European Distribution System Operators for Smart Grids

Coordination of transmission and distribution system operators: a key step for the Energy Union

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Introduction

Distribution System Operators (DSOs) and Transmission System Operators (TSOs) are today in charge of maintaining the electricity system stable for all consumers in a society ever more reliant on uninterrupted power supply. This task is more challenging now than in past decades: renewable energy sources are being connected to distribution grids at an extraordinary rate, consumers are installing solar panels on their roofs, new market players are starting to sell flexibility services, and electric vehicles (EV) are starting to appear on the roads. All of these evolutions are impacting the electric systems, notably the DSOs and the way they operate and develop their grids and are leading them to adapt and innovate. New policy objectives such as the European 2030 targets, and technology developments lowering the cost of renewable technologies and electric vehicles, will drive these changes further.

In order for this shift towards a decentralised energy system to be as smooth and efficient as possible for all consumers, additional cooperation and coordination between system operators is required. This cooperation must be conducive to the development of new market players and better services at affordable prices, increasing choice for consumers in the process.

Public authorities are starting to acknowledge the need to foster better cooperation between system operators. In the "Energy Regulation: bridge to 2025" paper (2014), the Agency for the Cooperation of Energy Regulators (ACER) highlighted TSO-DSO cooperation as a pivotal step for the efficient development of our electricity grids. The Energy Union Communication (2015) also stressed the need for a coordinated power system, in order to increase security of supply, complete the internal energy market and integrate renewables.

In this paper, EDSO draws a series of recommendations to improve cooperation for system planning, network user connection, system operation, data management and market facilitation.

Key messages

1. **Being responsible for the operational security and the quality of supply of its own networks, each system operator should be entrusted to monitor and interact with its own grid users**:
   - DSOs should be the entities collecting data from all of the users connected to their grid (generators, consumers and other DSOs)
   - If deemed necessary, data from distributed generation and other users should be channelled from the users to the TSO, through the DSO control centre(s)
   - One system operator should not interact directly with a grid user connected to another network. TSOs should not interact with customers connected downstream to DSO networks
   - Procedures along these principles should be designed at national level for distributed energy resources (DER) and demand side response (DSR) controllability and congestion management.

2. **TSOs and DSOs should define the data they need from each other**, and mutually agree on the data models, data format and communication protocols to be used for exchanging this data.

3. **System planning should be coordinated between the TSO and DSO**. More regular exchange of simplified electrical models of the grids and demand/generation forecasts between system operators are needed.

4. **TSOs and DSOs should define together connection requirements for grid users.** Future revisions of the European connection network codes should be based on a joint TSO-DSO technical and economic analysis.

5. To facilitate the integration of renewable energy sources (RES) and customer connections, **TSOs and DSOs should regularly exchange and publish information regarding their available network capacity at the TSO/DSO interface**.

6. **For new significant grid users requiring connection to the electricity grid, a joint analysis should be carried out by the DSO and TSO to establish whether connection to the transmission or distribution grid is more appropriate**. This is also applicable among DSOs when choosing between several DSO networks.

7. System security is a joint TSO and DSO responsibility, as such, **system operation network codes and emergency plans should be jointly designed by TSOs and DSOs.**

8. **DSOs will need to procure system flexibility services**, and oversee their effects on the grid. As a first step, DSOs should investigate the constraints and benefits of system flexibility services for their own system operation and work together with NRAs to adapt the necessary legislation.

9. **The procurement of services by TSOs (e.g. for balancing purposes) from users connected to distribution grids should be supervised by the DSO**, at all stages. Without this, there is a risk that a TSO action could put the distribution network's operational security at risk and create a greater threat to overall network stability.

10. **All electricity markets will have to evolve to take into account distribution networks and the location of generators and service providers.**

1. System planning

In order to develop a well-functioning and cost-efficient system, system operators collect structural data on their grids and plan their future extension or renewal. In the past, when generation was centralised and a steady growth of electricity consumption observed, this business process was simple. Currently, with the vast majority of RES being connected to distribution networks, and with less predictable DER, consumption and more active consumers or 'prosumers', system operation by the DSOs will increase in complexity. Both DSOs and TSOs will be more interdependent to coordinate long-term system planning.

