CIRED 2020 Berlin Workshop (CIRED 2020)

22-23 September 2020

Theme 3: Flexibility Platforms and the Role of future DSO's

Large-scale demonstration of TSO–DSO coordination: the CoordiNet Spanish approach

Journals
The Institution of Engineering and Technology

ISSN 2515-0855
doi: 10.1049/oap-cired.2021.0209
www.ietdl.org

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Abstract: The necessary energy transition to decarbonise power systems is leading to increasingly important challenges for the operation of power systems. On the one hand, the intermittent nature of renewable generation requires system operators to procure system services in larger volumes than in the past. On the other hand, the growing penetration of medium- and small-scale, flexible demand and storage systems in distribution networks might result in congestions or voltage problems in this grid level, but these resources could potentially offer system services, if they are aggregated effectively and there is appropriate coordination between transmission system operators (TSOs), distribution system operators (DSOs) and aggregators. Therefore, an interesting topic to be analysed is whether distributed energy resources can replace traditional generation in the provision of system services, how this replacement will affect the system operators' roles and how to improve the coordination between TSOs and DSOs. The CoordiNet project aims at demonstrating, through different TSO–DSO coordination schemes, options for providing system services with flexible resources located at different voltage levels. This study shows the Spanish demonstrators, in which REE (TSO) and the two largest DSOs, i.e. e-distribución and i-DE participate, as well as IIT Comillas and Tecnalia, among several European partners.

1 Introduction

This paper aims to describe the Spanish demonstrators in the CoordiNet project, which includes a wide variety of resources and services. Demand, generation and storage units, namely flexibility service providers (FSPs) are considered to provide system services to distribution system operators (DSOs) and transmission system operator (TSO), including balancing, voltage control, congestion management and islanding operation, as shown in Fig. 1. These resources are connected to DSOs and TSO networks, with a total installed capacity of >1 GW.

There are several and different resources considered in the Spanish demonstrators: large wind farms, photovoltaic (PV) plants, cogeneration plants, biogas plants, large industrial demand-side resources and batteries. These resources are located in widely dispersed in South and East areas in Spain.

Demonstrators include both transmission and distribution grids with high-voltage, medium-voltage and low-voltage networks. The wide varieties of networks and resources allow for considering different challenges, scenarios and withdraw consistent conclusions.

For the services considered in the demonstrators, key functions have been highlighted, following the Business Use Cases (BUCs) methodology [1] and the coordination schemes defined in CoordiNet [2]. In addition, to perform these BUCs, the information, communication and components layers have been identified using the Smart Grid Reference Architecture Model (SGAM) methodology proposed in [1] and applied to CoordiNet in [3]. These layers help to identify the needs for developments to be able to accomplish the BUCs, including interoperable and scalable platforms.

2 Coordination schemes

A coordination scheme is defined [4] as 'the relation between TSO and DSO, defining the roles and responsibilities of each system operator, when procuring and using system services provided by the distribution grid'. Following this definition, a coordination scheme highlights three key points for increasing TSO–DSO coordination: (i) the assignment of responsibilities and the interaction between TSO and DSO, (ii) the focus on specific market phases (e.g. pre-qualification, procurement) and (iii) how these market phases are organised through a proper market design.

There is not a one-size-fits-all coordination scheme, but a multitude of coordination schemes that propose different solutions to different circumstances with their pros and cons. Depending on the categorisation of the need –, that is the need which is addressed by the provided flexibility, and the potential combination of different needs – a certain coordination scheme fits better.

To define different scenarios, a distinction is made between central and local needs. Multiple active buyers on a certain market platform will also engender a different architecture for the TSO–DSO coordination. A third aspect is the number of markets coexisting. And, finally, the accessibility for the TSO to access to DER. Combining answers to previous questions, seven groups of coordination models are suitable [2].

