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The Role of Aggregators in the Electricity Market Development

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Category of article: Review article

Highlights

- Aggregators as a new market participant
- A significant factor of green transaction - aggregator
- Efficient optimization of electricity production and consumption
- Impact on the flexibility of the power system

Abstract

In recent years, there has been an accelerated transition of the distribution power system from predominantly passive to active, primarily due to a rise in the number of electricity producers from renewable sources connected to the distribution system. In addition, amendments to the Law on Energy determined new users of the distribution system, including prosumers and electricity storage operators, whose mass connection to the distribution system is expected in the coming period. Aggregator has been recognized as an important new market participant, providing a service for the merging of electricity production and consumption in order to further sell, purchase or auction in the electricity market.

In this work, possible business models of aggregators, existing legal regulations and preconditions needed for their functioning on the market of the Republic of Serbia, shall be analyzed. Also, good international practices in this area will be presented in the work. In addition, efficient ways of merging the production and consumption of electricity, including final customers and producers, by aggregators, will be discussed.

The impact of the aggregators on the operations of the distribution system operator will be discussed, with a number of challenges ahead. Some of these challenges are related to system management and changes in power flows due to the connection of a significant number of new system users. At the end of the paper, an example will be presented that illustrates the possibility of aggregator acting in order to increase the flexibility of the power system.

Keywords

Aggregators, Managing Electricity Production and Consumption,

Energy Efficiency, Renewable Electricity Sources

Note:
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1. INTRODUCTION

Regardless of the development speed of: innovations in the energy sector, acceleration of energy transition, or finding of alternative ways of energy sources use, the fact is that electrical energy (hereinafter: EE) is produced and consumed every day. In this process, we have producers on one side, and EE consumers on the other. Both strive to optimize the production and consumption of EE in such a way that it is more efficiently produced and consumed with lower marginal costs. Where it is technically and regulatory possible, and economically profitable, the key is in their cooperation for the sake of achieving a common goal, and this is where aggregators enter the scene.

The traditional division of EE producers on the one hand and EE consumers on the other, has shown shortcomings in practice, due to the fact that the supply and demand for EE on the market can never match perfectly, which shows that in certain periods during the calendar year there are significant deviations between the EE that is produced and the one which is consumed at a given moment. There are numerous reasons for this discrepancy, such as, for example, lack of EE from hydropower plants in the middle of droughts, increased consumption of EE in the winter months, a larger amount of EE entering the system from wind power plants during the night in a period when consumption is reduced, etc. Aggregation tends to achieve the optimization of the aforementioned inconsistencies and therefore it can represent a significant factor in the stability of the distribution system itself (hereinafter: DS) and the transmission system (hereinafter: TS). Aggregators have a positive impact on increasing the flexibility of DS and TS. Therefore, an example is given in the paper that shows the possibilities available to the aggregator to increase these flexibilities.

An essential prerequisite for the formation and development of aggregators and aggregating itself is the existence of appropriate legal regulations in this area. Since in the Republic of Serbia the aforementioned regulation has not been fully completed yet, this paper represents an opportunity to point out the existing legal framework, as well as the solutions that the regulation that should be adopted could contain, as well as business models of aggregators, including different ways of merging the production and consumption of EE, which in the author's opinion would represent the optimal solution in the existing market conditions. Furthermore, this paper will present one regional experience in this area.

The start of operation of the first aggregators in the Republic of Serbia will also be a challenge for the DS operator (hereinafter: DSO). In order to ensure the optimal management of DS, the DSO should, relying among other things on the missing regulation in this area, be able to control the operation of the aggregator at any time due to specific technical properties, such as for example the change of power flows due to the access of the aggregator to DS, i.e. producers and consumers whose production and consumption are aggregated by the aggregator. Therefore, this paper will pay special attention to the impact of aggregators on the operations of DSO.

2. CHALLENGES FACED BY DSO DUE TO THE CONNECTION OF NEW USERS TO DS

2.1 New users of DS

Environmental pollution, accelerated climate changes, as well as limited fossil fuel resources have led to an increase in global awareness of the need to produce EE from renewable sources, save electricity (as well as all other types) of energy, and increase energy efficiency.

In the Republic of Serbia, as well as in other countries of Europe and the world, production facilities for the production of EE from renewable sources, primarily from biomass, sun and wind, are being intensively built. Furthermore, a significant number of end customers decide to build their own renewable energy sources production facilities that they will connect to their internal installations, where they will use the produced EE for their own needs, and deliver the surplus to DS, thereby acquiring the status of prosumer [1,2,3]. The Republic of Serbia encourages the use of renewable energy sources in various ways (such as feed-in tariffs and auctions [2] for producers, while prosumers are offered, among other things, state subsidies [4], as well as a calculation model through net measurement, i.e. net calculation [2,3].

As an important DS user and market participant, an energy storage operator [1] is also recognized, who in periods when he has available EE surplus, would store it, so that it would be used when needed. The possibility of installing a storage is also given to prosumers [2,3].

In addition to changes in the behaviour of all EE end customers, caused by changes in lifestyles, modernization of numerous processes, as well as conditions on the EE market, the transportation sector should be especially taken into account. This sector is in a transition period, due to the need to preserve the environment, reduce exhaust gas emissions, and slow down climate change. The aforementioned circumstances affect the increasing number of electric and hybrid vehicles (hereinafter: e-vehicles) on the roads of the Republic of Serbia. In order to increase their number in the future, it is necessary to develop the adequate infrastructure, in terms of building a sufficient number of public charging stations whose consumption is extremely unpredictable. In addition to the above, we should take into account the advantage of using batteries for e-vehicles, which can represent potential mobile storage of EE [5].

Considering all of the above, DS becomes a dynamic, active system in which power flows are less and less predictable due to the connection of new, and changes in the operation of existing DS users with different roles in the newly emerging market conditions. As a result of the above, DSO faces challenges in DS management, voltage regulation, increased technical and non-technical losses, increase in DS load, reduction in capacity for connection of new DS users, congestion in DS, injection of EE from DS to TS, as well as the need for significant investments in DS in order to enable stable, reliable and safe operation of DS. All of the above leads to the need for better DS flexibility, which is also provided for in the Directive on common rules for the internal market of EE [6].

2.2 The flexibility of DS

Better flexibility of DS can be achieved in various ways. First of all, the DSO itself can reconfigure DS in order to increase flexibility. One of the ways to increase flexibility is to change the power source for individual users of DS due to the connection of a new production facility in order to use the produced EE more efficiently and put less burden on DS. Furthermore, a suitable choice of DS user connection point can be an additional source of flexibility, such as, for example, connection of production facilities at locations with a high load, in order to avoid their connection at low load DS locations, which may lead to new problems in DS management.

In addition to the above, users of DS can also increase the flexibility of DESS. With the development of the EE market, DS users can change their habits due to the fluctuation of the EE prices. Average hourly EE prices by month in 2021 from the Hungarian power exchange HUPX[1] are given in Figure 1 [7]. It can be noticed that the hourly price curve follows the DS hourly load curve, which is given in Figure 2 [8], and that in periods of higher load, DS and EE prices are higher and vice versa. If the suppliers were to sell EE to end customers at dynamic prices that would follow the described trends (different prices per hour, part of the day or similar), DS users, in order to reduce their costs for EE, would naturally reduce their consumption in the parts of the day in which DS is loaded (higher prices) and postpone their consumption for periods of less load on DS (periods of lower prices), thus contributing to the flexibility of DS.

