Title	スマートグリッド向けの住宅コミュニティエネルギーシステムのデマンドサイドマネジメント
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Abstract

The electrical grid has operated on a centralized, top-down model for the past century and heavily relied on fossil fuels for energy production. Grid operators are responsible for the reliable delivery of electricity to consumers where electricity generation must be matched with the total demand at all times. The main driving costs and capacity requirements are the electricity demand that occurs during peak periods. These peaks in demand require utility companies to operate costly and inefficient generators. Moreover, a concern of climate change and greenhouse gas emission leads to an expected widespread demand-side adoption of distributed energy resources (DERs), including renewable energy. The higher penetration of renewable energy resources causes the challenges of the grid operators to exacerbate. The intermittent nature of renewable resources and uncoordinated operation of DERs substantially limit the ability of the supply adaptation to the fluctuating demand and reverse power flow. One of the foreseeable solutions is to manage how end-users consume their energy. Demand-side management (DSM) is a technique to exploit the flexibility in the demand-side and change the consumption pattern of the end-users such that demand profiles match better with the supply and thus lower energy costs.

In this dissertation, a DSM method for a residential community with high penetration of DER is presented. In the proposed DSM method, a local energy sharing scheme is incorporated into a price-based demand response to exploit the value of DER, benefiting both the utility company and its customers. On the one hand, the utility company can adopt the DSM method to motivate the customers to shift their energy consumption and production such that peak demand and export energy can be reduced. As a result, the aggregate consumption curve becomes more flat and smooth. Therefore, the utility company can lower energy costs from the costly peak-time energy procurement and mitigate the problem of reverse power flow. On the other hand, the customers will be incentivized from participating in DSM and motivated to share their energy locally. Thus, increasing their energy bill savings and self-consumption, which maximize the value of DER.

We define a procedure of DSM into three sequential processes: day-ahead consumption scheduling, consumption rescheduling, and energy billing. In the day-ahead consumption scheduling, we propose energy price functions to motivate users to plan their energy consumption and formulate an energy bill minimization problem for each user based on appliance specifications and preferences. Then, we present an iterative distributed algorithm to solve for optimal consumption schedules while preserving the privacy of the users.

Furthermore, we aim to improve the practicality aspect of the proposed DSM model by addressing the uncertainty of human behavior and energy billing fairness issues. We propose the consumption rescheduling algorithm to allow the users to change their preferences during operating periods and recalculate consumption schedules for the remaining time in order to avoid unnecessary costs. The energy billing mechanism with a penalty/reward system is proposed to fairly allocate any energy bill discrepancy to users based on their deviated consumption from the assigned schedules.

Simulation results indicate the effectiveness of the proposed DSM model in terms of peak demand and export energy reduction while maximizing the energy bill savings of the users.
Simulation on the impact of battery, PV generation, and user participation in the system performance is carried out. Furthermore, the simulation results of the proposed consumption

rescheduling algorithm show improved consumption profile of the community in response to the changing preferences of users. Finally, the results of the proposed energy billing mechanism show the fair allocation of energy bills to each user proportion to the amount of deviated consumption.

Keywords: Demand-Side Management, Distributed Energy Resource, Energy Consumption Scheduling, Local Energy Sharing, Smart Grid