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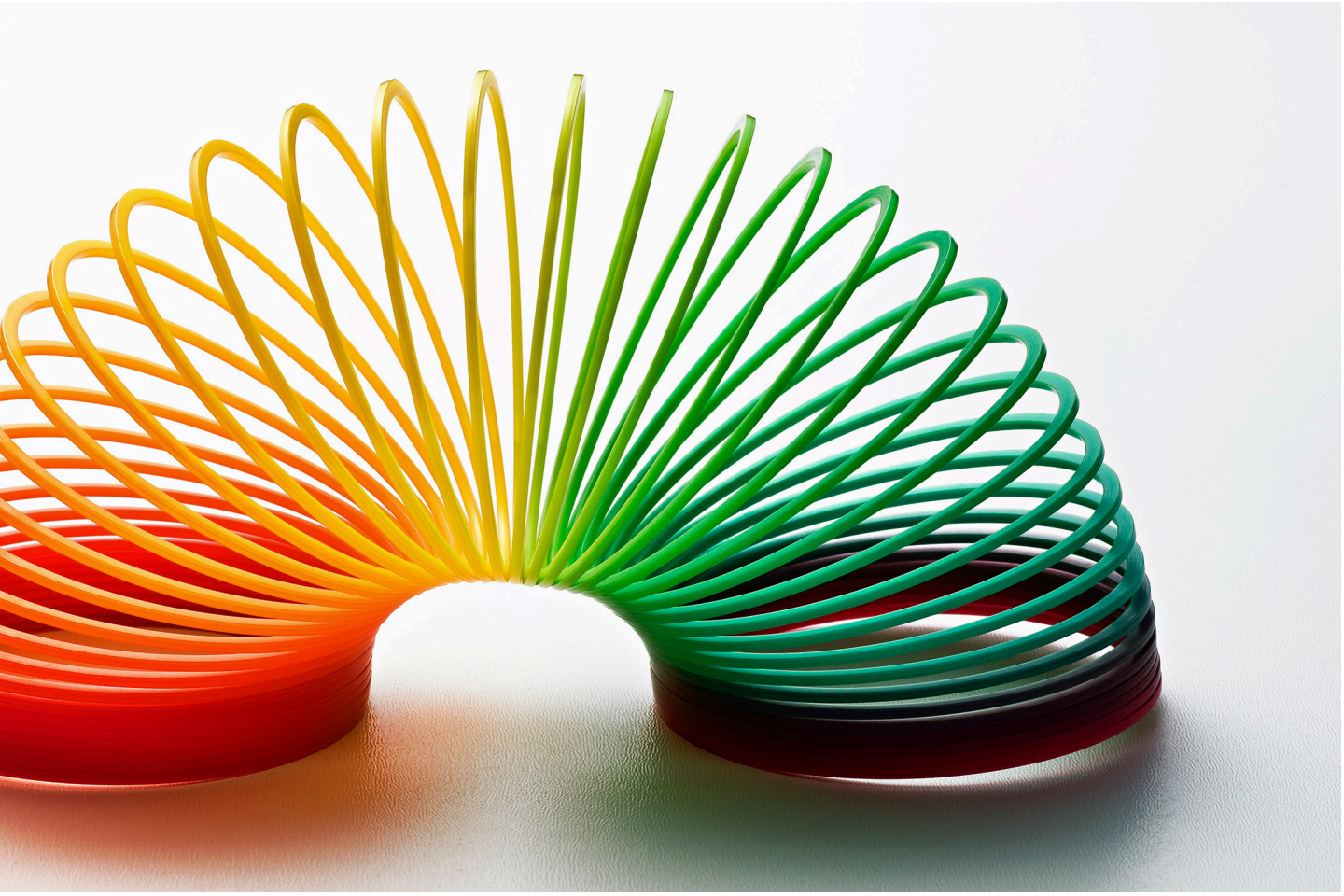

Flexibility of the Polish power system

Diagnosis, potential, solutions

EXECUTIVE SUMMARY

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Forum Energii is the Polish think tank forging the foundations of an effective, secure, clean and innovative energy system.

