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ADAPTATION DYNAMICS TOWARD A SMARTER GRID: THE CASE OF ELECTRICITY DISTRIBUTION SYSTEM OPERATORS

Guillermo I. Pereira [1 3], Patrícia P. Silva [1 2 3] and Reinhard Madlener [4]

1: Energy for Sustainability Initiative
MIT Portugal Program
Faculty of Sciences and Technology, University of Coimbra
Pólo II, 3030 - 788 Coimbra
e-mail: gpereira@student.dem.uc.pt, web: http://www.uc.pt/efs

2: Center for Business and Economics Research, Faculty of Economics, University of Coimbra
Av. Dr. Dias da Silva 165, 3004-512 Coimbra
e-mail: patsilva@fe.uc.pt, web: http://www.uc.pt/en/feuc

3: INESC Coimbra
Institute for Systems Engineering and Computers at Coimbra
Pólo II, R. Silvio Lima, 3030-290 Coimbra
web: http://www.inescc.pt/

4: Institute for Future Energy Consumer Needs and Behaviour, School of Business and Economics
E.ON Energy Research Center, RWTH Aachen University
Mathieustrasse 10, 52074 Aachen, Germany
e-mail: RMadlener@eonerc.rwth-aachen.de, web: http://www.fcn.eonerc.rwth-aachen.de/

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Abstract *The transition toward a smarter and more digital electricity system is inducing change for distribution system operators across the European Union. This has triggered concerns as to their future role, as new activities gain potential for uptake, such us the integration of distributed generation, deployment of electric vehicle charging infrastructure, and flexibility management. Contributing to a more detailed understanding of this shift, this study analyses the adaptation dynamics of DSO's business models. This is achieved through a policy oriented firm-level empirical data collection and analysis focusing on how DSO's, as regulated natural monopolies providing a service of general economic interest, are adjusting their business strategy to a smarter grid environment.*

1. INTRODUCTION

Electricity distribution system operators (DSO's) across the European Union (EU) are responsible for distributing electricity to 240 million customers, with high quality and availability standards [1]. This is achieved through a capital-intensive network industry business model [2], regulated at the Member State level and subject to EU Internal Energy Market Rules [3]. Considering this setting, DSO's as natural monopolies in their jurisdictions, have adapted to the local needs, which are generally related to the operation, management, and renovation of networks to distribute electricity.

However, this traditional business setting is going through a process of transition influenced by a smarter grid environment, which results from different interconnected aspects. Firstly, climate and energy policies are pushing forward the growth in the share of renewable energy, increased energy efficiency, and reduced carbon emissions [4]. Secondly, the development of technological innovations creates the possibility for the electricity system to become smarter and more digital, allowing new ways of operating the distribution grid and new possibilities for connected parties to use, generate, and manage electricity [5]. These are further stimulated by intensive Research and Development (R&D) efforts resulting from the Energy Union package [6], as well as the EU strategy for a Digital Single Market [7]. These aspects contribute to establishing an EU-wide framework for Member States to deploy smart distribution grids.

This shift in DSO's business model is often described as a move from a Passive Network Manager role to that of an Active Network Manager, respectively [8], [9]. The transition framework in which this is occurring can be described as the evolution of three main dimensions: organisational, technological and institutional [10]. This context has generated concerns regarding DSO's future role and activities developed as smarter grids are deployed [11]. Considering that their core activities must be secured whilst new possibilities are considered for providing smart grid services.

Through this article, we aim contribute to the ongoing efforts on better understanding the changing role of the DSO through a policy oriented firm-level empirical analysis of the adaptation dynamics to a smarter grid environment. The research question targeted centres on: *How are DSO's adapting their business model strategy for a smarter grid environment?* Through which we focus on the less explored business model innovation and organisational change aspects of the energy transition [12].

The article is structured as follows: Section 2 describes the methodology. Section 3, presents the empirical results obtained. Conclusions are presented in Section 4.

2. METHODOLOGY

The policy oriented firm level analysis conducted is based on the steps for exploring actors change dynamics, dedicated to the electricity sector sustainability transition described in Pereira et al. [13].. Based on this an inductive qualitative research process was applied through semi-structured interviews [14] conducted at two DSO's in west Germany. These were aided by an open-ended questionnaire. Given the differences in the energy transition dimensions considered in the study, the questions were elaborated by a multidisciplinary team, with expertise in energy technologies, environmental economics, and management. The preference for open ended questions is related with the exploratory nature of the study. The interviews were conducted in May and June of 2016. As the strategic orientations and future options of the analysed DSO's are confidential their identity is anonymised throughout the article, and referred to as *LargeDSO* and *SmallDSO*. The fact that the entities are anonymous does not impact the relevance of the research setting, considering that the study aims to provide insights for the broader context of DSO's adaptation to a changing habitat.

3. RESULTS

The semi-structured interviews aided by the open-ended questionnaire allowed for exploring the strategic adaptation dynamics from the experience of two DSO's in Germany. The two cases selected to inform the research question vary significantly in dimension. This allows for empirically analysing the situation for different DSO sizes, which can contribute to how future DSO's-oriented policies and market design are structured. Table 1 presents a general characterisation of the DSO's analysed.

