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Connecting the Last Mile: Demand Response in Smart Buildings

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Abstract

Demand response (DR) operates on the last mile in the smart grid that connects the building energy system with utility grid. It enables a building to actively participate in the whole grid energy system. With DR, a building may make a profit by optimizing its energy consumption while helping to achieve the overall targets of energy efficiency and emission reduction for the whole energy system. The recent US Supreme Court ruling on FERC Order 745 has reaffirmed the critical role and functions of demand response. It is expected that demand response will soon become a basic function of smart buildings. In this paper, we summarize the background of demand response, investigate promising automation technology such as OpenADR for demand response applications in smart buildings, and present an OpenADR Interface prototype demonstration for building energy management systems. We demonstrate the realization and benefits of OpenADR integration with state of art building energy management systems, which connects the last mile between the smart grids with the smart buildings.

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Keywords: Demand response; building energy management system; OpenADR; Smart building

1. Introduction

Demand response (DR) is defined as “changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized”[1]. Demand response is regarded as one of the most important applications of smart grids and smart buildings, a.k.a. the smart grid’s “killer apps”, according to former chairman of US Federal Energy Regulatory Commission[2][3].

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According to estimates from US Energy Information Administration [4], in the US alone, demand response programs saved about 1,300 GWh of energy in 2014, which is enough to power 120,000 US households for the entire year. The actual peak demand savings was around 12,000 MW, equivalent to the total generation capacity of Bulgaria or Denmark in 2012 [5]. In the US, about 9.3 million customers participated in demand response programs. Among those customers, the commercial and industrial sectors delivered more than half of all actual peak demand savings from demand response in 2014. The average annual commercial customer incentive was almost $600, while the average industrial incentive was more than $9,000. Residential customers received only about $40 household savings. In the industrial and commercial sectors, buildings are the major energy consumers and are often regarded as the last mile in energy system. Integrating demand response into smart buildings will not only contribute to the overall energy efficiency goal of the demand response program but also benefit the building owners with actual savings and even profit.

An important recent development for demand response was the January 15, 2016 decision by the US Supreme Court decided to uphold FERC Order 745. The Order stated that demand response providers could be compensated based on locational marginal price (LMP) as if they were generators. The Supreme Court's decision provides assurance that demand response will continue to play a role in wholesale electricity markets in the United States. From the building perspective, this means that smart buildings with demand response capability are able to participate in the wholesale electricity markets by providing demand response energy reductions, and they will be compensated as if they were generating electricity.

Both the large market space in energy sectors and the new demand response policies are expected to stimulate the market growth for demand response, especially for the building energy management market. While most new buildings are already equipped with building energy management systems (BEMS), old buildings are also being retrofitted with BEMS. Adding demand response functions to existing BEMS will allow the buildings to play an active role in the energy sectors, contributing to the whole energy system's goal of increasing efficiency while reducing emission, as well as making profits for the building owners from the market mechanism.

Since the policies have cleared the way for the huge demand response market, automation technology becomes the key driving factor of demand response for buildings. Traditionally, energy management inside a building is one of the key functions of the BEMS or building automation systems (BAS). For example, ABB's Emax 2 Power Controller is a real time advanced load management and control function within ABB's Ekip building electricity management system. It limits the average power consumption in each defined time interval to a pre-determined maximum value (contractual power) by disconnecting and reconnecting some loads according to building operator's load priority lists. The Emax 2 is also synchronized with utility meters, so it can perform optimization according to utility measurements to avoid penalties under certain contracts [6]. Although the Power Controller is originally designed for electricity system management inside a building, it has already been providing a certain level of automated demand response under the "contractual power" type demand response program. With the rapid deployment of demand response programs around the world, we expect to see more flexible and comprehensive interactions between the buildings and the grids.

To address the need of more flexible and comprehensive DR programs, a generalized Automated Demand Response (ADR) is needed, which consists of fully automated signaling from a utility, Independent System Operator (ISO), Regional Transmission Operator (RTO) or other appropriate entity to provide automated connectivity to customer end-use control systems, devices and strategies. ADR helps system operators reduce the operating costs of DR programs while increasing DR resource reliability. For customers such as building owners, ADR also reduces the resources and effort required to achieve successful results from these DR programs. Automation is what also makes it possible to translate changes in wholesale markets to corresponding changes in retail rates, enabling buildings to respond to DR signals in real-time to reduce demand. Among the ADR technologies, the OpenADR standard from the OpenADR Alliance is one of the most promising technologies. OpenADR is an open and interoperable information exchange model and an emerging smart grid standard [7]. OpenADR standardizes the message format used for Automated DR so that dynamic price and reliability signals can be delivered in a uniform and interoperable fashion among utilities, ISOs, and energy management and control systems [8].

In the following sections of the paper, we will review the overall status of ADR and OpenADR. We will present an example of intelligent load management inside the building, and propose a practical solution of integrating demand response into BEMS/BAS via the OpenADR standard. A research prototype built on top of existing building