The idea of procuring system flexibility services, or offering flexible contracts to grid users instead of investing in network capacity, need to be further evaluated and consistently tested by DSOs and should be integrated into system planning. As a first step, it is necessary to make information exchange between system operators in different time horizons (e.g. planning, operation) a formal business process.

Transparent exchange of forecasts: system development, generation and demand

Both transmission and distribution energy networks must be planned in a cost-efficient manner in order to minimise the total cost for consumers. To ensure the option with the maximum social welfare is chosen, DSOs, which have an extended knowledge of local grids, and TSOs which have an overview of the whole systems, notably on the traditional bulk energy generation and transportation needs, should **exchange information on their network development, demand and generation forecasts.**

Development of common simplified models of the electricity system

For the purpose of system analysis and planning, system operators can benefit from having access to a simplified electrical model of their network that allows them to simulate power flows accurately. To speed up the system planning process, TSOs should get access to simplified models of the distribution networks they are connected to. Similarly, DSOs should also have access to such transmission network models, allowing DSOs to simulate electrical flows in the transmission network (and distribution networks they are connected to). Grid adaptations needed to connect new significant grid users could be agreed faster, which would be beneficial all-round.

Example - German HEO-systems

In Germany, larger DSOs operating high voltage (HV) grids use so-called HEO-functions in addition to their classical SCADA system. HEO is an abbreviation of the German phrase for "Superior Decision and Optimisation Functions". These programmes calculate system states and support the control centre operators. Their database contains a complete model of the distribution system. The HEO also provides functions for system state forecasts, based on the integration of consumption and distributed energy generation forecast. Besides measurements from the distribution system, external data is used to calculate the system status and produce accurate forecasts:

- Observability area of the transmission system (current status as well as forecasts)
- Information on the current status and schedules of generators connected to the DSO's grid
- Minimum generation of certain generators to sustain system stability as defined by the TSO (such generators must not be curtailed further than the defined value)
- Data from decentralised generation
- Observability area and current status and forecasts of downstream distribution systems

2. Connection

The connection process is subject to specific requirements for users consuming and/or generating a significant amount of electricity. These requirements are set in order to optimise the connection cost, optimise the quality of supply and avoid any incidents on the user's side. With new types and higher quantities of users to connect (DER, EV), DSO-TSO cooperation in this area is necessary to efficiently meet connection demand, ease the process and set appropriate requirements that contribute to overall network stability.

Common optimal connection requirements

As TSOs and DSOs together operate the overall power system, a first basic step toward better coordination would be to define connection requirements in common as this is common practice today in several countries such as Germany. **Joint assessment of connection requirements is necessary when revising the two network codes in the future.**

Example – Network technology forum (FNN)

The FNN is part of the German Association for Electrical, Electronic & Information Technologies, organised as a board with its own staff and with more than 300 members from industrial manufacturers, network companies, and scientists. The main purpose of FNN is the development of technical codes for the interoperability and coordination of system operations in order to maintain the reliability of the power system in a cost-efficient way. These codes are complemented by guidelines and recommendations. The FNN actively coordinates the interfaces with economic questions, legal and regulatory topics. The interfaces with other infrastructures (e.g. the gas network) and other standardisation bodies (DKE, DIN) are also closely monitored.

Common optimal connection point

TSOs and DSOs should also coordinate when a consumer or a generator of a significant size intends to connect to the grid in order to determine the optimal connection point for the applicant party and to identify the possible impact on overall system operation. When the proposed connection point belongs to the distribution network, and before granting access to the grid, it may also be necessary for the TSO to analyse the impact on the transmission network. In the same way, when the proposed connection points belongs to the transmission network, the DSO may need to analyse the impact on its network. **To ease that process, a common and regular assessment of the grid hosting capacity at the TSO/DSO interface would help project promoters to connect to the network** in such a way that would minimise the need for further network development. This will positively impact the consumer's bill.

Example – Publication of network capacity in France

The French TSO (RTE) and the French DSO (ERDF) have develop together a public website illustrating the existing and future network capacity of both transmission and distribution networks (at the HV/MV substations level) for distributed generation connection. Anyone can access the information on the available hosting capacity of the network before launching a new generation plant development project. This tool has been developed for high-level informative purposes. It does not replace any of the steps within the existing official process for network connection granting.

