DEMAND SIDE MANAGEMENT POTENTIAL A CASE STUDY FOR GERMANY

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ABSTRACT

The increasing amount of renewable generation - especially fluctuating wind and solar power - has to be balanced for a secure power system operation. Currently, this is done by fossil power plants or pumped storages as long as they are available when needed. One option, which is not yet fully developed, is a more flexible load operation (Demand Side Management (DSM)) that is able to react to changes in the generation. This so called load shifting can be used in order to shift or balance power consumption load peaks. A VDE ETG Task Force is investigating the overall German potential for DSM by evaluating the sector, household, trade, commerce and services as well as the industry, for the years 2010, 2020 and 2030. The approach of this evaluation and some selected preliminary results is presented in the paper. Further, it is shown how a more flexible demand side operation can contribute to a stable and reliable power supply.

INTRODUCTION

The German power system is currently undergoing an enormous conversion. The main drivers of this are limited fossil resources, demographic and climate changes. The most relevant challenge is and will be the integration of renewable energies into the existing grid.

The theoretical potential of renewables exceeds the current demand for electricity in Europe. Due to a lack of storage capacity and fluctuating generation as compared to the static demand, new transmission capacities and new grid operation strategies are needed [1][2]. The European SET-Plan envisions 650 GW of renewable generation by 2020, representing approximately 25% of European energy demand.

The installations of wind and solar power plants will not be distributed equally throughout Europe or within Germany [4]. This means, for example, that the German power system estimates 39% of renewable energies with most wind power plants in the North and solar power plants in the South [1].

Regarding the 2020 targets, two different scenarios have to be considered (see Fig.1). In case of high load conditions it is expected that the actual generation by wind and solar can be directly consumed as well as feed in available large storage systems like pumped storage plants, assuming sufficient transmission capacities as described in [1].

The second scenario represents low load conditions if renewable generation (RG) exceeds the consumption periodically (typically between 11 p.m. and 6 a.m.). In that case, additional options for grid control will be needed if the RG should not be shut down.

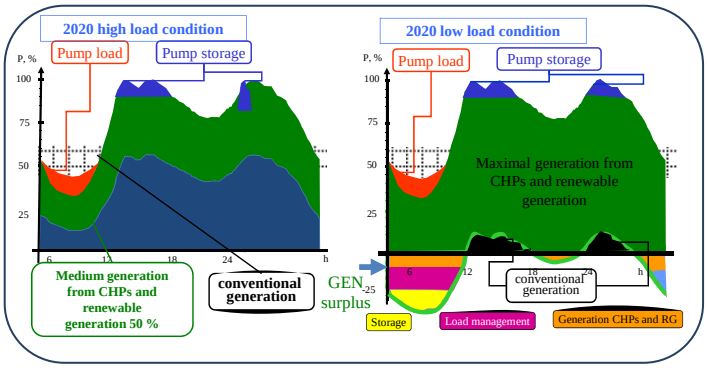

Fig 1: Exemplary scenarios regarding European SET-Plan for 2020 [3]

First, new storage capacities have to be installed. Taking into account a scenario with 50% wind generation and static load profiles in Germany, power storage capacities of about 182 GW are needed [5].

Due to technical and economical limitations it can be anticipated that storage capacities will not have the capability to fully cover the fluctuations of renewable energy resources. In addition to controllable combined heat and power units (CHP) demand side management (DSM) features the opportunity to adapt the static load profile to the actual generation.

The related strategies that allow for DSM can be generally distinguished between direct (shifted by a dispatcher) and indirect control (shifted by user) [6]. Different studies [2] have estimated the DSM potential for Germany. For network planning and operation purposes it is important to know the potential that can be used and the time at which it is available. Therefore, the ETG VDE Task Force “Demand Side Management” was recently formed to provide an overview of the technical DSM potential and how DSM can be used for grid operation and the further integration of renewable energies into the grid.

This contribution will describe the methodology for how the analysis estimates the potential in Germany`s main sectors for load shifting: namely, household, commerce, trade and services and industry. Furthermore some preliminary results from a scenario 2010 will be shown and discussed.

METHODOLOGY

Model region and simulation aims

The VDE ETG task force developed a synthetic model region representing 500,000 inhabitants that allows for indicating the average distribution and energy consumption of all sectors in the German power system considering relevant indicators like demographic changes, etc . Based on the annual energy consumption the separate amount of households, commercial, trade and service as well as industry is estimated [9] [10] [11]. Some exemplary results are presented in Table 1.

Table 1: Exemplary amount of sectors on annual energy demand in Germany (2006) [9, 10, 11]

Sector	Part of load block	Part of total demand
Households		
1 Person	40%	26%
2-3 Person	47%	
Commercial, trade & services		24%
Trade	27%	
Hotel + restaurant	15%	
Industry		47%
Metal industry	20%	
Chemical industry	20%	

For calculating the DSM potential in each sector (i.e. household) and type (retail, metal industry, etc.) so called average load blocks (LB) (see Fig.2) are defined for the further implemented simulation.
In the first step the maximal DSM potential is assessed. The following parameters are generally considered:

- Time to shift the load;
- Break after load shifting;
- Daily period of usage;
- Average power demand.