The *Local Market Model*$^{(s)}$ when flexibility needs are local and with limited impact in the transmission grid. A *Central Market Model*$^{(s)}$ assumes that flexibility services are solely procured to solve central needs for flexibility. In the *Common Market Model*$^{(s)}$, both system operators procure flexibility in a single market. The *Multi-Level Market Model*$^{(o)}$ applies when local and central needs are solved combining local and central markets, allowing the TSO

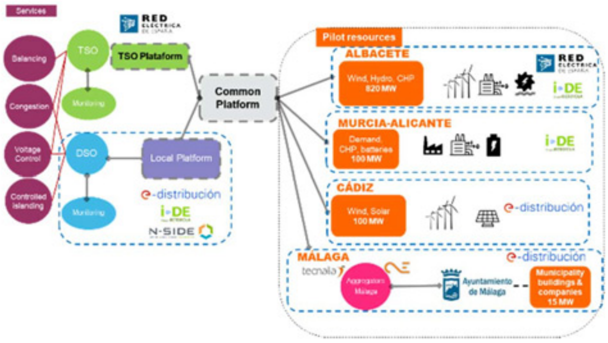

Fig. 1 *Schematic representation of the CoordiNet Spanish demo*

to access DER; if TSO cannot access to resources connected to the distribution grid, the alternative *Fragmented Market Model*$^{(o)}$ is proposed. The so-called *Integrated Market Model*$^{(o)}$, allows a threefold of market stakeholders, that is, the TSO, DSOs and commercial market parties, to jointly procure flexibility. In the *Distributed Market Model*$^{(o)}$, peers are the sole buyers (and providers) in the market (e.g. a peer-to-peer market setup).

(s): tested in the Spanish demo; (o): tested in other CoordiNet demos.

3 Platform architecture

One of the main aims of CoordiNet project is to develop common principles for the procurement of the system services in order to contribute to the standardisation of the future pan-European platforms for the exchange of such services. To that end, several theoretical models are developed and integrated within the CoordiNet platforms: (i) the *grid monitoring and operating module*, which identifies flexibility needs, (ii) the *market operation module*, which matches the flexibility needs from DSOs and TSOs with the flexibility bids sent by flexibility service providers, and (iii) the *aggregation and disaggregation module*, which estimates the available flexibility and selects the best strategy to send the flexibility bids to the market and, once the market is cleared, sends the activation signals to FSPs. These modules need to communicate with each other, and, for that purpose, inputs and outputs of each module are identified. Then, interoperability of the pan-European platform is ensured by the standardisation of the interfaces between those three modules.

This standardisation activity runs in parallel with the demonstration activities in the project. Hence, it takes information from them and provides valuable input for defining the corresponding communication architectures. In Spain, the TSO already receives flexibility bids from generation FSPs for providing balancing services, (Replacement Reserves (RR) through the new European TERRE Platform (Trans European RR Exchange) and manual frequency restoration reserves (mFRR)), even from those with an installed capacity of 1 MW or less, as long as the aggregated capacity is higher than 10 MW and clears the market for different balancing products and congestions at the transmission level. Therefore, the demo took this situation as a starting point to adapt the communication systems to allow for more efficient and fast communication between DSO and TSO to solve congestions also at the distribution level and improve the actual voltage control system. For that purpose, a portal has been established between DSO and TSO, which must be able to communicate with the actual TSO systems (i.e. G+ and E-SIOS) and DSO.

E-SIOS is the TSO information system, designed to (i) run all the processes necessary to ensure a reliable operation of the system, (ii) facilitate the communication between the Spanish market operator, market participants and other TSOs, and (iii) provide market results and historical data. *G+ tool* accesses real-time information and uses it to assess whether a potential generation scenario is feasible considering several security criteria. If not, it proposes re-dispatches to the E-SIOS platform, in order to include them in the corresponding schedules.

On the DSO side, actual computer systems are improved to be able of identifying congestions at the lower voltage levels of the grid and run a local market, where small flexibility service providers (<1 MW on aggregate) can participate to solve these congestions.

