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From distribution networks to smart distribution systems: Rethinking the regulation of European electricity DSOs☆

Sophia Ruester [a,*], Sebastian Schwenen [b], Carlos Batlle [c,d], Ignacio Pérez-Arriaga [c,d]

[a] Florence School of Regulation, European University Institute, Italy
[b] German Institute for Economic Research, Berlin, Germany
[c] Comillas Pontifical University, Madrid, Spain
[d] MIT, Boston, USA

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A B S T R A C T

Distributed energy resources allow for new business models that have the potential to substantially change today's power system functioning paradigm. In particular, these changes pose challenges for distribution system operators (DSOs) and their regulation alike. This article sheds light on missing aspects in current regulation, recognizing DSOs as regulated monopolies, but also as key players along the supply chain. We provide insights on how regulation should be adjusted so that DSOs are incentivized to facilitate the market entry of welfare-enhancing technologies in a timely fashion, and to manage the distribution system efficiently in the presence of distributed energy resources.

1. Introduction

Technological advances are reshaping today's power systems, in particular at the distribution-network level. More mature technologies for local renewable generation have decreased the related investment costs, and national support schemes have led to a significant market penetration of distributed generation (DG) in many EU countries. For instance, in Germany, "in many places, the DG output of distribution networks already exceeds local load – sometimes by multiple times" (Eurelectric, 2013) (p. 3). In addition, distributed storage might soon become viable at all voltage levels and in large amounts, becoming a critical component of "the grid of the future" (see Beaudin et al., 2010; Ruester et al., 2013). Likewise, the use of electric vehicles charging from the grid, and possibly also injecting power back into it and delivering so-called vehicle-to-grid services, is projected to grow (e.g., Kampman et al., 2011; Loisel et al., 2013).

In addition, recent innovations in metering and communication devices enable active demand response and enhanced distribution automation, thereby facilitating and allowing for a wider deployment of distributed generation, local storage and electric vehicles. Whereas at the beginning of the liberalization process demand response was considered only interesting for large, typically industrial, customers, technological advances (for example, intelligent metering and control systems that can optimize individual consumption patterns, thereby reducing risks and efforts related to reacting to price signals) also make this concept interesting for the smaller-scale commercial and residential sectors. According to a positive cost–benefit analysis, at least 80 percent of European households should be equipped with intelligent metering systems by 2020 (European Commission (EC), 2009).

This newly emerging broad range of distributed energy resources (DER) – be it distributed generation, local storage, electric vehicles or demand response – has the potential to drive significant changes in the planning and operation of power systems. These changes bring challenges for electricity distribution system operators (DSOs) and their regulation alike, ranging from increasing uncertainty in distribution grid flows and increasing volatility of net demand to the efficient integration of DER business models into retail markets. In the current state, some challenges are only possibilities that might arise once technologies mature and are more widely deployed. Other challenges, foremost related to DG, are established facts, and concern DSOs already today.

However, the same technologies that are causing substantial challenges can – with the right regulation and market design – be exploited to establish a more efficient, and also cleaner, electricity system than our current one. All DER technologies have the potential to provide downward or upward adjustment to the system; thus, employing and aggregating DER services offers a powerful and flexible tool for power trade, and guaranteeing balanced power

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* Corresponding author.
E-mail address: Sophia.Ruester@eui.eu (S. Ruester).

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networks. These local resources can provide a diversity of services with economic value, and may successfully compete with centralized generation in offering new tools for system control. A more active distribution system management can help to decrease the total cost of DSOs compared to the traditional “fit-and-forget approach” of merely connecting the new devices to the network (see Pérez-Arriaga, 2013).

Current distribution system structures differ widely among EU Member States, and today's DSO landscape resembles a patchwork with diverse national implementations of relevant pieces of EU legislation. Substantial differences arise regarding operated voltage levels, the scope of activities, the size and number of DSOs in a country, the level of unbundling, and applied regulatory formulas (see CEER, 2013; European Commission (EC), 2012a; Eurelectric, 2010a). Even though full eligibility of customers is mandatory, and the choice of suppliers and tariffs has increased in many retail markets, the degree of retail market liberalization and competition still varies significantly across the EU. Insufficient unbundling poses one of the most serious obstacles to competition in many distribution markets. This heterogeneity in regulation and market structures and distribution systems aggravates the problem of finding a unanimous approach to appropriate DSO regulation.

