The DSO network development with the increase of distributed energy resources number and their capacity

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Abstract: Energy transition is a continuous process, involving all elements of the energy sector. For Distribution System Operators the ability to cope with new challenges resulting from the energy transition (i.a. digitalisation, EV, PV, energy storage, distributed energy, energy communities, microgrids, energy sharing, geopolitical changes) is one of the most significant elements of this process. To meet the challenges of the transformation, it is necessary to develop new solutions adapted to the needs of all market participants, redefine priorities, establish new rules of cooperation in order to ensure security and stability of the power system at economically justified costs. The article describes network flexibility as a tool allowing DSOs meet needs of energy sector transformation process based on *flow-circle concept.* The idea of it is to use continuous observation tools (captured in the observability of the network), making predictions over different time horizons, across different areas, with varying observation granularity. The result of the calculations allows to identify constraints in the system, e.g., overloads, risk of failure or shortage of power or energy, and to select countermeasures commensurate with the threat and available at the selected time horizon.
Key words: DSO, network management, flexibility, local balancing, flow-circle concept

Introduction

The main objective of the energy market transformation is to accelerate the decarbonisation process of the European economy. One of the main factors contributing to the acceleration of this process in the energy sector is the decentralisation of generation through activation of consumers. Local energy balancing areas are also gaining in importance, especially in the context of their pursuit of self-sufficiency. At the same time, the increasing availability of new technologies and market incentives makes it possible to further accelerate these processes. This trend creates several opportunities for market participants, such as energy contracts based on dynamic electricity prices, providing demand response services both individually and through aggregation, production, and sale of electricity by the customer without the need of having a license, or creating self-balancing areas based on stakeholder cooperation. In addition, the changing geopolitical environment, which brings a new dimension to the concept of power system stability, creates the need to accelerate the energy transformation towards gaining independence from external sources of energy, which in turn means that rapid development of energy sources at the local level should be expected.

The article describes network flexibility as a tool allowing DSOs meet needs of energy sector transformation process based on *flow-circle concept.* The concept has been developed based on the authors' years of experience and operational knowledge of DSOs. The research method used in the article is an analysis of the experience of DSOs operation supplemented by knowledge available in selected literature on the subject. On the basis of the analysis made and the authors' own observations of the direction of the sector transformation, the general approach of DSOs to grid management taking into account the rapid development of distributed energy sources has been characterized.

Determinants of DSO operations with respect to trends resulting from energy market transformation

The main challenges for distribution system operators (DSOs) resulting from changes in the market environment can be grouped into six areas:

- Grid maintenance and development,
- Data management,
- Local balancing,
- DSO-TSO coordination in relation to services procurement,
- Electromobility and energy storage development,
- New services for customers.

One of the changes will consist in the development of power system at local energy balancing areas as a consequence of changes in the direction of energy flows from distributed generation[1] connected to the LV grid towards higher voltages. Local initiatives with the ability to maintain partial energy independence will be developed. At the same time DSOs will identify and manage the possibilities of flexibility resources connected to the grids (DSR, energy storage, EVs). The rapid development of distributed energy resources (DER), together with new technologies, including IT/ICT, will enable new solutions for DSOs to support network management (e.g., flexibility services platform, flexibility sources register).

Such a wide range of many variable factors in the DSO environment has a significant impact on the network infrastructure management methods related to network maintenance and development. Grid observability, the ability to access and process current information about the status of network elements, its topology and flows, are all becoming highly important. The increasing number of distributed generation will result in difficulties in forecasting bi-directional energy flows in the grid. This implies the need for DSOs to adapt the currently functioning technical and organisational solutions to new challenges. The future role of the grid operator will be to manage the grid in such a way as to enable the connected entities to use the power system (to withdraw or return energy and to ensure security of supply) while minimizing constraints, e.g., related to the capacity of grid components or the quality of energy itself (such as voltage level).

