Outline of using the Energy Cluster potential for the Distribution System Operator

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Abstract: The aim of the article is to present the possibility of cooperation between the Energy Cluster and Distribution System Operator (DSO) in order to improve the local grid operation, and indirectly, for the benefit of the National Power System. The possibility of creation and operation energy clusters in Poland, with particular emphasis on contractual relations with the DSO and the position of the cluster in the energy market is discussed at the first stage of the article. The following part analyses the impact of distributed energy sources (DER) on the distribution grid as well as the grid operation problems. The issue of distribution grid flexibility in relation to the development of distributed generation is presented. What is more the possible interactions between the Energy Cluster and the DSOs in this respect is elaborated. Finally, the ways of using the energy potential of the Energy Cluster by the DSOs is analysed, which take the form of specialized services for grid operators.
Key words: distributed energy resources, energy clusters, flexibility

Introduction

Another year has passed since the concept of the Energy Cluster was officially introduced to the Polish energy sector regulations, which found its place in the Renewable Energy Sources Act. At the same time, another year has been passing without full implementation of the REDII Directive (EC Directive 2018/2001) and the Market Directive (EC Directive 2019/944) in terms of "Renewable Energy Communities" and "Citizen Energy Communities" (RES Act).

Despite the initial enthusiasm of many communities, mainly from the renewable energy sector and local governments, as of today, most of energy clusters have not gone beyond the conceptual phase and the growth of new initiatives has been practically stopped. However, it should be emphasized, that most of the established energy clusters, as a goal of their activities have set themselves the construction of new generation sources to meet their own energy needs. Planned generating capacities are characterized by field dispersion, diverse technology of production and significant geographical distance from the places of energy consumption. The share of sources with intermitted generation (PV, wind) is important here; it covers about 2/3 of the planned capacity. The rest are stable sources (biogas, water, cogeneration) (Sołtysik, 2018). Few new initiatives, are based on the pursuit of energy self-sufficiency, mainly by building their own generation sources and even by building their own distribution network (KIKE, 2021).

Energy self-sufficiency, as indicated by clusters, is in fact an attempt to balance energy demand and supply in the cluster over a specified period of time. Clusters assume that such balancing should occur over a longer period of time, with the planned initial level of demand coverage by own production not exceeding 27% (Sołtysik, 2018). Balancing is not considered from the side of simultaneity of the process of electricity generation and consumption , i.e. real-time balancing is not assumed.

Due to the mentioned instability of generation and low self-balancing (also non real-time), the support of distribution grid is needed, by accepting temporary surpluses of produced energy or supplementing temporary deficiency. In emergency situations, distribution grid will act as a reserve for supplied energy to consumers. On the other hand, the energy potential of clusters can be useful for the DSOs to improve local distribution grid operation for the benefit of other system users and the National Power System (NPS). Such cooperation will always exist, regardless of whether the Energy Cluster has its own grid or is created on the DSO grid.

The purpose of this article is to analyse selected issues of Cluster-DSO cooperation and to answer the question whether a cluster's cooperation with DSOs is possible in the scope of using the Energy Cluster potential for the needs of local Distribution System Operator, and thus the National Power System.

General remarks on the Cluster-DSO cooperation

In the case of energy clusters, the purpose of which is to produce energy for the needs of its members, it is necessary to define how clusters would like to use the power system. Is it supposed to be only access to the network in order to transfer energy between clusters members, or they also need access to the Energy Market. Clusters can choose to build own grid connecting theirs participants or use the existing grid of the Distribution System Operator (DSO) located in the area of clusters operation. Regardless of the chosen solution, when building contractual relations in a cluster environment, several important issues should be taken into account, presented below, the proper understanding of which may guide further activities of the interested parties (Sikora, 2013).

From the DSO point of view, a cluster having its own grid is definitely easier to cooperate with because the network must have the right Operator. Therefore, it is a cooperation of two Distribution System Operators, which does not require special agreements, as a cluster is treated as a consumer connected to the DSO grid (Energy Law Act).

