THE IMPACT OF MODERN TRENDS ON CHANGES IN THE NATURE OF SMALL-SCALE

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Along with changes in the nature of low voltage consumption points, there are changes in load and supply profiles. The paper uses real data to illustrate the transition from the standard load profiles to the profiles influenced by modern trends such as photovoltaic power plants, electric heating, and electromobility. The examples show the potentially fatal consequences of the behaviour of active customers who use their connection up to the limits of the current contractual parameters.

1. INTRODUCTION

Over the past few years, there have been significant changes in the behaviour of some small customers. These changes affect both the overall energy and its season-scale to daily-scale progression. The trends and power balance are influenced by a massive increase in the installation of smaller photovoltaic power plants, but also by the spread of new appliances with very high consumption, such as heat pumps and electric cars.

The occurrence of certain changes in the behaviour of the small customers is almost universal, while in some cases it is still isolated and infrequent. However, even from these isolated occurrences, it is possible to deduce the performance impacts in the event that, as in other cases, they were to spread on a massive scale.

2. DATA INPUT

The analyses have been conducted on contractual data from individual consumption points and on data from type B and C continuous measurements, which are provided to customers having production facilities or customers included in the AMM pilot project. In the course of processing, a high level of anonymization of customers' personal data was maintained; the most detailed information used was the name of the municipality in which the supply point is located. Soon, the number of hourly power balance data from continuous measurements will exceed 2 billion per year. For this reason, the Data Management and Administration Department at EG.D has developed reports in the SAP BusinessObjects Business Intelligence environment that will enable working with such large volumes of data. The reports enable advanced processing of data from electricity meters in order to determine the average power balance behaviour of a certain type of customer, or, conversely, to search for customers who deviate significantly from the average.

3. PHOTOVOLTAIC POWER PLANTS

3.1. TWO GROUPS OF PRODUCTION PLANTS

At the small-scale consumption level, two distinct groups of locations with photovoltaic systems can be identified in terms of power balance behaviour.

The first of these are mostly the photovoltaic systems without storage from the time of the first solar boom, which have a significantly supply and consumption character on the same day. Power surpluses fed into the grid are limited almost from the start of the production in the early morning hours solely by consumption at the supply point, with very little overlap between production and consumption on weekdays in households with residents of working age.

The second case involves production plant with storage. These are usually easily recognizable in the consumption profile. Between April and October, they have a minimum consumption of between 200 and 400W, which is most often caused by imperfect regulation of the inverter to a zero power balance at the supply point.

To compare the characteristics of both points, a set of production plants with a reserved and installed capacity of 8–11 kW is used, divided into a group with the storage and a group without the storage. The data covers the period 1/2023 to 6/2023. The behaviour of an average production plant representing the entire sample is calculated from both groups. The graphs then plot the data that would be recorded in the electricity meter registers. The designation "production and consumption" therefore does not refer to production and consumption at the supply point, but rather to the value of the production or consumption flow of power at the transfer point in relation to distribution. The groups do not have to be homogeneous in terms of the composition of the load at the supply point; differences in load may be due to other representation of the heating tariffs within the group (which is reflected in winter). These are average values for a larger number of the supply point, so both consumption and supply values for a single hour are shown here.

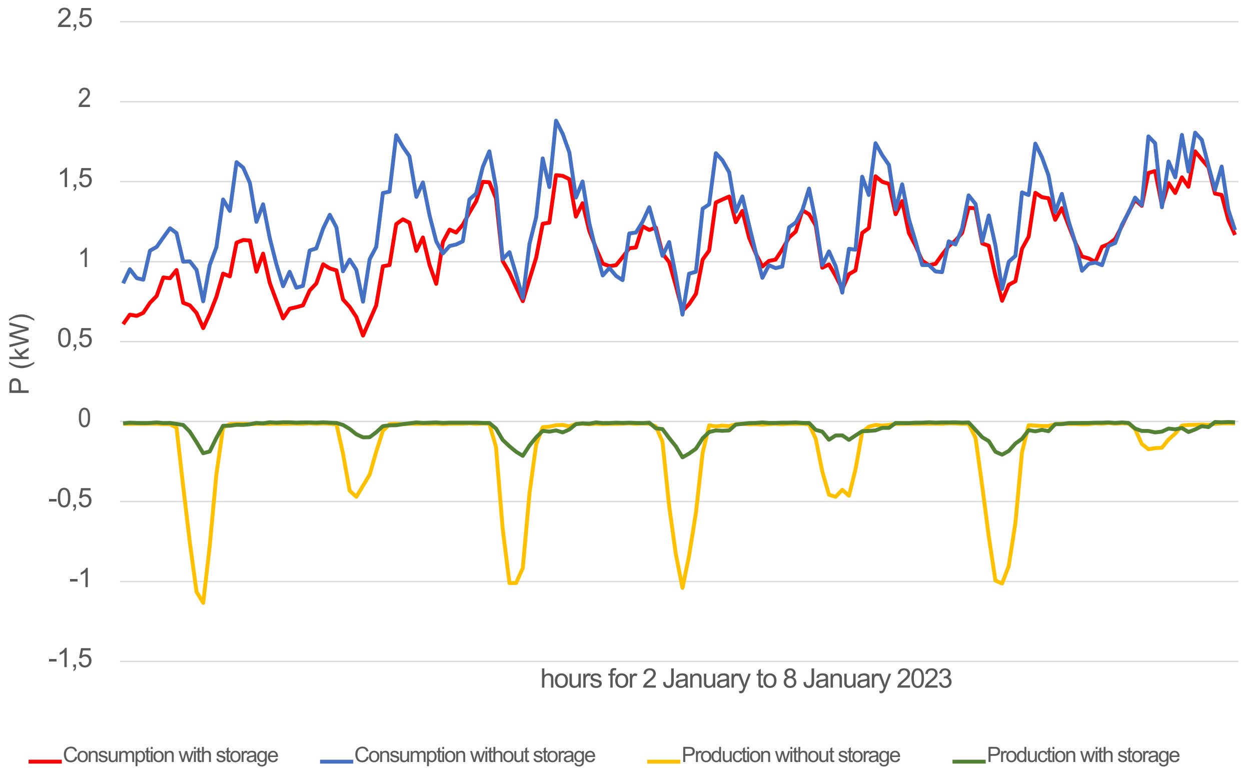

Figure 1 Power balance of an average household with a photovoltaic system – first week of January