The power system consists of interdependent and closely interconnected elements, therefore, the coordination of services between key network operators (TSO and DSO) is of crucial importance. In that regard it is necessary to develop a new understanding of this cooperation in the context of balancing the operators' needs considering the role of equal footing. The detailed definition and appropriate (active) management of flexibility resources will provide DSOs with support for the National Power System and the ability to counteract network congestion or system failures when necessary. The use of flexibility resources by DSOs shall also allow for greater influence on the shaping of peak demand for energy and planning of the transmission grid development. At the operational level of DSOs, network flexibility is an issue of high

[1] Directive UE 2019/944, art 2 (32) ‘distributed generation’ means generating installations connected to the distribution system.

importance for the future operations of the DSO area, due to the upcoming acceleration of decarbonisation indicated in the REPowerUE[2]. This will require a new approach to network management in which an important role will be assigned to the network at the LV level, saturated with DER installations and characterised by a high variability of customer behaviour.

The new market conditions and the new role of DSOs also translate into changes in customer service. This will particularly concern the area of customer relationship management, both in the field of concession business and product development, as well as sales and services related to new, non-tariff products. This means that DSOs should have an efficient service and sales mechanism with directional competences and appropriate tools to effectively carry out all the necessary activities (IT, procedures, teams). It is important for DSOs to ensure that consumers can benefit from the offers available on the energy market without unnecessary barriers and at the same time to guarantee the possibility of providing additional services to other market players. The introduction of appropriate support in the form of regulation and the availability of technologies that provide financial benefits is key to achieving consumer involvement.

The amount of data in the distribution network is growing and will continue to grow; therefore, it is important to implement an appropriate model for managing such a large amount of data, for its collection, processing and sharing. Due to decentralisation processes and the use of data in the day-to-day operation of the DSO network and in planning its development, institutional supervision over information and data flow should be built based on "regional" entities, such as distribution companies which receive more than 90% of metering data. This data is collected, stored, and managed for the purposes of planning, operation, and management of the grid, and will ensure proper use of available flexibility resources in the future.

In terms of flexibility sources, the issue of EVs and energy storage needs more attention due to its dynamics of development. Energy storage facilities available to DSOs will be significant, both in the operational area and in development planning. Also, the development of electromobility means for DSOs the need to take additional measures related to adapting the network to support charging processes and support for the construction of charging points. In this context DSOs should prepare for the challenges ahead, as well as take advantage of the opportunities that arise (methodology for low-cost locating of charging points, feeding energy back into the grid from storage facilities, and tools for influencing charging periods and possible feeding of energy back into the grid by EVs) [3].

Distribution system – general, technical view

Large power distribution systems in Poland are part of the National Power System based on the alternating current (AC) transmission grid owned by the TSO. These systems generally consist of EHV lines and equipment to transmit energy to distribution grids consisting of three voltage levels - high, medium, and low (HV, MV, LV). Distribution grids provide the connected

[2] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, EU Solar Energy Strategy, Brussels, 18.5.2022, COM(2022) 221 final: *As part of the REPowerEU plan, this strategy aims to bring online over 320 GW of solar photovoltaic by 2025 (more than doubling compared to 2020) and almost 600 GW by 2030. These frontloaded additional capacities displace the consumption of 9 bcm of natural gas annually by 2027. Solar photovoltaics (PV) and solar thermal technologies can be rolled-out rapidly and reward citizens and businesses with benefits for the climate and their purses. To reach the EU 2030 targets, energy demand covered by solar heat and geothermal should at least triple*.

[3] According to EC announcements, the production of conventional petrol and diesel cars will be banned by 2035.

customers with energy of a specified quality and technical parameters. In addition, the distribution grids enable the reception and distribution of energy generated from local resources. A significant part of the grid was designed to distribute energy in the central source - energy reception model, which determines it to be a unidirectional network. The connection of distributed resources causes flows in the network that are inconsistent with this general principle, disrupting network operation and leading to a number of technical problems. It is important for DSOs to effectively identify and mitigate these problems, therefore, the network must be observable and controllable at a sufficient level in order to increase its potential for connecting new load and generation installations.

Moreover, the development of high shares of PV and wind installations has an impact on the way the electricity grid is managed. As solar energy is produced in direct current (DC), conversion to alternating current (AC) to feed into the grid and then converting back to DC, e.g., to store energy, leads to energy losses. Such conversion losses are currently growing due to the fact that more devices and systems, such as batteries, heat-pumps, data centres, electric vehicles or appliances, operate in DC. Increasing the use of DC technologies could thus be beneficial to the electricity system[4].