3. System operation

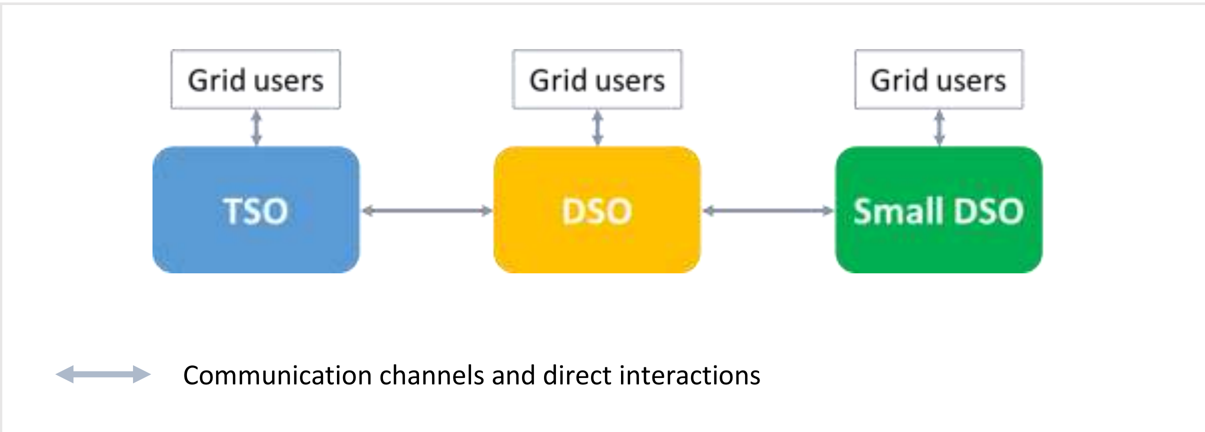
In order to enable smooth market operation and deliver the best possible service to consumers, system operations have to be coordinated, avoiding overlapping responsibilities between TSOs and DSOs.

Cascading responsibilities for system operation

With more decentralised generation and active users, network coordination cannot be managed centrally anymore. **EDSO supports a model based on the concept of "cascading responsibilities" where each system operator is responsible for its own grid and grid users.** It means that a system operator can only interact directly with the users connected to its network, and that each system operator collects data from its users and pass on relevant information to the upstream and downstream system operators.

In this framework, the TSO is responsible for monitoring the overall system balance, monitoring cross-border power flows and managing the extra high voltage lines, which form the backbone of the European grid, while DSOs operate the medium, low and, in some cases, high voltage distribution lines and are responsible for voltage control and congestion management.

When a risk or disturbance to the electricity grid is foreseen, but cannot be solved by market actions, the system operator experiencing problems has to influence the electricity flows by limiting consumption or generation. These actions must be controlled by the affected system operators and coordinated among parties in order to minimise disturbances for all network users. When the system operator cannot solve any issue on its own, it should be able to request the support of a DSO placed "downstream" and managing a lower voltage network. In such cases, the system operator *requesting* support should be in charge of assessing and executing the necessary measures in its *own* grid, but should pass on call for support to downstream system operators. Conversely, the system operator *receiving* a request for support should act on its own grid in the way it deems appropriate, report back to the upstream system operator, and if necessary, pass on a request for action to neighbouring system operators.



Voltage control, constraint management, remote control of distributed generation

With more distributed generation, DSOs more regularly encounter situations in which voltage control and reactive power control are required. On the one hand, these are local phenomena that should be managed by the DSO, on the other, actions taken on distribution networks should not create an imbalance in the overall network. As such, **TSOs should not interact directly with distribution grid users**, as this can create local constraints that risk degenerating into system-wide issues.

DSOs will need to interact directly with a user (e.g. through flexibility market or a variable access contract) in order to solve a local problem while avoiding unnecessary reinforcements. This type of action should be coordinated to only affect local users and not overall system stability.

For this reason, **constraint management and interaction with DER have to be carefully coordinated**. A recent study[1] presented two suggestions for coordinating the management of DSO and TSO reactive power needs: (1) the DSO procures a service from grid users and delivers the required effect at the TSO/DSO connection point, (2) the TSO and DSO express their needs and constraints to a common market place operated by an independent market operator. The latter could be a simple evolution of the current balancing/constraints management markets.

