Renewable and Sustainable Energy Reviews 30 (2014) 461–478

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Demand response and smart grids—A survey

Pierluigi Siano *

Department of Industrial Engineering, University of Salerno, Via Giovanni Paolo II, 132, Fisciano (SA) 84084, Italy

ARTICLE INFO

Article history:
Received 8 June 2013
Received in revised form
2 September 2013
Accepted 19 October 2013

Keywords:
Demand side management
Demand response
Smart grids
Energy management systems
Smart metering
Communications systems
Electric vehicles

ABSTRACT

The smart grid is conceived of as an electric grid that can deliver electricity in a controlled, smart way from points of generation to active consumers. Demand response (DR), by promoting the interaction and responsiveness of the customers, may offer a broad range of potential benefits on system operation and expansion and on market efficiency. Moreover, by improving the reliability of the power system and, in the long term, lowering peak demand, DR reduces overall plant and capital cost investments and postpones the need for network upgrades. In this paper a survey of DR potentials and benefits in smart grids is presented. Innovative enabling technologies and systems, such as smart meters, energy controllers, communication systems, decisive to facilitate the coordination of efficiency and DR in a smart grid, are described and discussed with reference to real industrial case studies and research projects.

Contents

* Tel.: +39 0 89964294.
E-mail address: psiano@unisa.it

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.10.022

1. Introduction

The smart grid (SG) is conceived as an electric grid able to deliver electricity in a controlled, smart way from points of generation to consumers that are considered as an integral part of the SG since they can modify their purchasing patterns and behavior according to the received information, incentives and disincentives [1–3]. As confirmed by some recent research [4,5], most of the advantages of SG are, in fact, due to its capability of improving reliability performance and customers' responsiveness and encouraging greater efficiency decisions by the customers and the utility provider. Accordingly, demand side management (DSM), including everything that is done on the demand side, represents an integral part of SG [6–9]. The complete integration of DSM requires communication systems and sensors, automated metering, intelligent devices and specialized processors. Smart metering and advanced information and communication technologies (ICT) solutions for energy management in buildings appear, in fact, as a tangible opportunity to achieve energy savings, exploit renewable energy resources (RES) and favor customers' participation in the energy market. New ICT infrastructures, supporting a more efficient network operation and allowing the communication of frequent price updates, offer new challenges for DSM. They allow a much more dynamic, reactive pricing mechanism required to take into account real-time availability of fluctuating RES [8–13] and to follow the evolution of the balance between supply and demand in real time. DSM commonly refers to programs implemented by utility companies to manage the energy consumption at the customer side of the meter [11,12]. Both utilities and customers can benefit of DSM programs that can help electricity power markets operate in a more efficient way [14], thereby reducing peak demand and spot price volatility [15,16].

A wide range of demand response (DR) programs and tariffs are already offered by utilities [13–28] that have been settled to use the available energy more efficiently and to encourage customer response and competitive energy retailers. These programs consist of conservation and energy efficiency programs, fuel substitution programs, demand response programs, and residential or commercial load management programs [12,29].

According to [30]: “Energy efficiency involves technology measures that produce the same or better levels of energy services (e.g., light, space conditioning, motor drive power, etc.) using less energy. The technologies that comprise efficiency measures are generally long-lasting and save energy across all times when the end-use equipment is in operation. Depending on the time of equipment use, energy efficiency measures can also produce significant reductions in peak demand”. According to this definition, energy-efficiency programs involve that, without modifying operating practice and, in order to reduce energy usage, new devices using less energy should replace existing consumers' devices. In order to push customers to acquire, install and adopt energy-efficiency measures in their facilities, energy-efficiency programs offer financial incentives and services. Different models for energy efficiency program administration exist that are generally administered by electric and gas utilities, state energy or regulatory agencies [31]. The most popular programs refund customers for installing energy-efficient equipment; however, other types of energy-efficiency programs exist.

Fig. 1 describes the potential impact of efficiency and DR measures on customer service levels. The opportunities and potential for both energy efficiency and DR depend on the customer's existing building and equipment infrastructure. The daily energy efficiency category of actions in Fig. 1 incorporates both short-term conservation actions and long-term investments in energy efficiency. End-use customers, in order to handle their electric service requirements and costs, can invest in energy efficiency or participate in a variety of DR activities such as signing up for a time of use (TOU) rate and shifting loads such as air conditioner or pool pump to off-peak hours. Some examples of DSM programs are real time pricing (RTP) and direct load control (DLC) programs. DLC programs for residential load management [18–20] are based on an agreement between the utility company and the customers. The utility, or an aggregator, can remotely control the operations and energy consumption of certain appliances such as lighting, thermal comfort equipment, refrigerators and pumps. An alternative to DLC is smart pricing, where users are encouraged to individually and voluntarily manage their loads, e.g., by reducing their consumption at peak hours [22–24]. In this regard, critical-peak pricing (CPP), time-of-use pricing (ToUP) and real-time pricing (RTP) are among the more popular options. According to RTP programs, the price of electricity varies at different hours of the day and each user is expected to individually respond to the time-differentiated prices by shifting its own load from the high-price hours to the low-price hours [26–28].

It is worth noting that effective DR behavior on shorter timescales requires additional investment to execute real-time or fast DR options (such as ancillary services or spinning reserves). Air conditioners or water heaters can be, for instance, integrated with demand-responsive controls in the basic electronics of the appliance to automatically provide day-ahead and real-time response capability. Key attributes and distinguishing features of various customer options include required frequency of response, underlying motivation and drivers, required customer actions, supporting infrastructure required to enable customers to participate and potential impact on the level of energy services [32,33].

2. Demand response

DR refers to “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” [34,35]. DR, by promoting the interaction and responsiveness of the customers, determines short-term impacts on the electricity markets, leading to economic benefits for both the customers and the utility. Moreover, by improving the reliability of the power system and, in the long term, lowering peak demand, it reduces overall plant and capital cost investments and postpones the need for network upgrades [31,36].

The response in electric usage is handled through DR programs designed to coordinate electricity use with power system