The characteristics of each network area by operating voltage, illustrating the observability of the network and its users are presented below[5].

The distribution network at the HV is controllable and characterised by a high level of observability. Its topology is mapped in the dispatching systems of individual distribution system operators. As regards metering, measurements of the basic values (power, energy, voltages, currents) are taken in practically all network elements (lines, equipment) and the connected consumers and generators are fully metered by means of remotely read meters. Moreover, most of the generation sources have the ability to remotely control active and reactive power, which creates certain opportunities to use their regulation potential (important in the context of flexibility and system services) for network management in the broad sense. The necessity of having network observability at the HV is one of the important elements for the proper determination of the balancing level of individual areas of National Power System through the Balancing Market.

The distribution network at the MV is not entirely observable and controllable, which in its current condition may cause difficulties in its management, among others, due to uneven saturation with remotely controlled switching devices. As regards metering, measurements of the basic values (power, energy, voltages, currents) are taken in some network elements (mainly lines connected directly to primary stations and secondary substations), and the connected consumers as well as producers are fully metered owing to remote access to the data. The number of available metering points varies across the network, which affects the overall assessment of observability. An additional element that influences the level of network observability at the MV is the remote reading of balancing meters installed at secondary substations. Data collected from such meters and reflected in SCADA systems will be an important element of the new

[4] *The European Commision is investigating how low-voltage DC technologies can enhance the clean energy transition. Based on the conclusions drawn from this process, it will engage with European and international standardisation bodies for the establishment of the necessary standards and protocols*. EU Solar Energy Strategy, Brussels, 18.5.2022, COM(2022) 221 final.

[5] Based on own experience and observations.

model of managing network operation with many distributed resources. Generating installations on the MV, mainly due to the nature of primary energy (RES), are controllable to a certain extent, yet mostly unidirectional through power reduction.

The LV grid has the lowest level of observability and controllability, mainly due to the lack of metering of both network elements and consumers with remote access to meter reading. The situation will be improved significantly after the implementation of a national program of smart meters installation. Nevertheless, the metering of all customers will necessitate the implementation of systems and algorithms that will be able to manage the large amount of metering data for its effective use for the purposes of network observability and management processes.

Bearing in mind the information outlined above, it may be concluded that the distribution grids, depending on voltage level, are prepared to a different extent for the changes related to energy transformation (transition from central generation to distributed generation and customer activation). For high-voltage grids, the situation seems to be under control. However, problems arise at other voltage levels where the existing grid will be challenged to serve new types of entities (distributed energy resources, prosumers, local energy communities, virtual prosumers, EV chargers) connected to the existing grid infrastructure.

Currently, distributed generation forecasted to be connected faces a large number of connection conditions refusals. In the future, if the rules for the connection of distributed resources are not changed, it will be virtually impossible to make new connections without significant development of the distribution network and its connections to the transmission grid. At present the most common reasons for refusal are the voltage criterion and the criterion of power reserve in the primary station node. The remaining criteria are currently of much lesser importance (overload, short-circuit and quality criteria). Furthermore, it has to be underlined that at the LV, RES installations are not obliged to apply for connection conditions, which means that there is no possibility for DSOs to analyse whether the number of connected resources in a given area (circuit) guarantees their stable operation while ensuring network operation security in this area.

Connection of distributed, intermittent, and unpredictable energy resources poses challenges for DSOs in terms of performing basic operator's duties, i.e., network management and ensuring its stability, but at the same time provides opportunities to use these resources in DSO network management and development planning. Therefore, it seems to be necessary to develop:

- additional, standardised IT tools to facilitate the forecasting of distributed generation resources (including consumer behaviour),
- regulatory-supported products that will ensure the use of the available potential of active customers, and
- competences and organisational structures facilitating efficient use of potential of connected resources (including development planning).

Assessment of the quality and stability of electricity supply carried out by DSOs currently considers the objectives and tasks resulting from the quality regulation defined by the NRA[6].

