ARCHITECTURES FOR OPTIMISED INTERACTION BETWEEN TSOS AND DSOS: COMPLIANCE WITH THE PRESENT PRACTICE, REGULATION AND ROADMAPS

Andrei MORCH
SINTEF Energy Research – Norway
andrei.morch@sintef.no

Gianluigi MIGLIAVACCA
RSE SpA – Italy
gianluigi.migliavacca@rse-web.it

Ivana KOCKAR
University of Strathclyde - UK
ivana.kockar@strath.ac.uk

Han XU
University of Strathclyde - UK
han.xu@strath.ac.uk

Julia Merino FERNÁNDEZ
TECNALIA – Spain
julia.merino@tecnalia.com

Helena GERARD
VITO - Belgium
helena.gerard@vito.be

ABSTRACT

Procurement and activation of resources from distribution network for ancillary services will require new grid organisation for ensuring and improving interaction between TSOs and DSOs. EU H2020 project SmartNet proposes five different architectures or coordination schemes (CSs) that each present a different way of organizing this interaction with a specific set of roles taken by the system operators and detailed market design. The study made a comparative evaluation of these CSs based on realistic scenarios for 2030 and implemented in simulations. The following study made a comprehensive screening of more than 40 documents based on a selection of key topics, which are essential for SmartNet and evaluated how the CSs are aligned with the present national and European policy goals and positions of the key industrial stakeholders. The screening was structured according to a set of so-called topics of interest, which the project considers to be essential for definition of well-functioning TSO-DSO interaction.

The general conclusion of the study is neither the main hypothesis nor the suggested CSs directly conflict with terms of the EU regulation. However, the regulation does not address several topics, which are crucial for large scale utilisation of Distributed Energy Resources in ancillary services. Without common EU regulations different solutions will develop in the distribution areas, the most diverse and non-harmonized solutions will be implemented in agreement between DSOs and adjoining TSO (e.g. nation- or region-wise under influence of TSO). This will not necessarily hamper the utilisation of local flexibility in the transmission grids, but it will certainly make more difficult the development towards cross-border utilisation of distributed energy resources.

INTRODUCTION

The increasing share of intermittent renewable energy sources (RES) in the European electricity grid results in higher need for flexibility resources providing ancillary services (AS) to compensate for the power fluctuations. The DER units feeding into the distribution grids provide an additional opportunity for system operators to use these resources for services such as frequency control, voltage control and congestion management both at the distribution and transmission level. This will, however, require a radically new architecture for ensuring and improving the interaction between TSOs and DSOs. This necessity has been recognized by several Pan-European legislative acts and documents as Network Guidelines and Directive on common rules for the internal market in electricity [4]. The process however is still under development, making it necessary to consider alignment of the future architectures with the present and coming regulatory acts.

The present paper is based on results of EU H2020 project SmartNet [7] (2016-2019), which aims at providing architectures or so-called coordination schemes for optimized interaction between TSOs and DSOs in managing the exchange of information for monitoring and for the acquisition of ancillary services (reserve and balancing, voltage regulation, congestion management) both at national level and in a cross-border context.

SMARTNET COORDINATION SCHEMES

SmartNet proposes five different architectures or coordination schemes (CSs) that each present a different way of organizing the coordination between transmission and distribution system operators (TSOs and DSOs), when distributed resources (production, storage or demand) are used for ancillary services (for details, see [2] and [3]). Each coordination scheme is characterized by a specific set of roles, taken up by system operators and a detailed market design.

- *Centralized AS market model (CS_A)*, where the TSO operates a market for both resources connected at transmission and distribution level, without involvement of the DSO.
- *Local AS market model (CS_B)*, where the DSO organizes a local market for resources connected at the DSO-grid and, after solved local grid constraints, offers the remaining bids to the TSO.
- *Shared balancing responsibility model (CS_C)*, where balancing responsibilities are divided between TSO and DSO according to a predefined schedule. The DSO organizes a local market to respect the schedule agreed with the TSO while the TSO has no access to

resources connected at the distribution grid.