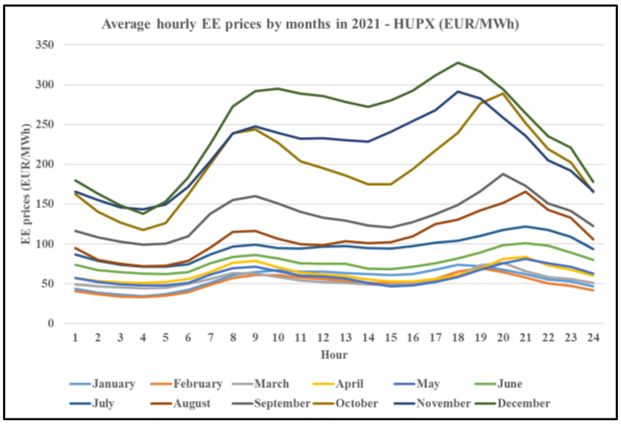

Figure 1. Average hourly EE prices by months in 2021 - HUPX stock exchange (EUR/MWh) [7]

In order to increase the described effect, DS access tariffs may become more dynamic in the future. By redefining tariffs through amendments [9] end customers (including charging stations for e-vehicles), prosumers, energy storage operators etc. would be motivated not to take over EE from DS in periods when DS is heavily loaded, but in periods of lower load. The current tariff concept with a daytime tariff lasting 16 hours and a night tariff lasting 8 hours does not achieve the desired effect completely, and the proposal is to determine at least four different tariffs that will reflect the objective situation in DS. The most expensive tariff would be in the period from 17:00 to 21:00, and the cheapest in the period from 00:00 to 08:00. (see Figure 2) [5]. Also, the modelling of special tariffs for producers and energy storage operators through amendments [9] is suggested which will stimulate energy storage operators and producers to deliver EE to DS in periods of the day when DS is loaded, i.e. to reduce or suspend deliveries in periods of less load. With the described changes, DS users would be encouraged to adjust their consumption and production independently, caused only by price signals, to the situation in DS, which would help the operations of DSO.

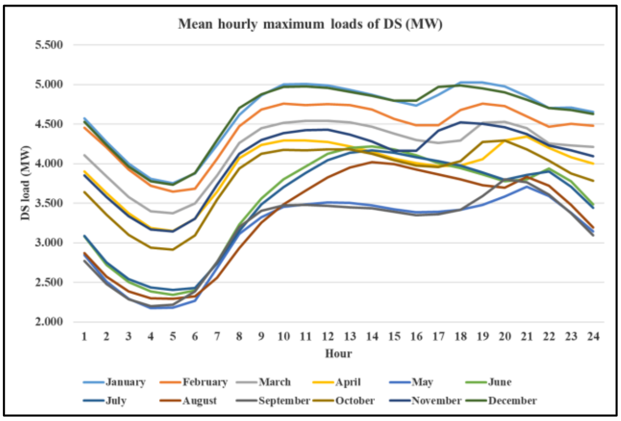

Figure 2. Mean hourly maximum loads of DS by month in 2021 (MW) [8]

In addition to the above, DSO is encouraged to explicitly procure flexibility services in transparent, non-discriminatory and market-based procurement procedures [6] in order to encourage operations and development of DSO. In view of the above, DSO may in the future conclude special contracts with DS users that would define the relationship between DS users and DSO in terms of increasing the flexibility of DS. DSO would issue orders to the users with whom it has concluded a contract, the implementation of which would facilitate DSO's operations, and the DS user would receive appropriate financial compensation. Also, in the coming period, the DSO may give DS users who want to participate in increasing the flexibility of DS various privileges in terms of reducing the costs of connection to DS, priority access to DS and the like.

DS users, motivated primarily by financial savings and additional income, but environmental protection as well, are becoming active participants in the EE market, and thus will be interested in getting involved in increasing the flexibility of DS in some of the described ways. It is reasonable to expect that the described trend will continue in the future because there has been a sudden and significant increase in EE prices on the EE market, which do not tend to fall (see Figures 1 and 3). However, due to

[1] In this paper, EE prices on the HUPX exchange are used. In Figure 3 comparison of average monthly EE prices on the HUPX and SEEPEX exchanges from January 2020 to March 2022 is given. They are almost identical.

their relatively small capacities, DS users often cannot operate on their own in the EE market. This is the reason why the aggregator [1,6] was recognized as a DS user and market participant.

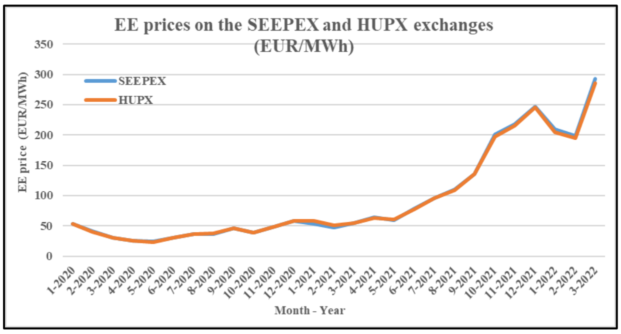

Figure 3. Average monthly EE prices (EUR/MWh); January 2020 – March 2022; SEEPEX and HUPX exchanges [7, 10]

3. REGULATION IN THE FIELD OF AGGREGATORS IN THE REPUBLIC OF SERBIA

Although the concept of aggregator is already widespread globally and is constantly developing [11], the Energy Law [1], with its amendments from April 2021, for the first time introduces the concept of aggregator into the legislation of the Republic of Serbia. Thus, in Article 2, paragraph 1, item 1a) of the Law, an aggregator is defined as a legal entity or natural person that provides the service of merging the consumption and/or production of EE for the purpose of resale, purchase or auctions on the EE markets, while in item 1) of the same paragraph, aggregating is defined as pooling consumption and/or production of EE for purchase, sale or auctions on EE markets. The aforementioned legal definitions, stipulate that the aggregator can aggregate only consumption, or production of EE, and can combine both production and consumption. This actually means that the aggregator coordinates the consumption or production of market participants in accordance with the law, where e.g. prosumers, due to their nature, can coordinate both production and consumption.

The law recognizes the aggregator as both a user of the system and a participant in the EE market, which guarantees them a wide range of both rights and obligations arising from [1], primarily the right to access DS, the right to non-discriminatory treatment, etc. Article 195, paragraph 1, item 17 [1] stipulates the supplier's duty not to expose end customers who have concluded a contract with the aggregator to unreasonable costs or contractual restrictions. In this way, the legislator wanted to guarantee that EE end customers will not be imposed additional obligations in case they decide to cooperate with the aggregator apart from those they already have in accordance with the law, which indirectly ensured the free will of end customers in the EE market to aggregate their consumption.

