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Flexibility services and strategy of integration of distribution system users in the electricity market

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SUMMARY

At the moment, focus in electricity markets in SEE region is on establishment of sustainable day-ahead and intraday markets and its integration on regional level. But it is a good time to think about new market principles and further development of electricity market on distribution level. Rapidly increase in deployment of renewables and other alternative sources (batteries), active participation of customers in demand response, and rise of electric mobility, have made us reconsider the expected future developments regarding the transition and growth of the power sector and electricity markets. This paper explains the flexibility of distribution energy resources and presents potential concepts of integration of distribution system users into the electricity market. As a passive market player so far, DSOs have a chance to become more active, because almost all renewables are connected to DSO level. All distributed resources that have an ability of intentional deviation of planned consumption/production profile are potential flexibility market players. Three different options of flexibility (implicit, explicit and combined) for using resources are proposed, primarily end-users as an active consumers (prosumers), and their participation in the electricity market, especially in terms of congestion management and balancing market. The most challenging step would be an integration of distribution system in the market procedure and implementation an aggregator as a new member of power sector. It can be different from country to country because it is based on a national regulation which must be in line with security and reliability of the system operations.

Some of the recommendations based on TSO-DSO report are proposed in this paper. In addition to defining the strategy for integration of the stated power system users into the electricity market, guidelines for future cooperation between transmission system operators and distribution system operators are included as well. Transmission and distribution system operators define core principles for establishment of congestion management market, as well as the possibilities of integration and common use of flexibility resources for managing congestions and balancing the system. In this case DSO will take a responsibility to manage voltage stability and congestion on their grids and the regulatory pressure will be one of the main drivers that lead companies into this challenge. Due to technical limitations in the transmission and distribution networks, the specific market properties, as well as the regulatory constraints, three different market models are given which define concept of the future congestion management and balancing market.
The new strategic directions for the electricity market development will provide new perspectives for all market participants. Having been assigned a new active role, consumers would be given the opportunity to save or profit, while system operators would be provided with new resources to use in order to maximize sustainability and security of supply of power system with minimal societal costs.

KEYWORDS

Flexibility service provider – Aggregator – Electricity market – Flexibility services – Congestion management

INTRODUCTION

Apart from the requirement to ensure the fundamental goal of safe, reliable and economical operation of the electricity system based on the principles of transparency and non-discrimination, the development of the European electricity market was also conditioned by the needs of its market participants since the beginning of its liberalization. Moreover, it has been the case that exactly these needs, among certain other factors, have been immensely affecting the future electricity market development.
After more than twenty years of deregulating national power sectors, the concept of centralization of market processes at the pan-European level has been introduced into the European electricity market development strategy. In accordance with the regulations of the European Commission, projects have been defined which aim at centralizing energy, primarily market, functions, which are currently within the competence of transmission system operators and within the framework of national legislation. The Multi Regional Coupling (MRC) project for pan-European Day-Ahead Coupling, implementing coordinated auctions of transmission capacities, establishing a single European platform for the balancing market and setting up regional security coordination centres are the first projects of the aforementioned concept of centralization of the power sector. On the other hand, considering the steady increase in distributed electricity from distribution resources, especially renewables and other alternative sources of electricity (batteries), as well as the increasing involvement of end customers as active market participants in terms of controlled demand, a key issue for further market development is how to integrate distribution system users into the electricity market.
Potentially large number of market participants and the fact that their resources can be used in multiple manners at the same time, for both congestion management and system balancing, but also for wholesale market participation, result in the need to clearly define strategic directions for further development of the electricity market. Having regard to the nature of the service which can be provided by the distribution resources in the function of safe and reliable operation of the electricity system, transmission system operator (TSO) and distribution system

operator (DSO) play a key role in defining the market development strategy. However, the current role of DSO needs to be re-examined in the first place, and then the perspective of future cooperation between the two operators should be considered. All that have to be supported by regulation at the national level.

FLEXIBILITY OF POWER SYSTEM USERS

What does flexibility exactly imply? The simplest answer would be - It is the ability of intentional deviation of planned (usual) consumption or production profiles.
Considering from the market viewpoint and from the aspect of distribution system users, the previous definition could be extended as follows - flexibility relates to the ability of a distribution system user to deviate from its planned electricity consumption (or production) profile in response to price signals or market incentives. In line with this, actually, the initial question would be - Whether flexibility can be traded and whether its purpose is to make savings or to make profit?
Flexibility of distribution resources, primarily active consumers and alternative sources of electricity (demand side flexibility), undoubtedly represents a new product in current electricity markets such as wholesale market, balancing market and market of system services.

