Providing flexibility with detachable loads Procurement and commodity product prediction

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***Abstract*— Flexibility is generally considered as the potential of a facility (generation/consumption or storage) to actively change the amount of its generation/consumption/accumulated energy based on price signals or direction. This control strategies is managed to correct deviations of the electricity grid or to ensure that the purchase/sale of electricity is profitable for the flexibility provider. This paper presents a comparison of the control of heat pump consumption to provide consumption flexibility.**

Keywords— flexibility, heat pump, demand response, baseline, rebound effect, aggregator, renewable energy, national action plan, smart grid

I. Introduction

Currently, several working groups in Czech Republic are dealing with the concept of flexibility, for example, we can mention the working group of the AKU-BAT Association, the ČK Cired working group, or the DFLEX project led by ČEPS. In general, flexibility can be seen as a newer approach with respect to ripple control technique (HDO), which is still technically capable of working, but no longer offers higher utility value to the requirements of electricity traders. Flexibility is now also associated with the concepts of Peak Shaving and Load Shifting. The first option reduces consumption during peak periods by limiting certain types of loads in order to avoid unwanted energy peaks. However, the conditions for the possibility of using such an intervention need to be evaluated before the actual operation starts so that the flexibility provider is not affected.

The second possibility of using flexible management is load shifting, which is shifting the load to a part of the day that is more beneficial for both the provider and the system operator.

Flexibility can also be found, among other things, in households, especially those with electric heating systems. Due to the thermal capacity of the household, it is possible to heat the room space to the required temperature during off-peak periods or to shut down the pump for a period of time during peak periods, but with respect to the comfort of the provider. One of the barriers to this application of controlled flexibility may be the unwillingness of customers to provide flexibility, so in the future it is necessary to come up with a suitable direct or indirect way to motivate the customer.

II. Terms related to flexibility

Prosumer - is a customer who has an electricity generation plant connected at his point of connection to cover his own consumption with the possibility to supply part of this electricity to the electricity grid.

Demand side response (DSR) - represents a change in customer demand or supply in response to a price signal or command.

Flexibility Provider (PoFl) - This is an entity providing flexibility individually or through an aggregator.

Flexibility Resource - this is a facility providing flexibility by consuming, storing or generating electricity.

Activation of a flexibility resource - this is an action by the aggregator or flexibility provider to reduce or increase consumption or generation or to change the output of the flexibility resource.

Positive flexibility potential - this is a potential reduction in load on the consumption side or a potential increase of output on the production side [2].

Negative flexibility potential - this is a potential increase in load on the consumption side or a potential decrease of output on the production side [2].

Flexibility Purchase - the conclusion of a flexibility contract between the aggregator and the flexibility provider, which allows the aggregator to vary the amount of electricity consumed and supplied at the provider's point of consumption. This contract should include the parameters of the flexibility provision (maximum load change, duration) and the method of financial compensations.

Baseline - this is a diagram of the estimated value of consumption or generation that would occur without the activation of flexibility [3].

Rebound effect - this is the potential shift in the flexibility provider's consumption or production over time due to the activation of the flexibility, which causes further deviation of the entity responsible for the flexibility provider's deviation.

Baseload - this is the minimum continuous consumption of electricity. Its delivery zone is every day of the week from 0:00 to 24:00 [4][6].

Peakload - this is the load during the peak demand for electricity. Its delivery zone is every weekday from 08:00 to 20:00 [6].

Offpeak load - this is electricity off-peak. Its delivery zone is every weekday from 20:00 to 08:00 the following day [6].

III. Methodologies for establishing the baseline

The default load diagram relates to a specific point of consumption and represents the magnitude of consumption over time, assuming that flexibility would not be activated, Fig. 1. This diagram is therefore a basic tool for evaluating the potential and actual flexibility of a given provider, especially the impact on the trader.

The baseline, as the default load diagram can otherwise be called, allows the measurement of the load on the customer sites and its good design benefits all stakeholders by aligning the activation conditions and interests of flexibility providers, aggregators, suppliers and network operators. However, the baseline is still only an estimate and the choice of an appropriate methodology is a prerequisite for its proper design.