In a slightly more detailed manner, the rights and obligations of the aggregator are determined in Article 210b [1]. Thus, it is prescribed that the aggregator acts on the EE market in the name and on behalf of the market participants for whom they perform the service of unifying consumption and/or production, thus giving the aggregator the role of an agent in accordance with the general rules of the Law on Contracts and Torts. This actually means that the legal consequences of actions undertaken by the aggregator on the EE market, within the limits of legal authority, directly affect the producer or consumer of EE who has concluded a contract with the aggregator. Therefore, the clauses that are related to agency from the current Law on Contracts and Torts should be applied to the aggregator, including the clause of transgressing the limits of authority, if they are not in conflict with the nature of the aggregator. Therefore, it is necessary for EE producers and/or consumers who decide to aggregate their production or consumption to familiarize themselves in detail with the legal consequences of the aggregator's actions, especially with regard to the responsibility they could possibly bear due to actions taken by the aggregator on their behalf and for their account.

The same article [1] further stipulates that the aggregator is obliged to: 1) treat the market participant in a non-discriminatory manner; 2) publish the general conditions of the offer for the conclusion of the contract, that is, to inform the market participant in a convenient way about the offered conditions; 3) provide all relevant data to the market participant free of charge at least once during the accounting period if the market participant requests it; and 4) to inform the market participant about the aggregation function on its website, or in another appropriate way. The aforementioned rules are only set in principle and their further development is expected, primarily through amendments to the valid Rules on the operation of the DS [12, 13] and Rules on the operation of the EE market. [14].

4. THE ROLE OF AGGREGATORS ON THE EE MARKET

Each user of the system, including the aggregator, is obliged to arrange access to the system to which he is connected, as well as balance responsibility. All users of the system independently arrange access to the system and balance responsibility, except for those who have concluded a supply agreement for the entire production of the EE with the supplier. In the described case, the supplier has the obligation to regulate access to the system and balance responsibility for the points of handover of the system users in question. System users who are part of an aggregated group, in addition to contracts regulating supply, access to the system and balance responsibility, conclude a separate contract on aggregation with the aggregator. Furthermore, the aggregator as a system user and market participant is obliged to regulate access to the system and balance responsibility. [1]

4.1 Relationship between DSO and aggregator

The main goal of DSO is that at any time there is enough EE in DS to meet the needs of all users of DS. In the realization of this goal the aggregator can play a key role in the future. As already stated, its role is to aggregate the consumption and production of several market participants with their different functions (end customers, producers, energy storage operators, prosumers, etc.) in order to complement each other and enable greater financial savings for the aggregated participants on market (hereinafter: aggregated group), profit to the aggregator, the supplier and the balance responsible party (hereinafter: BRP), but also enable greater flexibility of DS, which achieves the full effect of aggregation. The aggregator will receive financial compensation from the DSO, while the members of the aggregated group will receive financial compensation from the aggregator (direct financial compensation, or various privileges in terms of reduction of electricity bill, etc., depending on the conditions under which the aggregation contract was concluded).

In order to implement the orders of the DSO, examples of the aggregator's action on the members of the aggregated group will be given below. For the purposes of this paper, the case of an aggregated group in which final customers are aggregated will be analyzed (industrial final customers, public e-vehicle charging stations, households, final customers who own e-vehicles, etc.), producers from renewable sources, prosumers (with and without own storage) and energy storage operators.

In the event that DS is overloaded, DSO will issue an order to the aggregator, in accordance with the concluded contract, to provide the amount of *X* EE to DS. At the same time, the aggregator, in accordance with the aggregation contracts it has with the members of the aggregated group, can issue an order to:

- controllable production units to increase the production of EE by the amount of PRp;
- end customers (including public e-vehicle charging stations) to reduce consumption by the amount of KKp, compared to their initial plan, which will reduce the amount of required EE for the end customers in question;
- storages (if they are filled) to deliver an additional amount of EE Sp over the planned amount of EE for delivery to DS, that is, to reduce the offtake from DS for Ssp, compared to the plan;
- prosumers to increase the delivery of EE to DS (if at the given moment the production facility produces EE, i.e. from the battery if they have one) by the amount of KPIp, i.e. to reduce offtake from DS (to reduce consumption or to use EE from their own battery if they have one and if it is filled) for the amount of KPPp.

With all the described measures, acting of different market participants who are part of the aggregated group, through the aggregator, the total available EE in DS increases, in accordance with the request of DSO, by the amount *X*:

$$X = PRp + KKp + Sp + Ssp + KPIp + KPPp \qquad (1)$$

There are also opposite situations, in which there is more EE in the DS than is needed at a given moment (e.g. during the night). The DSO issues an order to the aggregator, in accordance with the concluded contract, to reduce the total amount of available EE in the DS system by the amount Y. At the same time, the aggregator, in accordance with the aggregation contracts it has with the members of the aggregated group, can issue an order to:

- controllable production units to reduce EE production by the amount of PRs;
- end customers (including public e-vehicle charging stations) to increase EE consumption by the amount of KKs compared to their initial plan, which will increase the required EE for the end customers in question,
- storages to reduce the delivery of EE to DS by the amount of Ss compared to the plan, i.e. to increase the offtake from DS by Sss compared to the planned amounts,
- prosumers to reduce the delivery of EE to DS by the amount of KPIs (if at the given moment the production facility produces EE to increase the consumption of produced EE, i.e. to charge their batteries if possible), i.e. to increase the offtake from DS by the amount of KPPs (to increase consumption or to use EE from DS instead of its own battery if it is charged).

With all the described measures, the action of various market participants who are part of the aggregated group, through the aggregator, the total available EE in DS is reduced, in accordance with the requirement of DSO, by the amount Y:

$$Y = PRs + KKs + Ss + Sss + KPIs + KPPs \qquad (2)$$

The aggregator determines, primarily on the basis of economic parameters and the aggregation contract, which of the listed resources it will engage in order to fulfil the order of the DSO. The effect of the aggregator is equivalent to one power plant that produced the amount of EE X at the required time in case it is necessary to increase the total available EE in DS, i.e. reduced its production by the amount of EE Y and thereby reduced the total available EE in DS by that amount. In view of the above, it can often be seen in the literature that aggregators are named as virtual power plants [15, 16, 17].

4.2 Business models of aggregators on the EE market

The supplier, which is also a BRP, or has transferred the balancing responsibility to another BRP, can also play the role of an aggregator. The practice of European countries so far has shown that suppliers are reluctant to take on the role of aggregators [18], because this affects the reduction of EE sales (especially in periods of high prices), which is their core activity, thereby reducing their own profits.

On the other hand, the aggregator can operate independently from the supplier, which is also the so-called BRP, independent aggregator [6]. By activating its mechanisms, an independent aggregator can cause additional costs to both the supplier (unsold purchased EE in a certain hour) and the BRP (imbalance in the observed hour). In such cases, compensation for unsold EE to the supplier and costs of BRP imbalance by market participants is provided, but only to the realistic extent caused by the action of the aggregator [6]. In [6] it is defined that the method of calculating the amount of the mentioned compensation is approved by the regulatory authority.

