OPTIMAL USE OF DEMAND RESPONSE POTENTIALS IN MEDIUM-SIZED INDUSTRY USING DYNAMIC ELECTRICITY TARIFFS

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ABSTRACT

Stimulating industrial customers to shift a part of their electrical load by offering dynamic tariffs could help to synchronize electric load and generation in a system with a rising share of fluctuating generation.
This paper describes the requirements for the identification of suitable customer processes as well as an appropriate structure of dynamic tariffs. Furthermore it gives an example of possible savings using this demand response program for an industrial process realised within the research project "Happy Power Hour".

INTRODUCTION

Due to the German energy transition the prices at spot markets are more and more volatile since the production of electrical power from mainly wind turbines and photovoltaic systems generally fluctuates. Until now all Households and most of the medium-sized companies conclude long-term energy supply contracts and thus cannot benefit from volatile energy prices.
The aims of the presented demand response program developed in the framework of the public-funded research project "Happy Power Hour" are on the one hand reducing the energy costs for the involved medium-sized industry companies by shifting a part of their processes to cheaper hours within the day. On the other hand positive effects for the whole power system like reduction of grid expansion costs and the opening of the market for ancillary services to industrial flexibilities can be achieved.
Many industrial processes are expected to offer a flexibility potential which is not used until now because its use for purposes like balancing markets require an external control of this processes by an aggregator or energy retailer. A lot of industrial customers do not want to relinquish the control of their processes. With the described demand response program they can keep the control of their processes as well as achieve additional savings.

IDENTIFICATION OF APPROPRIATE PROCESSES

The first step of the implementation of this demand response program into another industrial customer is the identification of the suitable processes providing the needed flexibilities. Within this investigation processes are sought which are either not highly integrated into a process sequence or have storage possibilities. The storage could be an inherent temperature buffer or a space for storing an intermediate product before or after the process.

Need for a preselection algorithm

The ongoing investigation shows that within the identification of suitable processes a huge amount of parameters have to be considered. This can be technical parameters like the installed load, the consumed energy and the part load capability as well as organisational parameters like the utilization rate, dependencies with other processes or process planning requirements. Due to the large number of data which is requested to determine the load shift potential a previous quick check by a preselection algorithm based on few measured data would be helpful to identify the processes that are expected to have the biggest load shifting potential. These processes could be investigated in details thereafter. With this two-step approach the identification of suitable loads could be simplified.

Examination by a detailed questionnaire

The loads that were selected by the preselection algorithm are examined by a detailed questionnaire, which is divided into two parts. The first part has to be filled out only once per company. It evaluates the general conditions of the company like working times, the maximal load peak which is relevant for the calculation of the grid fees, the existence of an energy management system and a load measurement concept and other general conditions.
The second part of the questionnaire has to be filled out separately per process, where a process is a single machine or a combination of machines which are operated together. All relevant parameters of the process, like the electrical data, information about the running

times, the utilisation rates, possible storages before, in or after the process and the control hardware and software are collected.

Example of a load shifting potential

For the simulation of possible savings at the end of this paper a forging process is used. It consists of a conductive heating unit and the forging hammer. This process is the first part of a tool production line and has the possibility to store the forged metal pieces afterwards. The utilization rate is not on all days of the examined year very high. These three facts open up the possibility to shift a part of the load curve as shown in Figure 1. A further shift of the production times is not possible due to operational restrictions such as noise protection regulations during the night.

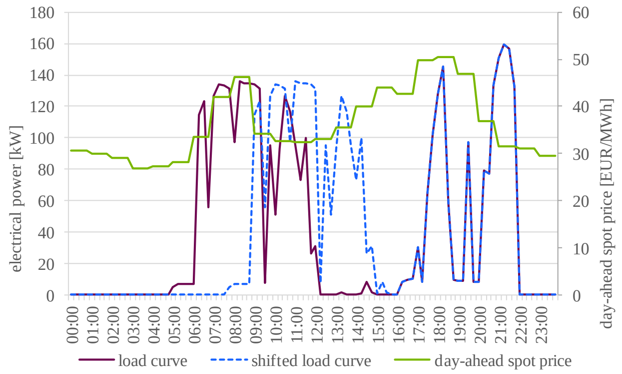

Figure 1: Price curve, load curve and shifted load curve of an exemplary forging process [1]

DYNAMIC TARIFF WITH HOURLY PRICES TRANSMITTED DAY-AHEAD

The dynamic prices are based on the day-ahead spot market. At the day-ahead spot market the bids have to be placed until 12 am. Because the energy retailer has to know the expected load curve of his customers, which depends on the daily price curve, to trade the requested energy volume a forecast of the spot market price send to the customers at 10 am. Based on this forecast the optimization algorithms of each industrial customer execute a forecast for their next day load curve. After aggregating these load forecasts the energy retailer places his bids at the day ahead spot market.