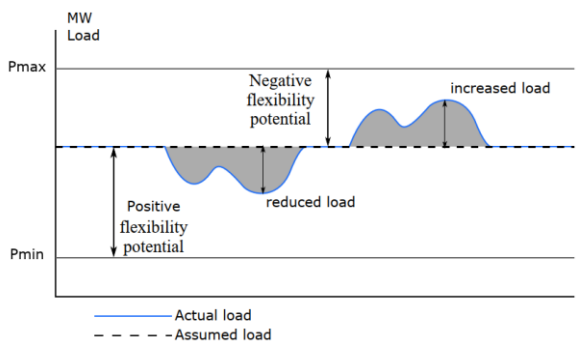

Figure 1 Load flow and load changes

There are several methodologies that can be applied, each bringing different benefits and different possibilities of application. However, 3 key factors are critical to its selection - accuracy, simplicity and integrity.

A. *Baseline type 1*

Today, the most common methodology is the baseline type 1, with common variations including:

1) Averaging,
2) regression,
3) moving average,
4) comparable day.

The characteristic elements of a Type 1 baseline are the shape of the baseline based on average historical load, measured data for each sampling point, the use of data measured on the days immediately prior to activation, and in addition, it may also consider the effects of weather or other events. Another major advantage of this method is its relative ease of application and, with the appropriate choice of time horizon and methodology to exclude inappropriate data, its relative accuracy [1].

B. *Baseline type 2*

Unlike the other methods, the Type 2 methodology does not use data measured at specific consumption points, but works with aggregated data from multiple customers with similar consumption and behaviour. It then uses the measurements at several individual sites to produce an estimate of the average load of the units in question and then uses this data to redistribute it between the individual consumption sites. This method is only advantageous in the savings for reducing the number of metering devices.

C. *"Before and after" method*

The before/after measurement method can be applied especially when the activation period is of short duration, typically from 10 minutes to a maximum of 3 hours. In the case of activation of longer duration, it can no longer be considered reliable.

D. *Reference group methodology*

The reference group method, as the name suggests, uses a reference group of similar providers to determine a substitutional baseline.

E. *Rebound effect*

In the case of DSR, the activation of flexibility also has an impact in the time following the activation, a phenomenon we refer to as the "Rebound effect". Rebound effect arises as an impact of postponed consumption. The rebound effect also has an impact on the trader as it prolongs the duration of the deviation from the established type diagram on which the trader purchases energy, and therefore, in the case of providing flexibility through an independent aggregator, it is necessary to determine how to settle this effect [5].

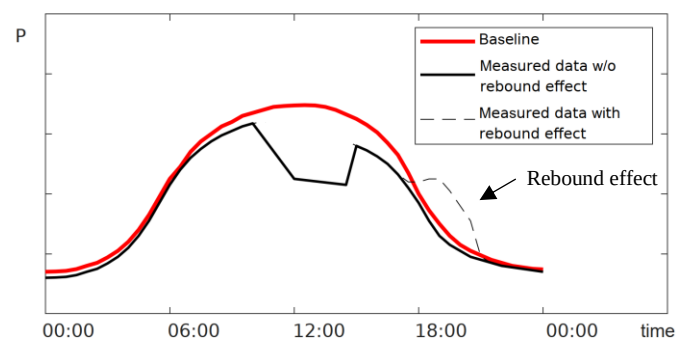

Figure 2 Rebound effect

IV. Analysis and evaluation of measured data

In the framework of cooperation with ČEZ Prodej, a.s., data from real measurements were obtained, which took place from December 2021 to March 2022. The data from this dataset usable for subsequent evaluation amounted to only 20 controlled consumption points and 6 uncontrolled ones in the period 13 December 2021-30 January 2022. The objects examined in this work fall under tariff rate D57d, which is

intended for consumers using an electric heating appliance as the main source of heating, especially a heat pump. It is a two-tariff rate, where a low tariff is used for 20 hours per day.