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Introduction

Flexibility of the power system means its ability to maintain uninterrupted operation under conditions of rapid and huge fluctuations in electricity consumption generation. It is an inherent part of the system design and control of its operation. In the past in Poland, it was provided by the centrally dispatched generating units. In the future, the share of variable renewable sources will grow. The electricity consumer will assume increasing importance. Thanks to the smart metering system and digitalization, the possibilities of improving flexibility are becoming a large resource. E-mobility and heating sector can be included to balance the Polish power system. Therefore, while thinking about flexibility, we should always look into the future.

In the analysis, Forum Energii puts forward solutions supporting the improvement of the Polish power system flexibility. In addition to reducing the costs of the power sector and the improvement in quality and reliability of the electricity supply, their objective is to reduce emissions by the power sector.

2. Key conclusions

- Considering the upcoming challenges, the Polish power system is insufficiently flexible.
- Consistently planned and implemented improvement of flexibility will increase the security of system operation and security of energy supply in a short-term perspective and will reduce the costs and CO_2 emission over the long-term.
- The ability of the transmission system operator to make use of the flexibility of the power system users is limited. It is, therefore, necessary to increase the role of the operator who will reach for the flexibility resources connected to the grid.
- Increasing the share of renewable energy sources (RES) to 32% in 2030 in the member states, which is the goal of the European Union, requires a constant reduction in the costs of these technologies. In this context, cost-effective and technically reliable integration of RES is very important.
- The operation of conventional and renewable sources must complement each other. It is, therefore, necessary to change the entire supply chain: in production from conventional units and RES, transmission and distribution, on the part of the recipients and in regards to energy storage.
- Comprehensive market mechanisms should be implemented, the task of which will be to provide the entities who can offer operational flexibility with economic incentives.

3. Challenges

3.1. Changes in recipients' demand for power

In the forecasts for covering peak power demand up to 2030, the disproportion between the off-peak and peak demand for power is expected to increase. Growth of these differences in a daily and hourly system will affect the demand for power reserve and regulatory system services. Increasing the level of reserves generates costs that could be avoided in a more flexible system.

3.2. Increase in the share of sources with variable production characteristics in the Polish power system

Improving operation efficiency and a significant decrease in investment costs will increase the competitiveness of renewable sources, in particular wind and solar energy. After 2020, new regulations resulting from the Winter Package, according to which the share of RES in EU countries is to amount 32%, will apply. Dynamic development of RES over the next few years will therefore exacerbate problems in balancing the Polish power system.

3.3. System transmission congestion

Network congestion occurring in the Polish power system is caused, among other factors, by:

- poorly developed transmission network in the northern part of the country,
- uneven location structure of generation sources (the majority of centrally dispatched generating units are located in the south of the country),
- unplanned flows on cross-border connections.

3.4. Operational flexibility of professional power stations

Coal-fired power stations provide nearly 70% of the capacity installed in the Polish power system. Out of the 90 units, 70 exceeded the assumed operation time. In the long-term perspective, the availability of operated conventional units is deteriorating and the number of unplanned shutdowns is increasing, which creates problems in balancing the Polish power system, especially when large emergency units with a capacity of over 500 MW are shut down.

3.5. Impact of technological changes

Development of new energy production technologies (wind or solar farms) has increased the ability of recipients to obtain electricity as well as also having reduced the marginal costs of electricity production practically to zero. The further drop in technology costs forecast will enable individual recipients to gain partial energy independence and will contribute to the decentralization of the energy sector. The use of prosumer installations will allow the profile of demand for power to be controlled and will increase the flexibility of demand.

Due to the development of e-mobility, measures should already be taken to promote flexibility in the behaviour of electric vehicle users, with direct or indirect methods to influence their power demand profile.

4. Recommendations

Conventional generating units

Further revitalization of conventional coal units should be characterized by a short start-up time (within the desired three hours from the cold state), low technical minimums at 25%[1] level and the ability to rapidly change load and to be adapted to frequent (about 200/year) start-ups assuming operation for fewer hours (about 1500-4500/year).

There should be a diversification in the use of fossil fuels towards the increase of the role played by gas sources, which are more flexible than coal sources.

The heating sector

We recommend the increase of the installed capacity of cogeneration sources to around 11GW$_e$ by increasing the efficiency of their use in the summer and replacing the withdrawn coal sources with *Combined Cycle Gas Turbines* (CCGT). Adaptation of electricity production profiles to the recipients' demand for power with the use of heat accumulation will help to fully take advantage of the potential of heating systems.