In case of clusters created on the DSO grid, both consumers and producers are still connected to the DSO network, which provides them distribution service - the same as before joining to a cluster. In this case, the DSO's task is primarily to enable the participation of entities in the cluster as well as to fix its activities on the network. If cluster participants are treated as independent entities, changes are required in the contractual relations between the Operator and all interested parties.

There is a postulate from both DSOs and Clusters that the cluster area, apart from the geographical limitation, should also have a grid limitation, i.e. points defining a cluster area belong to the grid of the same DSO (WKB, 2019). This postulate is justified by the fact that if cluster’s area includes more than one Operator grid area, firstly, this cluster with each DSO must establish individual contractual relations, and secondly, there is a risk that cluster participants will not have the distribution service provided in the same way. It is also to be considered whether a mixed cluster should be allowed to operate on the DSO grid, i.e. some participants are connected to the DSO grid, and some to the own grid. It seems that this is possible provided that the cluster own grid is connected to the DSO network.

Effective functioning of any cluster requires the exchange of information and metering data with the DSO, which is primarily associated with ensuring the proper status of metering. While generators and some of the consumers are metered correctly from the point of view of cluster needs, i.e., meters with load profile registration, remote and automatic data acquisition, the metering of other consumers, including households, for the most part does not meet these requirements. By 2028, it is planned that each DSO in Poland will have installed Smart-Metering meters for at least 80% of household customers (Energy Law Act), which will significantly increase the possibility of new participants joining to clusters.

If clusters start using energy market mechanisms, e.g. purchase and sale of energy, it is necessary to grant it an appropriate status and define its rights and obligations. Typically, this task is performed by the system operator on which a cluster is connected. The role of the DSO is to legitimize the activity of a cluster in the operator's grid by adopting a minimum framework for cooperation, as is done for example for energy suppliers and the Third Party Access (TPA) principle. The operator should also take into account the energy potential of clusters both from the technical side, associated with distributed generation, as well as from the market side - as customers or providers of new services such as DSR, flexibility.

The applicable national rules (RES Act) do not prejudge contractual relations between cluster members and the DSO on whose networks the cluster was established. In the case of distribution services, they are always provided by the Operator of a grid to which a cluster is connected. As for the delivery of energy, cluster participants are clients of the Electricity Suppliers who sell it or buy energy from them. It is also possible to combine both the purchase of distribution services and energy into one contract, i.e. a master agreement.

Along with clusters development it is natural for the structure of clusters to be changed. Usually there is an increase in the number of consumers and producers. Other elements also appear, e.g. energy storage or the need of changing existing business model in a way of using the potential of a cluster in the energy market - to provide flexibility services to the NPS or DSO. The cooperation agreement with DSO must provide for both, a change in structure and behaviour of cluster participants. Any change, if planned, should be analysed by both - the cluster and the DSO. This reduces the risk that, as a result of a planned change, clusters will cease to function for formal reasons.

The loss or resignation of participation, especially in clusters on DSO grid, need a special protection from a situation where clusters ceases to function. DSO, as a public trust entity, must ensure that customers and energy producers are not left on their own.

The distributed sources impact on the DSO grid

According to the latest information, in the last two years in Poland there was a fivefold increase in the number of micro-installations connected to DSOs grid, the number of which has already exceeded the level of 760 000 pcs. and 5 340 MW of installed capacity (PTPIREE, 2021). Such a large number of distributed resources is a challenge for DSOs, both from the technical and organizational point of view. Therefore, the impact of distributed resources on distribution network should be considered as opportunities and threats for the network.

The undeniable advantage of distributed generation is the production of energy near to their consumption, which significantly reduces the need for long-distance energy transmission (typical transmission is mainly from conventional sources), reducing grid energy losses and the load of grid components. Proper stabilization of source operation by using energy storage or mix of generation technologies strengthens the positive impact of distributed sources on DSO network (PEP 2040, 2021). In the case of energy clusters, sources are in principle supposed to balance the energy demand of customers in a cluster, contributing to the creation of energy balanced areas, usually in the long term.

With the increase of distributed generation in distribution network, phenomena such as appeared (Pijarski, 2018; PTPIREE, 2021) :

- problems with maintaining power quality indicators in the network, mainly voltage level,
- overloading of selected grid sections and elements (e.g. MV/LV transformers) due to excessive local generation,
- export of energy surplus to other network areas or voltage upper levels as a result of mismatched production and consumption or excessive concentration of sources in a given area,
- necessity to maintain power reserve in the system for the sources whose production profile depends on the weather conditions (unstable sources - solar, wind).