The data evaluation was based on a modified Baseline Type1 methodology with temperature corrections.

However, the size of the aggregation intervals significantly effects the duration of the rebound effect, the duration of which is evaluated by overcoming the initial load diagram by the measured load in the direction in which the activation acted. Throughout the measurement, it was possible to observe states where this limit was not reached due to external influences. These formally uncompleted rebound effect waveforms were subsequently plotted at 120 minutes. As can be observed in the waveforms (Fig. 3,4,5 and Fig. 6) the influence of the aggregation intervals is noticeable. The load change waveform for a aggregation interval of 15 min indicates a rebound effect duration on average up to 45 minutes longer than what can be achieved using a aggregation interval of 10 min. Fig. 2 through Fig. 5 show the rebound effect response for aggregation intervals of 1 min, 5 min, 10 min, and 15 min.

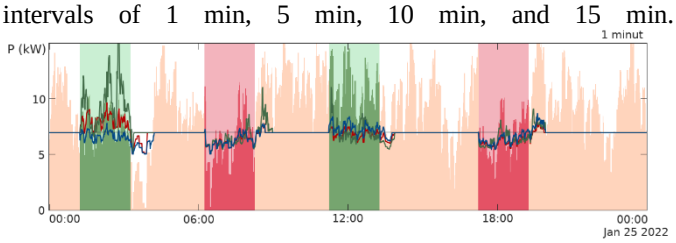

Figure 3 Relative load change for aggregation interval 1 minute

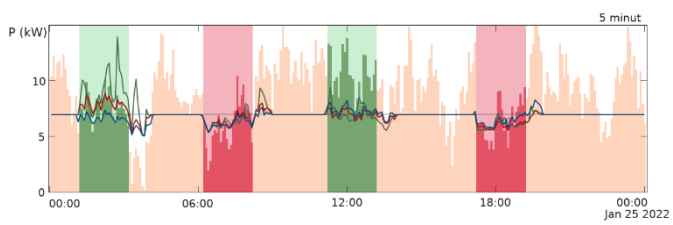

Figure 4 Relative load change for aggregation interval 5 minute

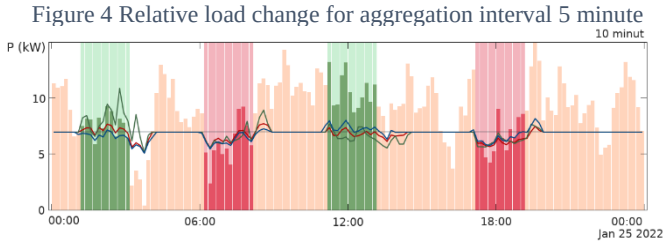

Figure 5 Relative load change for aggregation interval 10 minute

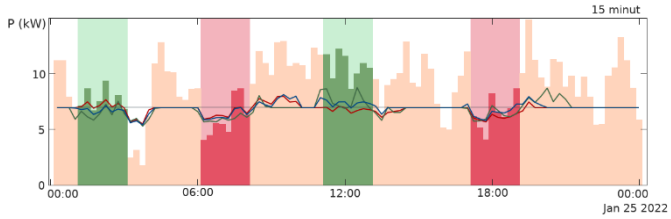

Figure 6 Relative load change for aggregation interval 15 minute

However, if the activation of flexibility is based on commands issued by an independent aggregator, it distorts the expected load diagram of the point of consumption and thus significantly affects the trader. Thus, for subsequent settlement, a substitute baseline must be established based on the selected methodology. This may be based, for example, on historical data or data obtained from reference groups. A correction is then made, which may be based on pre- and post-activation measurements, or weather or other possible variables. From the subsequent evaluation of the measured load and the established substitutional baseline, an evaluation of the impact of activation on consumption at the time of activation can be made.