4 Business use cases

The following sections present the BUCs tested in the Spanish demo [3, 5].

4.1 BUC common congestion management

During normal operation, grid constrains can arise both at transmission and distribution networks. Congestions might arise considering overload limits or $N-1$ security criteria. When congestions are detected by TSO, all potential FSPs that might contribute to solve these congestions are identified. If congestions are detected by the DSO, he also identifies the potential FSP that might solve these congestions. In both cases, TSO and DSO notify the common platform of the situation and potential FSPs. Common platform located in the TSO, via the Renewable Control Centre (CECRE), determines the optimal market solution to solve the congestion by limiting or re-dispatching FSPs previously identified.

The main objective of this BUC is to procure flexibility from resources, connected to transmission or distribution networks, to solve congestions in either network, but in a coordinated way and always considering the optimal market solution. Additionally, this BUC is used to test the participation of the demand in the congestion management process, both at the day-ahead and in real-time.

For all these purposes, a new platform (CoordiNet Platform) is developed, which allows DSO to inform directly the TSO the limits of the FSPs causing congestions and ensuring that the limits introduced by the TSO and DSO are compatible.

4.2 BUC balancing

Balancing aims to keep a balance between energy generated and consumed at every instance. According to the European Regulation, this task is performed only by TSO.

This BUC evaluates how to improve the actual coordination between TSO and DSO. In the last years, DER can also provide balancing services, which might produce congestions in the distribution network due to the activation of balancing services. Additionally, this BUC is used to test the participation of consumption in the balancing services.

According to [6], TSOs and DSOs shall cooperate to facilitate the delivery of balancing services from FSPs located in the distribution systems. Accordingly, the DSO, in the CoordiNet platform, sets the limits to or excludes these FSPs to deliver balancing services (mFRR and RR).

4.3 Voltage control

The replacement of traditional synchronous generators by renewable energy sources (RES) might result in voltage control problems in some areas of the network. However, the latest technological improvements and Regulation UE 2016/631 [7] go a step further in requesting RES capabilities to provide grid voltage control. In [7], three voltage control modes are also required as mandatory: power factor setpoint, reactive power setpoint and voltage setpoint.

CoordiNet aims to improve the actual Spanish voltage control mechanism based on power factor setpoints, to another based on voltage setpoints. Moreover, this BUC aims to make available to TSO and DSO, FSP voltage capacities beyond the mandatory requirements as follows. First, both TSO and DSO identify specific 'pilot nodes' across the grid considering the potential impact on the grid voltage. Other nodes which belong to an 'influence area' are associated with a specific 'pilot node'. Second, FSPs are prequalified to participate in the provision of the service considering voltage capabilities beyond the mandatory capabilities. Third, both TSO and DSO calculate reactive power needs within in each 'influence area' in order to fulfil grid voltage requirements. Finally, the TSO and DSOs evaluate if the FSP mandatory voltage capabilities are enough and if not, they define additional reactive power to be bought in the market and determine the corresponding FSPs setpoints.

4.4 Controlled islanding

As last resort to improve continuity of the energy supply in areas of weak distribution grids, the operation of controlled islands allows to supply temporarily loads. This service must take into account the topology, available resources which can control voltage and frequency inside the island, the size of the island and the interconnection points with the rest of the grid.

4.5 Local congestion management

In addition to the CoordiNet common platform, CoordiNet local platform is tested in this project. The local platform is used to solve congestion problems at DSO's low-voltage grid and far away from the TSO grid.

FSPs that participate in the local platform are named small FSPs (sFSPs). Minimum bids are from 1 kW and the maximum quantity that can be offered (including aggregation) is 1 MW. Additionally, the sum of installed capacity in the local market considered in CoordiNet has been agreed to be lower than 1 MW.

DSOs send potential congestions problems to the CoordiNet local platform and each potential sFPS' contribution to solving them (i.e. sensitivity factor). Then, each sFSP submit their bids to the platform and after the market clearance, the DSO activates sFSPs.