Energy recipients

We recommend the consistent development of Demand Side Response (DSR) towards the aggregation of smaller and smaller recipients connected to the distribution network up to individual recipients covered by advanced metering infrastructure (AMI). The flexibility obtained thanks to these mechanisms is a very important resource. The total potential of the reduction mechanism in Poland is estimated at a level of 2.5 GW with the availability of 1.2 GW.

1 The target of 25% of the technical minimum is an ambitious target, but it is nevertheless necessary to really improve the flexibility of the PPS.

Market

The most important market mechanisms recommended for stimulating the behaviour of power system users are as follows:

- change of the energy pricing mechanism to include not only the costs of its production, but also its supply to the recipient. This will create the proper signals for network location and generation in a specific geographical area,
- development of short-term markets with higher liquidity, in which everyone will be able to participate on equal terms (producers, recipients, storage facilities), and the prices of electricity will reflect its value for the recipients,
- new tariff rules – introduction of real-time pricing.

Transmission and distribution

Expansion of the network is necessary in order to increase the geographical areas of balancing. We recommend the use of a dynamic transmission capacity assessment system that allows the transmission capacity of overhead power lines to be increased from a few to 30%.

There should be a shift from deterministic methods of network development planning to probabilistic methods allowing, among other things, for the changing nature of RES generation, various recipients' demand for power and flexibility of power system users to be taken into account.

Regulatory services

We recommend the increase of the distribution system operator's competences in the use of regulatory services, especially in the context of solutions introduced by the Winter Package and changes related to the implementation of network codes developed by ENTSO-E, ACER and the European Commission. Modern RES technologies, in particular wind turbines and PV system, offer regulatory parameters corresponding to at least the technical regulatory requirements of system services defined by the transmission system operator, and for selected services they outweigh them. It is necessary that RES also take over the obligation to provide regulatory services, replacing conventional energy sources.

Energy storage

The first power market auction reported 15 installations with 111 MW capacity, which is a positive signal. It is necessary to enable the share of energy storage technologies on other markets, such as balancing market and regulatory services market, as well as production resources.

E-mobility

It is estimated that reduction of the daily load variability in the range of 5 to 25% (0.7-1.8 GW) can be achieved thanks to the development of e-mobility.

Due to the very early stage of this industry, its development must be stimulated towards full use of the potential of flexibility, in particular vehicles to grid technology (V2G) and price incentives in the processes of loading and unloading vehicles.

5. Description of flexibility resources

5.1. Production

Flexibility of coal units

Increasingly, coal units will be used irregularly as mid-merit sources. In order to meet the new requirements, works on the revitalization of 200 MW power units commenced in the country. The modernization of coal units, the impact of which on the system's flexibility will not be high, should primarily include the reduction of the start-up time, including from the cold state (from the current 8 hours to 4-5), reduction of technical minimums to no more than 40%, and increasing the capacity of load changes up to 4% of nominal power per minute and up to 200 start-ups during the year. Modernized units should be adapted to operate for about 1500-4500 hours per year.

Germany's experience shows that increasing the flexibility of coal units is technically feasible. The costs of modernization and increasing flexibility varied depending on the unit and ranged from 100 to 500 EUR/kW. The concept of duo-units, in which two boilers are connected to the steam collector supplying one turbine, is also interesting. One advantage of this solution is the possibility of designing each of the boilers for a different type of fuel and significantly reducing the technical minimum of duo-units in relation to conventional units.

Flexibility of gas units

Poland primarily uses steam and gas units which are part of combined CHP plants (municipal or industrial). The capacity of installed natural gas sources is about 2 GW.

Normally, gas-steam units operate in a heating and condensing system, and the volume of electricity generation varies and depends on the demand for heat. These sources are characterized by a considerable efficiency (in cogeneration operation at full load of about 80%), high operational flexibility and high share in the cost structure of fuel expenses (about 80%).

Steam and gas units with a total capacity of about 900 MW are planned by 2020. The leading product in these units will be heat. Therefore, they may have a limited operational availability. In addition, as part of the general certification, gas sources with installed capacity of 4.37 GW were reported as planned units. Some of them are simple gas turbines with an open cycle producing only electricity, which will improve the flexibility of the power system.