[6] Regulacja jakościowa w latach 2018-2025 dla Operatorów Systemów Dystrybucyjnych; URE, Warszawa wrzesień 2018

In the future, the following measures (as indicated in the *Energy Policy of Poland until 2040 [PEP2040]*) should be implemented to improve supply stability[7]:

- the indicators of the quality of energy supply, i.e., the duration and frequency of interruptions in the NPS, should be constantly improved - in line with the targets set by the NRA,
- due to the age of the infrastructure (most of which is more than 25 years old), DSOs are obliged to reconstruct the network - the reconstruction rate should be at least 1.5% p.a. until the average age of the infrastructure falls below 25 years,
- the reconstruction of the LV lines should be done with the use of insulated cables or wires,
- the change of the overhead LV lines to underground (cabled) ones and increase in the number of medium voltage line switches equipped with remote control systems. For this purpose, a national plan for the MV cabling by 2040 was developed in 2021.

Ensuring security of electricity supply also requires readiness to act in emergency situations in the power system. For this purpose, it is envisaged to increase emergency response capabilities by, among others:

- increasing the use of control and automatic reconfiguration elements at the MV,
- expansion of IT systems and MV and LV line equipment with network operation diagnostics and analysis of grid operation,
- implementation of a digital grid communication system,
- construction of an intelligent energy infrastructure (smart grid) enabling the optimal use and integration of the distribution system, including the development of algorithms to create new optimal configurations.

The scale of challenges associated with distributed resources faced by grid operators

An important direction in the structure of distribution system users is the progressive replacement of stable and inflexible conventional generation with distributed generation - intermittent and unpredictable in production due to the existing technologies, mainly PV. On top of that, since consumers are looking for cost-effective ways to meet their own energy and transportation needs - the expansive development of *prosumerism* and ecological transport should be underlined as well. Both these directions lead to an increase in the number of micro-installations and electric vehicles requiring adequate charging infrastructure, both individual and public.

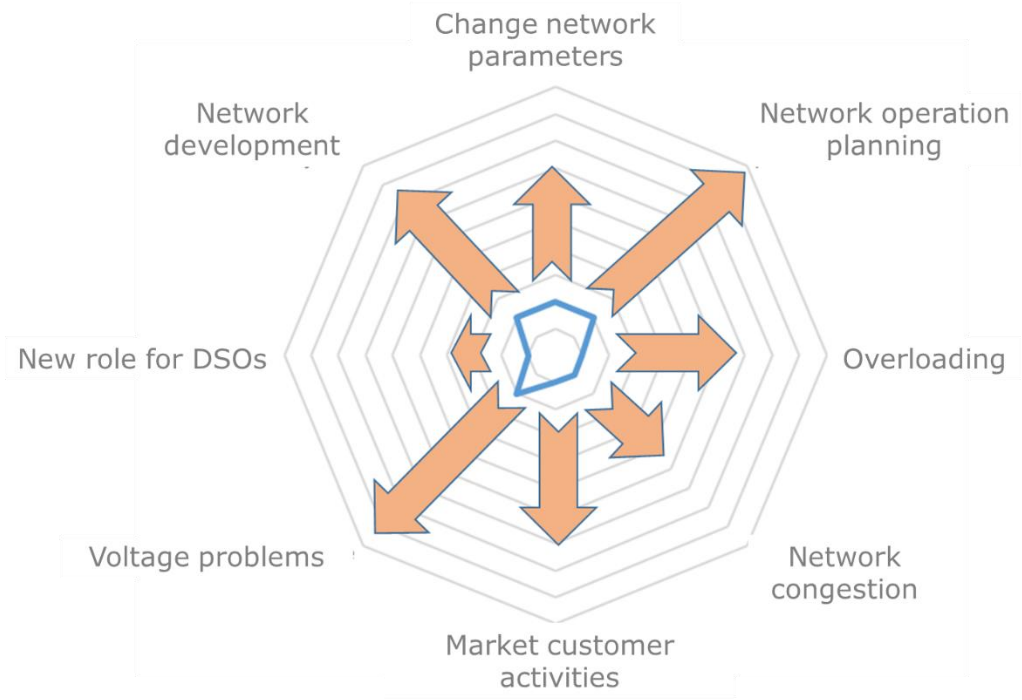
The forecasted increase of the installed capacity requires an appropriate operator approach, both in terms of technical feasibility of connection, which is realised on the grounds of development plan, and in terms of network flow management, which is realised by dispatching centers. It is of utmost importance to utilise the potential of the network users so that their energy resources could be appropriately used by the operator and support the elimination of congestion in the distribution system.