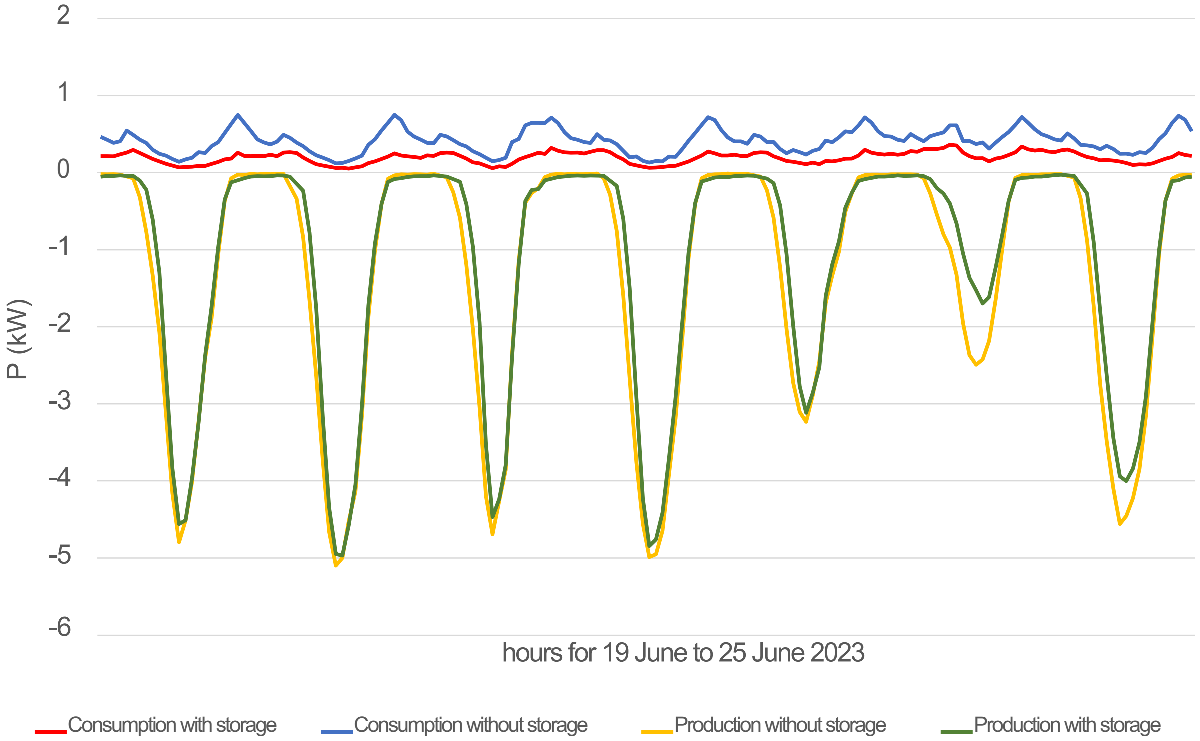

Figure 2 Power balance of an average household with a photovoltaic system – a week of June

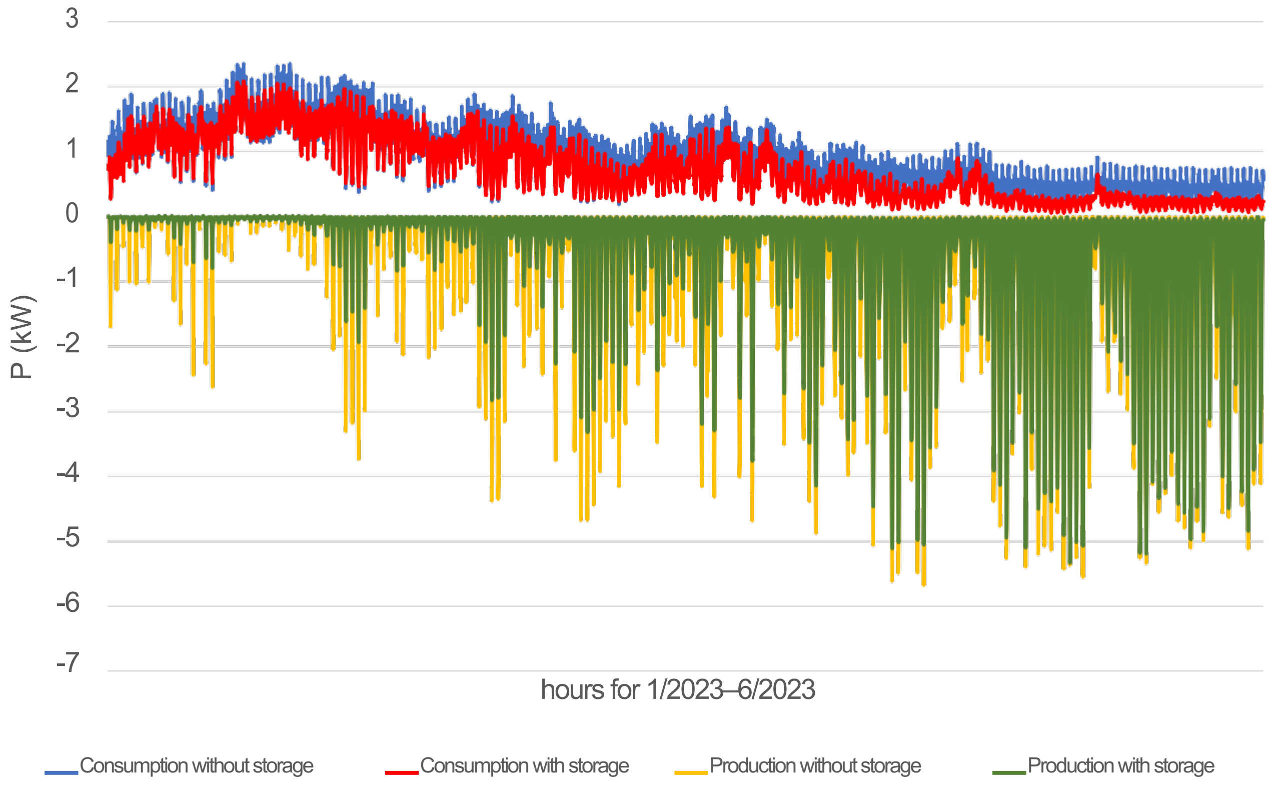

Figure 3 Power balance of an average household with a photovoltaic system for six months 1/2023 to 6/2023

3.2. BEHAVIOR OF PRODUCTION PLANTS WITH STORAGE

During the winter season, the storage system is clearly operating, with significantly reduced export to the grid into the distribution system. However, this is due to very low production, which is partly consumed immediately at the supply point and partly stored in the storage system, which is also very likely to be empty at the start of the day.

