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Design and validation of a methodology for standardizing prequalification of industrial demand response resources

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ABSTRACT

Current energy policies around the world are encouraging integration of renewable electricity generation into the power system. However, these resources are so unpredictable and variable that the need of more flexible resources increases. Demand Response (DR) resources may be a realistic solution, but increasing the credibility among agents by means of the standardization of DR procedures is necessary.

This paper proposes a methodology based on an energy analysis of industrial processes to quantify and validate the flexibility potential of industrial customers in order to contribute to create a certification procedure. This methodology can be helpful for industrial customers themselves, energy service companies (ESCO) and DR aggregators, among others.

The methodology was validated in three different factories whose industrial segments have a high-energy intensity in Europe: a paper factory (Klingele, Germany), a meat factory and a refrigerated logistics centre (Campofrio, Spain).

1. Introduction

The progressive integration of Renewable Energy Sources (RES) in the mix of electricity generation brings unquestionable environmental benefits. However, it requires wider variety of solutions to guarantee the electricity supply due to the variability of RES. In this context, Demand Response (DR) could be an important resource to integrate RES [1–3], considering demand-side resources in electric usage, shaping their normal consumption patterns in response to the variations in the electricity price over time or to incentive revenues designed to induce lower electricity usage at times when system reliability is jeopardized [4].

According to this, DR policies and directives have already been established to address the demand side participation in electricity markets in many countries, such as EU member countries [5], United States of America (National action plan-FERC) [6], China [7], etc. There are several examples in Europe, and especially in the United States, of DR programs that have already been offered by system operators or utilities [8]. For instance, large industries such as metal industry, cement, chemistry, iron and steel and vehicle manufacturing have traditionally been willing to reduce part of their energy consumption in exchange for some economic benefits [9–12].

There are different prequalification procedures to validate balancing resources in which the conventional generators must be qualified according to some technical specifications that are tested before taking part into balancing markets [13,14]. However, there is not a common standardized procedure to guarantee the reliability of DR resources.

In this vein, the only DR standards that currently exit around the globe are related to communication protocols for control systems in commercial and residential sectors [15]. Some examples are “ISI/IEC 15067-3:2012” that is an international smart appliance standard [16], “Open Automated Demand Response (OpenADR)” developed in the United States [17], “AS/NZN 4755” that is from Australia [18] and “Echonet Life” from Japan [19].

Due to a lack of specific standards for the certification of DR resources, most system operators have developed their own procedures to guarantee the reliability of customers’ DR bids prior to take part into their energy markets [20,21].

In fact, there are some studies with special focus on the technical aspects of the procedure for the validation of DR resources [22], but they focus on the specific problems that aggregators could have using this kind of resources instead of on the flexible demand of customers.

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In this context, a standardized procedure for the certification of DR resources was proposed in the "Demand Response in Industrial Production (DRIP)" project [23] attending to three different points of view: Certification of DR Providers, Certification of DR Products and Certification of Energy Service Traders [24]. Regarding the certification of DR Providers, it could be used to prove if an industrial customer is able to reliably implement their DR actions, which are defined as the technical specifications associated with a change in the electricity usage of a particular industrial process in response to specific request from a system operator on a type of day.

Industrial customers can hide a high DR potential in their production processes [25–27], but it is necessary to carry out sophisticated analyses to take into account all the constraints linked to critical parameters of production processes such as temperature, humidity and pressure, among others. In other words, the inadequate implementation of DR actions could affect to the final quality of products, which could be a relevant barrier for the participation of industrial customers in any DR option [28].

As a whole, this paper presents a novel methodology whose main objective is to determine and demonstrate the flexibility potential that exists in industrial customers (DR Provider). This methodology could be used as a basis for the development of a certification procedure of reliable industrial DR resources. In order to address the abovementioned objective, the following issues were performed:

- The actual minimum reducible or interruptible power for each identified DR actions was demonstrated in a set of field tests whose results were compared with the theoretical values identified on the flexibility audits previously performed.
- The evolution of the critical parameters of the industrial processes was analysed to determine the potential impact on the final products during the field tests.
- The potential participation of industrial customers in reserve electricity markets was validated by means of the implementation of a set of DR events in order to simulate a real situation.

The methodology was applied to three different customers with sensitive production processes: a paper factory (Klingele, Germany), a meat factory and a logistics centre of the same segment (Campofrio, Spain).