The third possibility is that the independent aggregator is BRP, independent from the supplier. This concept is initially more realistic, because in the case that there are no orders from the DSO, the aggregator can manage the participants in the market it aggregates in such a way as to contribute to the reduction of its own imbalance costs. Suppliers acquire EE to sell to end customers, prosumers, energy storage operators, etc., which they supply according to their EE needs plan. However, suppliers plan the amount of EE that they will buy from producers, prosumers, energy storage operators, etc. BRP reports the hourly amounts of EE for their balancing group to the TS operator (hereinafter: TSO) one day ahead. By comparing the real, realized hourly values and the reported position for BRP, TSO calculates the cost of imbalance on an hourly basis for each BRP [14]. Realization that in the observed hour differs from the reported position (e.g. a rainy day instead of a sunny one and the production of solar power plants is significantly below the planned, sudden stoppage of work of a large industrial end customer due to an accident and his consumption is 0 kWh instead of the significant one that was planned, or a sudden unplanned increase in consumption, e.g. heating of a large number of households with devices that work on EE due to failure of the district heating) will cause significant imbalance costs for the BRP in question. Precisely in such situations, when there are no DSO orders for the aggregator, the aggregator can play a key role in reducing the costs of the BRP imbalance. In the event of an unplanned reduction in consumption, he can reduce the production of EE controlled power plants, increase the consumption of other end customers, reduce the delivery of EE from storage, etc. and vice versa in the event of an unforeseen increase in needs in the observed hour for BRP. In the described way, the aggregator, which is also the BRP, will have income from ensuring the flexibility of the DSO, but also a significant reduction in costs of the imbalance of its balance group.

Therefore, the aggregator, through its functioning, can bring financial benefits to the aggregator itself, but also to the supplier, BRP, as well as to the members of the aggregated group. Furthermore, aggregators have a significant positive impact on DSO in terms of increasing the flexibility of DS (general and local) e.g. by shifting consumption from the part of the day in which DS is overloaded to the part of the day in which the load on DS is less, better balancing of the entire DS, neutralization of the effect of intermittent production of variable EE sources, reduction of losses in DS, integration of new production capacities from renewable sources without large investments in DS , as well as increasing the flexibility of TS and delaying investments in it. Also, the action of the aggregator can replace the management of expensive production capacities by managing consumption, storing or using stored EE or activating production units whose management is cheaper.

5. METHODS OF MANAGING PRODUCTION AND CONSUMPTION IN AGGREGATED GROUP

Aggregators can manage production and consumption by issuing orders to increase/decrease production, i.e. consumption to market participants that they aggregate. Market participants can implement the order of the aggregator in full or to a lesser or greater extent than the given one. Another way of management is automatic, where the aggregator remotely issues an order to automation that physically reduces/increases consumption, i.e. production. For this type of management, a certain level of technical equipment of the members of the aggregated group is required, whereby those who already have the possibility of automatic management with relatively small financial investments can realize the requirements of the aggregator. For other members of the aggregated group, it is necessary to make an assessment of the profitability of automatic management compared to management through the classic order of the aggregator. The second model is significantly more reliable than the first, because it does not depend on the member of the aggregated group, but its consumption or production is automatically reduced or increased by the aggregator. In both cases, the aggregator must take care of both the issued order and its execution. In the literature, it is suggested that the independent aggregator shall be equally responsible for its imbalance (the difference between the issued order and its realization) [18].

In the Republic of Serbia, there is the possibility of remote control of boilers on EE, ETS heaters and instantaneous water heaters with some end-customers from households category. A special tariff for access to DS is defined for the specified manageable consumption [9]. DSO's experiences have shown that this concept is used by a small number of end customers, with negligible amounts of EE, and does not have a major impact on the flexibility of DS. However, the described management model can be an initial idea for the further development of remote consumption management, because heating and cooling systems have significant potential for increasing the flexibility of DS, as well as large industrial consumers with separate consumption that can be directly managed.

6. PREREQUISITES FOR FUNCTIONING OF THE AGGREGATOR

The prerequisites for the successful functioning of the aggregator are, first of all, a precise forecast of the production and consumption of EE within the aggregated group, as well as the monitoring of the realized production and consumption in real time. The production forecast is influenced by many parameters depending on the type of production facility (location, temperature, wind speed, irradiation, etc.). Consumption forecasting is also extremely demanding, in terms of different types of end customers, their habits and activities. Furthermore, both consumption and production depend on the time of day and year.

Smart meters, provided in [1], are necessary so that aggregators can monitor the production and consumption of the aggregated group at any time, as well as the response to orders issued by them to change consumption, i.e. EE production [19]. In 2020, in the Republic of Serbia, TSO had metering devices at all metering points with the possibility of two-way measurement (from the grid and to the grid), data storage, tariff management, remote reading by TSO, as well as by users through the application, etc. [20]. At DS, the situation is somewhat different, where a smart meter is installed at 1.6% of end customers' handover points, as well as at 99% of producers [20]. Due to the described situation with EE measurement, DSO created predefined, substitute load profiles [12] which are used for calculation of the hourly consumption of individual end customers based on their monthly consumption. By applying predefined load profiles, the specific consumption of individual end customers are ignored, and it is not possible to obtain a completely realistic picture of their actions. In order to facilitate and improve the operations of DSO and aggregators, more intensive market development, better reaction of market participants to price signals, as well as to increase flexibility and reduce losses in DS, DSO is intensively working on the development of smart meters.

In addition to the above, it is necessary to work on the improvement of DS management, digitalization of DSO, data protection systems and more efficient data exchange with users of DS and TSO [21].

7. EXAMPLE OF THE NEED FOR INCREASING THE FLEXIBILITY OF DS IN THE CURRENT PRACTICE OF DSO

By increasing the number of production capacities connected to DS, DSO faces the problem of injecting EE into TS. The described phenomenon is primarily observed in the case of the connection of huge production capacities in areas with generally low consumption (e.g. devastated areas, mountainous uninhabited or sparsely populated areas). Given that in the described case the basic principle that produced EE must be consumed is not fulfilled at the DS level, EE goes to TS. In 2017, the first amounts of EE were delivered to TS in the amount of 3 GWh, and 12 GWh would be delivered already in 2020 [20]. The tariff for the delivery of EE from DS to TS (at 110 kV voltage level) has not been determined [9], and DSO delivers the subject EE to TS without compensation. TSO considers the described EE as the production of a virtual power plant that it further delivers to its system users (among others, DSO) and calculates TS access for it.

In addition to the mentioned financial loss, the EE in question increases losses in DS, and therefore costs for them, and additionally burdens DS. Given that the described phenomenon most often occurs in areas with a poorly developed network, network reconfiguration is not possible. By defining the new tariff system, which was described earlier, as well as choosing a suitable point for the connection of production facilities, and especially by the operation of aggregators, the described problem can be successfully solved by harmonizing consumption in the given areas with production, and adapting production to the real needs of consumers.

The above example is just one of the many challenges that the DSO is currently facing and will face in the future. Therefore, in the future, the actions of the aggregator, as well as the orders issued by the DSO, may be of a general nature for the entire aggregated group, but also localized to a certain geographical area (i.e. to a part of the aggregated group) in which overloading/under loading occurs.

8. EXAMPLE OF AGGREGATOR WORK IN THE ELECTRICITY MARKET

8.1 Description of the data used in the calculations

Within this paper, a practical example of some of the possible modes of operation of the aggregator will be given, as well as financial benefits for the aggregator and members of the aggregated group, as well as benefits for DSO in terms of greater flexibility.

233 households that are fed from one transformer station (hereinafter: TS) were observed, where each of them has a smart metering device with the ability to detect and save hourly data, as well as remote reading. For the purposes of this paper, their EE consumption was used on an hourly as well as a monthly basis. Monthly amounts of EE were used by DSO to calculate access to DS households that were taken as an example [1, 9] during 2022. Some data on the hourly consumption of EE for some of the metering points were missing, which is expected considering the type of metering devices and the technology of collecting hourly data [22]. The missing hourly data were estimated based on the monthly consumption of the observed household and the consumption profile defined by the DS Rules of Operation [1, 12].