However, in the June samples, the storage effect practically disappears and the waveforms for both groups are almost identical. This is mainly due to oversized installations in all respects, which, combined with long days, maintain a constant storage close to full capacity. The storage is often fully charged shortly after dawn. Therefore, the storage has no real impact on the dimensioning of the grid linked to power supply, and no positive effect could be expected even if charging took place at midday. The positive effects could only be observed if the storage during the night or early morning hours were discharged into the distribution grid and its regulatory effect could be used the following day to limit export into the grid.

Both groups of the production plants show massive utilization of the grid in the production direction of power flow, which is significantly greater than the average winter peak load. In terms of transmitted power and power peaks, a typical customer with a production plant uses the grid significantly more than a customer without a production plant.

3.3. POWER BALANCE IMPACT OF SUPPLY POINTS WITH THE PRODUCTION PLANT

At the time of writing this paper, based on data from early September 2023, approximately 350MW of low voltage production plants were connected to the EG.D distribution grid. The supply profile of these production plants is compared with the level of small-scale consumption and with the expected situation that will arise after all production plants connected to the low voltage grid are put into operation (a total of 750MW has been contracted). Production plants that have already been contracted or implemented are therefore likely to cover more than 50% of small-scale consumption in EG.D at midday next spring.

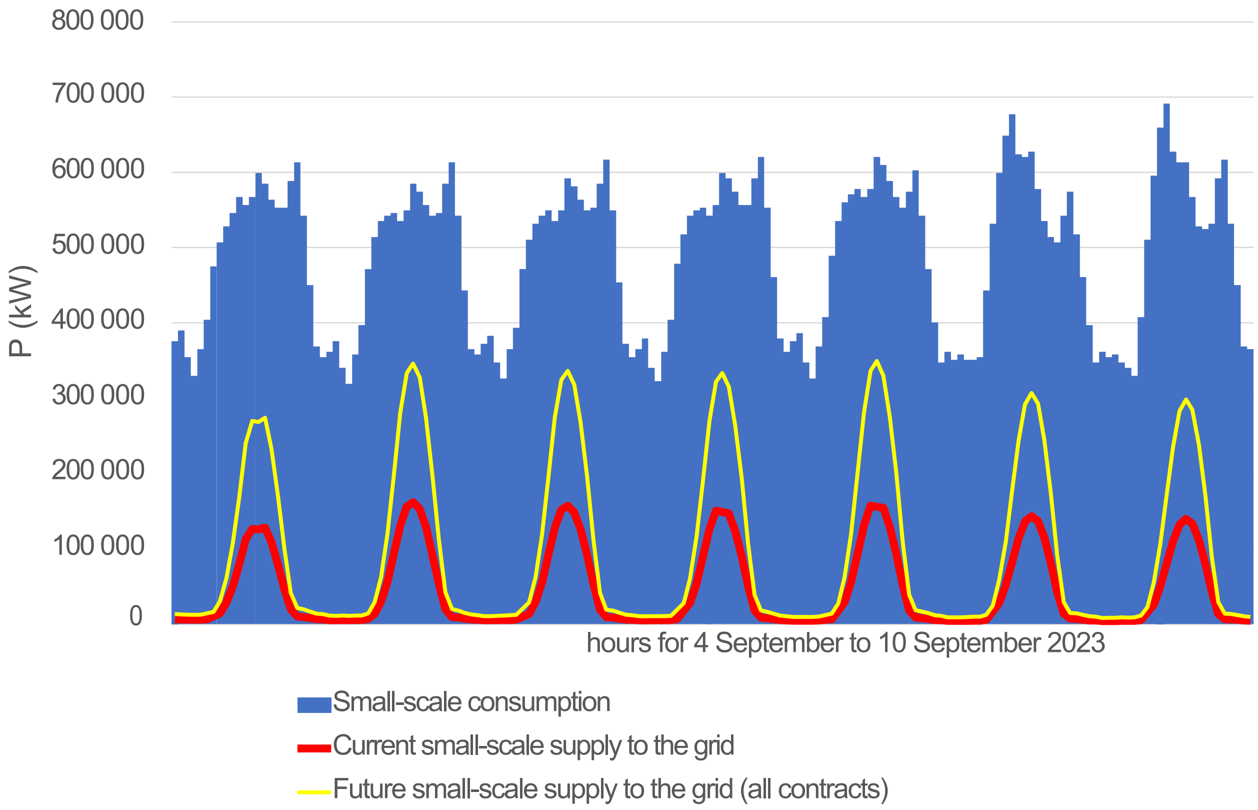

Figure 4 Comparison of small-scale customers' consumption with the small customers' supply for the first week of September 2023

4. HEAT PUMPS

Slightly neglected by media covering the photovoltaic power plants, there is also a boom in the installation of heat pumps. In 2023, 100,000 units are expected to be installed in the Czech Republic, which, with an average power consumption of 4kW, means an increase in load of 400MW. On cold days, this output is largely reflected in the grid, often increased by the power consumption of electric bivalent heat sources.

Data obtained from pilot smart meters shows that the average power consumption of households with heat pumps ranged up to around 3.5kW at peak times, which is approximately six times more than the consumption of a typical household with a D02d tariff. At the same time, this is the output that, if deployed across the board, would bring a significant part of the low voltage grids to the brink of collapse.