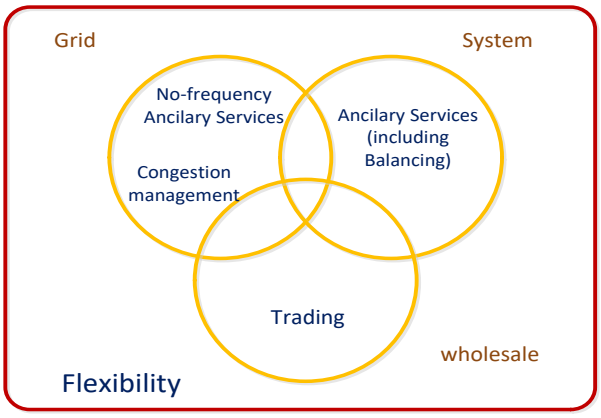

Figure 1 – Flexibility services

Establishing a flexibility services market and the inclusion of distribution system users in today`s electricity markets is not a simple process, especially having in mind that observed from the individual perspective of the distribution users, potential scope of the services, which will be provided, is generally negligible compared to the size and the needs of the system. Considering that this does not cover the main activity of the stated market participants, a lack of their knowledge and expertise in this area can be expected. With the constant increase in distributed renewable generation and storage, the only obstacle would be how to integrate the flexibility services for congestion management and balancing.
The simplest and easiest manner to integrate these users into markets would be via an aggregator. In such case, the aggregator would act as a flexibility services provider. The aggregator would serve an intermediary (through trading counter party) in the provision of services to the distribution system users either on the wholesale market or to the distribution or transmission system operators. One aggregator could represent the interests of a single user in several different markets or could be a flexibility service provider on behalf of multiple users of the distribution system. In line with the above, it naturally imposes the conclusion that the role of the aggregator in the new concept of the electricity market belongs to suppliers, but

it is not necessary that the supplier of the consumer should also be a provider of flexibility services.
System users which applied variable tariffs, for electricity or for accession to system (Time-Of-Use (ToU) tariffs), depending on market price signals, could optimize their process of electricity supply. It means that they can change, automatically or manually, their production processes planned in advance and decrease the cost of electricity supply. This type of flexibility services is called implicit flexibility [1]. In this case, a distribution system user provides flexibility services directly without aggregator.The relations between market participants in case of implicit flexibility are presented in Figure 2 a).

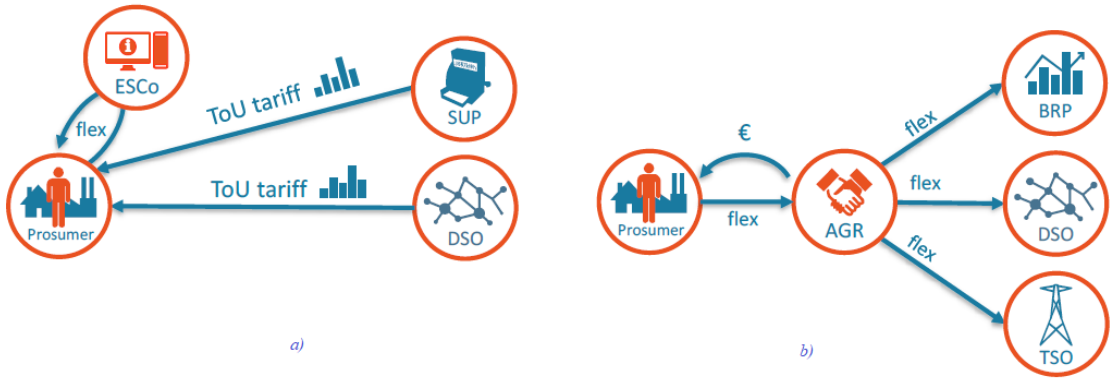

Figure 2 - Relations between market participants in case of a) implicit flexibility and b) explicit flexibility

On the other hand, providing flexibility services may be planned. In such situation, flexibility services provided by distribution system users are the products of different electricity markets. This type of flexibility services is called explicit flexibility [1]. The main goal of explicit flexibility is not decreasing electricity-supplying cost followed by profit-making. Relations between market participants in case of explicit flexibility are presented in Figure 2 b).
A distribution system user can simultaneously provide implicit and explicit flexibility services [1]. However, in this case, the issue of manipulation (abuse) may arise where the initial flexibility providers could be manipulated or misled. Special attention should be paid to defining the concept of the future market and specifying the role of the participants in the electricity market.