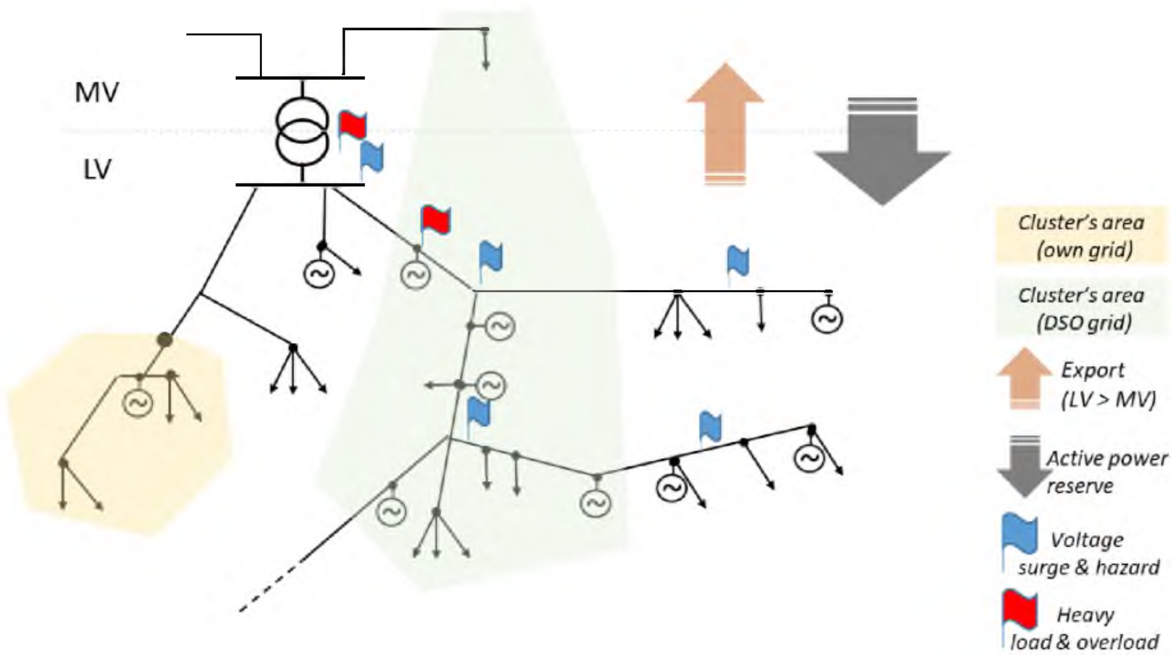

Fig.1 Graphical interpretation of network problems. Cluster areas as background.
Sources: Own Study

One of the reasons for the described problems in distribution grid, is an unprecedented growth of distributed generation in such a short period of time, which cannot be matched by network investments. These investments, which are made in order to improve the grid and accommodate more RES, require sufficient time for implementation and an appropriate level of financing (PEP 2040, 2021).

It should be emphasized here that a development of distributed generation is the main direction of energy decentralization and decarbonization. In such an approach, the role of the DSOs is to broadly support market changes and to reduce or eliminate barriers that prevent this transformation from taking place. It is necessary to maintain efficiency, security and stability of the electricity grid (Roadmap, 2021)

Distribution network flexibility

Saturation of distribution network with distributed energy sources means that DSOs must accept higher variability of energy generation, which in many cases is closely related to weather conditions. This results in moving away from the "generation follows demand" principle to the "demand follows generation" principle. Most of renewable generations are intermittent and (apart from downwards) not controllable. The more type of generation will be connected to the grid, the harder it will be to keep pace with demand by dispatchable generation. Energy storage will play an important role due to fact that not all demand is able to follow renewable. 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 (Vision Paper, 2015). On the other hand, grid users increasingly would like to actively participate in the energy market by adjusting their energy potential (generation, consumption, storage) to the market. In other words, they respond to market signals, e.g. energy prices, by changing their typical behaviour - they optimize energy consumption, produce energy, transforming themselves into Active Consumers (Mataczyńska & Kucharska, 2020).