V. Frequency of Heat Pump Response to an Command

The average frequency of response to an command is the basic information indicating the success of the activation. For this statistic, the data measured in the spring period 2021 from 10.03.2021 to 30.06.2021 can be used, since this file contains information about the issued command in addition to information about the actual execution. The group used in this measurement consists of 6 examples of customers providing flexibility from the same location, identified as shown in Table 1. For this evaluation, I do not consider the instruction as a whole, but as each separate minute that the issuance/execution of the command lasted.

Tab. 1 commands to reduce heat pump power input

command	executed	issued
device_001	2902	3180
device_002	1430	2041
device_003	8660	8762
device_004	2616	3359
device_005	2741	3240
device_006	3205	3660
Total	21554	24242

Command success rate is 88.91%

Tab. 2 commands to increase heat pump power input

command	executed	issued
device_001	1098	3005
device_002	2892	3614
device_003	480	780
device_004	1199	2496
device_005	1340	3067
device_006	1851	9059
Total	8860	22021

Command success rate is 40.23%

Measurements show that the instruction to increase the power has less than half the success rate of the instruction to decrease. This is mainly due to the nature of the heat pump, which tends to maintain the temperature at the upper limit of the comfort limit and switch on when the limit drops. Its control

override temperature loop. Consequently, there is considerably less scope for increasing the input power than for decreasing it. This fact is well noticeable in the waveforms from the whole measurement, where the boost instructions are significantly more divergent and less effective.

VI. Conclusion

The growing share of volatile resources in the distribution systems brings risks associated with grid instability. One possible solution is to use flexibility on the consumption side. For the residential sector, the use of electric heating management represents the highest potential for this purpose.

In the context of designing appropriate methodologies for determining the initial load diagram, two of the three methodologies tested produced satisfactory results. There was a significant intersection between these methodologies, with the calculated data varying with an average deviation of 1.14% across the project. The low level of variation between these methodologies is the evidence of functionality and reliability of both of them, with even a relatively simple methodology such as the before/after measurement methodology producing satisfactory results. For the reference group methodology, the conclusion is unsatisfactory as it achieved an average deviation of 14.78% when compared to the primary baseline type 1 methodology. This level of bias, together with the observed patterns from the entire measurement, led to the conclusion that the methodology was unreliable. This is mainly due to the variability of the individual objects. Within a small portfolio size, a baseline cannot be established with sufficient precision based on a different group of customers. This is mainly due to the number of variables, the differences between objects and the randomness in user behaviour.

Within the commands themselves, there was a significant difference between the increase and decrease commands. From the measured data, the success rate of each type within the frequency of response to the instruction was found to be 88.91% for the decrease instruction and 40.23% for the increase instruction. A significant disparity between these values can be observed, this is mainly due to the nature of the heating system which tends to keep the temperature in the building at the upper end of the comfort limit, therefore not providing the necessary scope for negative flexibility. This finding is consistent with the assumptions and is also supported by the data from the evaluation of the amount of flexibility gained, where the amount of negative flexibility was generally lower and more volatile compared to the amount of positive flexibility.

An interesting outcome is the finding of the effect of the daytime of a given instruction, with increasing instructions typically achieving higher efficiency during nighttime hours and decreasing instructions achieving the opposite during afternoon hours. this is primarily due to the typical temperature profile of residential properties during the day. This behaviour is favourable due to the orientation of consumption peaks during the day.

In terms of the observation of the duration of the rebound effect, the work did not meet expectations, mainly due to the uniqueness of the individual results, which led to significant variation and inaccurate evaluation of the data obtained. The work then made observations about the impact of the aggregation interval on this parameter.

Based on the evaluated data, it is therefore possible to proceed with the recommendation to use significantly lower aggregation intervals such as 5 or 10 minutes. This aggregation interval will ensure higher accuracy and sensitivity just for the evaluation of the impact on deferred consumption.

The main contributions of the paper includes an introduction to the issue, a suggestion of possible methodologies for establishing a baseline load diagram, and an insight into the behaviour of the small portfolio of households with a heat pump used in the flexibility framework, including illustrations of different types commands and aggregation intervals.

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