Flexibility in the heating sector

Integration of the heating and power sectors allows for an increase in the flexibility of the power system operation. The essence is the use of cogeneration through:

- increasing generation in the summer due to, among other things, generation of electricity in pseudo-condensation and use of hot water,
- the use of district heating for cold production,
- storage of surplus energy in the form of heat.

Meanwhile, only 30% of generators produce heat in cogeneration. In the summer, the technical possibilities of CHP plants are used in around 40%, while the potential of cogeneration units to be used in the Polish power system in the summer could amount to as much as 1.7 GW. Furthermore, if a CHP plant with backpressure turbines is modernized to systems with a condensing unit, the additional generation potential in the summer will be about 3.3 GW according to estimates.

The use of district heating for the production of cooling for the needs of air conditioning in buildings, such as large

cooling centres in office buildings, shopping centres and public buildings, offers additional possibilities in increasing the use of the available capacity of heating systems.

The use of heat storage tanks in combination with the heating network will allow for their use as energy storages. The estimated potential of the heating sector resulting from heat accumulation amounts to several dozen GWh of electricity within a few-dozen hours.

Replacing the withdrawn coal units with steam and gas units will enable the installed capacity to increase by about 1.7 GW_e net to about 3.5 GW_e. Modernization carried out in small heating systems, currently supplied by coal-fired boilers, would increase the installed capacity in flexible, from the point of view of the Polish power system, steam and gas units by another 4 GW_e.

The use of regulatory possibilities of renewable energy sources

Adaptation of RES, in particular wind farms, to provide active power regulation services is necessary from the point of view of security and reliability of the power system operation. It is estimated that 2.5-2.8 GW is the available wind generation capacity that can be used as part of the provision of services (e.g. as a reserve of power towards generation reduction).

Wind turbines offer a standard of services in accordance with the requirements of the transmission system operator. Modern wind turbines can, however, be equipped with additional devices that can be used to improve the security and reliability of the power system operation. These are:

- quick response to frequency change,
- fast reactive current generation,
- regulation of voltage and reactive power in the absence of active power generation.

Implementation of the system of service provision and settlement of their costs by wind farms requires a number of organizational changes on the part of the distribution system operator and wind farm operators. Legislative changes are also vital. Wind turbines have the technical ability to respond quickly to regulatory signals. On the other hand, PV farms will not participate in the regulation of active power due to the correlation of their production with the peak demand for power.

Local balancing areas

The amendment to the RES Act introduced new solutions, the so-called clusters and energy cooperatives consisting of groups of local generators and energy recipients balancing within the group. They are beneficial from the perspective of the flexibility of the functioning of the Polish power system and may be the basis for creating local balancing areas cooperating with network operators in the future.

Local balancing areas can be used to:

- regulate the Polish power system, in which the possibilities of local balancing areas would be used by the operator to balance the system in real time: frequency and power regulation.
- regulate the active and reactive power in the distribution network, in which the operator would use the local balancing area depending on the needs, e.g. to improve the reliability of energy supply indicators (SAIDI, SAIFI), compensation of fluctuations in network voltage levels caused by the existing load variability or generation in the MV network and limiting losses in this network, etc.

5.2. Demand management

Electricity demand is characterized by relatively high price inflexibility. It is difficult for recipients to change the method of consumption or the amount of electricity consumed in a short time due to the need to change technology. The price of energy will affect the behaviour of recipients only to the extent to which they are able to optimize (e.g. postpone) the operation of devices.

Load management can relate to both large recipients such as energy-intensive industries and small individual recipients.

DSR is one of the options to increase the flexibility of the power system. Its advantage is the time of implementation and start-up of reserves in comparison to the time of construction of new power units. In Poland, the demand reduction mechanism is estimated at around 2.5 GW. For a single event, it is about 1.2 GW (5% of peak demand). Another positive signal increasing the possibilities of using DSR in the power system is its inclusion in the power market and the launch of the new DSR simplified current program planned by PSE.

5.3. Energy accumulation and storage

The significance of energy storage in the power system will increase along with technological development and growth in share of sources with variable production characteristics. Energy storage can be treated as both generation and consumption in the system enabling the postponement of energy consumption when there is a surplus or deficit thereof.