These customers were selected because both the paper and the food industries represent a high percentage, 11.7% (10,071 ktoe) and 11.65% (9981 ktoe) respectively, of the total electrical consumption in the industrial sector (235,665 ktoe) [29].

Additionally, the aforementioned segments have a high degree of replicability in Europe, as it can be observed in the following figures that present the number of European factories [30]:

- Around 2300 paper factories manufacture pulp, paper and paperboard.
- Around 28,000 meat factories manufacture pork products.
- Around 2400 refrigerated logistics centres belong to the meat segment.

This work was carried out in the framework of the aforementioned DRIP project that was co-funded by the Environment LIFE programme of the European Commission and developed by six partners with different roles: a grid operator, two industrial customers, a certifier, a retailer and a research centre.

The paper is structured as follows: Section 2 describes the proposed methodology that includes two relevant points such as the description of the verification process for the assessment of a DR event and the technical parameters of DR actions according to the presented methodology. In Section 3, the DR actions implemented in the industrial processes involved in this study and the results obtained are described in detail. The final conclusions are drawn in Section 4.

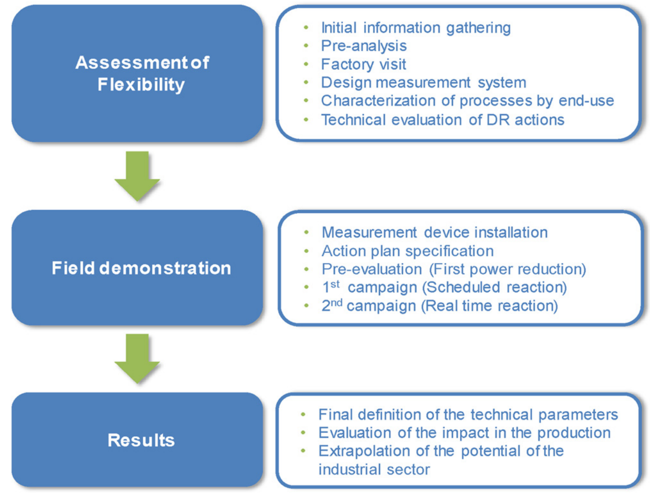

Fig. 1. Proposed methodology.

2. Proposed methodology

The methodology was developed to demonstrate the actual potential flexibility of industrial customers that will enable their involvement in a reserve electricity market to provide ancillary services in a profitable way for both the customers themselves and the power system. Fig. 1 presents an overview of the proposed methodology.

According to Fig. 1, three main stages are proposed. The first stage focuses on the theoretical assessment of the flexible industrial processes. Firstly, the most relevant information related to the industrial facilities and their production processes are requested to the industrial customer. Secondly, this general information is analysed to prepare the visit to the plant. At this point, some potential flexible processes or DR actions should be identified. Then, the potential impacts on the production process and the internal interdependencies among them are analysed in collaboration with the engineers and technical staff of the plant. The aim of this analysis is to guarantee that the identified DR actions can be carried out and quantify the potential cost associated with the implementation like the extra labour cost due to implementation of the flexible actions. Apart from the technical evaluation, an economic assessment, which is completely described in Ref. [31], is also performed at the same time.

In addition, the **measurement system** has to be designed taking into account the further tasks of flexibility validation in the field demonstration. Moreover, the total electricity consumption of the factory is disaggregated by flexible processes in which some DR actions can be implemented. According to this, a total number of 31 power meters was installed in the three factories and they were integrated into the control and monitoring system provided by the "**Polytechnic University of Valencia**" (UPV) [32]. Apart from this, one of the most relevant tasks at this stage is the technical evaluation of the DR actions in which all the technical parameters described in Section 2 are properly assessed. The second stage is the field demonstration where the DR actions in each industrial customer are tested empirically. A detailed **action plan** has to be designed for the implementation of the field tests, and customers have to receive it and accept it before starting the pre-evaluation. The field demonstration was divided into three parts: pre-evaluation, first and second campaign.

In the **pre-evaluation**, customers have to carry out the first reduction in their production processes in a controlled way. The main objective is to demonstrate their ability for reducing demand power without considering the duration time of the implementation. Once the pre-evaluation is finished, a more intensive campaign of implementation of scheduled DR actions started in the three factories (**first campaign**) and it lasted around three months. In this period, each customer