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Electrical network capacity support from demand side response: Techno-economic assessment of potential business cases for small commercial and residential end-users

Eduardo A. Martínez Ceseña*, Nicholas Good, Pierluigi Mancarella

School of Electrical & Electronic Engineering, The University of Manchester, M13 9PL Manchester, UK

HIGHLIGHTS

- We present three business cases for DSR from domestic and commercial end-users.
- A comprehensive techno-economic methodology is proposed for the quantification of each DSR business cases.
- The regulatory implications associated with each business case are discussed.

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ABSTRACT

Demand Side Response (DSR) is recognised for its potential to bring economic benefits to various electricity sector actors, such as energy retailers, Transmission System Operators (TSOs) and Distribution Network Operators (DNOs). However, most DSR is provided by large industrial and commercial consumers, and little research has been directed to the quantification of the value that small (below 100 kW) commercial and residential end-users could accrue by providing DSR services. In particular, suitable models and studies are needed to quantify potential business cases for DSR from small commercial and residential end-users. Such models and studies should consider the technical and physical characteristics of the power system and demand resources, together with the economic conditions of the power market. In addition, the majority of research focuses on provision of energy arbitrage or ancillary services, with very little attention to DSR services for network capacity support. Accordingly, this paper presents comprehensive techno-economic methodologies for the quantification of three capacity-based business cases for DSR from small commercial and residential end-users. Case study results applied to a UK context indicate that, if the appropriate regulatory framework is put in place, services for capacity support to both DNOs and TSOs can result into potentially attractive business cases for DSR from small end-users with minimum impact on their comfort level.

1. Introduction

Demand Side Response (DSR) is deemed a potentially efficient means to tackle emerging challenges in the power sector brought about by environmental concerns and the ever growing global dependence on electricity, among other factors. As a result, a large body of research has focused on analysing and quantifying the different benefits associated with DSR, particularly the economic benefits end-users, system operators and other actors receive from energy consumption and peak demand reduction, reserve capacity provision, supply and demand balancing, improved network operation and reduced network investments (Bradley et al., 2013; Strbac, 2008; Strbac et al., 2010). The outcomes of this research are encouraging, as DSR is expected to reduce future investments and energy costs in the power sector. These potential benefits are expected to drive investments in DSR enabling technologies, even at the small end-user level (e.g., the smart meters rollout in the UK (Ofgem, 2014a)). Furthermore, new policies and regulatory arrangements are emerging with the aim of facilitating efficient use

Abbreviations: ADDRESS, Active Distribution network with full integration of Demand and distributed energy RESourceS; DCC, Demand Chargeable Capacity; DNO, Distribution Network Operator; DSR, Demand Side Response; EHV, Extra High Voltage; HH, Half Hourly; MIC, Maximum Import Capacity; TSO, Transmission System Operator; TNUoS, Transmission Network Use of System

* Corresponding author. Tel.: +44 161 306 8721.
E-mail address: Eduardo.MartinezCesena@Manchester.ac.uk (E.A. Martínez Ceseña).

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of DSR, protecting the interests of end-users, and guaranteeing that the active end-users providing DSR receive adequate compensation (e.g., the smarter markets programme in the UK (Ofgem, 2014b)). However, in order to maximise the benefits from DSR, it will be critical to secure the participation of small (below 100 kW) commercial and residential end-users in DSR programmes, as small end-users can comprise a significant portion of demand (e.g., 36% in the UK (DECC, 2013; SINTEF, 2003). This is a fundamental challenge, as it is unclear whether the aggregated benefits that are highlighted at a system level are sufficient to justify investments in DSR enabling infrastructure (e.g. smart meters and automation), and hence to generate profitable DSR business cases for small end-users. In fact, small end-users may receive negligible profits after the economic benefits from DSR are distributed between all active end-users providing the service whilst being required to provide DSR services frequently (e.g., once per day) (Bradley et al., 2013; Gottwalt et al., 2011; Prüggler, 2013; Torriti, 2012). Indeed, little research has focused on actual quantification of potential benefits under existing or emerging market structures with the objective of developing specific business cases, particularly from the perspective of small end-users. In addition, research in this area tends to disregard the techno-economic effects associated with DSR such as impacts on the power system associated with, for instance (i) energy payback determined by the need for resuming the service interrupted due to DSR action and (ii) energy imbalances created in the wholesale market due to the DSR actuation. Finally, while many DSR studies involving exposure of small end-users to price signals have dealt with energy markets (Gottwalt et al., 2011; Prüggler, 2013; Torriti, 2012), there is a lack of understanding and quantitative assessment of the potential to provide capacity support services to transmission and distribution networks and the associated business cases for end-users and intermediate market agents such as aggregators.

