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Review

A survey of industrial applications of Demand Response

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ABSTRACT

Industrial consumers have traditionally provided flexibility for power systems through various Demand Response (DR) programs in different regions of the world, but below their real potential. Utilizing DR in industries will reduce the need for more expensive alternative forms of flexibility like storage or backup plants. In current increasingly flexible electricity market, it is an excellent chance for the industrial sites to carry out the most of energy management with DR, especially for those plants that are already equipped with the required facilities for DR. This paper aims at providing a comprehensive review of applications of DR in the industrial sector. On this basis, this survey firstly presents the contribution of ancillary services and their potential in industries and then introduces different types of industries with higher potential for DR programs. Finally, the main barriers that hinder the widespread utilization of these programs in industries are presented and categorized.

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1. Introduction

At its first introduction, Demand Response (DR) was considered as a solution to improve the reliability of the power system by actively following the supply or quickly reacting to system contingencies. Due to the advent of smart grid concept, to the increasing use of distributed generation and to the contribution of end users into the electricity market, DR is effectively considered as a new kind of resource [1].

Considering that industrial plants are extensive energy consumers having an already applied infrastructure endowed with sensors, metering technologies and personal operators, a larger amount of DR participation in this sector is expected if compared to residential and commercial ones [2]. However, based on the recent literature, it is contrariwise. This is mainly due to the fact that the industrial potential of DR is not completely comprehended, especially with regard to the emerging modern technologies in smart grids [3]. Fig. 1 illustrates the following factors that lead to a potential increase of industrial DR: environmental concerns related to the increase of fuel consumption, reliability concerns to prevent blackouts, advancement in smart meters technology that allows controlling and monitoring responsive loads in near real-time scales, advent of aggregators that can manage smaller loads participating in power markets, and the Auto-DR promising technology.

In some aspects, it is more complicated to implement DR for electrical loads in industrial plants if compared to non-critical loads of residential or commercial consumers mainly due to the reliability management that is more complicated for industrial plants. An interruption of service may lead, in fact, to stoppage of production and/or violate the daily operational and production constraints of the plant. In some cases, processes are indeed dependent and have correlations that make them hard to isolate, interrupt or shed separately. Moreover, in some other changes materials should be stored for every process interruption and this operation is costly and complex. In fact, large scale and energy demanding operations, that are generally based on a single source of demand, are potentially the best solution for the application of DR in the industrial sector [4].

Besides, many manufacturing processes are critically dependent on time and must be scheduled exactly with high timing precision. In contrast to the residential or commercial consumers, where load control in near real-time data suffices, in most of the industrial plants, monitor and control on a millisecond scale is, indeed, vital [3].

Generally, an industrial consumer manages electrical demand by utilizing distributed generation, energy storage, load shifting, interruption of noncritical loads such as lighting, ventilation, or by temporary interruption of one or more possible processes [5]. Storage devices are employed to proactively store energy to compensate for the uncertainty due to renewables sources. However, storage devices at larger industrial scales are not an economic solution, instead, DR approaches can be considered in order to provide flexible load solutions to increase renewable resources exploitation and reduce costs related to energy consumption.

Recently, some review articles in different areas related to smart grids and DR have been published [6–13]. In Ref. [6], some developing technologies, like smart metering, energy control and communication systems are introduced by analyzing real industrial case studies. In Ref. [7], four major aspects of DR including programs, issues, approaches and future extensions are surveyed. The means and tariffs that the power utility takes to incentivize users to reschedule their energy usage patterns are described. Then, the existing mathematical models and problems are analysed followed by the state-of-the-art approaches and solutions to address these issues.

In Ref. [8], various DR schemes and programs are classified according to their control mechanisms, the motivations offered to reduce the power consumption and the DR decision variables. Various optimization models for the optimal control are also categorized based on the target of the optimization procedure.

DR is investigated as a way to plan and schedule the operation of renewable energy resources [9] and a comprehensive cost/benefit evaluation of DR is also reported. In addition, several assessment methods in combination with impacts of DR on electricity prices are presented.

A review of DR is presented in Ref. [10], including the existing applications and a possible implementation strategy in smart grid environments. Furthermore, classification and status of DR programs in different U.S. electricity markets have been also discussed.

Possible business models for energy efficiency and DR providers in different electricity market segments are analysed in Ref. [11]. The analysis covers three types of characteristics: Demand Side Management (DSM) transaction characteristics, renewable energy correlation and load control characteristics.

DR modeling approaches and their impact on operations and outcomes of home energy management systems are surveyed and analysed in Ref. [12]. An outline of the impact of policy and regulation changes, electricity market enhancements and technical advancements on DR participation is provided in Ref. [13].

In general, the previous review papers mostly refer to DR in residential or commercial sectors and in some of the mentioned papers only few articles focus on DR in the industrial sector. Nevertheless, implementing DR in industries is a more challenging task and careful knowledge and attention are needed. In addition, it is necessary to understand the importance of ancillary service programs more than ever before as they are able to add higher flexibility into the smart grid. On the other end, due to an increasing level of renewable power penetration into the grid, it should be useful to provide ancillary services making also the use of DR where industrial consumers may play a central role.