INTEGRATION OF DSO USERS INTO ELECTRICITY MARKET

The first impression upon summarizing the above stated leads to the conclusion that integrating a potentially large number of participants into the existing electricity markets is an outstandingly complex process. For this reason, it has to be completely planned and coordinated by the transmission and distribution system operators.
Conventional electric power systems have been organised as centralised structure which is consisted of generation, transmission and distribution, where each part has different role in order to make system sustainable, reliable and affordable for all customers. This can be described as unidirectional structure where electricity goes in only one direction, from large power plants through transmission system and distribution networks to final customers. However, increasing share of renewables connected to the distribution level, such as rooftop solar PV installations, micro wind turbines, battery energy storage systems, plug-in electric vehicles and smart home appliances, are becoming active participants in the electricity system.

They can be defined as distributied energy resources (DERs) or active demand & supply (ADS), in both cases they represent all type of system that either demand or produce energy which can be actively controlled, and in contrary to conventional power system, this will make power system decentralised. The increasing penetration of decentralised energy resources and the emergence of new market players – such as prosumers, aggregators and active consumers will bring a new market concept. It is expected that this energy transition will affect the distribution network directly, and in order to optimize customer needs, distribution system operators will need to adjust their current role. This leads to extension of DSO's roles, as such, DSOs could have access to the distributed flexibilities connected to their grid for the benefit of both the distribution grid and consumers. In their new role, DSOs could operate the distributed energy resources, if the regulatory framework allows it (explicit flexibility). If not, DSOs could at least act as neutral market facilitators and provide high-resolution price signals to the market players that own such flexibility assets (implicit flexibility).
Depending on the regulatory framework in place, The new role of DSO would include:

- DSOs as neutral market facilitators (e.g., by avoiding ownership of electricity storage and EV charging infrastructure);
- Market-based procurement of grid services from distributed energy resources;
- Optimising the use of existing distribution grids and deferring new investments, either through direct control (operation) of distributed energy resources or through market-based price signals to other actors in the electricity system, such as aggregators[2].

The new concept could be extended on TSO – DSO level as well, both as system managers, are responsible for the secure operation of respective networks, which involves managing congestion and voltage levels of their grids. Effective mutual interaction between TSOs and DSOs become increasingly important to ensure cost-efficient, sustainable and reliable system and grid operation as well as facilitating markets throughout Europe, more details about this matter are given in the following chapter of this paper.
The new role of DSOs and inclusion of DERs as a flexibility service providers, will have a positive impact on the way the power system is operated today, and three key advantages are:

- Using flexibility services would further contribute to the integration of renewables in the distribution grid and especially the integration of variable renewable energy sources.
- Managing DERs across the distribution network and mandating them to comply with certain communication requirements and dispatch signals, DSOs could avoid congestion and defer costly network investments,
- DSOs can serve as the central hub for managing consumer data related to electricity consumption, production, billing and location, as well as the type of DERs. Using these data, DSOs can better forecast demand, leading to better planning and system operation. Such data also can enable greater deployment of renewable energy by helping consumers understand their consumption and/or production patterns and make efficient decisions about their distribution network use.

To effectively benefit from the available flexibility of DERs connected to the distribution network, DSOs could deepen their role as active system operators, in addition to their role as network operators. Distribution system operators could procure flexibility services from their network users, such as voltage support and congestion management to defer network investments. In addition, DSOs might provide reactive power support to transmission system operators (TSO).
Beside advantages of this concept the increasing penetration of DERs could lead to:

- a less predictable and reverse flow of power in the system, which can affect the conventional planning and operation of distribution and transmission networks.
- to cause congestion in the distribution grid, which must be actively managed. This raises the need for a change in the role of the DSOs that have conventionally planned, maintained and managed networks and supply outages [2],

- greater variations in voltage at the distribution grid and different reactive power characteristics.