Example - French project for PV and wind farm monitoring

In France, the IPES platform has been developed together by ERDF (DSO) and RTE (TSO) in order to help the TSO reach an adequate observability level of distributed generators connected to the MV network. Measurement data from MV lines with DER (wind farms and PV plants) are provided by the DSO to the TSO. The data corresponds to the active power injection of distributed generators derived on a 1 minute basis (with an accuracy related to measurement errors and the assumptions made to calculate the active power from the current measurement of lines). The data are used by the TSO for real-time operation as well as to feed into a power production forecast model, the results of which are sent back to the DSO for the operation of its network. The forecast data correspond to active power injection forecast at 0:00, 06:00, 12:00 and 18:00, and for the following three days.

Work is underway by ERDF to develop its own power production forecast for wind farms and PV plants connected to its network.

Defence plan and emergency operations

System defence plans and restoration schemes are modes of operation for emergency situations, put into action to avoid power interruptions and blackouts, and to restore electricity where interruptions were not successfully avoided. In these states of emergency, close coordination is required between all actors playing an active part in the defence and restoration schemes (TSOs, large power plants, significant grid users and DSOs).

All existing emergency and restoration actions executed at distribution level are designed to contribute to the distribution system stability and, thus, to the overall system stable. They must, therefore, be activated according to the current needs. As emergency tools are connected to distribution networks, implementation and activation should be supervised and controlled by DSOs.

Coordination between TSOs and DSOs is the cornerstone of system defence plans, since a large number of actions within these plans take place in DSO networks in order to help both operators to restore system balance. Potential actions include:

[1] ECN/ECORYS, "*The role of DSOs in a Smart Grid environment*", April 2014

- Automatic low frequency load shedding: actions based on frequency relays and currently implemented in primary substations to automatically disconnect MV feeders at predefined frequency settings and help to prevent frequency collapse and widespread power outages.
- Rapid operation of emergency tools: TSOs and DSOs can agree on actions to be undertaken in real-time to stabilise the systems. Schemes such as reduction of voltage on the distribution side or on-load tap changer blocking can be implemented. Good coordination is required both in the design and activation phases.
- In cases of localised outages in areas with flexible loads and DER, DSOs can isolate the part of the network experiencing a fault (islanding operation), thus maintaining electricity supply elsewhere on the network.

With the growth of DER connected to distribution networks, new actions for emergency situations could be required in the future, for example, changing the active power set-points of the largest power plants connected to the DSO network. **As for the current emergency and restoration plans and actions, any new measures should be coordinated between TSOs, DSOs and generators**.

4. Information exchange and data management

The way in which electricity grids are managed is undergoing substantial change with the growing availability of data. New streams of information coming from smart meters, energy services providers, new automated grid equipment and sensors are progressively reaching DSOs. TSOs are also collecting more data from installations connected to transmission networks. These data will have to be handled rigorously and cautiously to guarantee flawless market functioning, grid operation, and the protection of grid user privacy.

Improved data exchange between system operators

For TSOs and DSOs this means that aggregated information on their respective observability area should flow smoothly from one to the other. At each stage (planning, operation, emergency), network observability will be key. Each system operator will have to process aggregated data received from upstream and downstream, merge it with its own data and forward it. In this way, all system operators will share an overview of the network situation while remaining responsible for managing their own grid in the most efficient way. More specifically, in order to react fast enough to dynamic generation and consumption patterns, **DSOs and TSOs will have to exchange three types of information on grid users:**

- Data used for coordinated operation and control of the networks, close to real-time
- Static data used for medium-term or long-term purposes (management of connection requests, planning)
- Technical data for market operation: energy market, ancillary services markets, load shedding market, capacity market.

Moreover, **secured telecommunications channels must be reinforced between the TSO and DSO control centers for the activation of any actions (e.g. defence plans)** and for the exchange of information. These channels are already in place for the biggest DSOs in Europe, but will have to be extended. In order to improve TSO-DSO cooperation, the first step will be to define what data is needed by each system operator and how to exchange it (data model, data format, communication protocol). Last but not least, the cost of data collection should not be underestimated. In order to avoid a bill increase for final consumers, data communication requirements should be differentiated between categories of users, as small users are plentiful but individually have a limited effect on system security.

