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Coordination between transmission and distribution system operators in the electricity sector: A conceptual framework

Helena Gerard [a, b, *], Enrique Israel Rivero Puente [a, b], Daan Six [a, b]

[a] VITO, Boeretang 200, 2400 Mol, Belgium
[b] EnergyVille, Thor Park, 3600 Genk, Belgium

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ABSTRACT

The increasing share of distributed energy resources in the distribution grid provides opportunities to use the resources for the overall benefit of both the Transmission System Operator (TSO) and the Distribution System Operator (DSO) to solve problems related to frequency control, congestion management, and voltage control. Consequently, coordination between system operators is needed to guarantee a safe, reliable, and cost-efficient use of flexibility-based services. This article presents five coordination schemes to enhance interaction between system operators. For each scheme, roles, responsibilities and market design are discussed. The advantages, disadvantages and feasibility of each coordination scheme are evaluated.

1. Introduction

The energy market is undergoing important changes, driven by the realization of the European internal energy market on the one hand and the increase of distributed energy resources (DER) on the other hand. The increase of DER not only results in a higher need for flexible services for system operators but provides new opportunities for system operators as well (Poudineh and Jamasb, 2014; Ruester et al., 2013; Dueñas, 2015). Both transmission system operators and distribution system operators could benefit from the use of flexible resources from the distribution grid. TSOs could use these resources for frequency control, voltage control or congestion management, while DSOs could acquire flexible resources for local congestion management and voltage control (Julia Merino, 2016; D'hulst et al., 2015; SWECO et al., 2015; Expert Group 3, 2015). However, it is not easy for TSOs and DSOs to make use of these flexibility services under the liberalization regime enacted in the Third Energy Package as this imposed the separation between transmission and distribution (Ferrante et al., 2015).

For both system operators to make optimal use of these resources, coordination is necessary (CIEP/PBL, 2014; Expert Group 3, 2015; Ruester et al., 2014). By increasing the level of coordination, system operators will be able to support each other in the efficient and cost-effective operation of their grid (Ochoa et al., 2016). Moreover, effective coordination will avoid that actions taken by one system operator will contradict actions taken by another system operator (CEER, 2016; CEDEC et al., 2015; Expert Group 3, 2015; Ruester et al., 2014; Eid et al., 2016b; Mallet et al., 2014). This means, among other things, that system operators could work together to improve the observability of the grid, including the quality and transparency of grid data (ENTSO-E, 2015a; CEDEC et al., 2015; Eurelectric, 2015; Expert Group 3, 2015; Dueñas, 2015; Mallet et al., 2014).

The need for increased cooperation between system operators is widely recognized, especially in a scenario with increasing renewable energy sources (RES) and increasing participation of DER to ancillary services markets (CEER, 2016; ENTSO-E, 2015b; CIEP/PBL, 2014; Ruester et al., 2014; Ochoa et al., 2016; Carlos Batlle and Michael Rivier, 2012). EU regulation (network codes) provides a first framework in which different concepts of coordination among system operators could be further developed. The different network codes highlight the need for system operator interaction with respect to the exchange of data, operational procedures, and market design (ENTSO-E, 2015c; European Commission, 2016a; European Commission, 2016b; European Commission, 2016c; European Commission, 2016d; ENTSO-E, 2015d; ENTSO-E, 2014).

Earlier research has focused to a large extent on the impact and possibilities of RES and DER to provide services from the distribution grid to system operators, including pricing mechanisms and the relationship between the aggregator and the DSO (Eid et al.,

* Corresponding author. VITO, Boeretang 200, 2400 Mol, Belgium.
E-mail address: helena.gerard@vito.be (H. Gerard).

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2016a). The aim of this work is to analyze different concepts of interaction between system operators. The advantages and disadvantages of each coordination scheme are assessed and the feasibility of the different models is further assessed. As a result, policy makers will be able to make the necessary modifications to the existing market design and regulation in order to improve the interaction between TSOs and DSOs. The work presented in this paper was carried out as part of the SmartNet project ("SmartNet - Integrating renewable energy in transmission networks," 2015).[1]

Section 2 gives an overview of the methodology. Section 3 discusses the different mechanisms of coordination between system operators. Section 4 evaluates the coordination mechanisms according to market and grid performance criteria. Section 5 assesses the feasibility of the different coordination schemes. Section 6 concludes.

2. Methodology

The selection of relevant coordination schemes is based on three distinct sources: a literature review, a country survey, and a theoretical analysis. The literature review analyzes the different needs and recommendations related to coordination between system operators, provided by European and national regulatory reference documents, i.e., European and national network codes,[2] European directives related to energy policy[3] and position papers from various power system stakeholders, e.g. ACER, CEER, EDSO for Smart Grids, ENTSO-e, Eurelectric, Smart Grid Task Force. In addition, outcomes of projects at European and national level that addressed the topic of TSO-DSO coordination from different angles were integrated.[4]

Findings from this review are combined with information, collected via a questionnaire for a selection of countries: Austria, Belgium, Denmark, Finland, Italy, Norway and Spain. The questionnaire examined the current cooperation between system operators with respect to the procurement, activation and settlement of flexibility-based services procured by system operators. For these countries, a condensed summary of the findings in respect to DER participation to ancillary service (AS) markets is shown in Table 1.[5] From the survey it was observed that member states are taking steps towards further integration of DER in the ancillary service markets.