Finally, both common and local platforms are interconnected, since the latter should send its market-clearing results to the former, in order to account for its impact on the common platform and on the system balancing.

5 Resources considered

5.1 e-distribución demo

Demo managed by e-distribución is divided into two areas. First, the Cádiz demo includes 103 MW of installed wind capacity, connected at 66 kV in a TSO/DSO shared substation. This is an example of FSPs connected at DSO with the capability to provide flexibility services to both the TSO and DSOs. FSPs in Table 1 participate in the provision of congestion management, voltage control and balancing services.

Second, the Málaga demo includes several FSPs connected to 20 kV and a low-voltage grid (see Table 2). FSPs in Table 2 provide congestion and balancing services. Moreover, FSPs connected at low-voltage also participate in the local market platform providing the congestion management service.

Table 1 Cádiz demo FSPs

FSP	Grid connection, kV	Installed capacity, MW
Wind1	66	10.68
Wind2	66	32
Wind3	66	42
Wind4	66	6
PV1	66	12.3

Table 2 Málaga demo FSPs

FSP	Grid connection	Installed capacity
Biogas1	20 kV	4 MW
CHP1	20 kV	10 MW
Consumption	low-voltage	0.761 MW (11 FSP)
PV + wind	low-voltage	0.142 MW (6 FSP)
Storage	low-voltage	0.110 MW (2 FSP)
EV charger	low-voltage	0.030 MW (2 FSP)

Table 3 Albacete demo FSPs

FSP	Grid connection, kV	Installed capacity, MW
Wind farms	132	721
Wind farms	66	24
Hydro plants	132	29
	66	16
	20	8
Cogeneration	132	24

Table 4 Murcia and Alicante demo FSPs

FSP	Grid connection, kV	Installed capacity, MW
Industrial	132	22
Building 1	20	0.78
Building 2	low-voltage	0.045
CHP4	132	90
Storage	20	1

5.2 i-DE demo

An i-DE demo is mainly located in Albacete, but also in Murcia and Alicante. Albacete demo has primarily wind generation connected to 132 kV lines, also several hydropower plants connected to different voltage levels, and one cogeneration facility (see Table 3). These resources participate in the provision of common congestion management, voltage control and balancing services.

Murcia and Alicante demo is focused on demand flexibility. FSP includes a big customer connected to 132 kV in Alicante which provides congestion management and aims to participate also in balancing services; two buildings in Murcia city, which participate in the local congestion market; and a big cogeneration plant in Murcia which participates in the common congestion management. Finally, one storage facility plays the role of a controlled islanding provider (Table 4).

Further details on the Spanish demo are presented in [5].

6 Conclusion

To improve the efficiency of the electricity system and the efficient integration of DER, improving the coordination between TSOs and DSOs is necessary. This paper presents how, through a large-scale demonstration, the main challenges of such coordination actions can be overcome and the way in which they have been applied in the Spanish context.

CoordiNet project defines different schemes to buy system services in a coordinated manner. Spanish demonstrators consider a wide diversity of flexibility service providers (including third-party aggregators), system services (e.g. balancing, congestion management, voltage control and controlled islanding) and diverse networks to evaluate the proposed coordination schemes through interoperable interfaces and platforms (e.g. from DSOs, TSO, aggregators).

The platform developments include different modules, some of which are completely new and others require modifications of existing platforms to (i) to increase the grid monitoring and operation which identifies the flexibility needs, (ii) the market

CIRED, Open Access Proc. J., 2020, Vol. 2020, Iss. 1, pp. 724–727

operation module, which matches the flexibility needs from DSOs and TSOs with the flexibility bids sent by flexibility service providers and (iii) the aggregation and disaggregation modules which estimates the available flexibility, selects the best strategy to provide system services. These developments are designed with the objective to be scalable and replicable at the national and, to a larger extent, at the European level.

7 Acknowledgments

The presented work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 824414.

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