Based on the above, further research on the quantification of potential benefits and costs associated with DSR services from small end-users is needed to understand whether or not there are business cases for DSR under current and new market frameworks, as well as to identify the factors that drive or discourage such business cases and which should be addressed in emerging regulatory frameworks. Accordingly, this paper presents some of the research findings of the "ADDRESS" ("Active Distribution network with full integration of Demand and distributed energy RESourceS") project, co-funded by the European Commission under the 7th Framework Programme. The aim of the project was to enable active participation of residential and small commercial end-users in power system operation. In this context, this work presents the techno-economic methodologies used to quantify benefits from three DSR services based on the provision of transmission and distribution network capacity (capacity-based services) from small commercial and residential end-users, namely:

1. Avoidance of transmission level capacity charges for electricity retailers;
2. Avoidance of charges between interconnected Distribution Network Operators (DNOs);
3. Avoidance or deferment of system reinforcement costs for DNOs.

It is worth mentioning that the capacity-based services presented in this work are a sample of potential applications of DSR, and their associated benefits are a fraction of the total value of DSR. These capacity-based services (normally neglected in the literature, at least from the point of view of actual quantitative assessment) were chosen for the potential low service call frequency and high value associated with the provision of network capacity. The potential low service call frequency can be attributed to the typical peaky seasonal characteristics of electricity demand, as it is likely that demand will approach network capacity in only few hours per year or even less frequently, which is when capacity from DSR is needed. The capacity-based services are expected to offer high economic value, as the services can facilitate valuable network investment deferral or even avoidance. The low service call frequency and high potential value are desirable characteristics from the perspective of small end-users, for which potentially large benefits can be accrued with minimal comfort level impact. This is a fundamental contribution with respect to previous studies that have focused on energy-based services that might have to be called upon even several times a day, for instance to respond to real-time pricing mechanisms (see for instance (Gottwalt et al., 2011; Prüggler, 2013; Torriti, 2012)).

In this work, particular emphasis was placed on modelling relevant techno-economic effects related to DSR, namely, the (i) payback of the electricity that is curtailed due to DSR, as some activities, such as laundry, may be postponed to provide DSR, requiring energy to be "paid back" at a later time; and (ii) imbalances that DSR can introduce into the electricity market, as electricity consumed by end-users that provide DSR may differ from the energy that retailers have to buy in advance in the electricity market. By addressing capacity-based services and explicitly modelling the technical and economic aspects of DSR, the methodologies are meant to facilitate a better understanding of potential and realistic business cases for DSR, which can be used to inform policy makers and regulators.

This paper is organised as follows. In Section 2, a general overview of DSR is provided, with particular focus being placed on existing DSR programme types and the payback and imbalance effects associated with DSR. In Section 3, the capacity-based DSR business cases explored in this paper are described in detail, while Sections 4 and 5 present the techno-economic methodologies used to assess these business cases and relevant numerical results, respectively. In Section 6, the main conclusions and associated policy implications of this research are presented.

2. Demand side response

DSR can be defined as an intentional change relative to the normal demand profile of end-users made in response to control, incentive or price signals (Albadi and El-Saadany, 2008). The signals and associated DSR actions (e.g., reduce or increase energy consumption) are normally specified in DSR programmes which use available policies, market mechanisms, and incentives to deliver benefits to the power sector by providing services to the network or particular actors such as DNOs, Transmission System Operators (TSOs) and renewable generators. Nevertheless, calling DSR may also result in other effects related to payback and electricity market balancing, which might not be beneficial. It is thus critical to understand both the rationale of specific DSR programmes and all associated effects of DSR in order to properly model and quantify potential business cases.

2.1. Demand side response programmes

A DSR programme is an agreement formulated under existing regulatory frameworks which stipulates the characteristics of a DSR service. That is, the signals that will be sent to end-users, expected DSR actions, and compensation mechanisms and penalties associated, respectively, with the provision or failure to provide proper DSR actions, and so forth. Generally speaking, the DSR programmes can be classified based on the manner by which signals are sent to end-users, namely, as *incentive-based* programmes and *price-based* programmes (Tan and Kirschen, 2007;