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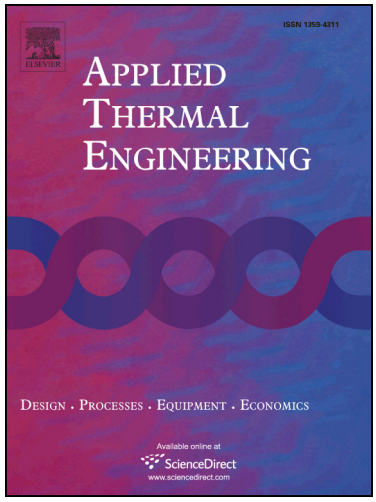

DISTRIBUTED INTEGRATED ENERGY MANAGEMENT SYSTEMS IN RESIDENTIAL BUILDINGS

Johannes Honold, Christian Kandler, Patrick Wimmer, Bernhard Schropp, Roland Reichle, Matthias Gröne, Mathias Bünemann, Jens Klein, Maximilian Kufner

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DISTRIBUTED INTEGRATED ENERGY MANAGEMENT SYSTEMS IN RESIDENTIAL BUILDINGS

Johannes Honold[a*], Christian Kandler[a], Patrick Wimmer[a], Dr. Bernhard Schropp[b], Dr. Roland Reichle[b], Matthias Gröne[b], Dr. Mathias Bünemann[b], Dr. Jens Klein[b] and Maximilian Kufner[a]
[a] Technische Universität München (TUM), Arcisstraße 21, D-80333 München, Germany
[b] SMA Solar Technology AG, Sonnenallee 1, D-34266 Niestetal, Germany
[*]corresponding author: johannes.honold@tum.de

ABSTRACT

This paper explains the concept of a distributed integrated energy management (diEM) system for residential buildings. The overall goal of the system is to minimize operational energy costs of the household. This is obtained by load shifting in order to enhance the self-consumption rate of the on-site renewable electricity production. The crucial difference to centralized energy management systems (where data from household devices must be gathered and evaluated centrally) is the presence of multiple smart energy managers that negotiate with each other on the switch-on times of their dedicated electric devices. The major benefit is that devices of various manufacturers can be incorporated in the same home energy management system with open standards and open protocols without any additional decision-making unit. The basic procedure of the diEM is divided into a discovering phase and a negotiation phase. Best practice parameter settings are deduced from realistic scenarios with constant and variable electricity tariffs, and a run-time analysis indicates that up to seven devices can run simultaneously with a one minute renegotiation frequency. The monetary evaluation shows that the diEM can reduce the operational energy costs at a rate dependent on user behavior and tariff structures.

Keywords: Decentralized energy management, distributed energy management, demand-side-management, home energy management, multi-agent system.

1 INTRODUCTION

Due to its nature, solar driven photovoltaic (PV) modules feed heavily fluctuating power into the grid over time. The ongoing rollout of renewable capacities worldwide [1] is leading to an increase in situations in which the grid or parts of it are oversupplied or undersupplied. Conventional power plants or energy storage systems must balance the grid in these cases. Another way to deal with this problem is demand-side management (DSM) at the electricity consumer, for example in residential buildings [2]. One measure to employ DSM and to cut feed-in peaks of renewables is to incentivize self-consumption of on-site produced electricity in microgrids that are connected to the low voltage grid [3]. The incentive mechanism is feed-in tariffs which are lower than purchase tariffs. The German Renewable Energy Sources Act (2014) may serve as an example for that mechanism, since the feed-in tariff for rooftop systems of less than 10 kWp (launched in February 2015) accounts for 12.92 €ct/kWh [4] and the electricity purchase tariff averaged out at 28.81 €ct/kWh [5]. If home and PV-system owners want to act in an economical way, they can install a home energy management system (HEMS) that takes over the decision-making process, when to switch on or off, for many household devices. Those devices with the highest power and energy consumption should be operated by the HEMS. Most such systems employ a central unit with varying levels of computational power [2, 6, 7, 8]. This unit collects all necessary data from connected household devices and calculates an optimal strategy for the overall load curve. Different methods have been developed in recent years to generate an optimized schedule. Some researchers use binary linear optimization [8], mixed-integer linear (MIL) or nonlinear optimization [9, 10, 11], while others apply genetic algorithms [12] or heuristics [11, 13]. Multi-objective optimization is also an option in order to reduce the number of optimization variables [14]. However, all systems have in common that they are centrally organized and operated, which comes with some drawbacks. For example, high complexity with many decision variables in MIL programming requires more computational time, setting limits for recalculating schedules when any input parameter has changed [11].

In contrast, this paper discusses a decentralized approach: A distributed integrated energy management system (diEM), where all household devices come with a computational unit. These components are called energy managers, which detect each other in the