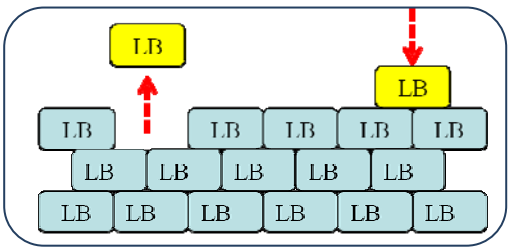

Fig 2: Schematic display of the DSM potential analysis

In the second step, a mathematical optimization (generic algorithm) is used to identify a so called DSM band (Fig. 3.) representing the availability of controllable load for each application or type of sector.
Finally, the estimated DSM potential is used to calculate the amount of renewable energy sources that can be integrated into the grid by adapting the load.

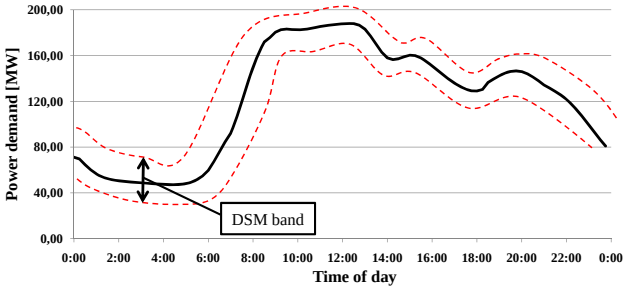

Fig 3: Exemplary DSM band

Household

Since household appliances account for a large fraction of the overall load, they are a major contributor to the daily load peaks. This study investigates how a pool of similar household appliances can be used for load shifting. In order to assess the household sector's DSM potential within active distribution networks in the future, this study examines the DSM potential for several different appliances on the household level. For that purpose this sector is split up into one person, two to three person and multiple person households.
In contrast to many competing projects the approach at hand is not limited to appliances with thermal storages and allows direct scheduling of basically any type of appliance as long as it is possible to influence its' operation.
Based on comprehensive research a set of appliances was identified as having an option for load-shifting, see Fig. 4. The basic idea here is to aggregate a high number of each appliance in a pool, a so called virtual device. Instead of controlling each appliance individually, load shift measures are scheduled for virtual devices as mentioned here [12].
To this, specific characteristics of each application shown in Fig. 4 as well as period and hours of operation, energy consumption, etc. have to be taken into account. Focusing on further scenarios for 2020 and 2030, other aspects to be considered are long-term changes in appliance usage and energy efficiency. The most intuitive examples are air conditioners and heating devices whose usage is subject to environmental influences.

Type of application	Penetration level (%)	Load (kW)	Shift potential (mins)
Air conditioning	5	5	150
Night storage heater	6.10	3.6	120-150
Electric heat pump	10	0.3	60
Electric water heater	21.70	2.7	15-180
Washing machine	95.80%	2.8	180-540
Laundry dryer	39.40%	2.0	180-540
Freezer	55.00%	0.1	15-120
Refrigerator	106.00%	0.1	15-120
Dishwasher	65.00%	2.1	150

Fig 4: Selected relevant applications on the household level [11]

Commercial, Trade and Services

To evaluate the load shift potential for the trade and service sector a different approach is required due to the diversity of the types of commercial, trade and services organisations. Therefore, a so called top-down approach is applied to estimate the DSM potential in this sector.
Based on an evaluation of the trade and service sector a number of DSM-relevant subsectors of commerce, trade and services were identified. These relevant types were analysed by ranking their energy consumptions as well as the usage of effective energies to get an understanding of what kind of storage capabilities could be possible. The evaluation progress is presented in Fig 5.

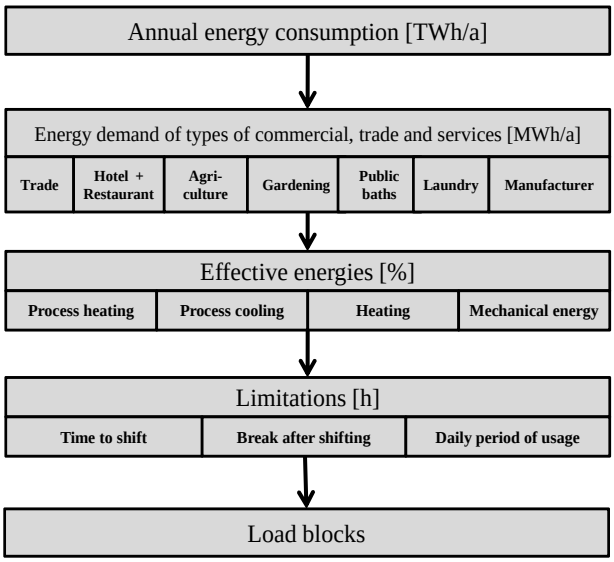

Fig 5: Methodology to build load blocks

For simulation purposes single load blocks are needed that allow for load shifting within a day. Therefore, the already mentioned parameters regarding time to shift etc. were applied. If one takes in account process cooling, typical applications will be refrigerated warehouses. The food can be stored within a temperature range of -18° to -27°C [14]. Within that range it is possible to shift the operation of the cooling compressor by using the storage capabilities of the warehouse. Taking into account these restrictions an average load block can be build per unit.