This unique ability of a power system to respond to most of change in demand and supply, caused by the dispersion of many types of generation resources and/or activating users on the energy market, is called the energy system flexibility.

Interaction between Energy Clusters and DSO

Taking into account the previous considerations, clusters and DSO (representing also other grid users) may interact in the following areas:

- the assumption of energy self-consumption of a cluster, results in investments in new generation capacities, which may negative affected on the distribution network, if realized
- due to the territorially limited area of a cluster, there may be a concentration of DER, which may result in sources redispatch ,
- not all network users in a given area are willing or able to participate in clusters. The operator must ensure that everyone has the same level of distribution service, and guarantee the same quality and reliability parameters of supply, including power capacity reserve in the system,
- balancing of an energy cluster through active management of demand, as well as participation in organized forms of the energy market, cause greater variability of flows in the network, which may adversely affect its operation. The operator must increase the flexibility of its own network,
- existing or planned network congestions may effectively prevent clusters from achieving its objectives.

The above outlined Cluster-OSD interaction could be mutually beneficial if the parties find common ground and understand each other's needs.

In the initial phase of development of such initiatives, Cluster-OSD cooperation should occur at least in the following areas:

- location of clusters on the DSO network,
- build new capacity by clusters, including the selection of generation technology,
- support for balancing of clusters by energy storage facilities,
- using the energy potential of cluster participants for the local improvement of grid operation.

In the case a cluster does not plan to build its own distribution grid, i.e. cluster members are connected to the DSO grid, the assumed cluster objectives (related to energy production or ensuring energy self-consumption) must be analysed in terms of the technical capacity of the grid. At least the following aspects need to be taken into consideration:

- whether the geographical area of a cluster coincides with the area of the grid of the same DSO. Otherwise, there is a risk of cluster division into sub-areas, which together will not give the desired effect,
- whether the area of a cluster includes multiple voltage levels e.g. LV, MV, or the area is not too vast. In this case, the location of the sources may be on a different voltage level as the loads or at a considerable distance. This results in additional flows in the network and departure from the principle of production as close to the load as possible,
- whether in the area of a cluster, the Operator has the possibility of connecting new sources.

An important issue for clusters, is the choice of the future energy generation technology. From the Operator's point of view, it is important if the source generates energy stably, is supported by energy storage and if it has the regulatory capabilities. Stable generation allows the DSO to plan grid flows more accurately, which increases the flexibility of the grid and the possibility of connecting new customers without the need for grid expansion (Wasiak, 2015). Furthermore, by appropriately selected the source location, it is possible to significantly reduce technical problems in the grid associated with the expansion of distributed generation (Pijarski, 2018). Operators, on the basis of conducted observations and analyses of the network condition, can indicate locations where it would be advisable to build a new RES. Additional definition of requirements regarding generation stability or control capabilities would allow clusters to build such source on request of DSOs. Benefits from such an action would accrue to clusters - the possibility to build a source for needs of clusters and the Operator - a stable source supports the operation of the network and in some cases, postpones the need for network expansion.

Clusters as service providers for the DSO

Activities described as Cluster-OSD interaction, lead to the conclusion that the Energy Cluster can support the operation of distribution system. Properly defining the framework for such cooperation will benefit both clusters and the DSO. This idea of supporting operators in increasing the flexibility of their networks (as defined previously) is reflected in the provisions of the internal market regulation (EC Regulation 2019/943). In line with the provisions of the Regulation 2019/943, to integrate the growing share of renewable energy sources (RES), the electricity system should make use of all available flexibility resources. The flexibility resources consist of flexible generation, interconnection, demand response and energy storage.

Each network user is entitled to offer its flexibility to the market, and the DSO is entitled to obtain flexibility from entities connected to its network as a service on a market basis (EC Directive 2019/944, Articles 15, 17, 32). In other words, the system user who owns the flexibility resources can, in response to a market signal, commit to a certain behaviour in terms of energy production, consumption or storage. Since the members of a cluster (in the sense of "Citizen Energy Communities") act together, offering flexibility is only possible through aggregation.

