ACTIVE AND ANTICIPATORY DEMAND-SIDE-MANAGEMENT IN HOUSEHOLDS

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ABSTRACT

A high density of Photovoltaic generation can lead to problems in low voltage grids. This paper addresses the problem by actively and anticipatory using the load shifting and load influencing potentials in households. The goal is to achieve a local generation/load balance. To analyse the potential in Austrian households, a model settlement is generated, which represents Austria as a small village. For each device in these households an uninfluenced load profile is generated. Also the limits of load shifting are described.

INTRODUCTION

This paper addresses issues of integration of Photovoltaic (PV) generation in low voltage grids. In areas with a high density of installed PV power, situations occur where the power flow reverses when the generation power peaks exceed the maximum load. By reducing the peaks of the residual load profile, the share of decentralized renewable power generation can be increased.

Demand side management (DSM) is often associated with the objectives of reducing peak load and smoothing the load curve. The goal within the project “aDSM”, however, is to achieve with DSM a very flexible electric load profile which adapts to the given volatile supply of renewable sources. Renewable generation forecast is an essential element to actively and anticipatorily use the existing load shifting potentials.

MODEL SETTLEMENT

The use of DSM potentials focuses in a first step on the level of a single household as well as the whole low voltage grid area. Within the project “aDSM”, a general statement about the benefits of DSM in Austria is made. Therefore a “typical” low voltage is needed as research object.

The goal of the model settlement is to represent the overall Austrian residential structure. The synthetic low voltage grid consists of a rural and an urban area. The generation of a synthetic distribution network has the advantage that different network situations can be represented in a single study area. Furthermore, the compilation of the actual settlement is freely selectable.

Based on the population survey [1], the number of buildings, the type of these buildings, the number of households per building and the number of people per household are known.

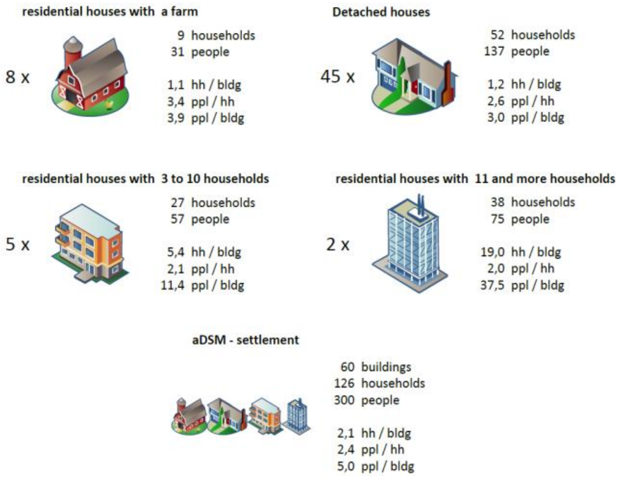

Figure 1: Austria mapped on a settlement with 300 inhabitants

By defining the number of inhabitants of the settlement, all other characteristics are defined. The Number of 300 people was chosen. Therefore the load in the settlement matches typical values for a single MV/LV transformer. Figure 1 shows the compilation of the model settlement. The 300 people live in 126 households within 60 buildings.

POWER GRID

The aim of this step is, to build a low voltage grid for the model settlement. The typical distances between buildings are based on practical experiences.

The structure of the network is determined by the parameter "load density". At low load densities, as for example can occur in rural areas, radial networks are preferred. This network configuration consists of a series of branched lines which are supplied from a common power unit. A disadvantage of this network configuration is that when heavy loads are switched, the voltage drops can get too big. Furthermore, even simple failures lead to supply interruption for many consumers. [2]

An alternative form is the openly operated ring network. This topology is often found in areas with higher load densities (e.g. urban areas). Here preferably cables are used. During normal network operation a separation point in the middle remains open. Thus the ring line behaves as a radial network. In case of failure, this separation point will be closed at the end of the half-ring. At additional separating points the faulty section is removed. All other consumers can continue to be supplied. [2]

Figure 2 shows the basic structure of the model network. The model settlement represents the Austrian building and living conditions. Therefore the different network types should also be found in the grid model.

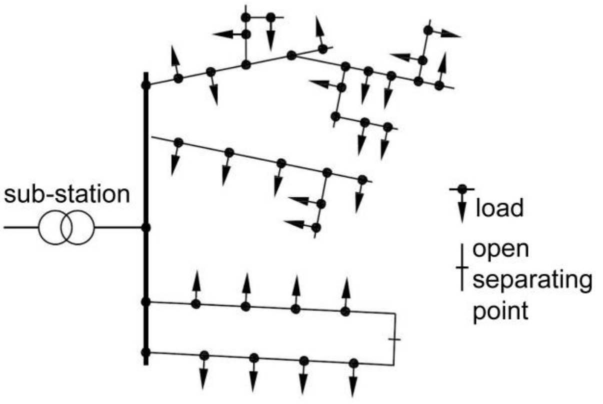

Figure 2: Grid topology - radial network (upper feeder) and open ring (lower feeder) [2]

In practice, one network station will be either in a more rural or in a more urban region. So there'll be only one of the two shown network types. In the model grid however the two types are combined for one station like shown in figure 2.