Table 2: Overview of the amount of units in the model region and the particular energy demand per year

Type	No. of units	Consumption per unit (MWh/a)
Trade (Retail-and wholesale)	1610	91.02
Hotel + restaurant	1673	49.50
Agriculture	1043	25.02
Gardening	106	14.23
Public baths (Pools?)	23	1053.76
Laundry	31	47.84
Manufacturing	225	89.32

Industry

The approach to assess the potential of DSM for reducing load fluctuations and leveling the power generation of renewable energy resources is similar to those of the commerce, trade and service sector.
First, from all the different industry types only those that have the option for shifting power consumption load peaks were taken into consideration. Within this sector a lot of efforts due to individual pricing are in line with market and competition. Therefore a lot of DSM potential is already covered by individual energy supply contracts with utilities. Despite a huge degree of DSM-activities that are already in use, this study focuses on the overall technical DSM-potential. To do this the VDE ETG taskforce used their most useful industry contacts to conduct a survey.
The challenge for the assessment of this sector is the lack of secondary data related to DSM. Therefore, the taskforce used the complex methodology of a primary data collection- a personal survey - in order to get an impression of the DSM potential for each identified industry subsector. Participants of this survey are experienced professionals as well as fully trained power engineers of several different German industry associations, such as the “Verband der Industriellen Energie- und Kraftwirtschaft” (VIK).

PRELIMINARY RESULTS AND DISCUSSION

In this section some preliminary results of the analysis of the DSM potential in Germany are presented.
The positive DSM-potential in Germany for households has been calculated by following the described approach of around 5.4 GW for leveling the fluctuating load curve of renewable energy generation. For the load shifting potential in regard to negative load, the simulation led to a DSM potential of almost five times higher with about 23.8 GW. Important factors when first introducing DSM in the Household sector will be freezers and refrigerators as well as electric heat pumps and night storage heaters. Cooling units are relatively easy to implement because the user in not integrated in the process of demand side management. The other important applications for DSM on the household level are heating and water heating devices that are going to have noticeable positive changes in the market penetration in the coming years.

Table 3: Maximal DSM potential in the sector commerce, trade and services

Type	Maximal DSM potential [MW], 2010	Maximal DSM potential [MW], 2020
Trade (Retail-und wholesale)	1100	1000
Hotel + Restaurant	600	530
Agriculture	675	600
Gardening	20	18
Public baths(pools?)	1400	1200
Laundry	170	150
Manufacturing	1200	1040
Total	**5165**	**4600**

Table 3 shows that there are three main types of commercial, trade and services for DSM programs. For trade the most important applications are refrigerated warehouses and freezers. In addition air conditioning systems also allows for load shifting. In public pools the heating and the circulation process of the water can be shifted without any notice by the customers. Furthermore, if there are any financial incentives for manufacturing companies to shift their power demand a significant DSM potential will be available by shifting production processes to low peak times.

If all DSM potentials were simultaneously activated and DSM ready (necessary ICT infrastructure), a total power of 5.2 GW would be available for shifting purposes. That represents two times of the current primary control reserves in the synchronized ENTSO-E power grid [15].

For a possible 2020 scenario it can be assumed that the energy demand will decrease yearly by 1% compared to economical growth (increased energy efficiency for production or building service engineering). Thus, the DSM potential would decrease to 4.6 GW using the mentioned model.

No DSM-Potential has been calculated yet for the approach of data collection for the industry sector via survey. There are several different industry subsectors that still show some potential for load shifting from a technical point of view, even though most of the "low hanging fruits" have already been covered in utility supply contracts. Regarding [2] and [7] it can be expected that the total maximal DSM potential for industry in Germany accounts for 2.8 GW.

SUMMARY AND OUTLOOK

The first results of the DSM estimations of the VDE ETG task force together with previous studies show that there is a high potential in Germany for DSM. Financial incentives and an information and communication (ICT) infrastructure are needed to make DSM useful.

In households a maximal potential of 5.4 GW (max. load 23.8GW) can be used for leveling the grid load. The sector commerce, trade and services can contribute with up to 6.5 GW mainly in trading and manufacturing companies as well as in public pools. Previous studies showed a DSM potential of up to 2.8 GW in the industry sector. The survey mentioned in this work will probably show what amount is already used and what can be activated with the right conditions.

In the next step of the analysis, the load blocks will be put into the simulation tool to find the optimal allocation of the load shifting over one typical working day and one weekend in both summer and winter. Based on the expected results it might be possible to estimate a DSM potential with a 15min precision.

Furthermore, scenarios for 2020 and 2030 will be specified taken into account an increased level of efficiency, economical development and other trends of relevant parameters.

ACKNOWLEDGEMENT

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