After market closing at 1 pm the energy retailer transmits the binding price curve to his customers who may execute a 2nd optimization if the binding price curve differs significant from the forecast from 10 am. Any deviations of the load curve caused by the 2nd optimization have to be cleared by the energy retailer at the intraday market. A flowchart of this process is shown in Figure 2.

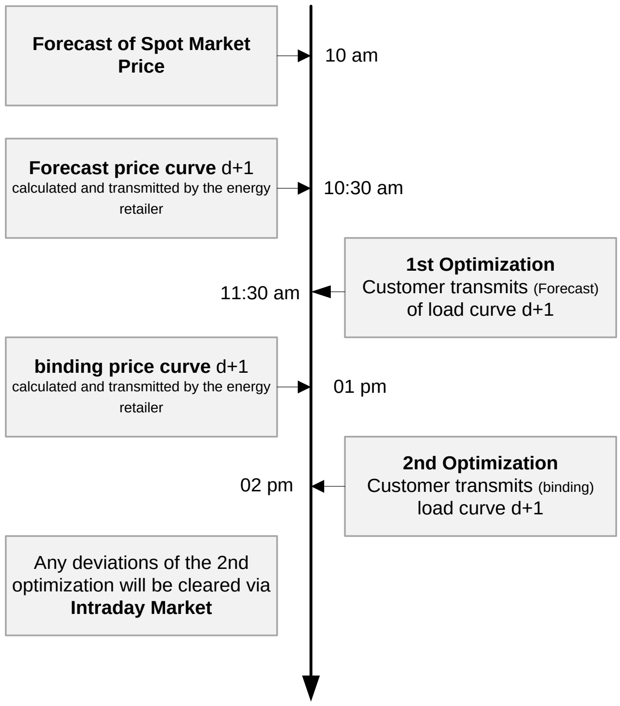

Figure 2: Flowchart of the price- & load curve forecast

Analysis of typical spreads at the day-ahead spot market

Figure 3 shows the distribution of day-ahead spot market prices in the last 4 years. It can be seen that the prices are sinking in total and the volatility is also decreasing. From the viewpoint of a demand response program these effects are reducing the incentives. On the other hand a variety of studies are prognosticating rising prices at the markets for electrical energy with respect to the shutdown of old fossil power plants in the next years [2], [3], [4].

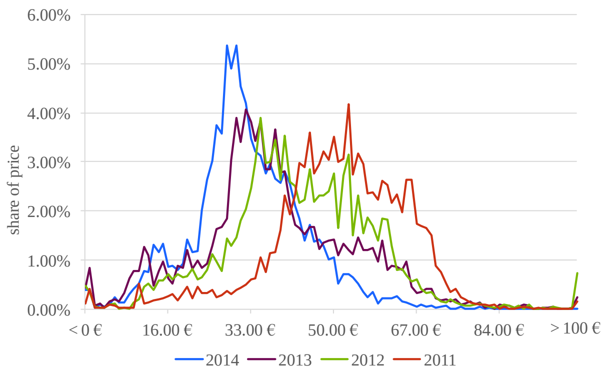

Figure 3: Distribution of day-ahead prices [1]

Because the dynamic tariffs are based on the day-ahead spot market prices the possible incentives are arising from the spot market price spreads. In Figure 4 the price spreads in 2014 are shown. Due to the fact, that a great share of flexible processes cannot be shifted for a long time the spreads within an interval of 4 hours are shown additionally to the more commonly used 24 hour spreads.