The purpose for which the DSO will use the flexibility resources determines the type of service that clusters (or other system user) will provide to the Operator. The referenced Directive 2019/944 and Regulation 2019/943, indicate three types of services that the DSO may use:

(1) flexibility services - defined by the Operator so that the owner of a flexibility resource is able to change of electricity load, generation or storage from their normal or current patterns (reduction or increase) in response to signals (price) from DSO.

    Flexibility services can be used for "congestion management", i.e. elimination by DSOs of situations in which all requests from market participants cannot be accommodated, because they would significantly affect the physical flows on network elements which cannot accommodate those flows. A typical example of network congestion is the overloading of power lines or substations caused by excessive concentration of generation on a grid, not adapted to the consumption existing there. Such a situation makes it necessary for the DSO to prevent the negative impact of such a condition (by means of manage the network), reducing the risk of outages. As a result, clusters are unable to achieve its objectives, or this achievement is very limited.

    Another area of utilization of cluster resources can be support for planned and unplanned operational activities. As we know, the Operator is obliged to keep the network in good technical condition. Due to the safety of these operation, it is often necessary to switch off the voltage and interruptions in supply. In such cases, energy generation sources or storage facilities in a cluster could provide power to some areas of the grid that are not related to the area of maintenance work but due to network connections have been switched off. The same can be done in case of failure in the grid.

    The long-term cooperation of clusters with the DSO may, for a certain period of time, replace the need for network expansion, especially if the new source is built in a location agreed with the Operator. The network development plan shall also include the use of all resources that the distribution system operator is able to use as an alternative to system expansion.

(2) non-frequency ancillary services – services used by a distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability (Directive 2019/944).

    The most significant application of this service, is to use technical capabilities of sources operating to control and maintain voltage. This is an important problem in networks with high saturation of renewable sources, described in detail above, usually mitigated by proper management of reactive power. Other applications require clusters to have either generation sources stable in production or energy storage. A special case here is "island operation", which can be provided in a given grid area in case of e.g. long-term outages.

(3) redispatching service - means a measure, including curtailment, that is activated by distribution system operator by altering the generation, load pattern, or both, in order to change physical flows in the electricity system and relieve a physical congestion or otherwise ensure system security (Regulation 2019/943).

If the DSO has no other options, it can agree with the network users, including the Cluster, that it is necessary, for example, to reduce generation or stop it altogether. The primary objective here is system security.

The provision of the services outlined above, may take a form of a long- or short-term commitment for which a cluster will receive appropriate remuneration. In principle, the length of the commitment can be determined by the purpose for which the service will be used. For alternatives to network expansion, the duration of the service is calculated in years. For the purpose of congestion management, the periods can be counted either in years - as readiness for service, or in near real time - as countering physical congestion. In the case of voltage control and maintenance, near real-time service times become important (Mendicino, 2021).

Conclusions

Clusters, as renewable or citizen energy communities, are presented as a new actor in the electricity market. Typically, they aggregate distributed generation, loads or storages over a small network area for self-consumption. They are also places where new technologies can be applied, e.g. energy storage, e-mobility development, smart grid management or local balancing. Clusters have a significant energy potential that comes from distributed resources, therefore they have an impact on the operation of the grid - they can improve or disrupt its operation. This potential, properly used by the operator may support the operation of the power system, i.e. directly the distribution grid and indirectly the National Power System.

The analysis conducted from the perspective of the possibilities of creating a cluster on the DSO network, its potential and possible interactions justifies the thesis that proper Cluster-DSO cooperation supports the operation of the power system. This cooperation should be conducted at least in the scope of considering the needs of the grid when selecting sites for new sources and supporting the flexibility of the grid and the power system through active management of a cluster so that it can provide services to DSOs in a market-based formula. Therefore, it is necessary for the DSO to properly recognize and consider the Energy Cluster as a new market participant with its potential and opportunities. The operator should also develop rules for such cooperation that are non-discriminatory and without unnecessary barriers. Ultimately, the Operator, should design an appropriate local flexibility market to address the problem of congestions in the distribution network and to deliver ancillary services to the power system.

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

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