Before the implementation, the regulatory framework should ensure a market model that incorporates congestion management, including DSO and TSO, where clear roles and responsibilities are defined with a particular accent on a non-discriminatory access and a level playing field. According to the TSO – DSO Report, three different models are managed, from fully separated to fully combined and more details about this subject are provided in the last chapter of this paper. Secondly, there is a need to standardise the collection and sharing of data by DSOs as this will be supported by NRAs to define their national regulatory framework accordingly and serve as a basis for market parties to develop their business model. Lastly, smart hardware backed by communication infrastructure is needed to facilitate complex interactions between DSOs and DERs.
In what follows, CROSSBOW project examinated potential benefis and risks of the proposed regulatory mechanisms that can be used to assist DSOs to operate and plan their networks more flexibly and these can be divided into four categories:

1. Rules-based approach
Rules-based model refers to compulsory rules in network codes and regulations to impose flexibility technical requirements. It might give DSOs the tools to assist with the prevention of a black out and may allow the DSOs to manage grid situations with low transaction costs. It is transparent and non-discriminatory where all customers have the same duties and rights, but it is not on a voluntary basis and the compensation to concerned actors has to be determined by the regulator.

2. Network tariffs
These are connection agreements on a voluntary basis wherein the use-of-system tariff structures send price signals to network users, incentivising them to modify how and when they use the network and this approach would require a rather complex IT infrastructure as well as a complex design. In this case, particular attention should be devoted to the alignment between network tariffs and retail tariffs since potential interferences might arise. In order to incentivize flexibility, future changes in network tariff methodologies might be desirable – yet, such changes should be left to the regulators, since network needs might differ from MS to MS due to different network topologies, different levels of renewable energy penetration and generally different regulatory frameworks.

3. Connection agreements
This kind of connection agreement would be especially beneficial for the local network problems by engaging with the closest grid user. Under such schemes, new grid customers commit to being flexible in their use of the network when requested by the DSO in exchange for a cheaper connection. This model may put the principle of non-discrimination at risk. Some customers could make special arrangements with the DSO due to their location in a congested area while others do not have this possibility which will hamper the development of market based procurement.

4. Market-based procurement
This refers to local flexibility markets for distribution system services in which DERs could participate to support the distribution grid. The flexibility could be procured via (bilateral) contracts or in a short-term market, e.g. via a platform or other forms of interfaces. The output of these markets could be technically validated by the DSO, in co-operation with the TSO. By nature this approach would lead to the most efficient outcome if there exists a level-playing

field and the market is sufficiently liquid, but on the other side it requires some time to develop and possibly teh higher transaction costs could be expected if market for flexibility is not liquid enough to achieve a competitive price formation [3].

A relevant initiative in this regard exists within the new regulatory framework of the European Commission's Clean Energy for All Europeans legislative package in November 2016.

TSO AND DSO COORDINATION AND THEIR ROLES IN FLEXIBILITY MARKET

Implementation of the flexibility market has to be defined from the aspect of safe, reliable and economical management of the power system, but also proactive enough in terms of easier integration of the mentioned users, all while respecting the core principles:

- power system must be sustainable, reliable and accessible to all users,
- the user approaches the system observing the technical limitations and specific features of the system and has the opportunity to participate in all electricity markets under equal conditions,
- market design must be with low entry barriers, ensuring economic efficiency and market liquidity.

For this reason, the primarily issue at the moment is to define the roles of TSOs and DSOs in the development and management of the future electricity market. It is necessary to achieve their full coordination and very close cooperation, focusing on the processes of congestion management and power system balancing.
Research conducted within CROSSBOW project give us more practical solutions and recommendations to handle this issue on a proactive manner. A clear hierarchy of functions between TSO and DSOs has to be established. Namely, there are various options to organize the hierarchical structure of network optimization, and hence market structure. Perhaps the most traditional approach is whole-network optimization in which case the TSO would by default be the responsible entity considering the current state of play (TSO tasks, functions and responsibilities). On the opposite end of the spectrum is the option where priority is given to the DSO to optimize its grid in a secure way and to provide high-quality service to its customers. Then, notify the TSO of resulting power flows and offer balancing services, if available. However, arguably the most effective option that weighs the importance of balancing the system and upholding local security of supply is a 'back to back' structure, where the TSO engages with DSOs, while DSOs engage with DERs. The argument for the third option is the following. The TSO is the party that is responsible for system balancing. DSOs, after having undertaken their DER-related activities should submit their protocols to the TSO. Such protocols are especially important for those DERs that can provide services to both TSO and DSO. In this sense, all DERs have to be monitored with respect to what product they are offering and at which time. Subsequently, the data on dispatch should be given to DSOs as soon as possible, so that the DSO can react accordingly in emergency situations and control the most appropriate DER. Furthermore, any action on distribution network users requested by the TSO should be agreed with the respective DSO. A TSO should not act on any individual DER connected to distribution grid, but an order from a TSO towards DER embedded in distribution systems should be examined and executed by the DSO. However, with the current legislative framework, this option is difficult to establish. In line with the integration of the internal energy market in Europe, the EU network codes have to take account of the new tasks and need for coordination for system operators. These network codes have to account for the possibilities for cost recovery of European DSOs and TSOs, as otherwise the respective system operators do not have sufficient incentives to engage in their tasks. Lastly, it is important to highlight the fact that with the substantial increase of concerned agents and information exchange, cyber security and data privacy became a major concern and an

additional obstacle. Therefore, any solution needs to adhere to the latest trends and guidelines on data protection, including relevant legislation [3].