Based on the available measured and estimated hourly data on EE consumption of all observed households, the hourly consumption of the average household supplied from the observed distribution TS (hereinafter: average household) was determined. The active EE consumption of the average household, by month in 2022, and by tariffs – higher and lower [9] is shown in Figure 4.

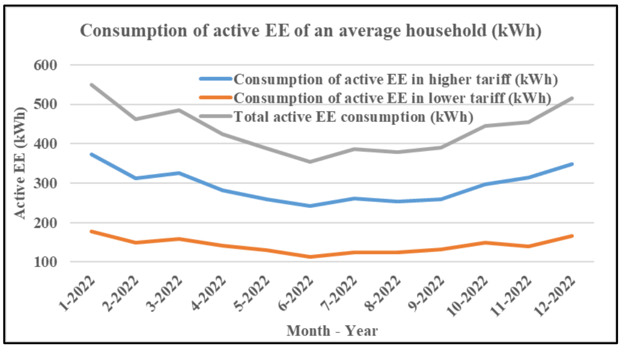

Figure 4. Active EE consumption of the average household in 2022 (kWh)

The average hourly consumption of active EE by month in 2022 of the average household is shown in Figure 5.

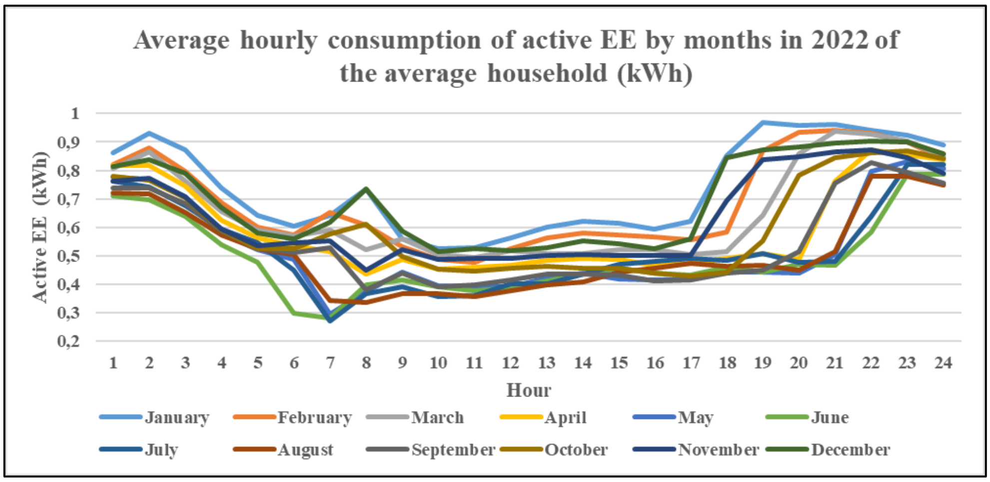

Figure 5. Average hourly consumption of active EE by month in 2022 of the average household (kWh)

8.2 Possibilities for increasing the flexibility of DSO at the level of an average household

From Figures 4 and 5 it can be concluded that in all months the consumption of active EE is low in the period from 8 a.m. to 5 p.m. which is expected because this is household consumption during working hours. After 5 p.m. there is a sudden increase in consumption that lasts until 9 p.m., 10 p.m. followed by a renewed drop in consumption that lasts until the morning hours. This specific example also confirms the justification of the proposal to change the tariff system described in chapter 2.2. However, the displayed consumption diagram provides many possibilities for improving the flexibility of DSO based on consumption management (shifting consumption from the period 5-9 p.m. to the period 0-8 a.m. or to the period 8-5 p.m.).

If the average household would build its own facility for the production of EE from renewable sources and connect it to its internal installations and thereby acquire the status of prosumer [1, 2, 3], the possibilities for consumption management would be even more diverse with a more pronounced favourable influence on the prosumers, BRP, aggregators and suppliers (financial savings and profit), as well as on DSO (less burden on DS, less losses, easier management). Figure 6 shows the prosumer exchange of EE, which is an average household, with DS by month, while Figure 7 shows the exchange at the level of an average hour on an annual level. In the calculations, a production facility with optimal installed power was used to meet the needs of the prosumer, which is an average household.[2] [23, 24].

To determine the optimal installed power of a photovoltaic power plant, it is necessary to know the solar energy resources at the target microlocation, the geographical latitude, the characteristics of the system elements and the ambient conditions [24, 25]. The optimal installed power was determined using the PVGIS[3] software package and its integrated databases [26]. Based on calculations from the program package PVGIS, data on the hourly production of the optimal solar power plant for the average household was also taken.

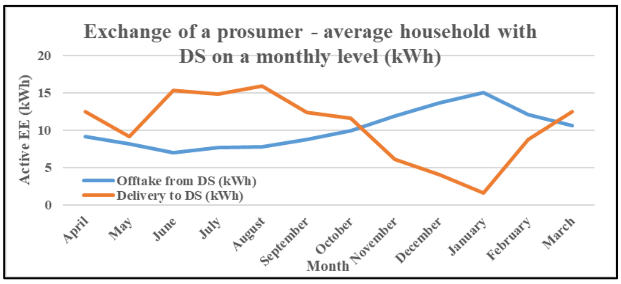

Figure 6. Exchange of a prosumer - average household with DS on a monthly level (kWh)

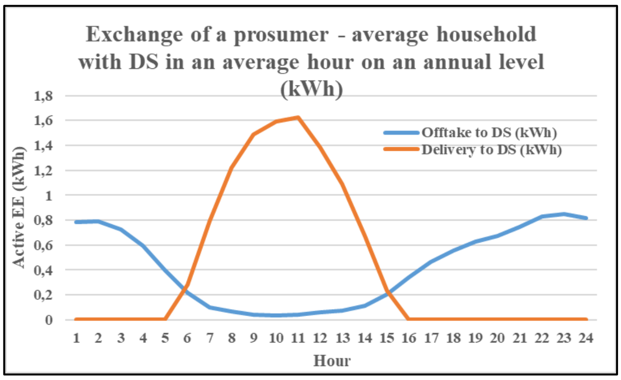

Figure 7. Exchange of a prosumer - average household with DS on an annual level (kWh)

In Figure 6, it can be observed that the delivery to DS is significantly higher than the offtake from DS in the summer months, while in the winter the situation is

[2] For the purposes of this paper, it was assumed that the production facility of the prosumer is a solar power plant, because all prosumer connected to DEES until the date of writing this paper installed solar power plant [23]. It is expected considering the amount of investment and the later relatively low needs for maintenance.

[3] PVGIS is a free online software package. It can be used for estimation of the production of solar power plants, for any location in Europe. For calculations, it uses databases on solar radiation, ambient temperature, wind speed and terrain characteristics based on satellite images. [26]

reversed. From Figure 7, as expected, delivery to DS is significantly higher in the period from 6 a.m. to 3 p.m.. from offtake of EE, while in other periods of the day the situation is reversed. This leads to the conclusion that consumption management is fully justified with the aim of moving it from the part of the day when the solar power plant does not produce EE to the part of the day when it produces EE. This is exactly how the minimum exchange of EE with DS is achieved, which brings all the previously described benefits for the prosumer itself, its supplier, BRP as well as DSO.