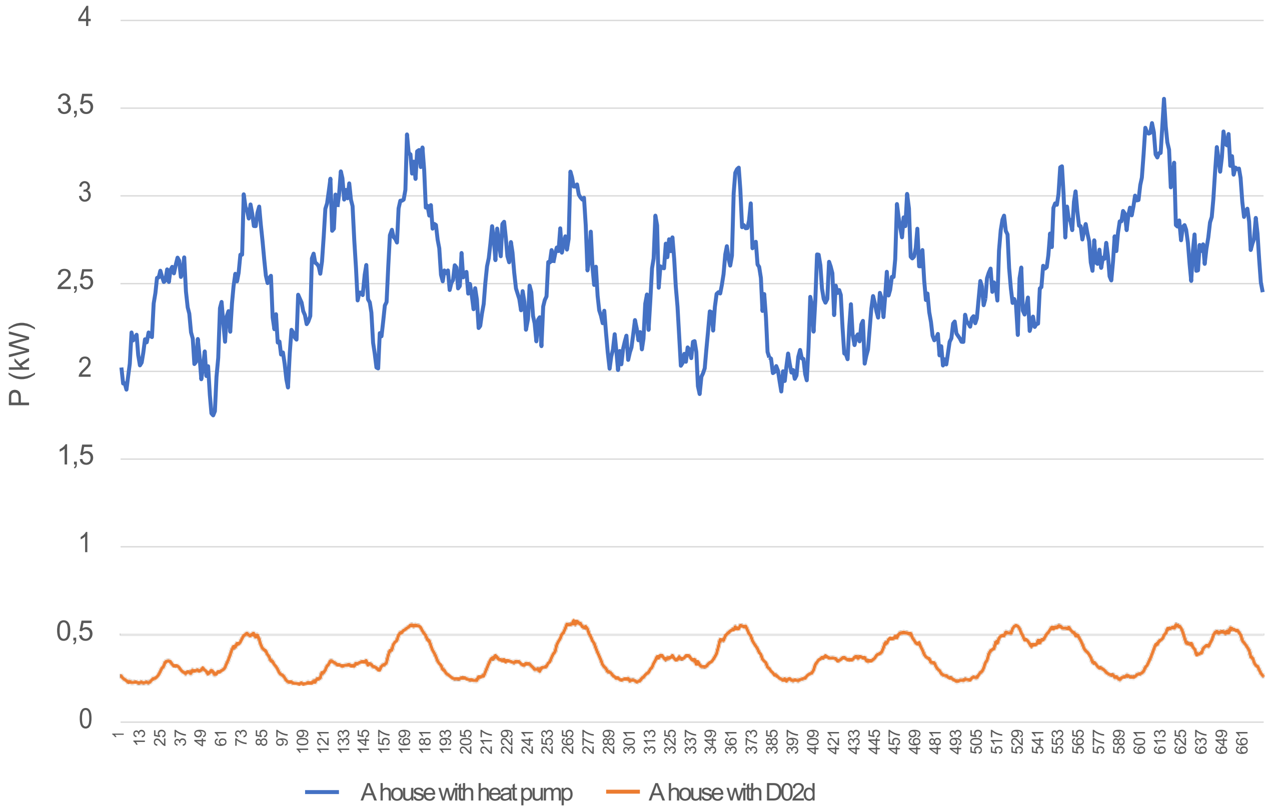

Figure 5 Comparison of consumption between an average conventional household and an average household with a heat pump, December week 2022

It is clear from the very narrow range of power fluctuations during the week that there are practically no real possibilities for controlling the power consumption of a heat pump supply point during days with sub-zero temperatures. During a week of freezing temperatures, the heat pumps are often operated at the limits of their capacity in order to supply the required amount of heat to the building. In such situations, any control measures in the form of blocking operation or postponing start-up may lead to the subsequent activation of a bivalent electric heat source with a power consumption many times greater than that of the heat pump itself. With a larger number of bivalence starts, the impact on the grid can be fatal.

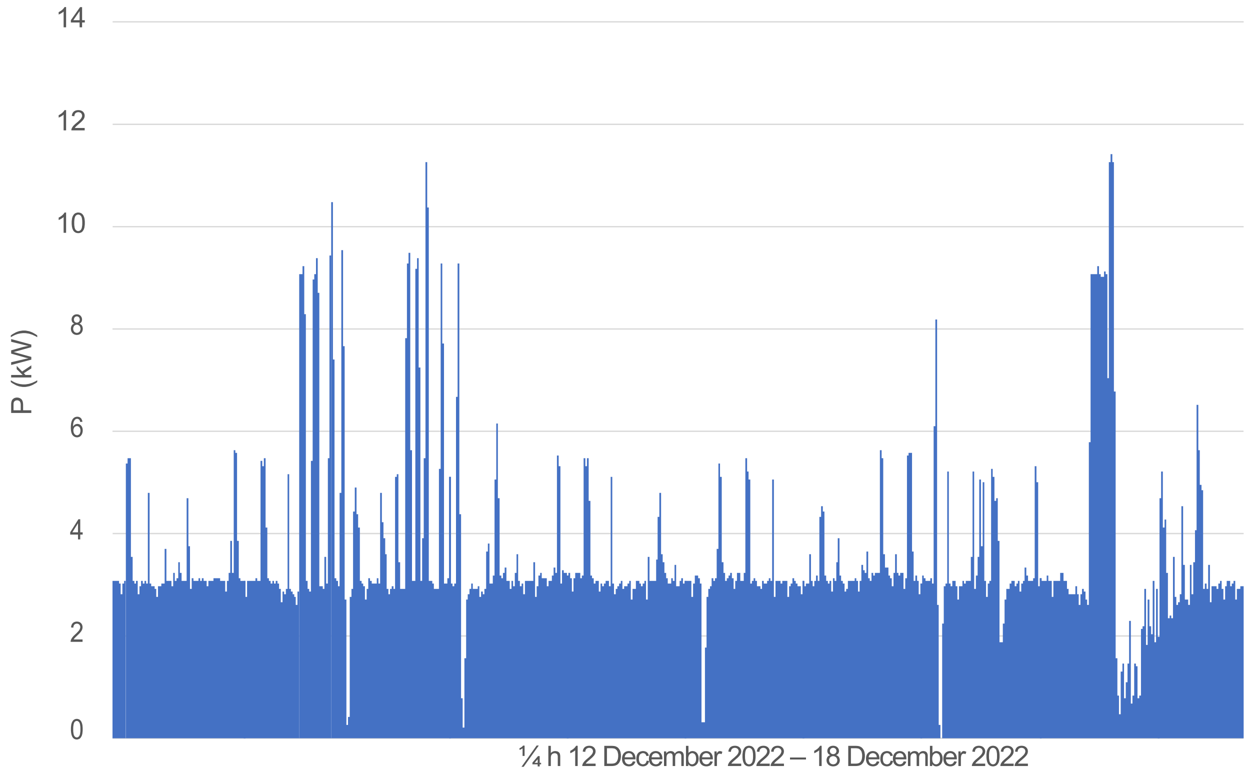

Figure 6 Weekly consumption of a household with a heat pump and bivalent heat source start-ups

If the same rate of the heat pump installations continued in EG.D as in 2022, the power consumption of the heat pumps in 2030 would be approximately 1000MW. This is almost double the current maximum winter power consumption of the entire EG.D small customer group.