Table 1. General DSO characteristics

		LargeDSO	***SmallDSO***	
Structural data	Population coverage	7 233 544	237 144	people
	Territory coverage	31 224	473,9	km²
Network length	Medium Voltage	38 905	929,4	km
	Low Voltage	107 039	2 398,5	km

From the outputs of the semi-structured interviews it is possible to analyse how DSO's are adapting their business strategy to a smarter grid environment. The synthesis of results presented in Table 2 highlights the main outcomes of the empirical data collected across a range of topics which were identified through the data analysis and classification stage after the interviews. The coding of the interview's content, which resulted in the following topic areas, was conducted by the researchers in iterative steps to increase the reliability of the results. For the observations presented in Table 2 when a specific aspect of one of the DSO's cases is presented its origin is made explicit (e.g.: "*The SmallDSO…*" or "*The LargeDSO*"), otherwise the observations apply to both cases under analysis.

Table 2. Interviews synthesis

Business model (Current role)
The current business model is very hard to sustain, considering the growth of distributed generation (DG) and the existing economic regulation. The *SmallDSO* representatives in particular indicated that the planning horizon is also limited in time and mostly driven by new DG installations. In addition, the shared ownership of grid assets also increases the challenges of planning future investments. Their operational efficiency is now achieved in part by staff reductions, leading to increasing complexity in managing the business.
Grid asset management – *Operation & Maintenance*
The growth in DG results in a significant need to reinforce the network, which is capital- and time-

intensive. For the *LargeDSO* small isolated areas are a normal part of the business and represent no specific challenge, whilst for the *SmallDSO* these isolated areas are often challenging to operate.
Grid asset management – *Integration of DG*
Integration of DG, particularly Wind, and Solar PV, is challenging the grid operations. This leads to expensive expansion plans and the need for reinforcing the fault detection systems in place.
Grid asset management – *Smart grid technologies*
Electric vehicles represent a disruptive opportunity for DSO's, however some uncertainties need further exploration (*such as: Will there be charging stations at home? There is uncertainty if charging stations are stranded capital*). Energy storage also represents significant potential. In addition, technologies that provide more grid information and automation, however, a smart meter in every home is unnecessary for this purpose, given this data collection in 10% of the homes in an area is enough."
Grid asset management – *Mature technologies*
Mature technologies are important, as these have a low cost and allow for increasing operational efficiency, such as: controllable Low Voltage transformers and standardised automated control.
Innovation
DSO's are active in exploring innovation through the participation in R&D projects in cooperation with universities and other industrial partners. Current focus areas include: smart metering, energy storage, virtual power plants, solar PV integration and grid control algorithms.
Natural monopoly regulation
The existing focus in operational efficiency creates challenges for deploying smart grids. DSO's tend to focus on activities that give greater levels of operational efficiency and ensure an adequate revenue, normally grid expansion.
DSO market structure
The German DSO industry is highly fragmented, with 880 DSO's, due to the interest of local communities to control their energy infrastructure. In terms of DSO business scale, the *SmallDSO* representatives perceive that big DSO's are too large to adapt in an efficient way, whilst small DSO's are too small to capture the necessary resources for adapting.
Business model and strategy adaptation (Future roles)
The future role of the DSO's is one in which flexibility management is part of their core operations as ancillary services providers. Achieved through the implementation of smart grid technologies. The grey areas being discussed are attractive business possibilities for DSO's in the future. The *SmallDSO* representatives indicated that outsourcing of business activities and staff reduction are part of their future strategy, in addition to the possibility to merge with another small DSO, which is seen as an opportunity to enable greater operational efficiency.

From the outcomes of the study it is possible to conclude that the present business model for DSO's is not sustainable, mostly due to an increased penetration of distributed generation and a regulatory framework that is incompatible with the necessary business model changes. The current situation at DSO's is one in which present technical challenges are being solved, through grid planning and expansion, for a future with greater levels of DG, whilst smart grid-related possibilities are explored through innovation alliances with universities and other industrial partners. It is possible to see the interest of DSO's in the opportunities brought forward by electric vehicles and storage. In addition to a clear indication that the large-scale rollout of smart meters is beyond their current strategy for grid monitoring. From a market structure and design perspective we observe a greater number of challenges perceived by

DSO's with a smaller business scale.

4. CONCLUSIONS

The present study aimed at understanding DSO's adaptation dynamics to a smarter grid context. In terms of strategic adaptation and business model innovation, DSO's see their future role as flexibility managers, to optimise the use of distributed energy resources and ensure a cost-effective electricity distribution business. Internal efforts to explore new areas are being pursued; however, there is a perception from the DSO's representatives that regulation is not yet supporting a transition towards the implementation of new technologies and the adaptation of business models to provide innovative grid services.

The exploratory outcomes of this study should be considered as a building block toward designing a larger scale analytical framework to conduct policy oriented business adaptation analyses.

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