Every increase in the power of distributed generation is accompanied by a commensurate increase in network problems, whose elimination or reduction to acceptable levels should be

[7] Polityka energetyczna Polski do 2040 r.[PEP2040], Ministerstwo Klimatu i środowiska, 2021, access: 10.05.2022, https://www.gov.pl/web/klimat/polityka-energetyczna-polski

the essence of the model of operation and development of the distribution network comprising distributed energy resources.

Fig. 1. A conventional scale of DSOs challenges associated with distributed resources. The arrow reflects the strength of the impact on the category.



Own study

The expected increase in the number and capacity of distributed resources, territorial and grid dispersion, as well as customer market activity, means that the operator must be able to translate future events into anticipated problems that may arise as a result.

Operator challenges are expected to be materialised in the following areas:

- technical - in terms of changes in network parameters, voltage problems and overloads,
- network management - traffic planning, network congestion,
- network development in terms of connecting new generation capacities,
- customer market activities,
- the role of the TSO as regards the use of resources connected to the distribution network for the purpose of transmission network balancing.

Flexibility as an answer to challenges in DSOs network operation

Saturation of the distribution network with distributed energy resources means that DSOs must accept higher variability of energy generation, which in many cases is linked with weather conditions. This results in a shift from the *generation follows demand* principle to the *demand follows generation* principle. Most of the renewable generation is intermittent and not controllable. The more generation of this type will be connected to the grid, the harder it will be to keep balance with demand by dispatchable generation. The existing grids are designed to transport and distribute energy from central power plants to local customers. Changing this principle by adding local generation and storage systems will require a total review of their architecture[8]. On the other hand, grid users increasingly want to actively participate in the energy market by adapting their energy potential (generation, load, storage) to the current market situation. In other words, they respond to market signals, e.g., energy prices, by changing their typical behaviour - optimizing energy consumption, producing energy themselves, transforming themselves into active consumers[9]. This unique ability of the power system to respond to most of changes in demand and supply, caused by the dispersion of many types of generation resources and/or activating users on the energy market, is called *flexibility of energy system*.

Network flexibility should be considered in two dimensions[10]:

- technical (operational), allowing connected entities to exchange energy with the grid according to their needs and taking advantage of the natural ability of network elements to carry varying loads over time, and
- market-based, understood as the modification of production and consumption patterns at an individual or aggregated level, in response to an external signal (price signal / grid tariff / activation / congestion) to provide a service within the power system or to maintain stable network operation.

In view of the above, a fundamental distinction must be made between the market flexibility offered by market participants and the technical (operational) flexibility used by network operators. In the context of market participants, flexibility always refers to activities performed under the influence of external, mainly commercial, incentives. In the case of DSOs, it results from the obligation to ensure effective planning and efficient operation of the network. This type of flexibility is related to quality and security of supply. This flexibility can help system operators to maintain the expected level of network performance when the network is threatened by congestions.

For distribution system operators, changes in the energy market that directly affect network user activity pose several technical challenges. Handling all the behaviours of system users is a *sine qua non* of the grid flexibility issue and requires substantial investments by DSOs at various levels.

The occurrence of congestion in the distribution system depends on the confluence of many components: capacity and generation demand in individual nodes of the network area, topology of the network area and the topology of the superior network (TSO), conditions of dynamic network loading elements as derivatives of atmospheric conditions. Where technical flexibility is insufficient to achieve the intended results, i.e., to prevent congestion in the system, increase security of supply and improve the quality of distribution services provision in the most efficient way, the DSO may procure market flexibility from system users in the form of a service/product.

