, this is one of the main cost components for practical realisations of demand side management.
4. **Concrete business cases for demand side management** on a system level are still rare. The potential service provided by load shift resources is still missing an appropriate remuneration scheme. Apart from state-of-the-art peak power reductions, the only options in today's market environment are provision of secondary/tertiary control power or balancing energy cost reduction.

From the viewpoint of the project results, pooling of homogeneous resources seems the most likely path towards successful load management implementations.

Acknowledgement

Literature

[1] Deutsche Energie-Agentur, "dena-Netzstudie II - Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015 – 2020 mit Ausblick 2025", in German language, 2010, p. 8

[2] Ibrahim, H.; Ilinca, A., Perron, J., "Energy storage systems - Characteristics and comparisons", Renewable and Sustainable Energy Reviews, 2008, 12, p. 1221 - 1250

[3] Stadler, I. Bukvic-Schäfer, A. S. "Demand side management as a solution for the balancing problem of distributed generation with high penetration of renewable energy sources", International Journal of Sustainable Energy, Volume 23, Issue 4 December 2003, pp. 157–167

[4] Strbac, G. "Demand side management: Benefits and challenges", Energy Policy, 2008, 36, p. 4419 – 4426

[5] Kupzog, F., Rösener, C., Palensky, P. "Konzepte zur Koordinierung verteilter Energiespeicher", Internationale Energiewirtschaftstagung IEWT 2007, Wien, February 2007, in German language

[6] Ygge, F. & Akkermans, H., "Power Load Management as a Computational Market", 2nd International Conference on Multi-Agent Systems ICMAS'96, 1996, 393 – 400

[7] Kok, J. K.; Warmer, C. J. & Kamphuis, I. G. "PowerMatcher: multiagent control in the electricity infrastructure", Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems, ACM, 2005, 75-82

[8] Kreutz, S.; Belitz, H.-J. & Rehtanz, C., "The impact of Demand Side Management on the residual load", Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES, 2010, 1 -5

[9] Bruckner, J.; Frantes, B.; Hutterer, A.; Iglar, B.; Kupzog, F.; Lippert, L; Pol, O.; Prüggler, W.; „CO_2-neutrale Gemeinden im ländlichen Raum – Ein Leitfaden am Beispiel der Gemeinde Großschönau", Sonnenplatz Großschönau, in German language, 2012

[10] Pollhammer, K.; Kupzog, F.; Gamauf, T.; Kremen, M.; "Modeling of demand side shifting potentials for smart power grids," AFRICON, 2011, vol., no., pp.1-5, 13-15 Sept. 2011

[11] Kupzog, F.; Roesener, C., "A closer Look on Load Management," Industrial Informatics, 2007 5th IEEE International Conference on , vol.2, no., pp.1151-1156, 23-27 June 2007