5. ELECTROMOBILITY

There are still relatively few electric cars in operation in the Czech Republic at present. If they are charged at very low power (up to 3.7kW), they are very difficult to identify in household load profiles and can easily be confused with the consumption of an electric water heater, for example. In the case of heating tariffs, they may disappear between heating switching cycles. In summer, the cars may be charged from photovoltaic power plants, and this may have almost no effect on the consumption profiles.

For the reasons mentioned above, the households with the D27d distribution tariff, which is intended for electric vehicles, were selected for the demonstration, although due to the very low number of the households using this tariff, especially in combination with continuous tariff metering (these are also households with photovoltaic power plants), the resulting data cannot be expected to provide fully representative information.

According to the peaks at individual supply points, chargers with various power ratings ranging from 3.7kW to 11kW were found in the sample of households. In most cases, charging was started at 10 p.m. when the low tariff rate began.

The power balance of electric vehicle charging in the sample corresponds to the theoretical assumptions of the statistical simulations from NAP SG 17 for signal activation at a single point in time. The graph shows hourly energy consumption. With short sampling intervals, the average peak after widespread activation of the charging would probably be higher than 3kW (impact of vehicles with very low energy consumption).

On a small scale, charging the electric cars causes no problem, even when done at the same time. Charging could be considered a problem in the event of widespread use and when combined with other high consumption, for example, the heat pumps. A very serious problem would arise if the aforementioned appliances were deliberately shifted in time by the customer and activated simultaneously as so-called wild flexibility.

The waveforms show that control in terms of shifting charging power over time has very limited potential in the future, because the charging power of electric vehicles is so dominant that, in the case of nighttime charging, it creates the highest peak of the day during the night. The solution would be to distribute the charging power over the maximum possible time, i.e., to charge at the lowest possible power for the longest possible time (all night, entire work shift, etc.). The potential impact of electromobility is further amplified by the fact that the average charging power is around 8kWh per the supply point per day, which is roughly the same consumption as that of an average household today.

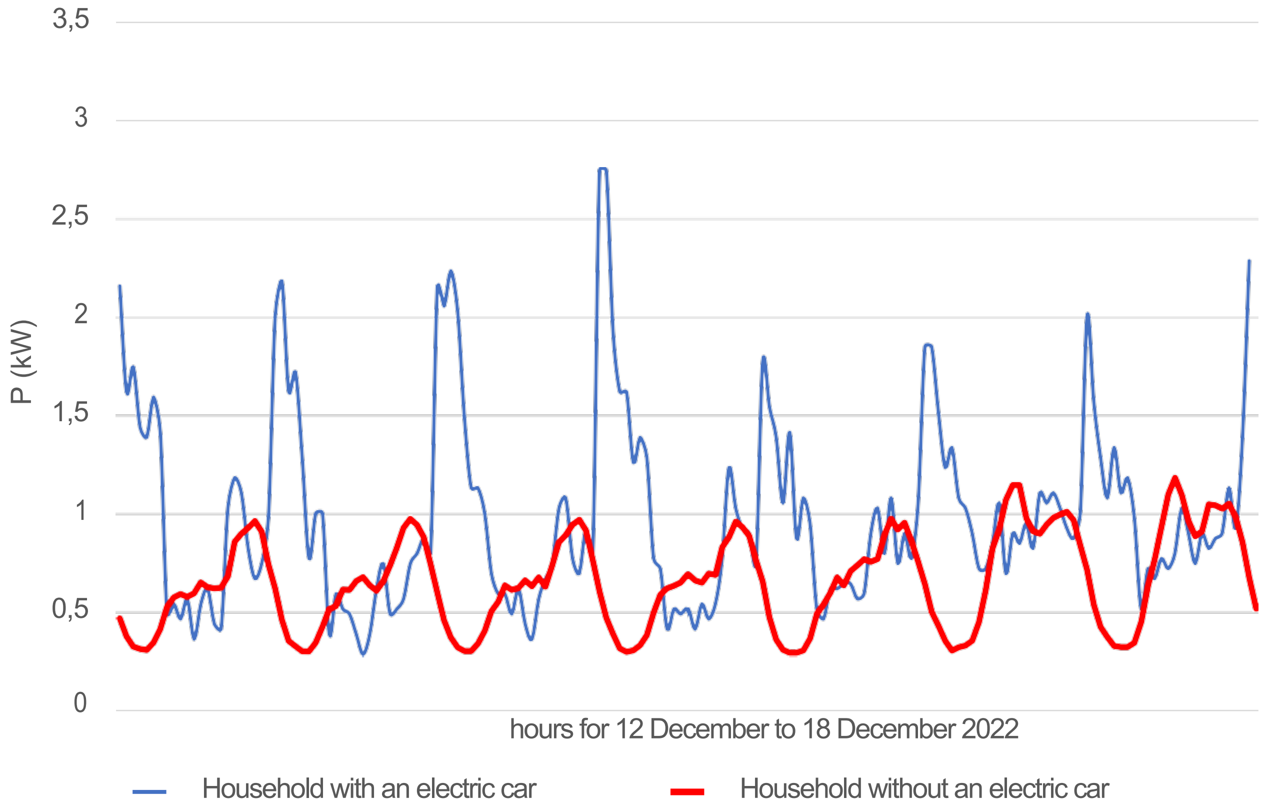

Figure 7 Comparison of average household consumption with the D27d tariff (with an electric car) and the estimated consumption of a similar average household without an electric car

6. WILD FLEXIBILITY

Until now, a customer flexibility has mostly been discussed in theoretical terms, as a tool for future power balance management at the low voltage level. This usually referred to a controlled or aggregated flexibility, where the customer's consumption is actively authorized by another entity. Indeed, this method is more a question for the future, as it is a solution that requires relatively complex communication, control algorithms, and continuous measurement with a short evaluation period. Last but not least, it also requires a sufficient number of customers who are willing to participate in such a scheme.