As the scale drawing of the model village shows (see Figure 3), in the urban area, a building configuration was found such that all requirements are met. Roads and buildings were drawn with the assumed size. The cable length of the nodes of the ring towards the land was sufficient for all the buildings, but also at the same time it led to no unrealistic line lengths within the ring network.

In the rural area (lower right part of Figure 3) a "village arrangement" can be seen. Here occurs a mixture of relatively densely populated one-and two-family houses and small farms. In the left area, the case of a distant farm is covered. For the distribution system operating these distant farm buildings are very important. The large roof area and thus potentially high photovoltaic power represents the most critical cases in the LV power grid.

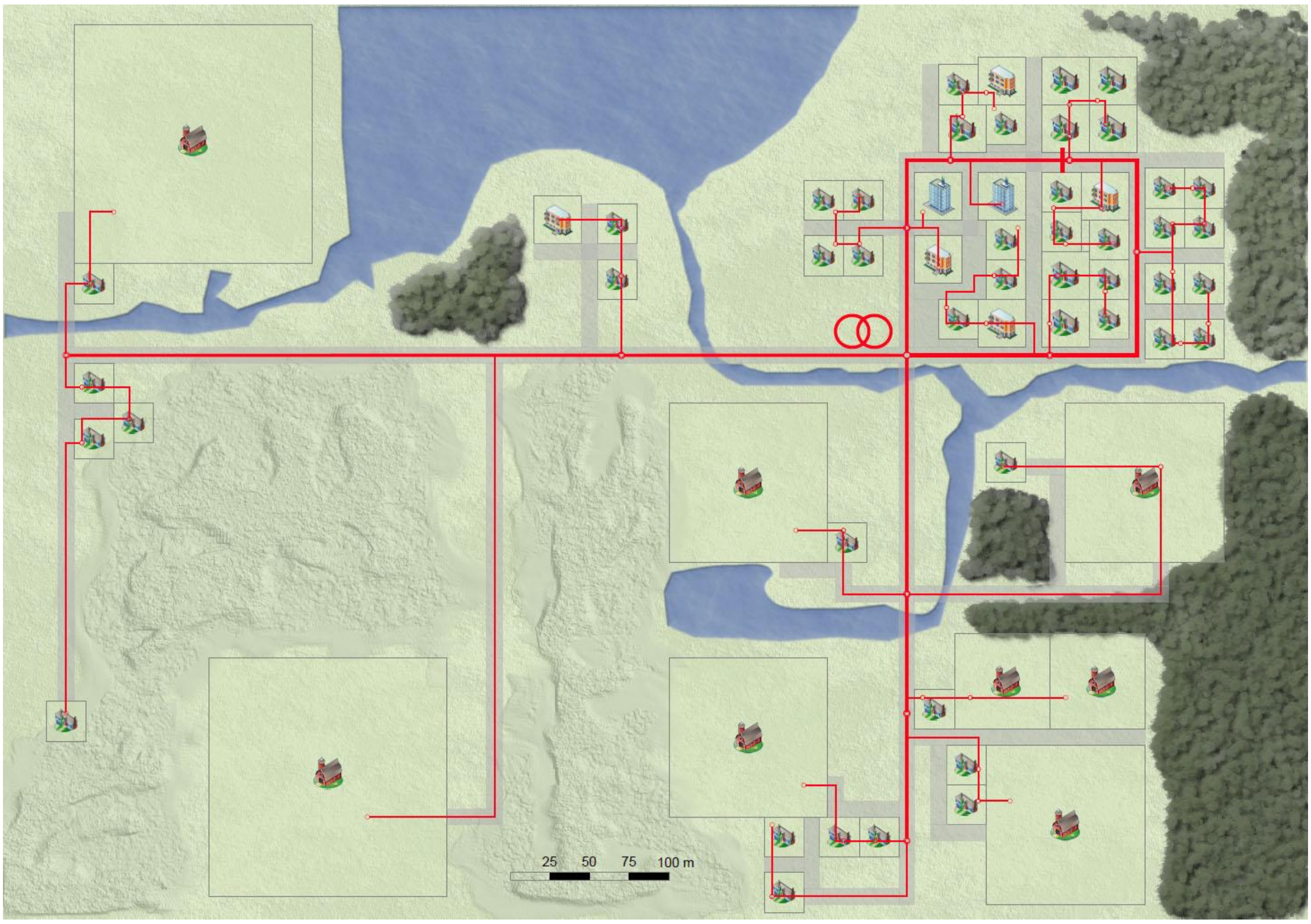

Figure 3: True-scale plan of the model settlement

With the full-scale representation of the building arrangement in figure 3 on the one hand it is shown that the assumptions about line lengths, building plot of land distribution and sizes match in itself. On the other hand, it is shown, what Austria broken-down upon a settlement of 300 inhabitants could look like.