- *Common TSO-DSO AS market model (CS_D)*, where the TSO and the DSO have a common objective to decrease costs to satisfy both the need for resources by the TSO and the DSO. This common objective could be realized by the joint operation of a common market (centralized variant) of the dynamic integration of a local market, operated by the DSO, and a central market, operated by the TSO (decentralized variant).
- *Integrated flexibility market model (CS_E)*, where the market is open for both regulated and non- regulated market parties, which requires the introduction of an independent market operator to guarantee neutrality.

ASSESSMENT OF THE COORDINATION SCHEMES

During the course of the project a comparative evaluation of the CSs has been done. Each coordination scheme involves a different market architecture. To make the results in terms of costs and benefits comparable, realistic scenarios for the 2030 horizon have been defined for the different countries where the schemes are going to be tested: Italy, Denmark and Spain.

From the simulation results the cost-benefit analysis (CBA) will draw conclusions concerning the best coordination scheme. To help analysis or system and markets operation under each of the five CSs, a large-scale simulator, has been developed to realistically model the behaviour of complex systems which include transmission and distribution networks, bidding and market processes, as well as fundamental physics behind each flexible device connected to the system. This simulator comprises three different perspectives (layers): market, bidding/dispatching and physical layer. The market layer receives the bids (from the bidding layer) and optimizes the activations in the system taking into account the transmission and distribution grid topologies and constraints (included in the physical layer).

With all the data needed by the simulation platform the simulations have been carried out for the different coordination schemes. It has to be highlighted that in the CBA analysis, scheme *Integrated flexibility market (CS_E)* has not been tested due to its complexity and scheme *Common TSO-DSO market (CS_D)* has been split into two: *CS_D1*, a centralized market with the optimization calculated in a single step and *CS_D2*, where a decentralized market is considered, where a local optima is found for the DSO, and the TSO finds a compatible solution to meet its needs.

Based on the simulation results, the CBA has been done using a two-step methodology:

1. System-level CBA build of ad-hoc defined indicators that evaluate the impact of each coordination scheme over the costs of the power grid.
2. Profitability analysis: to evaluate the benefits and allocate the costs derived from the schemes to the different stakeholders in the value chain.

As the goal of the CBA analysis is to quantify the benefits/costs of the different coordination schemes, the definition of certain indicators, then can be easily monetized is required. This way, the total cost in any country for every coordination scheme is the sum of the evaluated indicators.

Four indicators have been selected:

1. System balancing cost as result of the ancillary services market.
2. Cost of the additional actions taken by the network operators after the manual Frequency Restoration Reserves (FRR) market clearing.
3. System balancing costs after the gate closure of mFRR market (also called automatic Frequency Restoration Reserves market - aFRR).
4. Costs of Information and Communication Technologies (ICT) deployment

The emissions of CO2 are also an indicator of the CBA. However, as this cost has been already included as a component of the submitted bids, they have not been considered as an extra indicator to be added to the four previously mentioned. By way of example, the results corresponding to the evaluation of the system balancing costs in the mFRR market after the aFRR market for the Italian case are shown in Figure 1

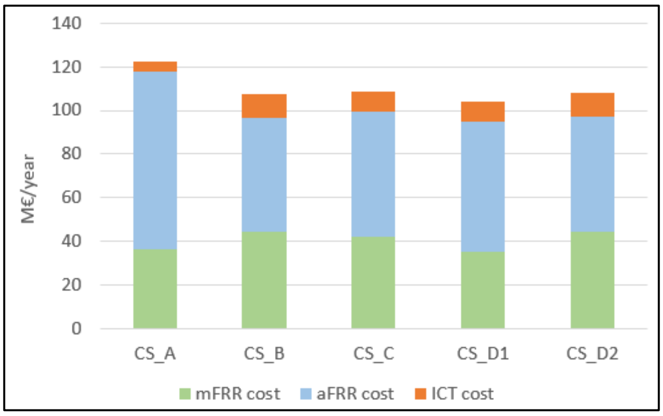

Figure 1 Results of evaluation of indicators 1, 3 and 4 for the Italian case

From the evaluation of the indicators for the Italian case can be seen that *CS_D1* is more economically profitable than the remaining schemes. However, *CS_A* has lower ICT costs and *CS_C* manages a large amount of energy due to the simplifications of the network model that are used in the clearing algorithm.