However, there are already customers in the grid who are taking advantage of so-called wild flexibility, where they control their consumption without the intervention of another entity, using a local control system or even manually, with the sole aim of achieving minimal electricity costs. The time course of the flexibility activated in this way can usually be described as drastic. The principle lies in finding the lowest spot price on the daily market and activate maximum possible consumption during a very short time window. In some cases, the activation is directed to the time window with the lowest spot price and, at the same time, to the period of validity of the low distribution tariff. The low-tariff window is then usually not used in its entirety; activation only occurs during the period when power electricity prices are at their lowest.

The current massive expansion of small-scale storage, the spread of spot tariffs, and the incipient wider adoption of automated supply point power balance control suggest that this phenomenon will become much more widespread in the near future. At present, there are approximately 100 customers in the EG.D grid who actively use consumption management according to the rules described above.

The following graph shows the consumption pattern of a household with large storage and an electric vehicle for a week in December 2022. Virtually all consumption is concentrated in a few night hours when the spot price is lowest. For the rest of the day, the household draws minimal power from the grid, with most of its energy needs covered by storage. The peak load is limited by the capacity of the circuit breaker and reaches approximately 22kW. During peak consumption periods, this household's consumption corresponds to that of approximately 150 standard family homes with a D02d tariff. The charging activation is directed to the low tariff time window D27d (tariff for charging electric vehicles), which the household has contracted.

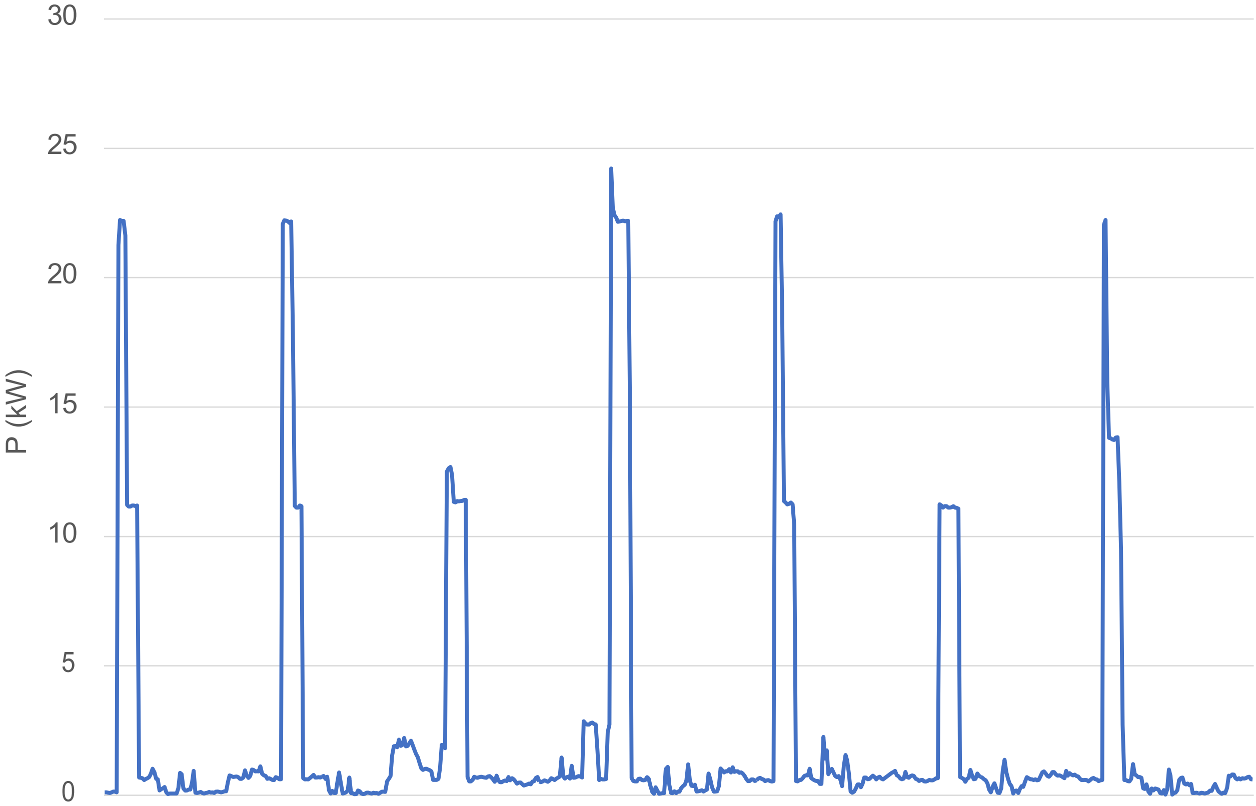

Figure 8 Weekly household waveform with an example of extreme flexibility 12 December 2022 – 18 December 2022

The next graph shows the trends for 10 selected supply points with the wild flexibility. The trends reveal a single trigger for consumption activation, which is the spot price of electricity. The resulting peak, given by the sum of individual consumptions, is then considerable.