Consumer data handling

Through smart meters, DSOs will receive detailed information on grid events and electricity consumption which will contribute to improving control and supervision of LV, MV and indirectly HV networks. Today in most countries DSOs are entrusted to carry out a number of key processes for retail markets: supplier switching, billing, settlement. The same data needed for these processes, as well as the more detailed consumption data from smart meters, will be passed on to market parties (suppliers, aggregators, energy services companies) so as to offer innovative energy services, and will be used by system operators for network planning, demand forecast and operation. Due to the sensitivity of such data, a **regulated organisation such as the DSO should be kept in charge of handling the data. Examples of neutral data management and market facilitation by a single DSOs or groups of DSOs, already exist and can be used as a model for Europe**[2].

[2] EDSO, "*Data Management: The role of Distribution System Operators in managing data*", June 2014

5. Market facilitation

Already today, the DSO is a neutral market facilitator, entrusted to collect consumption data, to manage the switching process, and contributor to the settlement process needed for the accurate tracing of grid user generation and consumption. These tasks will involve the processing of larger quantities of data in the near future, but will not change dramatically.

However, as the retail market is becoming more flexible, system operators must adapt to the entry of new market players that can affect primarily the operations of distribution networks. In this context, the flexible resources connected to distribution networks could be used to address TSO needs (balancing, network constraints), DSO needs (voltage control, congestion management) or for market purposes (portfolio optimisation). Irrespective of the services considered, **DSOs will play a major role in future market facilitation**.

Validation of flexibility services, balancing services and congestion management

With new competitive players entering the retail market and new services being offered, DSOs will have to **validate the technical availability of flexible resources connected to its network** in order to guarantee operational security and quality of supply to all consumers. This is one of the early findings of the ongoing FP7 evolvDSO project, which takes this one step further by considering that DSOs may build on its validation and market facilitation roles by one day operating local flexibility markets[3]. Validation should be carried out over three stages: pre-qualification of the flexible resource (in terms of potential constraints on the distribution network), activation of the resource, and control of the energy effectively consumed or produced (ex-post check).

Similarly to TSOs today, DSOs will soon have an important role to play in congestion management and balancing. In current electricity markets, balance responsible parties (BRP) act to match expected consumption with expected production. Their portfolio can contain many network users, including users equipped with DER, usually connected to the distribution grid. In order to balance their portfolio, BRPs trade on the power exchange to sell expected surplus or buy extra energy if a shortage is expected. At a certain point in the day, trading stops (gate closure time) and the TSO calculates whether the energy flow resulting from all plans can physically be channelled through the grid. When a network congestion is expected, preventive measures must be taken by the TSO. In the medium-term, **DSO will have to perform the same tasks in order to avoid congestion at distribution level.**

With regards to balancing – which starts after the gate closure time – the TSO is in charge of dispatching extra generation or reducing energy consumption if a shortage or a surplus of energy is expected. It is now becoming important that, when the TSO procures extra generation, congestions are not created at DSO level. Consequently, the **DSO will also have to be involved for prequalifying, and prior to the activation of services from balancing service providers, and other flexibility service providers.**

Flexibility market enabler

The power system will soon be in need of different types of flexibility, especially at distribution system level. Different options are possible for the use of flexibility: new regulation and grid codes, bilateral

[3] evolvDSO, "D1.3 - Preliminary assessment of the future roles of DSOs, future market architectures and regulatory frameworks for network integration of DRES", July 2014
evolvDSO, "D2.1 - Business Use Cases Definition and Requirements", July 2014

contracts and market creation. If the latter option is judged the most appropriate, flexibility services could be offered on an intra-day or day-ahead basis, or offered and contracted in the long-term through a call for tender. Their activation would depend on forecasts and contractual arrangements (e.g. availability, provision capability) which would require a strong coordination with market participants and between grid operators.

In those cases, the DSO should take on the role of flexibility market enabler and perform all necessary calculations to create a merit order list, before selecting and activating the best offers. This could be achieved through the creation of a market (or several markets) centralising system flexibility services based on bids. This means **an appropriate mechanism is needed for procuring system flexibility services**. **This mechanism should include locational information** for each bid as the potential congestion or voltage issue encountered by the DSO will require action from a local service provider.

Dialogue between TSOs, DSOs and national regulatory authorities (NRAs) are needed to coordinate the use of demand response and distributed generation it the most efficient way. A similar reflection should be made when storage comes to technical maturity. This is a crucial step to ensure that consumers are able to make the most of their own flexibility potential.

EDSO for Smart Grids is a European association gathering leading electricity distribution system operators (DSOs), cooperating to bring smart grids from vision to reality.

www.edsoforsmartgrids.eu