These services are referred to as *flexibility services*. Using flexibility services to maintain voltage and manage network congestion can provide benefits such as:

[8] Vison Paper - “The Journey to ‘Green’ Energy or ‘a Quest for Flexibility’”, tech.rep. Eandis 2015, https://www.edsoforsmartgrids.eu/a-journey-to-green-energy-2/, access: 10.05.2022

[9] Mataczyńska E. & Kucharska A., *Klastry Energii. Regulacje, teoria i praktyka*, IPE, 2020, pp.46-85, SBN: 978-83-946727-7-5

[10] Kara G, Tomasgard A., Farahmand H., Characterizing flexibility in power markets and systems, Utilities Policy, Volume 75, April 2022,101349, ISSN 0957-1787, access: 15.05.2022 https://www.sciencedirect.com/science/article/pii/S0957178722000145

- optimised investment in the distribution network,
- reduced technical losses,
- increased connectivity of unstable sources.

Perceptions of flexibility solely in economic terms (among others, through terminology such as service, service pricing, service provider, product) somewhat misses the point of the energy power system as a frequency-synchronised and balanced mechanism subject to *de facto* regulatory actions, which are called services more for the sake of better understanding. They should only be embedded in the process of day-to-day management and planning of network development.

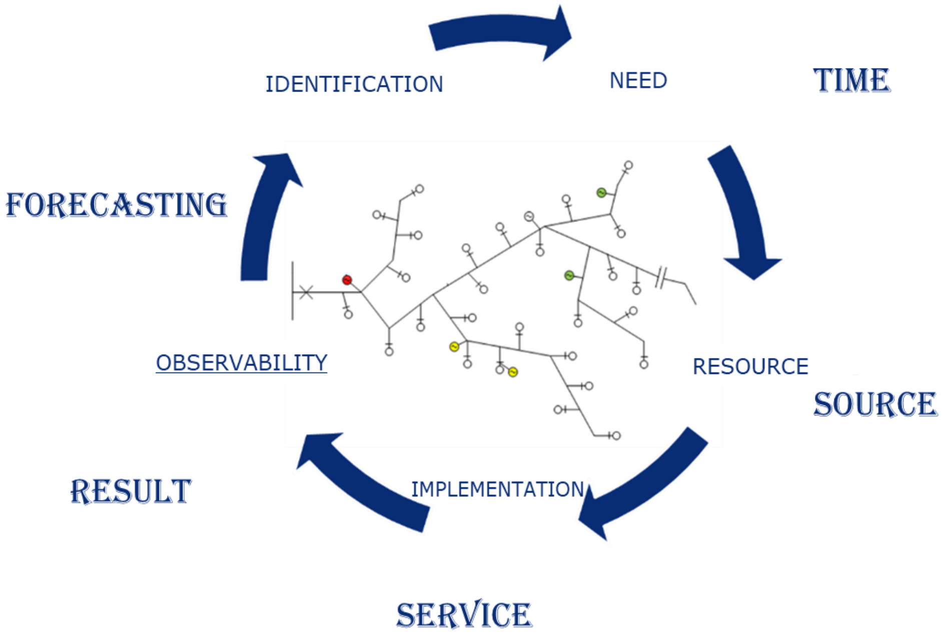
Apart from the availability of flexibility resources (networks and services), procedures for the connection planning of flexibility resources as well as IT procedures and tools that enable network observability and allow flexibility management constitute a prerequisite for the improvement of system flexibility.

The above implies a general approach of DSOs to the issue of flexibility. Thus:

- the operator must know the flexibility framework of its own system, it is necessary to have a proper representation of the network both from the topology side and from the energy flows and available power in the system,
- flexibility can be a tool in network congestion management, such an approach being derived from the possibilities offered by system users' willingness to manage their energy potential, especially if an appropriate economic incentive exists,
- congestion management must be considered from the point of view of both the current operation of the network and its development plans,
- day-to-day congestion management implies the ability of the operator to predict, over fixed time horizons, the behaviour of system users. This requires basic data on the state of network operation as well as information on user activity in the market - either directly or through third parties,
- in network development planning, it should be assumed that appropriate motivation and cooperation with system users may be an alternative to small range of network development. An expected level of energy consumption can be achieved through appropriate power differentiation over time,
- in the operational planning for day-to-day congestion management, existing contracts with other entities, e.g., aggregators, should be taken into account,
- all entities interested in using system users' energy potential may be the source of signals (incentives) addressed to the users ,
- the role of DSOs is also the proper grading (queuing) of access to the energy potential of users connected to their network (the rules of cooperation with the TSO with respect to access to flexibility sources should be viewed as important),
- the whole issue must be managed by a specialised IT system.