In order to ensure information exchange and transparency, a flexibility resources register could be developed to collect structural information of the connection points that can provide flexibility services (by FSP) to system operators. The objective of the flexibility resource register is to gather and share relevant information on potential sources of flexibility and provide transmission and distribution system operators with a better insight into the available capacity in real time and would make the congestion management process more efficient and effective. This register, depending on the selected concept of the future market, could be established individually and independently for distribution service providers and transmission system providers, or it could be set up as a National Flexibility Services Register. In this sense, if a DSO or TSO has a congestion, they have a visibility of a potential flexibility resources at all voltage levels. It can also be developed into an important source of information for market platforms and used for verification how much energy is delivered when comparing the measurements of the meter to the baseline of the unit. The flexibility resource register would contain minimal technical information on the flexibility resources such as location, approved capacity limits, duration, ramp rate, mode of activation, flexibility provider, baseline information. The attributes depend on the type of service required by the system operators. A flexibility resource can deliver multiple flexibility services to system operators (e.g. congestion management, balancing, etc.). Once a resource is qualified to provide a service, its connection point is flagged as a potential provider of a specific flexibility service in the register. TSOs and DSOs jointly recommend that the concept of flexibility resources register should be acknowledged at the European level and the implementation (entering and maintaining the data) should be decided on a national level [4].

Guidelines agreed by the European transmission and distribution system operators also define the main principles upon which the future market of flexibility services will be established:

- full support for TSOs and DSOs in establishing market congestion management principle,
- key role of TSOs and DSOs (observing the principles of complete neutrality and non-discrimination) in supporting the involvement of system users in the flexibility services market,
- full coordination and exchange of information between TSOs and DSOs are essential,
- flexibility services can be traded in different markets with previously clearly defined market products and timelines,
- full transparency of market processes and the adoption of separate rules to further regulate the congestion management market,
- defining clear responsibilities and obligations of providers and users of flexibility services (publicly available agreement models),
- interoperability is essential (it is necessary to define appropriate standards in this respect).

In addition, providing information and education to system users, but also assistance in establishing the required infrastructure to participate in the flexibility services market, are of utmost importance. TSOs and DSOs are obliged to define the minimum required conditions for participation in this market. However, such conditions should in no way serve as obstacles to potential service providers, but should instead aim at promoting and facilitating the integration of these actors into these markets. The ultimate goal is the complete automation and establishment of appropriate information platforms to manage this process. Taking into account the potential of flexibility services providers to participate in multiple markets at the same time, TSOs and DSOs should ensure full interoperability between market platforms and timely exchange of data to enable efficient use of flexibility resources.

POTENTIAL MARKET MODELS FOR CONGESTION MANAGEMENT AND BALANCING

Previous part of the paper emphasized that a flexibility service provider with one of its resources can simultaneously participate in several different markets. Each market is defined by basic features - a specific product which can be activated within a certain timeframe on the basis of an Engagement List containing aggregated and ranked offers of all market participants.
In accordance with the technical limitations in the transmission and distribution networks, the specific market properties, as well as the regulatory constraints, it is possible to define three basic market models, namely the concepts of coordination between the congestion management market and the electricity balancing market (Figure 3).