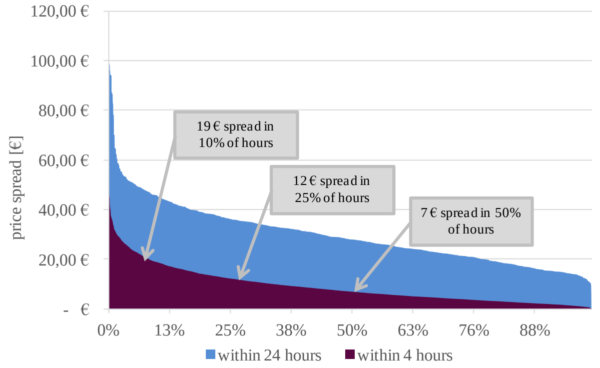

Figure 4: Day-Ahead spreads in different periods, 2014 [1]

Obviously the spreads are smaller within shorter periods of time with is caused by the still remaining differences between peak and off-peak prices. Although most processes cannot be shifted into night-time interesting price spreads can be seen within shorter periods of time, for example the shown 4 hours. Spreads greater than 19 € can be obtained in 10% of all hours of 2014, shifting a process for up to 4 hours still is causing price spreads of at least 7 € in the half of all hours of the year 2014.

Different structures of a dynamic tariff

Due to the different requirements of the industrial customers different structures of a dynamic tariff can be suitable. Three levels of automation are possible:

1. High level of automation – the flexible processes are controlled autonomously by a production planning software
2. Medium level of automation – each process is controlled by specific automation hardware system which is not expendable with a DR software
3. Low level of automation – the process is controlled manually by the staff.

The largest savings can be expected in processes of level #1. For these processes the prices can change quite often, for example hourly or every quarter of an hour. The price signal can be processed as one additional information in the process planning software, which considers it when all other signals (like production deadlines e.g.) enabling this flexibility [5].

Level #2 and #3 processes require additional automation hardware. For level #2 processes the new hardware can either control the process directly via a process bus system or communicate with the actual automation hardware. A dynamic tariff for these level #2 processes can also consist of small time steps.

Level #3 processes which are manually controlled should be coupled to a price signal with longer price zones for not overstraining the operator of the machine. With a tariff changing the price for example only 4 times a day at static time steps the operator of the machine only has to check the price signal a few times a day. For additional simplification a traffic light could signalize the operator cheap and expensive times so that he even doesn't have to take care of the prices.

With the aggregation of day-ahead price signal to fewer price zones a smoothening of price extremes and thereby a reduction of possible savings cannot be avoided.

In Figure 5 two example tariff structures for one day are shown. It can be seen, that the intraday prices show a higher volatility what can be taken as an advantage. A disadvantage is that only the day-ahead auction delivers a price curve for the whole next day, the continual trade at the intraday market doesn't provide a reliable development of the price curve within the next 24 hours. Due to the higher liquidity at the day-ahead market and the higher complexity at the intraday market a dynamic tariff based on day-ahead prices will be preferred at the moment.

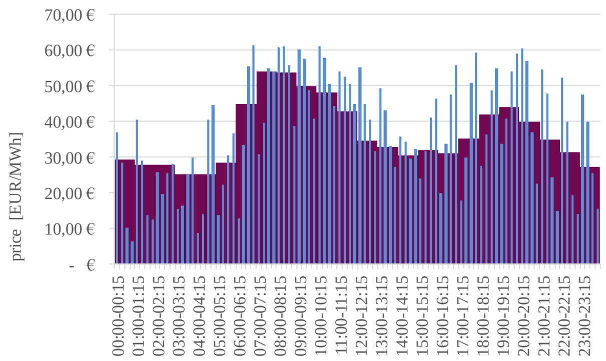

Figure 5: Tariff structure with 60 min. and 15 min. prices (based on day-ahead spot prices from 25.09.2014) [1]

For reducing the complexity for the presented level 3 processes a tariff structure with 5 static price blocks has been developed. The length of the price blocks has been adjusted for an optimal match to the historical price curves. The height of the blocks differs every day with respect to the block-wide average of the day-ahead spot market price. On every day the prices are changing at the same 5 times, so an operator of a flexible process has to check the prices only at this fixed times. In Figure 6 an example of this tariff structure is show. Although in this example a day with a low volatility is presented the disadvantage of the block structure can be seen. Caused by averaging the prices of all hours of a single block extreme prices will disappear and the differences between the price blocks are smaller.