In addition to all of the above, the installation of storage, or the use of e-vehicle batteries as EE storage [5] can replace consumption management by storing EE in periods when the production facility produces EE and then using it in periods when the production facility does not produce EE. The best results would, of course, be obtained from a combination of consumption management and EE storage.

8.3 Possibilities for increasing the flexibility of DSO by aggregating EE production and consumption

If all observed households (233 of them) that are fed from the observed TS were members of one aggregated group, the potential for increased flexibility would be even more significant. Figure 8 shows the diagram of the consumption of all 233 households together, if only 20% of consumption in the period from 6 p.m. to 9 p.m. was moved to the period from 8 a.m. to 4 pm.

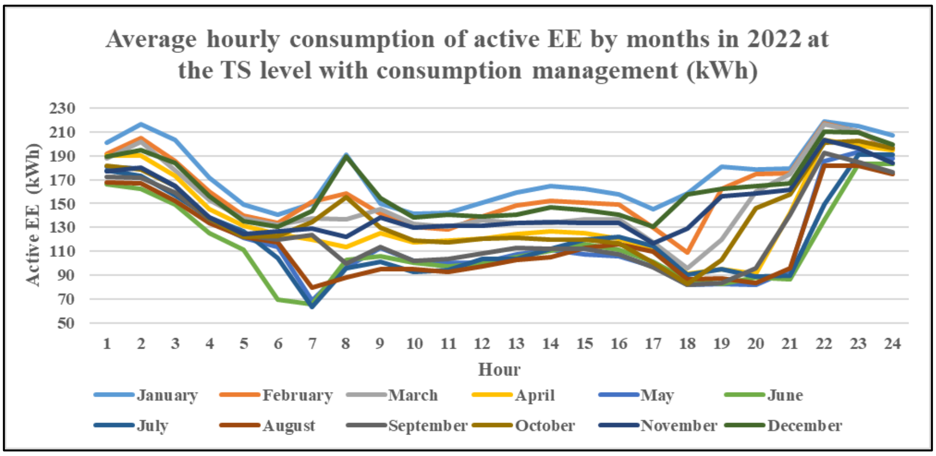

Figure 8. Average hourly consumption of active EE by month in 2022 at TS level with consumption management (kWh)

Analyzing the diagram from Figure 8, and comparing its shape with the diagram in Figure 5, it can be concluded that the described minimum consumption management can contribute to the savings of end customers in case of changing the tariff system and dynamic prices of EE, as well as easier planning of BRP work. This can lead to a reduction in balancing costs, i.e. an increase in income for BRP and aggregators. Also, DSO can more easily manage DS (a more balanced consumption diagram), and there will be less load on DS in terms of reducing peaks, i.e. increasing minimum consumption.

If some of the households that are members of the observed aggregated group acquire the status of prosumer or install electricity storages (or both at the same time), the positive effects of the work of the aggregator in question would be more visible, and its business easier to maintain and more profitable.

The above would be even more noticeable if the aggregated group included solar power plants as well (one or more of them) whose production meets the needs of end customers of members of the aggregated group. Figure 9 shows a diagram of the average hourly consumption or production of EE on an annual basis in the case of the observed 233 households and a solar power plant with optimal installed power. In production calculations, the program package PVGIS was used [26]. Figure 9 shows the production or consumption within the observed aggregated group at the level of an average hour on an annual basis.

If the aggregated group included solar and wind power plants and biomass power plants, due to the nature of their production, the positive impact on the flexibility of DSO, BRP, suppliers and aggregators would be even better. An additional potential of the aggregator can be the storage of EE as part of the aggregated group. EE can be stored in periods of lower EE price and delivered from storage in periods of higher EE price and can also work to reduce BRP balancing costs, as well as to increase DSO flexibility through aggregation.

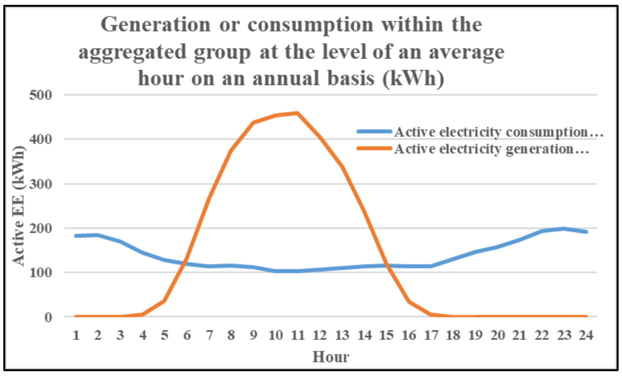

Figure 9. Generation and consumption of EE within the aggregated group at the level of the average hour on an annual basis (kWh)

8.4 The impact of the aggregator's work on the members of the aggregated group, other market participants and DSO

The aggregator can manage the members of the aggregated group in the manner described in chapter 4. In this way, which is shown in the concrete example within this chapter, the aggregator can generate income on the market of ancillary services [6], reduce the costs of BRP imbalance as well, because by operation of the aggregators, the production or consumption of the aggregated group can be planned more easily or the implementation adapted to the plan. Members of the aggregated group can have financial savings, i.e. additional income, from compensation by the aggregator in case of its action, as well as from adjusting the offtake of EE from DS in periods of lower prices, i.e. delivery of EE to DS in periods of higher EE prices in the case of a contract with the supplier with dynamic prices [6], i.e. EE consumption from its own production facility in case of prosumers. Through the desired effect of the aggregator, DSO can increase flexibility, i.e. provide more EE in DS when there is not enough of it or provide greater demand for EE when there is more in DS than needed (example given in chapter 7). The aforementioned facilitates the management of DS, reduces or postpones the need for additional investments in DS and TS, and leads to a reduction of losses in DS and TS [27].

All the described effects would be even more pronounced in the case of aggregation of the consumption of end customers with higher EE consumption (e.g. industry) because there are greater opportunities for consumption management and exploitation of EE storage capacity, and the impact on the flexibility of ODS would be more significant, as well as financial effects on the end customers, suppliers, BRP and aggregators because the price of EE for end customers who are not households and small customers is not regulated [1, 28] it is market price (Figure 3), that is significantly higher. The effects would of course be significant even if the members of the aggregated group were only households (as in the given example), EE producers from renewable sources and storage, especially bearing in mind that a large number of them are connected to DS. For the sake of illustration, at the end of 2021, a total of 3,307,538 metering points for households were connected to DS, and slightly more than half of the total EE delivered to DS users [8] was delivered to them.

An aggregator that aggregates production and consumption that is geographically grouped, for example, could contribute to an additional increase in the flexibility of the DSO at the TS level. However, although desirable, it is not a prerequisite for the functioning of the aggregator, and DS users do not have any restrictions when choosing an aggregator.

In addition to all of the above, aggregators, through their work, which is described in this paper, contribute to the reduction of environmental pollution and the transition to renewable energy sources.

