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Review

Challenges and barriers to demand response deployment and evaluation

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HIGHLIGHTS

- A review of the challenges related to DR deployment and evaluation is presented.
- There is a pressing need to evaluate DR as it could be a key resource in the future.
- Uncertainty in the value of DR compromises understanding of the resource.
- Poor understanding leads to poor representation of DR in valuation methodologies.

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ABSTRACT

Demand response is increasing in popularity and many utilities are developing demand response programs. However, there exists many challenges to the deployment of demand response. One of the main barriers to widespread rollout is the uncertainty surrounding the value of demand response. In this regard, there is a real and pressing need to evaluate demand response if its full potential is to be realized. This paper presents a comprehensive review of the literature and identifies some of the key barriers to the deployment and the challenges to the evaluation of demand response and provides some recommendations on evaluation methodologies.

Contents

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1. Introduction

Demand response (DR) is often described as the changes in electrical energy usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, to incentive payments or to signals from the system operator [1]. It is widely acknowledged that this is not a new concept. Historically, demand shedding was used for emergency contingency response and, in more recent times, DR programs have been targeted at large industrial energy users [2]. However, there has been much interest recently in more continuous DR, that is, DR on a continuous time-frame, and DR across all sectors. The reason for this burgeoning interest relates to the potential for DR to assist in integrating variable generation [3], the fact that it could be a more cost-effective means to meet occasional peaks in electricity than peaking plants [4] and could thus, potentially, reduce system costs [5] and harmful power plant emissions at times of peak demand [6]. Furthermore, in parallel to developments in variable renewable generation penetration, there have been rapid advances and cost reductions in the area of telecommunications, control systems and computation, which has resulted in greater controllability and flexibility of demand-side resources. Additionally, regulatory changes and electricity market reform have played a major part in allowing DR to become a more viable resource [6].

There has been significant and beneficial work in the area of DR in recent years, highlighting the potential benefits of DR [1,7]. Studies have shown that using DR to facilitate the integration of variable renewable generation is technically feasible [3,7], but there are barriers that limit the use of demand side strategies for integrating wind and solar, some of which are identified in [8]. The work in [9] develops models of DR on the Irish power system and demonstrates that DR can contribute to overall system adequacy and can displace some conventional generation.

There has also been much work reported in the literature focusing heavily on detailed modeling of individual buildings and demand control systems, as well as in the telecommunications and equipment required to implement DR [10–13]. There has, however, been less work in the evaluation of DR from a power system perspective.

Despite significant advances in power system analysis in recent times, many traditional power system models have neglected to incorporate DR. There is now a need for these models to be enhanced in order to better account for the unique characteristics of the demand side [14]. Additionally, there is a requirement to develop tools which are appropriate for quantifying the impacts of DR resources on market performance, generator dispatch and other system effects [15].

Despite the many barriers associated with DR deployment, some of which are documented and explored in this paper, it is apparent from the literature that there is considerable interest in DR because of its potential to provide significant value to the power system. There is evidence that DR could deliver some system services more reliably than conventional generation [16]. Thus, if DR proves to be the neat and sophisticated solution it is claimed to be, failure to exploit the resource is clearly suboptimal. On the other hand, if the potential value of DR is over estimated, considerable resources could be invested in order to exploit a service which ultimately cannot be realized effectively. There is evidently a pressing need to quantify the potential system and market value of DR. Indeed, it has been suggested that the limited DR capability at present in the US [1] is set to rise if it is shown that the "*flexibility it offers is valuable and properly valued*" [17]. Evaluation of the DR resource is clearly a vital step in its large scale deployment and could increase understanding of the impacts of DR on the system and markets.

DR can potentially enter into the energy, capacity and ancillary services markets and avail of multiple revenue streams. DR is capable of participating in the energy market by providing services such as peak shaving and load shifting. Such services could help to reduce system demand at times of typically high prices, potentially reducing output from expensive peaking plants and thereby lowering system costs. A study reported in [18] found that the benefits of DR also lie in the realm of avoided capacity costs, thus DR could be a prominent player in the capacity market. The literature has also shown that one of the benefits of DR lies in its ability to assist with facilitation of variable renewables through reserve provision [7]. It has been illustrated that in some cases demand can provide some responses which are greater than the responses garnered from generators [16,19]. This illustrates the potential for DR to operate in ancillary services markets. Indeed, it is indicated in [20] that an understanding of the value of DR gives an indication of the potential or opportunities that exist within particular ancillary services markets.

An understanding of the value of DR should also inform which sectors DR is most suited to operating in. The authors in [21] advocate focusing DR activities on specific large consumers, consumers who are capable of responding appropriately to real-time prices. This is, in effect, exploiting the easiest resources first. Similarly, the work in [22] demonstrates that most of the total benefit of exposing all sectors to real-time pricing (RTP) can be achieved by implementing DR through RTP in the industrial and commercial sectors only. The work in [22] is based on one specific power system and consequently, it is important to be aware that the results are likely to be quite system specific. Nevertheless, further research may show that there is no major benefit or value in extending DR to the residential sector.

To-date there has been minimal work on evaluating DR from a system level. As a result, considerable uncertainty exists regarding how DR is going to be deployed and the potential revenue for those engaging in DR programs. This consequently impedes the evaluation process of the resource. Similarly, the lack of understanding and knowledge relating to the value of DR imposes a barrier on widespread deployment. This results in a 'Chicken and Egg' type dilemma; DR will be deployed if it is valuable to do so, but an understanding of the methods of deployment and operation of DR is necessary before evaluation studies can produce meaningful results.

This paper aims to identify the barriers and uncertainty that exist for widespread DR deployment and to then show how these barriers could impact upon the analysis of the value of the DR resource. Section 2 explores opportunities that exist for DR to participate in electricity markets and some associated barriers. Section 3 then discusses the barriers to deployment associated with the demand-side of the power system as a result of the uncertainty surrounding consumer behavior and due to the requirement for a greater flow of data and information. Section 4 examines potential methodologies for determining the value of DR resources to the power system and discusses how the uncertainty and barriers in DR deployment can impact upon the methodologies. Section 5 ties together many of the elements discussed in the paper and also identifies issues for synthesis and dissemination of evaluation analysis results. Section 6 concludes the paper.

2. Demand response opportunities and barriers

DR represents a paradigm shift in how we view electricity markets since electrical load can now appear on both sides of the