In the recent years, a dominant technology in electrochemical energy storage is lithium-ion batteries. These can be used as domestic energy storage installations, and also increasingly in professional power engineering. The main reason for increased use of batteries is the costs of technology. Since 2010, the price of lithium-ion batteries has decreased by about 80% and a further drop is forecast.

Currently, the main pumped storage facilities with the capacity of 1.5 (generation power and pump power) are primarily used to store energy in the Polish power system. The remaining types of energy storage facilities, mainly battery systems, are the subject of research and demonstration implementations. As part of the power market introduced in Poland, 15 energy storage installations with the capacity of 111 MW were reported as planned units for general certification.

The development of e-mobility in the vehicle-grid version (V2G) will be a chance to use the batteries in electric cars to store energy depending on the current operation of the power system. Another option is to use the closed mines and salt caverns as energy storage facilities, e.g. compressed air.

Development of electricity storage facilities requires the adoption of legal provisions regulating their access to the market and creating economic incentives for their use.

6. Improvement of flexibility of transmission networks

6.1. Increase of use of transmission and distribution infrastructure and expansion of the power network

One of the methods by which to increase the efficiency of the transmission system is to apply a dynamic assessment of the permissible line load based on real-time line temperature monitoring. The current limitation of line load to static load capacity may result in inefficient use of transmission capacities, e.g. in more favourable weather conditions. The global experience of operators demonstrates that systems for dynamic assessment of transmission capacity enable the transmission capacity of overhead lines to increase from a few to even 30%. More up-to-date information is necessary in order to reduce the assumed security margins and increase the capacity for the needs of market operations.

Dynamic assessment systems for the permissible line load have been implemented on the Polish power system for several years. It should be mentioned that the implementation of the permissible line load system may be several times lower than the modernization of the line consisting in adapting it to operation at higher temperatures (+ 60°C or + 80°C).

The need for network investments results from the necessity of replacing old, worn-out network elements, growing demand for electricity, connecting new generation and changing the control model of the power network. In the coming years, there will be an expansion of transmission network planned by PSE.

6.2. A new role of distribution system operators

The so-called local energy communities will have the right to produce, consume, store and sell energy from renewable sources. The distribution system operator will assume responsibility for the integration of dispersed sources and will be able to purchase system services not related to frequency regulation on market terms. The services will be provided by all interested market participants, including RES, controllable recipients, energy storage facilities or aggregators of these services.

Thus, the distribution system operators will be at the centre of the power system transformation. Transformation of the distribution network into the active network will require significant investment costs for network automation. Its use, supported by smart decision support system in the distribution network traffic management systems, combined with increased network observability, including the use of smart metering system, will contribute to the increase of operational flexibility, and thus reliability and quality of energy supply.

7. Market solutions that help increase the system flexibility

Geographical size of the market. Along with the increase of the geographical size of the market, the variability of RES is compensated and as a result, local imbalances have less impact on the whole system. This applies in particular to regions with a source structure diversified in terms of production technology and different weather and climate conditions.

Market coupling. On coupled markets, instead of explicit transactions involving inter-system transmission capacities, total supply and demand from different market areas are matched in order to use the existing network capacity in the most efficient way.

Short-term market. Services on the electricity markets are the subject of trade at specific time intervals. Shorter dates of the contract implementation are conducive to opening the market for RES and resources on the demand side. Enabling transactions in operational periods may additionally reduce the demand for power reserves and increase the accuracy of operation schedules.

Time of gate closure. The accuracy of the RES generation forecast increases with the shortening of the forecast horizon: the closer to the implementation period, the smaller the forecast error. Postponing the time of gate closure closer to the real time allows for more accurate forecasts of the generation of RES to be taken into account. With lower uncertainty, the demand for balancing reserves is decreasing.

Transparency. The results of transactions, such as reserve prices and costs of balancing energy should be published as soon as possible. Delays make it difficult for the market participants to undertake measures to adapt.. A large number of suppliers on the market affects the reduction of prices for balancing reserves and is needed.