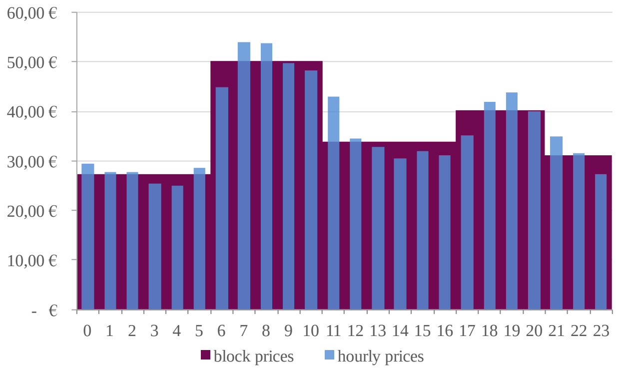

Figure 6: Tariff structure with 5 different price blocks (based on day-ahead spot prices from 25.09.2014) [1]

SIMULATION OF POSSIBLE SAVINGS

For convincing future customers of the energy retailer and for supporting the selection of suitable processes a simulation of possible savings is needed.

Structure of the Simulation algorithm

The developed simulation can deal with different levels of detail for the input data. An unshifted load curve as a reference is mandatory – the way of defining the possible load shift is optional. One possibility is to provide a second load curve which represents the shifted load. An alternative is selecting a percentage share of shiftable load or mark single hours (or quarters of hours) as shiftable. In the last option a maximum time of shifting can be selected as well as explicit hours to which the load should be shifted.

The simulation is based on historic spot market prices of the last years and could be extended to a stochastic simulation based on future price forecasts.

The result of the simulation algorithm is the possible saving of the examined flexible process with respect to the selected scenario (average of the last 5 year prices, prices of single years or forecast for future prices with raising number of price peaks). For a more detailed simulation opportunity costs, for example extra costs for a production break, could be taken into account [6], [7].

Based on this simulation an estimation about the length of the amortisation period for an investment in additional measurement- and automation hardware can be made.

Results of an exemplary process

The utilization rate of the examined forging process is not maximal at all days. In Figure 1 the load curve of such a day is shown. The forging machine was active in two periods with a break of four hours in between. By producing the first batch 2 hours and 45 minutes later 5.35 % savings could be achieved. Assuming the same mode of operation for every workday of the year the initial load curve would have caused costs of **9,777.85 €**, after shifting the operation time the costs are **9,254.58 €**, so a saving of **523.27 €** could be achieved.

A further shifting was not possible due to restrictions of noise prevention and working times. The simulation of achievable savings is based on the day-ahead spot market price; additional handling fees of the energy retailer are neglected, which is acceptable because this additive constant would not change the result. All other parts of the energy price, like for example grid fees and the EEG levy are also neglected.

The biggest spread used with this load shift was between 8 am and 11 am and was 13.84 €. Considering other days with bigger spreads, or even negative prices bigger savings would be possible.

The results show that **savings of 5.35 %** could be achieved by responding to a dynamic electricity tariff. If additional hardware like measurement or control modules are required these costs have to be considered. Processes which are already controlled automatically and that offer flexibility potentials should be integrated to demand response programs to benefit from dynamic tariffs and to support the synchronization of electrical supply and demand.

The crucial point is minimizing the effort for an implementation of new customers and new processes to such a demand response program by standardizing the methods and the used hardware.

SUMMARY AND CONCLUSION

New ways of synchronising electrical demand and generation have to be developed with the raising share of fluctuating renewable energies. Stimulating industrial customers with dynamic tariffs to shift a part of their load could be one part of the solution. In this paper the requirements of such a demand response program, especially the identification of suitable processes and the structuring of special adapted dynamic tariffs are presented. One exemplary industrial forging process is shown and the load shifting potential as well as the possible savings are discussed. For future applications dynamic prices will be an additional parameter in advanced automatic industrial process planning algorithms.

Beside the presented process a lot of studies assume a huge flexibility potential in the industry [8], [9], which could be used to reduce the costs for the costumers. In further investigations much more industrial processes will be analysed in order to find optimal, fully automated dynamic tariffs which provide enough incentives for industrial customers to shift their production in phases of low electricity prizes.

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