9. REGIONAL EXAMPLE OF REGULATION FRAMEWORK FOR AGGREGATORS

Until the date of writing this paper, the member states of the European Union have, to a greater or lesser extent, transposed the provisions of the Directive on common rules for the internal market for electricity [6] into their legislation, which basically regulates the position of aggregators on the EE market. The Republic of Serbia as a EU candidate country is in the process of harmonizing its legislation with the "acquis communautaire", and will therefore be obliged to transpose the provisions of this directive in its legislation in the future. The Republic of Croatia, as a member state of the European Union, has transposed this directive in its legislation. It represents a country with a similar legal tradition as the Republic of Serbia, and the electric power system (hereinafter: EES) in these two countries has been developing in a similar way for decades. Therefore, in order to meet the more detailed regulation of aggregators in the Republic of Serbia, this paper will present the regulations related to aggregators in the Republic of Croatia.

In general, the issue of aggregators in the Republic of Croatia is dealt with by the EE Market Law (hereinafter: the Market Law) [29] as well as other regulations such as the General Conditions for the Use of the Network and the Supply of EE [30], Rules on Changing Suppliers and Aggregators [31] adopted by the Croatian Energy Regulatory Agency (hereinafter: CERA), which regulate the conditions and procedure for changing suppliers and/or aggregators with regard to the supply of EE, the purchase of EE and aggregation.

In terms of the Market Law, an aggregator is defined as a market participant engaged in aggregation, an independent aggregator is an aggregator that is not connected to the supplier of end customers, i.e. it is not a related entity to the supplier of end customers, while aggregating is considered an activity performed by a natural person or legal entity which can combine the power and/or the electricity taken from the network of several customers, or energy storage operators, or the power and/or the electricity delivered to the network of several producers or active customers or operators of energy storage, for the purpose of participating in any electricity market. Furthermore, the law stipulates that aggregation is an energy activity [29].

This law prescribes the rules for change and the rules on fees for changing suppliers and aggregators, which stipulate that this change should be carried out in the shortest possible time without compensation, except in the case when the system user voluntarily terminates the contract with the aggregator, that stipulates a mandatory duration and fixed prices. A special article regulates the rules related to the aggregation contract, which also stipulates the rule that suppliers may not subject end customers with whom they have a supply contract to discriminatory conditions, requirements, procedures and mandatory additional fees, based on the fact that they have a contract for aggregation [29].

Article 28 of the Market Law sets out the rules for managing consumption through aggregation, which provides that the end customer can independently or through aggregation participate equally in all EE markets in accordance with the rules governing individual EE markets, and that the aggregator can be a participant in all markets EE in accordance with the rules governing individual EE markets. It is clearly stipulated that the supplier may not charge its end customer who has concluded a contract with an independent aggregator unjustified costs or liquidated damages, i.e. impose other unjustified contractual restrictions of discriminatory, technical, management requirements or procedures, as well as that the end customer who independently or through an independent aggregator participates in consumption management pays a fee to its supplier who is directly affected by the activation of consumption management. The character of the said compensation is also determined, so among other things it is stipulated that the compensation is strictly limited to covering the costs of the customer's supplier who participates in consumption management through aggregation, the costs of the customer's supplier who independently participates in consumption management, or the costs of the supplier's BRP, which are caused by the activation of consumption management.

The aforementioned system of rules in the Republic of Croatia creates a clear and transparent basis for the development of aggregators and increase of their number and functionality, which will contribute to the strengthening of auxiliary systems for the supply system as well as DS in the Republic of Croatia. On the other hand, despite the fact that in the Republic of Serbia a set of by-laws related to aggregators has not yet been adopted, experts have begun to consider their importance and role for the EES, and the presentation of regulations on aggregation in the Republic of Croatia should contribute qualitatively to this. Completing the necessary regulation should provide the solution of the challenges aggregators are facing and ultimately, among other things, enable DS to work more efficiently.

10. CONCLUSION

In the previous period, a significant number of new participants in the EE market were included in the legislation of the Republic of Serbia. Some of them already existed in practice and performed their function, for example, e-vehicle charging stations, while some others such as the aggregator are yet to come to life. The prerequisite for this is defining regulatory rules so that all participants in the process can have certainty about the procedures and standards that are needed so that aggregators operating on the market of the Republic of Serbia could fulfil its role.

The development of aggregators, besides the producers, consumers and aggregators themselves, should bring the most benefit to EES itself, so that the aggregators would help in periods of high production or high consumption, by managing the members of their aggregated group and providing support for the stable and efficient management of the EES. Therefore, the biggest support for the introduction of this participant in the EE market should be DSO and TSO, as potential future daily users of aggregator services.

The adoption of legislation related to aggregators is only the beginning towards the promotion of the aforementioned benefits for EES. Further development of regulations in this area should contribute to more energy-efficient use of EE by prescribing clear rules that will enable minimizing of inefficient forms of consumption as well as production. The solutions presented in this paper, including the regional practice, serve to familiarize the legislators with certain aspects of the topic related to aggregators and to use them when considering the content of future relevant acts. The paper is also intended to reach wider professional public that has an interest in understanding the nature and importance of the aggregator before its implementation in practice.

BIBLIOGRAPHY

[1] Zakon o energetici ("Sl. glasnik RS", br. 145/2014, 95/2018 - dr. zakon i 40/2021)
[2] Zakon o korišćenju obnovljivih izvora energije ("Službeni glasnik RS", br. 40/21)
[3] Uredba o kriterijumima, uslovima i načinu obračuna potraživanja i obaveza između kupca – proizvođača i snabdevača ("Službeni glasnik RS", br. 83/2021 od 27.8.2021. godine, 74/2022 od 01.07.2022.)
[4] Dostupno na: https://www.mre.gov.rs/lat/aktuelnosti/javni-pozivi/javni-poziv--za-dodelu-sredstava-za-finansiranje-programa-energetske-sanacije-porodicnih-kuca--solarni-paneli--koji-sprovode-jedinice-lokalne-samouprave-kao-i-gradske-opstine--jp-3-21, [pristupljeno 07.04.2023. godine]
[5] Kuzman M., Grujić D., "Punionice električnih vozila na tržištu Republike Srbije", CIRED 2022, Kopaonik
[6] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU ("Official Journal of the European Union", No. L 158/125).
[7] HUPX Historical data, dostupno na: https://hupx.hu/en/market-data/dam/historical-data, [pristupljeno 07.04.2023. godine]
[8] Energetski podaci 2021, Elektrodistribucija Srbije d.o.o. Beograd, dostupno na: https://elektrodistribucija.rs/o-nama/informacije/dokumenta/GI_ODS_2021.pdf , [pristupljeno 07.04.2023. godine]
[9] Odluka o utvrđivanju Metodologije za određivanje cena pristupa sistemu za distribuciju električne energije („Službeni glasnik RS", broj 105/12)
[10] SEEPEX tržišni podaci, dostupno na: http://seepex-spot.rs/sr/market-data/day-ahead-auction, [pristupljeno 07.04.2023. godine]
[11] International Renewable Energy Agency, Aggregators Innovation Landscape Brief, str. 12, dostupno na: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Aggregators_2019.PDF, [pristupljeno 07.04.2023. godine]
[12] Pravila o radu distributivnog sistema, jul 2017. Godine, dostupno na: http://aers.rs/FILES/AktiAERS/AERSDajeSaglasnost/2017-07-19_Pravila%20o%20radu%20ED-ODS%20EPS%20distr.pdf, [pristupljeno 07.04.2023. godine]
[13] Pravila o radu prenosnog sistema, mart 2020. godine, dostupno na: https://ems.rs/wp-content/uploads/2022/07/PRAVILA-O-RADU-