DEVICE EQUIPMENT IN HOUSEHOLDS

In this chapter the device equipment in households is described. The households itself are separated in 8 categories. The survey [4] describes the equipment level of different categories per household type. In Table 6 the average number of devices per household is shown. [3]

Table 1: Number of devices per category in Austria [3]

household-type	number of households	Devices per household							Heating			hot water	
		Fridge	Freezer	washing machine	dryer	dish washer	TV Set	Computer	heat pump	heater	circulating pump	water boiler	water heater
house 1	13	1,06	0,60	0,91	0,12	0,50	1,62	0,48	0,00	0,13	0,69	0,29	0,08
house 2	17	1,58	0,97	0,94	0,36	0,81	2,00	0,85	0,05	0,03	0,86	0,22	0,03
house 3	12	1,83	1,11	0,92	0,42	0,81	2,82	1,62	0,05	0,14	0,72	0,43	0,04
house 4+	19	1,87	1,20	0,91	0,44	0,87	2,62	2,13	0,09	0,05	0,85	0,30	0,03
flat 1	29	1,09	0,26	0,83	0,09	0,50	1,12	0,70	0,00	0,13	0,20	0,46	0,08
flat 2	19	1,25	0,54	0,86	0,12	0,69	1,55	1,16	0,00	0,08	0,39	0,41	0,03
flat 3	9	1,23	0,48	0,91	0,20	0,78	1,88	1,76	0,00	0,00	0,38	0,44	0,00
flat 4+	8	1,35	0,56	0,87	0,26	0,77	2,06	2,06	0,00	0,00	0,21	0,67	0,07
total	126	1,39	0,69	0,89	0,24	0,69	1,86	1,23	0,03	0,08	0,53	0,39	0,05

The household types are characterized by the two groups "detached house" and "flat" as well as the number of people per household. The average device equipment will now be allocated to the individual model households. This is achieved by the tool described in [5]. The values in Table 6 are used to calculate the probabilities for the number of devices per household. The actual equipment of the 126 households (broken down by eight different categories) is defined at random based on the equipment probabilities. The collective of households in the model village describe the average Austrian device equipment.

The average annual electricity consumption per unit is known for each of the 126 households. These data were collected as part of the survey [3] as well as the information provided by Statistics Austria [4]. By the given consumption and the device characteristics [5], the average annual operating time is known.

Synthetic load profiles are generated, by using the device equipment of households as well as the operation probabilities. As a result of the tool [5] for each device in the 126 households, a synthetic annual load curve is available. The time resolution for this is 1 min. Due to the underlying stochastic, the synthetic profiles represent the consumption characteristics of actually measured load profiles of individual households. [5]

DSM - POTENTIAL IN HOUSEHOLDS

The electrical consumption is separated in two groups "power-demand" and "energy-demand". In the first group, which contains energy services like lighting, consumer electronics and home office, the only DSM potential is to influence the power consumption. The group "energy-demand" is characterized by that the energy demand can't be influenced, but that the load occurrence can be shifted in time. Devices like refrigerators, freezers and washing machines belong to this group.

Table 2 shows the limits of the load influence. The variant "Basic" includes only those categories of devices, so the user is not influenced in its behaviour. The variant "full" describes the full potential in the household.

In [7] and [6] the maximum switch-off times of the device groups "heating", "hot water", "refrigerators" and "freezers" are specified. Starting from a normal operating state, these are those periods in which the device may be removed from the network without causing an impermissible operating state. These periods are derived from the thermal time constants of the devices and the requirements to be fulfilled.

The variant "Basic" uses as DSM potential only those device groups with a thermal time constant. The constant has to be large enough so that the user doesn't notice the load shift. This contrasts with the version "Full" which relies on additional potential in the household, which have a direct impact on the user behaviour.

The delay describes the maximum time between the start of the prospective program run, up to the actual execution. Based on the work [7] for the sectors "Washer", "Dryer", "Dishwasher" a maximum delay of 5 hours was assumed.

In exceptional situations the device groups "TV set", "computer" and "lighting" are also available for DSM applications. This temporarily affects the active power consumption. In [6] these potential savings have been described, which is mainly due to the reduction in brightness of illumination.

Table 2: Limits of load shifting

	Variant "Basic"									
	Variant "Full"									
Parameter	heating	hot water	fridge	freezer	washing - machine	dryer	dishwasher	TV set	Computer	lighting
Switch off time [h]	18 h	11 h	2,5 h	6 h						
Proportion P_{med} / P_N	0,25	0,083	0,25	0,25						
on-delay [h]					5 h	5 h	5 h			
Power reduction [%]								- 20%	- 30%	- 9%
Standby reduction	no	no	no	no	no	no	no	yes	yes	no

SUMMARY AND OUTLOOK

As of now, the composition of different household types was defined. The power Grid for this model settlement was created based on practical values. The load flow calculation implies active and reactive power. DSM potentials are used to operate within thermal limits as well as voltage levels.

At the moment the optimal use of DSM potentials is calculated. The benefit of DSM will be expressed in the increased share of directly used photovoltaic generation. Also the comparison of an equivalent storage, which achieves the same effect, will be drawn.

Acknowledgments

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