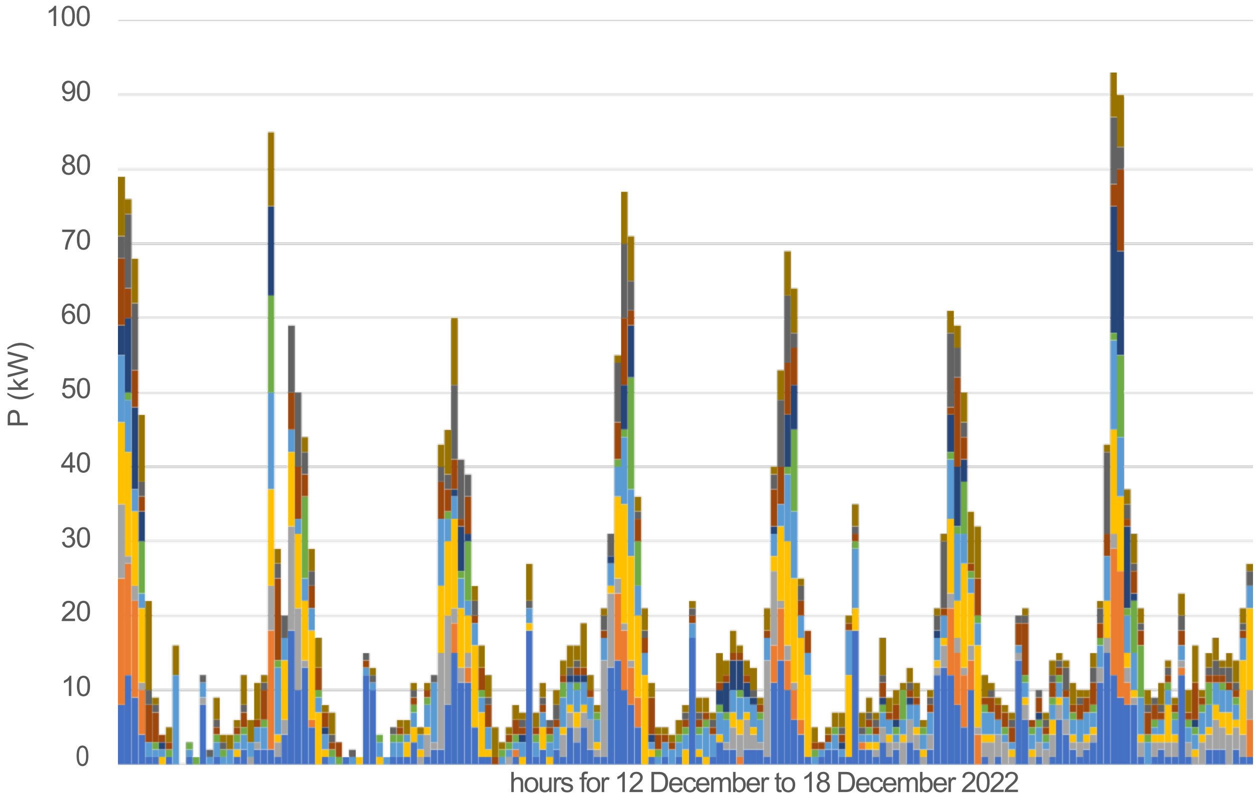

Figure 9 Summary impact of 10 households with the control focused on the lowest spot prices

However, the wild flexibility also works in the opposite direction. On Monday, 4 September, 2023, at 7:00 p.m., there was a sharp increase in the hourly price of electricity determined by the daily market to approximately CZK 11/kWh (the reason was an unfavouráble power balance situation abroad in terms of price).

Approximately 85 households in the EG.D grid responded by deliberately discharging their batteries into the grid. From the course of the selected households, it is clear that this was again an activation in a very short time window of two hours.

The source data supply waveforms showed that some customers were probably limited by the power output of the inverter or the battery. Without this limitation, the entire battery capacity would very likely have been discharged within an hour, resulting in an even higher peak.

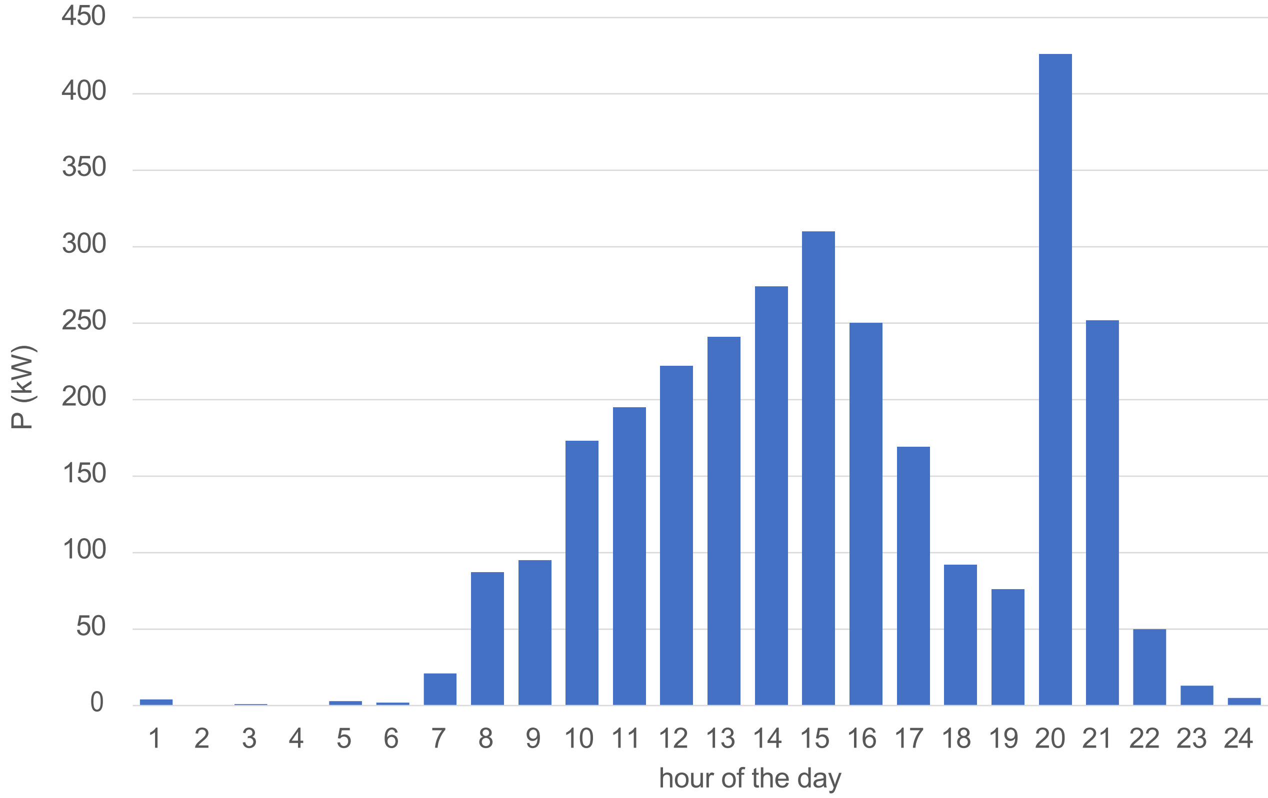

Figure 10 The supply process to distribution of 85 supply points with battery discharge to the grid during periods of low spot prices

Another example of flexible behaviour is the response of the small producers to low or negative spot prices. On Sunday, 23 July 2023, negative spot prices were reached for most of the day. Roughly 700 customers in the EG.D grid with their production plant <11kWp responded by preventing power export into the grid. For comparison, Saturday, when prices were positive, is also shown in the graph.