Further analysis of the Italian case as well as the evaluation of the Danish and Spanish cases is shown in [6].

THE SCREENING STUDY

The above-mentioned assessment of the coordination schemes provides an indication of the overall feasibility allowing to identify the most viable alternatives. In order to put the outcomes of the project in real time context it is also necessary to consider how the SmartNet's coordination schemes align with the regulatory framework, which has already been implemented or/and has been suggested for the implementation within a certain number of years. For this purpose, a comprehensive screening of legislative and regulatory documents has been done. In addition, the study considered stakeholders' views, which may show whether the given stakeholders may accept and even endorse SmartNet's outcomes and how challenging it may be to replicate these across Europe.

Organisation of the screening

The documents considered in this study have been issued by several types of stakeholders, including:

- Governmental Organisations e.g. The European Commission (EC)
- Organisations working with different aspects of Regulation and Standardisation (National Regulation Authorities (NRAs), Council of European Energy Regulators (CEER), European Network of Transmission System Operators for Electricity (ENTSO-E) and International Electrotechnical Commission (IEC)
- Interest organisations as Industrial Associations and similar (European Distribution System Operators' Association (EDSO) for Smart Grids for Smart Grids, WindEurope etc.)
- Other e.g. European Technology & Innovation Platform - Smart Networks for Energy Transition (ETIP-SNET)

The study evaluated all together more than 40 documents, including Pan-European and national legislation, strategic documents, position papers and roadmaps (for the full list of documents see [1]).

The screening was structured according to a set of so-called topics of interest, which the project considers to be essential for definition of well-functioning TSO-DSO interaction. These topics in general reflect some of the key assumptions and choices, which were done in the project prior to development of the coordination schemes. These components have in many ways influenced configuration of the project's final outcomes.

- Market sessions timeline
- Nodal market vs. zonal
- Local congestion management by DSOs vs centralized TSO market
- Prequalification of resources in distribution networks
- Inclusion of constraints (device-related) from distribution grid bidders
- Operation of possible local market
- Management of voltage constraints
- Availability of reserve capacity
- Relationship with previous markets
- Pay-as-bid vs. pay-as-clear
- Optimisation criterion for electricity market design – maximization of social welfare vs. minimum activation costs
- Roles and Responsibilities in the context of the prequalification, procurement, activation and settlement of AS markets including observability
- Ancillary services considered in the screened documents
- Possibility to create “virtual” copperplate bids vs nodal bidding
- Possibility for bidding negative prices in ancillary service (AS) markets
- Dimensioning of bidding zones
- Incentivisation mechanisms for RES vs price revelation in AS Market
- Minimum bid size and resolution
- Prioritisation of control traffic (support for network slicing) - how prioritisation for ICT control traffic for energy system management is ensured so to guarantee secure system operation.
- Responsibilities and ownership of components and data
- Energy supply for communication and ICT components (how to ensure sufficient power backup for ICT)
- Remote controllability of DER

The limitations of the present paper do not allow to present these in detail, while the description is available in [1].

Summary of the findings from the screening

This section summarises the most representative results from the screening of EU legislation, which is relevant for topics of interest identified in the SmartNet project and described above.

Local congestion management by DSOs vs centralized TSO market

In the issue related to priority of doing local congestion management by DSO vs centralized TSO market: neither the EC nor the CEER do express any clear position about market solutions. There are, however, several clear preferences from the stakeholders. It appears that mechanisms for the procurement of flexibility (either via common procurement or via market at each grid level) and the framework (since DSOs are regulated entities) for the recognition of costs is still missing.

Prequalification of resources in distribution networks

The screening indicates two main topics of the discussion:

- Which actor (-s)/role (-s) should be involved into the pre-qualification process i.e. TSO, DSO individually or in coordinated manner or aggregator

- What should be the qualification level i.e. individual or portfolio.

Recast of the Regulation of the European Parliament and the Council on the internal market for electricity makes a general definition of prequalification. It also stipulates that the procurement shall be organised in a non-discriminatory way between market participants in the prequalification process, either individually or through aggregation. Guideline on electricity defines that each balancing service provider intending to provide service, should pass the qualification process defined by TSO and if necessary, by DSO.