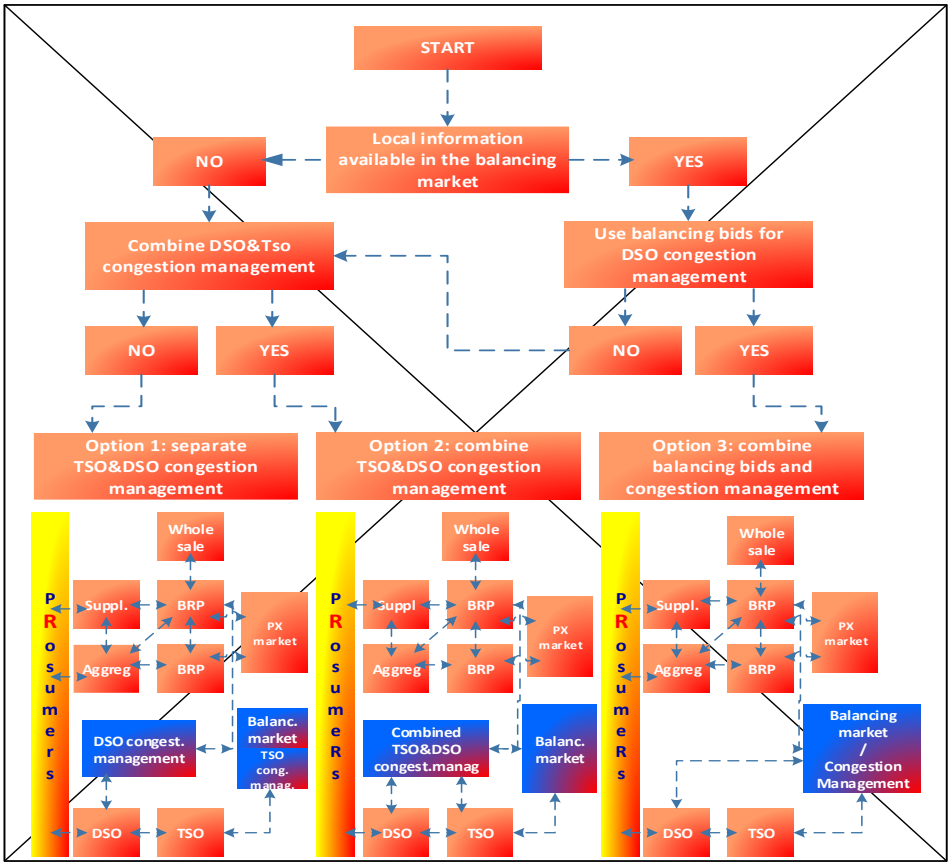

Figure 3 - Possible scenarios of future congestion management market and balancing market

Option 1 is a market model in which congestion management is completely separated between the distribution and transmission networks. In this market model the flexibility resources used to manage congestion in the distribution network are not used in the balancing market. From the aspect of flexibility resources and the transmission system, there are two options: it is possible to use these resources separately for congestion management and for participation in the balance market or to use the same resource for participation in both markets. The advantage of this model is its simplicity, as this model can be used to initially establish market congestion management principles.
Option 2 is a market model which implies combined congestion management in the distribution and transmission networks by the DSO and TSO. In this market model, the flexibility resources

for managing congestion in the distribution network are not used, like in Option 1, as balancing market resources. The unique feature of this model compared to the previous one is that there is a possibility of overlapping the needs of DSOs and TSOs. The advantage of this model is the rationalization of the use of flexibility resources, with previously agreed and harmonized principles of market functioning by DSOs and TSOs.
Option 3 is a market model in which the flexibility resources, regardless of whether they belong to the distribution or transmission system, are used both as congestion management market resources and as a balancing market resources. Naturally, this is with the assumption that the distribution system resources are available for participation in the balancing market. A single national market for the collection and activation of flexibility services would allow TSOs and DSOs to access all bids by all available market participants and to coordinate activations of valid bids between each other.
Since the strategy for the electricity market development implies the centralization of market processes, the latest market model could represent the preferred one, where centralization of congestion management processes at national level would be followed by centralization of this process at regional and European levels.

CONCLUSION

After more than two decades of continuous development of electricity market and global attempts to achieve ``social welfare`` and provide common benefit to all market participants, it is difficult to say whether success has been achieved in this regard. Market processes have undergone major modifications and roles of market participants have changed accordingly. Although the role of end customers or electricity consumers seemed passive over that time, they proved to be the leading actors in such environment.
Should the guidelines and agreed principles between DSOs and TSOs for establishing the market for flexibility services and integration of distribution resources be implemented in practice, the new strategic directions for the electricity market development will provide new perspectives for all market participants. Flexibility, as an ability of final users, can be recognized as a new product through active system management which will imply better coordination between TSO, DSO, BRP and prosumers. Having been assigned a new active role, prosumers would be given the opportunity to save or profit, while system operators would be provided with new resources to use mainly for congestion management and balancing.
Active approach to the electricity market by the largest group of market participants should take us one step further in achieving our goal - electricity market operating on the ``social welfare`` principle.

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