In this article, we investigate how regulation and market design can foster an effective integration of distributed energy resources into both retail markets and distribution grid management, with the focal point of the analysis being on European distribution companies. We ask how the regulation of European electricity DSOs should be adjusted so that – with the least friction between the two goals – DSOs are incentivized, first to create a level playing field for the market entry of DER technologies, and second to make use (directly or indirectly) of these local resources to manage the distribution system efficiently.

The article is organized as follows: Section 2 demonstrates how DER technologies boost new business models for local means of electricity trade, and illustrates the resulting challenges for key areas of DSO regulation. Section 3 presents an analysis of the identified key areas of regulation, and highlights what improvements are needed in each area in order to integrate DER into power markets and distribution system operation. After having identified required regulatory adjustments, in Section 4 we discuss whether they should be best pursued at EU or Member State level. Section 5 concludes.

2. Emerging business models challenge DSO regulation

The large-scale introduction of distributed energy resources will be made possible – and also reinforced – by new evolving business models. Successful business models can substantially alter the structure and organization of power systems. To this end, this section first highlights the potential for new business models, before showing how DER challenges the existing regulation of DSOs, and which areas of DSO regulation have to be reviewed in particular.

2.1. Business models arising from DER

Most business models associated with distributed energy resources involve some sort of aggregation, such as the aggregation of different DER technologies at the household level (for example, a combination of active demand response, rooftop solar PV, heat or electricity storage, and the family EV), the aggregation of several DER units of one kind (for example, a fleet of EVs), or the aggregation of several resources connected to a number of agents in different locations (such as a portfolio of loads of several types, a fleet of EVs and some local storage).

Key for the competitiveness of DER is the fact that, once aggregated, local management and control can make better use of the existing local synergies, and use resources closer to the existing generation, consumption and network constraints. The magnitude of these potential competitive advantages vis-à-vis power coming from upstream sources still remains to be proven. It is outside of the scope of this paper to present an in-depth elaboration on possible resulting new business models; nonetheless, we find several reasons to suggest that aggregation and hierarchical control might have sizeable advantages over the centralization of sources at the bulk level, and will thus inevitably leave margins for new businesses related to DER. At least three reasons speak in favor of aggregating local energy resources:

1. Aggregation can reduce the risk for each individual DER of not meeting its market commitments. For instance, where network tariffs for end consumers include a capacity component linked to a maximum instantaneous consumption limit, it can be profitable to aggregate a group of consumers to take advantage of the fact that not all of them will demand their maximum at the same time.
2. Aggregation can decrease potential costs arising from not meeting market commitments, especially when balancing markets lack liquidity. If markets were perfectly competitive, it would always be possible to buy or sell the commodity at the competitive market price. But in case of low market liquidity, individual DER units risk having to buy costly services from dominant actors in the market, in order to correct for imbalances. In such a setting, holding, for instance, a portfolio of a storage facility and an intermittent generation unit could decrease imbalance costs.
3. Furthermore, aggregating otherwise relatively inflexible DER units into one DER product bundle increases the possibility of taking part in the markets for system services. Aggregated DER can offer more complete and flexible products to system operators, who often demand system services (such as for voltage or frequency adjustments, or for congestion management) with particular technical features. Aggregated DER are also easier to manage by system operators, compared to a multitude of agents offering a variety of services.

Ultimately, whether business models for (aggregated) local resources might – or might not – cause a paradigm shift from the traditional centralized top–down system towards decentralized local sub-systems depends on the total costs of energy provision from DER compared to upstream sources, including the network costs. As mentioned earlier, the substantially increased market penetration of DER has mostly been due to many low-carbon energy policies at EU and Member State level. Hence, the degree to which these local resources will further change today's power systems not only depends on the competitiveness of DER relative to upstream sources, but also on whether policies for low-carbon power generation and consumption will continue to attract high investments in DER.

2.2. Distributed energy resources challenge existing DSO regulation

The more DER and resulting business models penetrate electricity markets, the more challenging it becomes for DSOs to pursue all tasks that they are assigned to by regulation. As DSOs are regulated entities, these challenges hold equally for regulators when designing proper incentive structures and assigned tasks for DSOs.

First, challenges relate to incentive structures for already existing tasks, mainly concerning the DSO as a regulated network manager: A