PRENOSNOG-SISTEMA.pdf, [pristupljeno 07.04.2023. godine]

[14] Pravila o radu tržišta električne energije, novembar 2022. godine, dostupno na: https://ems.rs/wp-content/uploads/2022/12/Pravila-o-radu-trzista-elektricn-1.pdf , [pristupljeno 07.04.2023. godine]

[15] Naval N., Yusta J., „Virtual power plant models and electricity markets - A review“, Renewable and Sustainable Energy Reviews Volume 149, October 2021, 111393, dostupno na: https://reader.elsevier.com/reader/sd/pii/S136403212100678X?token=65B314150E74FF7E9307D6D02FEF118364DE7D599CDFE5979E2D60FC70A69285B5280C1FFEA6FF7A99A1E860F91F533F&originRegion=eu-west-1&originCreation=20230407152242, [pristupljeno 07.04.2023. godine]

[16] Ma Z., Billanes J., Jørgensen B. N., “Aggregation Potentials for Buildings—Business Models of Demand Response and Virtual Power Plants”; Energies, October 2017, 10(10):1646; DOI: 10.3390/en10101646

[17] Bahloul M., Breathnach L., Cotter J., Daoud M., Saif A., Khadem S., „Role of Aggregator in Coordinating Residential Virtual Power Plant in “StoreNet”: A Pilot Project Case Study”; IEEE Transactions On Sustainable Energy, Vol. 13, No. 4, October 2022, pp. 2148-215; DOI: 10.1109/TSTE.2022.3187217

[18] Vukovljak M., Janković M., „Novi učesnici na tržištu električne energije“, Cigre Srbija, Zlatibor, 2021.

[19] Zajc M., Kolenc M., Suljanović N., “Virtual Power Plant Communication System Architecture”; Control, Communication, and Optimization of Smart Power Distribution Systems, 2019, pp. 231-250; DOI: 10.1016/B978-0-12-812154-2.00011-0

[20] Izveštaj o radu Agencije za energetiku za 2020. godinu, dostupno na: https://www.aers.rs/Files/Izvestaji/Godisnji/Izvestaj%20Agencije%202020.pdf, [pristupljeno 07.04.2023. godine]

[21] Kerscher S., Arboleya P. “The key role of aggregators in the energy transition under the latest European regulatory framework”, International Journal of Electrical Power & Energy Systems, Volume 134, January 2022, 107361

[22] Funkcionalni zahtevi i tehničke specifikacije AMI/MDM sistema, sveska 1, Tehničke specifikacije brojila električne energije i komunikacionih uređaja, verzija 4.0, Usvojeno na Stručnom savetu EPS Distribucije, Beograd, 07.02.2019. godine, dostupno na: https://elektrodistribucija.rs/interni_standardi/pravila/Specifikacija_verzija%204.0_Sveska_1_Usvojeno_na_TSS_EPSD_07022019_objaviti.pdf, [pristupljeno 07.04.2023. godine]

[23] Registar kupaca-proizvođača, Elektrodistribucija Srbije d.o.o. Beograd, dostupno na: http://edbnabavke.edb.rs/registar_kupaca/DOMACINSTVA/DOMACINSTVA.pdf, , http://edbnabavke.edb.rs/registar_kupaca/STAMBENA_ZAJEDNICA/STAMBENA_ZAJEDNICA.pdf, http://edbnabavke.edb.rs/registar_kupaca/OSTALI_KP/OSTALI_KP.pdf, [pristupljeno 07.04.2023. godine]

[24] Grujić D., Kuzman M., “Modeli korišćenja električne energije kupaca-proizvođača”, Energija, ekonomija, ekologija, 2022, god. XXIV, br. 1, str. 8-16.

[25] Grujić D, Đurišić Ž, „Uslovi razvoja projekta solarne elektrane u sklopu TS „Beograd 20“, CIGRE Srbija, Zlatibor 2015.

[26] Climate online baze podataka, dostupno na: https://re.jrc.ec.europa.eu/pvg_tools/en/ [pristupljeno 07.04.2023. godine]

[27] Rajaković N., Tasić D., „Distributivne i industrijske mreže“, Akademska misao, Beograd 2008.

[28] Odluka o regulisanoj ceni električne energije za garantovano snabdevanje sa primenom od 01. januara 2023. godine, https://www.aers.rs/FILES/Odluke/OCenama/2023-01-01%20odluka%20EPS%20struja.pdf [pristupljeno 07.04.2023. godine]

[29] Zakon o tržištu električne energije ("Narodne novine", br. 111/21)

[30] Opći uvjeti za korištenje mreže iTSOkrbu električnom energijom ("Narodne novine", br. 104/20).

[31] Pravila o promjeni opskrbljivača i agregatora ("Narodne novine", br. 84/2022)

BIOGRAPHIES

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Uloga agregatora u razvoju tržišta električne energije

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Kategorija rada: pregledni članak

Ključne poruke

- Agregatori kao novi učesnik na tržištu
- Značajan činilac zelene tranzicije – agregator
- Efikasna optimizacija proizvodnje i potrošnje električne energije
- Uticaj na fleksibilnost elektroenergetskog sistema

Kratak sadržaj

Poslednjih godina došlo je do ubrzane tranzicije distributivnog elektroenergetskog sistema iz pretežno pasivnog u aktivan pre svega usled porasta broja proizvođača električne energije iz obnovljivih izvora priključenih na distributivni sistem. Pored toga, izmenama i dopunama Zakona o energetici definisani su novi korisnici distributivnog sistema, među kojima i kupci-proizvođači i skladištari čije se masovnije priključivanje na distributivni sistem očekuje u narednom periodu. Kao bitan novi učesnik na tržištu prepoznat je i agregator koji pruža uslugu objedinjavanja proizvodnje i potrošnje električne energije u cilju dalje prodaje, kupovine ili aukcija na tržištu električne energije.

U ovom radu biće analizirani mogući modeli poslovanja agregatora, postojeća zakonska regulativa i preduslovi koji su potrebni za njihovo funkcionisanje na tržištu Republike Srbije. Takođe, u radu će biti predstavljene i dobre međunarodne prakse u ovoj oblasti. Pored toga razmatraće se efikasni načini objedinjavanja proizvodnje i potrošnje električne energije, između ostalog krajnjih kupaca i proizvođača, od strane agregatora.

Biće razmatran i uticaj agregatora na poslovanje operatora distributivnog sistema pred kojim stoje brojni izazovi. Neki od ovih izazova vezani su i za upravljanje sistemom i promene tokova snaga usled priključenja značajnog broja novih korisnika sistema. Na kraju rada će biti prikazan konkretan primer koji ilustruje mogućnost delovanja agregatora u cilju povećanja fleksibilnosti elektroenergetskog sistema.

Ključne reči

Agregatori, upravljanje proizvodnjom i potrošnjom električne energije, energetska efikasnost, obnovljivi izvori električne energije

Napomena:
Članak predstavlja proširenu, unapređenu i dodatno recenziranu verziju rada „*Modeli funkcionisanja agregatora na tržištu električne energije*“, nagrađenog u STK-6 *Tržište električne energije i deregulacija* na 13. Savetovanju CIRED Srbija, Kopaonik, 12-16. septembra 2022.

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