In summary, the use of flexibility in the operation and management of the distribution network and system can be captured in the form of the following diagram and the author's *flow-circle concept*:

Fig. 2. The flow-circle concept of network management using flexibility.



The concept of *flow-circle* type runs in the closed system shown in the diagram above and should be applied when using non-technical network management tools[11]. The idea is to use continuous observation tools (captured in the observability of the network), making predictions over different time horizons, across different areas, with varying observation granularity. Modern prediction tools are included in system state estimators. The result of the calculations allows to identify constraints in the system, e.g., overloads, risk of failure or shortage of power or energy, and to select countermeasures commensurate with the threat and available at the selected time horizon[12]. Each use of the available resource can be treated as the performance of a service (own or external) and be monitored and evaluated accordingly.

A grid development perspective that considers the increase in the number of DER and their capacity

According to the latest data, the number of micro-installations connected to DSOs network in Poland has increased 5 times in the last two years, with the number of such installations exceeding 1,006 thousand units and 7,336 MW of installed capacity[13]. Such a large number of installations is a challenge for DSOs, both on the technical and organisational side. Therefore, the impact of distributed resources on the distribution grid should be considered in terms of opportunities as well as threats to the grid.

[11] Miletić M., *Energy Flows and Energy Cycle From Resources to End Users*, In book: *Energy – Resources and Building performance*, Publisher: NL: TU Delft Open, March 2021, (pp.20-42)
[12] Mukherjee, D., Chakraborty, S. & Ghosh, S. *Power system state forecasting using machine learning techniques*. Electr Eng 104, 283–305 (2022).
[13] PTPIREE, Mikroinstalacje w Polsce, stan na dzień 31 marca 2022r, access: 13.04.2022 http://www.ptpiree.pl/energetyka-w-polsce/energetyka-w-liczbach/mikroinstalacje-w-polsce

The undeniable advantage of distributed generation is that it produces energy close to where it is consumed, which significantly reduces the need for long-distance energy transmission (typical transmission involves transporting energy mainly from conventional sources), reducing energy losses in the grid and the load on grid components. Proper stabilisation of source operation with energy storage or a mix of generation technologies strengthens the positive impact of distributed sources on the DSO grid. In small grid areas, sources are generally expected to meet the energy demand of customers in that area, contributing to the creation of *energy balanced areas*, usually in the long term. Based on the scenario of national energy system development and changes in the market environment presented in PEP 2040, three main groups of changes that may significantly affect the distribution network can be identified[14]:

<u>(G1) Renewable Energy Sources (RES)</u>

- Photovoltaics - in 2030 the installed capacity may reach about 5-7 GW in total in micro and large installations, and by 2040 between 10 and 16 GW.
- Onshore wind farms - expected to develop much less dynamically than in recent years (in 2021 installed capacity of about 7.06 GW).
- Energy from biogas and biomass - electricity production in co-generation is expected. One of the advantages of the sources is defined as the possibility to use the sources for regulation purposes, which will contribute to increased flexibility of operation.
- Hydropower plants - activities aimed at the use of hydropower plants potential are envisaged through the development of water resources management, enhancing the role of retention or revitalisation of water dams which will contribute to increasing the number of water thresholds. The regulatory potential of hydropower was indicated as an additional asset.

In the longer term, the connection of an energy source with high variability and low predictability of power supplied to the grid should be associated with the obligation to ensure balancing in periods when the RES does not supply electricity to the grid (through energy storage)[15].