In addition to the literature review and the country survey, alternative theoretical TSO-DSO coordination schemes were assessed, based upon existing role models for TSOs and DSOs. The role models considered are the TSO role model as proposed by ENTSO-E (ENTSO-E, 2015e) and the DSO role model as developed in the FP7 project EvolvDSO (Rivero et al., 2015a). An overview of roles for system operators is presented by Gerard et al. (2016).

3. Overview of the coordination schemes

Cooperation and information exchange between TSOs and DSOs in the context of flexibility-based services is still limited, and further steps are necessary (Ramos et al., 2014; CEDEC et al., 2016; Yuan and Hesamzadeh, 2017). Moreover, the premise of a more decentralized energy system in the future supports the idea that DSOs play a role in the collection and provision of small sized generation to the TSO in a coordinated manner (Zipf and Möst, 2016). In particular, a strong coordination and clear definition of hierarchical procedures is needed as the value of a specific flexibility service is different in the utility function of the TSO on the one hand and the utility function of the DSO on the other hand (Carlos Batlle and Michael Rivier, 2012).

This paper explores new mechanisms for coordination between system operators in a smart grid context. The proposed coordination schemes take into account current and potential future needs of network operators (Carlos Batlle and Michael Rivier, 2012; Dueñas, 2015; Rivero et al., 2015b; Ruester et al., 2014), new concepts for the provision of flexibility-based services from and to the distribution grid (D'hulst et al., 2015; Ramos et al., 2016; Manshadi and Khodayar, 2016), potential approaches and considerations for coordinated system operation (Antony Zegers and Helfried Brunner, 2014; Brunekreeft, 2015; CEDEC et al., 2015; CIEP/PBL, 2014; Maurizio Delfanti et al., 2014; Yuan and Hesamzadeh, 2017; Zipf and Möst, 2016) and the need for information exchange between system operators (Buchmann, 2017; CEDEC et al., 2016; Silva et al., 2012).

The country survey shows that coordination between TSOs and DSOs is mainly related to network planning, common data platforms or sharing of metering data. Although in most countries, DER units can provide flexibility-based services, there is still a wide heterogeneity in products and rules across countries, (Ramos et al., 2014; Gerard et al., 2016). Moreover, there is little interaction between system operators in the processes of acquiring these flexibility-based services from the distribution grid. Today, in most cases, the TSO contracts directly resources connected to the distribution grid, without involvement of the DSO. In addition, local markets where flexibility-based services could be procured are not yet a reality (Ramos et al., 2016).

The collaboration between TSOs and DSOs, in the context of the procurement of ancillary services (AS) and local services, could be organized according to five different coordination schemes: the *Centralized AS market model*, the *Local AS market model*, the *Shared Balancing Responsibility model*, the *Common TSO-DSO market model* and the *Integrated Flexibility market model*. Fig. 1 (two columns) illustrates these five coordination schemes.

A coordination scheme is defined 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. The design of the market[6] to procure system

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[2] An overview of EU network codes can be found in (ENTSO-E, 2015c). National network codes may be found on the website of the respective TSO. Network codes are relevant for this research because they provide the principles for the connection, operation and market aspects of the power system. Consequently, network codes determine the framework conditions for the collaboration approaches implemented between TSOs and DSOs.

[3] e.g. the Energy Efficiency Directive (European Parliament and Council of European Union, 2012).

[4] Subjects analysed were amongst others intelligent power networks and electricity load control ("CITIES – IT-Intelligent Energy Systems in Cities," 2013; "FlexPower – A market design project," 2010), current and future cooperation of system operators in smart grids (Antony Zegers and Helfried Brunner, 2014), future roles and interactions ("EvolvDSO Project," 2013) and communication standards among stakeholders of the power system ("CHPCOM project," 2011), aggregation services via energy markets in a smart grid context ("SGEM Project," 2010), and integration of virtual resources ("FENIX PROJECT," 2007) and demand response solutions ("ADDRESS Project," 2008).

[5] More detail on the markets and flexibility types for the surveyed countries can be found in (Gerard et al., 2016).

[6] This paper focuses on flexibility markets as defined in (Ramos et al., 2016). The design of these markets should allow the cost-efficient allocation of sophisticated products and services under time frames that comply with the flexibility requirements of system operators. Dependent on the needs for a specific country, the relevant time frame could be day-ahead or closer to real-time. In addition, it is assumed in our analysis that flexibility services are procured via a market platform organized by a market operator. The procurement of flexibility services via long-term over the counter (OTC) contracts is not analysed in this context.

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