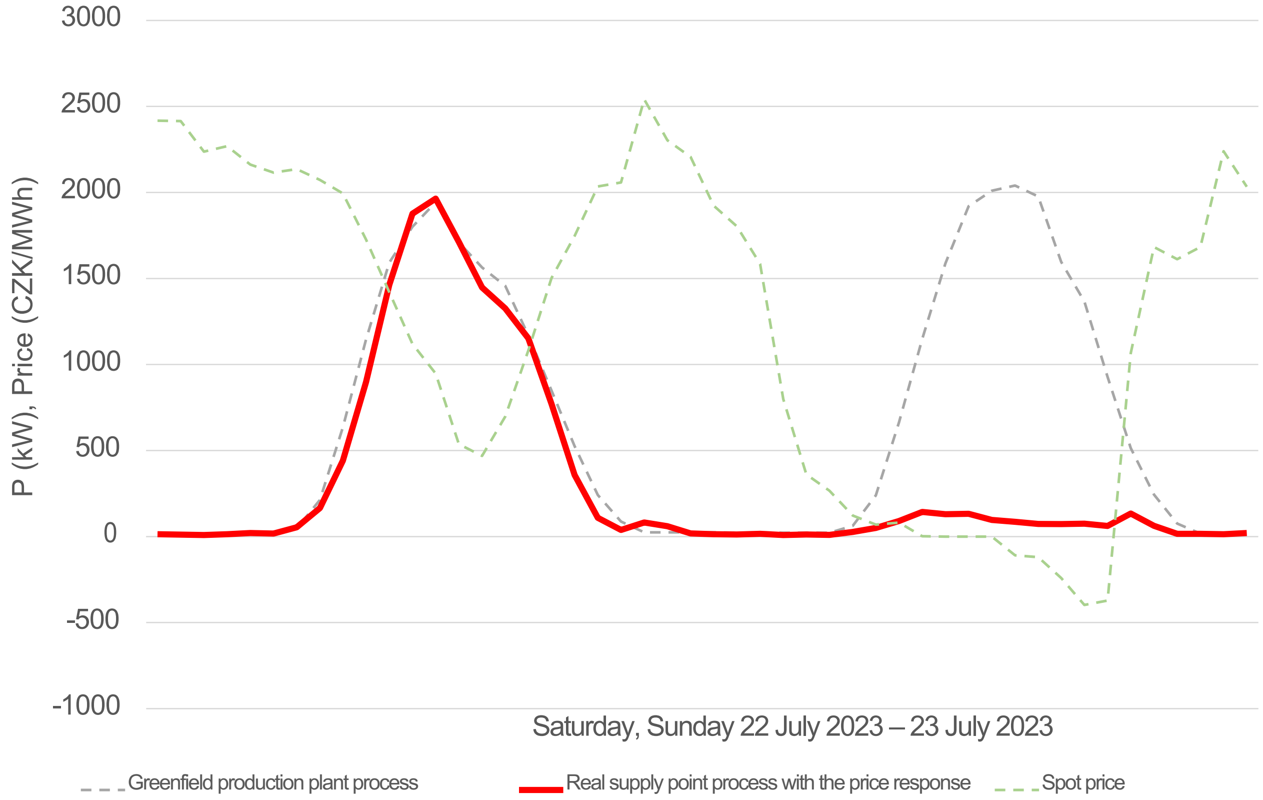

Figure 11 Response of 700 supply points to the price for 23 July 2023 – 23 July 2023 in terms of power supply to the grid

7. CONCLUSION

Although maximum attention is currently being paid to the connecting renewable energy sources, the future of their power balance behaviour is highly uncertain. Despite the increasing installed capacity in the low voltage grids, there may be a significant decrease in export into the distribution grid. This year has already seen a significant reduction in purchase prices for flat-rate electricity purchases, while purchases via spot prices are expanding significantly. Given the circumstances both at home and abroad, we can expect a significant increase in the number of days with zero or negative spot purchase prices in the near future. For some customers, this may result in restrictions or a complete blockage of the export into the distribution grid. When blocking only during hours with very low or negative prices, the change in power jumps for the whole of the Czech Republic can be up to several hundred MW.

A considerable attention must be paid to changes in the consumption, where an increase in small-scale consumption peaks to 3–4 times the current values can be expected over the next 10–15 years. This may be critical for some areas of the grid. Along with the change in the nature of consumption, it will be almost impossible to effectively manage such large outputs using existing tools such as ripple control system or time-of-use. The use of modern control methods, such as low voltage redispatching, purchasing low voltage aggregator services, and similar methods, is theoretically possible but untested, and also requires detailed real-time measurement at the low voltage distribution level. These modern control methods may generate extreme costs in their operation, which would have to be passed on to customers.

A big unknown is the area of flexibility, especially the wild flexibility, where the targeted performance behaviour of a single customer can be ten times higher than their average expected behaviour. A large accumulation of customers with the extreme flexibility can put the operation of the entire supply area in danger. Sudden changes in consumption or supply linked to the price set for a 15-minute interval can cause significant problems for the distribution, but also for the traders and transmission system operators. This is an additional response to the price resulting from the previous day's auction (energy volumes have already been contracted at a specific price).

Although a technical solution in the form of the network reinforcement is possible in the longer term, in some cases the impact of the changes in the power balance is so dramatic that reinforcing the network in the necessary time frame is not feasible in practical or economic terms.

The main role in rationalizing the impact of the increased consumption and its distribution over time will have to be played by a new tariff structure for low voltage, where maximum emphasis will have to be placed on motivating customers to spread their consumption over time and avoid creating peaks, all without the need for direct third-party control. The new tariff structure will therefore not only cover distribution costs fairly, but will also have a very significant technical regulatory aspect. A payment for peak power consumption, even at the low voltage level, will be far more effective for rational grid utilization than the current methods of the consumption management without any feedback. Another measure will have to be the specific law anchoring of the emergency procedures in the low voltage grid, which should make it possible in critical situations and after a prior warning signal to temporarily disconnect the supply points of customers who, through their behaviour, put the reliability of the system's operation in danger with a demonstrable threat to a large group of other supply points.

Without sufficient tariff and law support, the situation at the low voltage level could become unmanageable by the end of the decade.

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