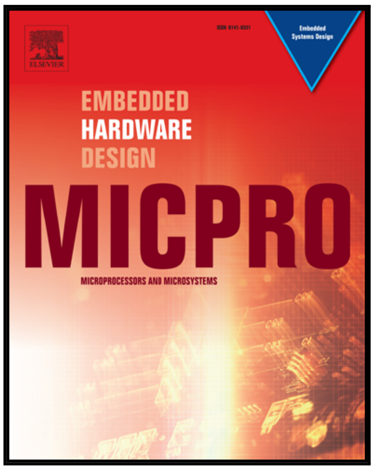

Implementation of a Building Energy Management System for Residential Demand Response

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Implementation of a Building Energy Management System for Residential Demand Response

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Abstract

Demand response is proposed as a solution to handle the fluctuations in the power supply in a scenario with higher penetration of renewable energy sources. Although demand response already offers a positive business case in certain domains, it still lacks maturity in other areas, especially in the residential domain. This paper presents a comprehensive study of a novel Building Energy Management System (BEMS) to strengthen the adoption of residential demand response. The proposed consumer-centric BEMS monitors the building performance and its surroundings, interacts with the residents, optimally controls Distributed Energy Resources (DERs) and provides demand response to an aggregator. The BEMS is conceived with a multimodal objective: exploit flexible consumption through demand response and run the building in a energy efficient manner. The system architecture and hardware and software design are detailed. A prototype of the envisioned BEMS has been developed and deployed in a 12-storey residential building. The prototype performance, the scalability, the data monitoring capabilities, and the interaction with the residents and controllability of DERs of the BEMS are demonstrated. Moreover, the study provides an estimated of the total flexibility potential of the testbed.

Keywords: Smart Grid, Demand Response, Residential Buildings, Building Energy Management System, Hardware and Software Design, Validation

1. Introduction

In 2013, the International Energy Agency claimed that more than 65% of the world's electricity was generated from fossil fuels, thus contributing to CO_2 emissions [1]. In this scenario, Renewable Energy Sources (RES) are proposed as a solution to meet the electricity needs and reduce the overall CO_2 emissions. High RES penetration raises many challenges, among them the security of the supply due to the intermittent generation of some RES (e.g., wind power). Although the key concept of demand response has been coined few decades ago [2], focus has for long been on cost saving potentials and the business case has been severely challenged by the cost of equipment installation and the small volatility of electricity prices. Today, demand response is proposed as a feasible solution to adapt the electricity consumption to the available renewable generation and thus supports RES integration [3]. This may be accomplished by shifting electricity consumption away from periods where electricity is primarily generated by conventional sources (e.g., fossil fuels) towards periods with RES generation.

The benefits of demand response are numerous and not limited to RES integration [3]. In the United States, demand response offers a strong business case for peak clipping with an estimated potential of 27 GW on peak reduction in 2013 [4]. More than 70% of this 27 GW is provided from industrial and commercial customers [4]. In Europe, it is estimated that the theoretical demand response potential for peak reduction is 61 GW [5].

While demand response experiences in the industrial and commercial domain are many, the lack of experiences in the residential domain is a key concern [6] that leaves an unfulfilled potential for demand response. One main reason for this tendency is that industrial and commercial facilities tend to have large electricity loads with an appealing demand response potential. In contrast, the residential domain is characterised by having many and relatively low electricity loads. The costs of activating these Distributed Energy Resources (DERs) for demand response are usually too large for the benefit it provides. In this scenario, it is necessary to introduce an aggregation layer that facilitates the controllability seen from a top-level controller [7, 8].

Depending on how the DERs are controlled, there can be two types of control schemes: direct and indirect [6]. In the former, a DER is directly regulated by a control unit (e.g., change set-points dynamically) [8, 9] while in the latter the controller sends a signal to trigger a change on consumption (e.g., by showing a varying price to consumer) [10, 11]. Demand response is provided through demand response programs that mainly fall into price-based programs (e.g., real-time pricing) and event-based programs (e.g., direct load control) [3, 4]. Different demand response programs and control schemes require a different level of consumer involvement. Using this involvement, three types of interventions can be defined: back-stage, where the consumer is not involved in any decision-making nor control action but can still feel the effects [12]; medium-stage intervention,

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