<u>(G2) Development of combined heat and power[16]:</u>

- Systemic - to improve energy efficiency, development of co-generation and trigeneration;
- Individual - anticipated low-carbon direction of transformation of individual sources (heat pumps, electric heating). Increase in the use of heat pumps is considered in government documents, PSE SA (Polish Transmission System Operator – TSO) and expert analyses. Forecasts of the Polish Organisation for Heat Pump Technology Development (PORT PC) indicate a significant increase in installed capacity in single-family buildings by 2030. Depending on the scenario, peak electric power may reach 2.5 to 5.4 GW.

[14] Polityka energetyczna Polski do 2040 r.[PEP2040], Ministerstwo Klimatu i środowiska, 2021, access: 13.04.2022, https://www.gov.pl/web/klimat/polityka-energetyczna-polski

[15] Pooja Y., Raghuraj S.,Divakar D., *Distributed systems, Formal methods, Load balancing, Proof obligations, Rodin, Verification*, Journal of Scientific & Industrial Research, Vol 80, No 12, December 2021, pp. 1078-1090

[16] Polityka energetyczna Polski do 2040 r.[PEP2040], Ministerstwo Klimatu i środowiska, 2021, access: 13.04.2022, https://www.gov.pl/web/klimat/polityka-energetyczna-polski

(G3) Energy communities and prosumers[17]

Enabling consumers to take an active role - using the possibilities of energy communities: prosumers of energy, energy clusters, cooperatives. Two groups are expected to develop:[18]

- Active consumers - individual entities, including prosumers, who, in addition to generating energy for their own needs, supply excess power to the grid and, if necessary, reduce electricity consumption by offering services to the system operator. It is estimated that the number of prosumers in Poland will have exceeded 1 million by 2030.
- Energy communities - collective entities (e.g., energy clusters, energy cooperatives, or other entities) that organize themselves to generate electricity for their own needs and other needs (e.g., storage, resale, etc.). By 2030, 300 energy communities were indicated as a target.

With the increase in the number of DER in the distribution network, the following phenomena are more frequently observed[19] :

- problems with maintaining power quality indicators in the network, mainly voltage level,
- overloading of selected network sections and elements (e.g., secondary substation transformers) due to excessive local generation,
- export of energy surplus to other network areas or voltage levels because of mismatched production and consumption or excessive concentration of sources in each area,
- the need to maintain power reserves in the system for sources whose operation profile is dependent on weather conditions (unstable sources, i.e. solar or wind).

Consequently, without the development of new rules for the operation of distribution systems, the scale of the predominantly negative phenomena will increase, posing a threat to the continuity of supply and security of the distribution system[20].

Summary

DER, being connected to DSO grid, have a significant energy potential, which in turn has an impact on the operation of the distribution grid - it can either improve or disrupt its operation. This potential, if properly exploited by the operator, can support the operation of the power system, i.e., directly the distribution grid and indirectly the National Power System.

It is important for the DSO to carry out analyses of the possibility of connecting the DER to the DSO network, the potential held and the possible interactions supporting the operation of the power system. Such analyses should be conducted at least with regard to considering the needs of the grid when selecting a location for new sources, in order to support the grid and the power system in the most effective way. This approach will unlock DER resources as providers of market-based flexibility services. The operator should also develop rules and procedures related to TSO/DSO/market cooperation based on non-discriminatory principles to reduce all

[17] *Ibidem.*
[18] *Ibidem*
[19] Pijarski P. Analysis of Voltage Conditions in Low Voltage Networks Highly Saturated with Photovoltaic Micro Installations, Acta Energetica 3/36 (2018), pp. 4–9
[20] Khezri R., Mahmoudi A., Aki H., *Optimal planning of solar photovoltaic and battery storage systems for grid-connected residential sector: Review, challenges and new perspectives*, Renewable and Sustainable Energy Reviews, Volume 153, January 2022, 111763, ISSN 1364-0321, access: 15.05.2022, https://www.sciencedirect.com/science/article/pii/S1364032121010339

barriers. Ultimately, the operator should design an appropriate local flexibility market to solve congestion problems in the distribution grid as well as to provide non-frequency ancillary services to the power system.

These recommendations are part of the new energy market model, shaped as part of the ongoing energy transition towards distributed generation.

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