Operation of possible local market (single DSO vs common distribution Market Operator)

The recast of the Directive on common rules for the internal market in electricity only advocates that regulatory framework in the Member States should give incentives to DSOs to use flexibility services to improve operational efficiency and distribution network development, e.g. congestion management at distribution level. The same document also recommend that DSOs shall procure flexibility services via market-based solutions.

Relationship with previous markets including Gate Closure Times (GCTs)

The only requirement for this in present legislative documents is that the participants in the balancing markets shall be allowed to bid as close to real-time as possible and at last after the intraday gate closure.

Possibility to create "virtual" copperplate bids versus nodal bidding

The regulation focuses on correct local price signals and transparency in the process of determining the locational signal. The review did not identify any legislation about copperplate versus nodal bidding.

Definition of bidding products

The legislative acts do not require but open the possibility to develop complex bids.

Minimum bid size and resolution

Currently, in practice the size of minimum bid is between 5-10MW, but a movement towards smaller balancing products (1 MW for mFRR vs currently typically 5MW) can be expected

Incentivisation mechanism for RES vs price revelation

While in most national markets there are legacy Incentivisation mechanisms for RES, there is longer term strategy to apply this only to smaller installation or less mature technologies. It is argued that larger installations of mature technologies should participate in the markets and phasing out of their subsidies is planned by 2030.

Prioritisation of control traffic

The SmartNet concept requires that the control signals are always very reliable transmitted to the Distributed Energy Resource in less than 0.5-1 minute. There is no regulation ensuring this requirement. The regulation is the other way around: traffic management need to allow low latency transmission of small real time control signals will be allowed as long as it does not reduce the quality of normal internet access of the end users.

Responsibility and ownership of components and data

The recast electricity Directive states that “eligible parties” (defined as customers, suppliers, TSOs and DSOs, aggregators, energy service companies etc) may have access to data of the final customer with their explicit consent. The review did not identify any legislation about ownership of components.

Remote controllability of Distributed Energy Resources

The Network Guidelines require remote controllability by DSO for all new generators and electricity storage that are of type B and above. In Central Europe, type B means all units that have at least 1 MW peak power. For other parts of Europe, the size of type B varies from country to country. In addition, it is necessary to define adequate requirements for the measurements and control dynamics (e.g. response duration, reliability and immunity to disturbances) of Distributed Energy Resources. The present situation in EU is such that voltage droops are not required, and the frequency droops requirement does not apply to electric energy storage nor electric vehicles.

CONCLUSIONS

The conclusions are twofold: on one hand the conducted CBAs support viability of coordination schemes, which have been suggested by SmartNet. The only exception is the Integrated flexibility market *(CS_E)*, where the assessment could not be done due complexity and corresponding computational challenges. The present results further indicate that *CS_B*, *CS_C* and *CS_D2* are more economically profitable than the remaining two schemes. However, *CS_A* has lower ICT costs and *CS_C* manages a large amount of energy due to the simplifications of the network model that is used in the clearing algorithm.

On the second hand, the main impression is that hardly any of the present or proposed European regulation is explicitly in contrast to the hypotheses at the basis of the SmartNet work. However, for one topic, the EU legislation is somewhat different with configuration of SmartNet's coordination schemes. For incorporating bottlenecks into the pricing, SmartNet selected to use nodal market organisation for ancillary services, while several legal documents refer directly to zonal organisation as the model for the electricity system in Europe.

When it comes to the stakeholders' opinions, currently the situation is that ENTSO-E suggests that all congestion management needs, both for TSOs and DSOs, should be fulfilled by a common bid submission process from providers of distributed flexibility resources, so a common process will among other ensure liquidity of the market.

The general conclusion from the screening study is that EU regulations are not directly addressing several of the topics identified by SmartNet, i.e. crucial topics for large-scale utilisation of Distributed Energy Resources in ancillary services, as for example timing of the markets. Without common EU regulations different solutions will develop in the distribution areas, the most diverse and non-harmonized solutions will be implemented in agreement between DSOs and adjoining TSO (e.g. nation- or region-wise under influence of TSO). This will not necessarily hamper the utilisation of local flexibility in the transmission grids, but it will certainly make more difficult the development towards cross-border utilisation of distributed energy resources.

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