Place of supply. Transmission and distribution of energy are connected with the costs of construction of infrastructure and removal of system limits. Costs of energy supply to particular locations are different. The energy market should also reflect the transmission costs. This will be a long-term incentive for locating production sources in network nodes, for which energy supply is associated with incurring high transmission costs. Diversification of energy supply prices depending on the network node is called the “locational market” in contrast to the zone market currently available in Poland (the entire country), in which transmission prices are identical, regardless of where energy is produced and received.

7.1. Changes in the functioning of energy markets resulting from the introduced and designed EU regulations as part of the Winter Package

The Winter Package proposes a wide range of measures adapting the power industry to technological changes and facilitating the implementation of energy and climate goals for 2030. From this perspective, the key element is the effective integration of electricity from renewable sources with energy markets. It is necessary to form short-term electricity markets (balancing market and day-ahead market and intraday market) enabling the participation of renewable sources, planned at short notice in relation to the date of physical supply.

Balancing market. In accordance with the proposed rules, balancing markets should be organized in such a way so as to:

- guarantee non-discriminatory participation of renewable energy generators with variable generation characteristics, energy recipients and energy storage facilities;
- provide transparent and technology-neutral definitions of services and market-based purchase;
- provide all pre-qualified participants with access to the market – individual or in aggregate form.

Day-ahead market and intraday market. According to the Winter Package regulations, day-ahead and intraday markets should be organized in such a way so as to enable all market participants to participate in international trade: the demand side, energy storage facilities and generators in small renewable sources. Market operators should provide the participants with electricity trading in near real time, and maximize their ability to effectively manage their own energy balance that affects the imbalance of the system. The prices created on these markets should reflect the value of energy in real time in accordance with market laws.

The tasks of distribution system operators regarding the use of flexibility. The distribution system operator should organize the orders for these services offered by the dispersed generation sources, recipients or energy storage facilities. It should reduce the need to develop networks and support the effective and safe functioning of the distribution system.

7.2. The present and future energy market and system services model

A profound reform of the one-good energy market. An important element of the efficiently functioning energy market is the freedom in price formation that allows for valuation of reserves, i.e. price increases when the difference between supply and demand decreases, and the marginal value of energy rises to a much higher level than usual accordingly.

The mechanism of reserve valuation is able to directly reward innovation and growth of effectiveness of market participants. Those who will be able to supply energy in a short time will be able to expect higher prices, and those who flexibly adapt their electricity production to price changes on the power exchange will be able to maximize it. This mechanism will also encourage investments in decentralized infrastructure ensuring safe transmission capacity in many small CHP plants. The planned changes in the organization of balancing market will support the implementation of this concept in accordance with the guidelines of the European Commission.

Capacity support mechanism. The participants supplying the product on the power market and receiving the payment will be power suppliers, i.e. entities with the so-called power market units. The product offered will be a power obligation, i.e. a commitment to be ready to supply specified power to the system during supply periods and the actual supply of a specific power during a threat when planned power reserves fail to reach the minimum required level.

In accordance with the EU rules of public aid, the power mechanisms should be temporary. Their implementation should be connected with the removal of deficiencies in the basic energy market. As a result, the Polish government agreed to heavily reconstruct the energy market.

The results of the regional assessment of resource adequacy according to the European methodology will be important for the functioning of the power market. If it shows that there is a surplus of electricity available in the neighbouring system, then the requirement for the power mechanism to be gradually phased out will apply.

Regulatory (system) services market. The domestic power system is dominated by heat generating units using coal fuels. They are the basic providers of regulatory services ensuring system operation security. Regulatory services can be divided into three main groups: frequency and active power regulation services, voltage and reactive power regulation services and services used in system security threats.

Currently, the system services market is integrated with the balancing market for the most part. With their help, the transmission system operator obtains the technical means to ensure the necessary level of power reserves and the balancing of temporary power values in the system.

After 2020, the present method of contracting capacity reserves will be replaced with mechanisms for their obtainment. The distribution system operator will be obliged to purchase such services on market terms, in a transparent and non-discriminatory manner ensuring their provision to all interested market participants. The EU solutions provide for the marketization of the process of conclusion of contracts for the provision of regulatory services.

From the point of view of power system operation flexibility, in connection with the successive replacement of the system generation with distributed generation, including RES, it seems necessary to expand the participants of the regulatory services market with new entities.

Notes

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