Chapter 6
Management of Scheduling and Trading in Hybrid Energy Trading Market

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ABSTRACT

We introduce a novel hybrid energy trading model in SG and illustrate the associated optimal energy scheduling and trading management. The hybrid model consists of an external retail market and a local energy trading market managed by a local trading controller (LTC) whose purpose is to coordinate the local transactions between energy consumers and suppliers. The flexibility in trading with the utility company and the LTC provide a new opportunity for benefiting the energy consumers and suppliers. We quantify such benefits and formulate the mathematical optimization problems, with the objective of optimizing the consumers' and suppliers' rewards through controlling their energy demands and provisionings, and controlling the pricing of the LTC. We model two different types of the LTC's objective when it manages the local trading, i.e., the nonprofit-oriented one and the profit-oriented one. Furthermore, we consider that multiple LTCs coexist in the hybrid market, and present the mathematical optimization problems regarding the optimal energy scheduling and trading problems.

1. INTRODUCTION

Future smart grid (SG) has been widely considered as a complex yet advanced power system capable of meeting the rapidly growing energy demand in a reliable, sustainable and economical manner (Keshav & Rosenberg 2010). A key feature of SG is its advanced information infrastructure, which enables the advanced capabilities of grid-state sensing and the two-way communications for connecting the energy

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suppliers and consumers. Facilitated by this advanced information infrastructure, future SG is convinced by efficient demand response (DR) mechanism, based on which the energy suppliers and consumers are able to flexibly schedule their energy provisionings and demands, respectively, for achieving a better performance. For instance, based on the state information collected from the energy suppliers, the energy consumers can wisely adjust their energy demands without suffering from a large dis-utility due to short of supply. Similarly, based on the real-time demand information collected from the consumers, the energy suppliers can appropriately adjust their provisionings for avoiding a large loss due to over-provisioning.

The DR mechanism has been expected to be even more important as the paradigm of bidirectional energy trading becomes prevalent in retailer market in SG. In particular, the wide exploitation of distributed and renewable energy sources as well as the deployment of distributed energy storage systems (e.g., electric vehicles) in SG yield an emerging dual-role of the energy consumers which not only consume energy to satisfy their respective load demands, but also can sell their stored energy back to the grid (under some favorable conditions) for reaping rewards. Achieving such advantages of the bilateral trading necessitates a careful design of the DR mechanisms for both the bidirectional energy scheduling and the associated economic reward optimization. At present there have been many studies that investigated the energy trading between the energy consumers and the energy retailers, e.g., the studies about how energy consumers schedule their consumptions in response to the retailers' prices, and the studies about how the retailers adjust their prices for shaping the consumers' demands. A comprehensive survey of these studies is given in Section 2.

Beyond the above interactions between energy consumers and utility companies in the retail market, the SG in fact has been envisioned to yield a hybrid energy trading market consisting of both an external retail market and a local energy trading market which managed by a local trading controller. Therefore, the energy consumers and suppliers have the flexibility in trading with the utility company and the local trading controller. Thanks to the advantages of local trading (e.g., the smaller energy transmission loss and more favorable trading prices), the hybrid energy trading market potentially can benefit all participants involved. A typical paradigm of such a hybrid market is the smart micro-grid, in which the residential households and/or the businesses are equipped with on-site energy supplies and can perform the local energy exchanges with each other, as a supplementary to the energy trading with the external macro-grid.

Therefore, this chapter is devoted to introducing a novel hybrid energy trading model in SG and illustrating the associated optimal energy scheduling and trading management. Specifically, we model the trading behaviors of the energy consumers and sellers in the hybrid market and quantify their rewards by performing the local trading. We also model the different objectives of the local trading controller when it coordinates the local energy trading between the consumers and sellers. Concrete mathematical optimization problems are then formulated based these modellings, and numerical results are provided to validate the benefit gained from the hybrid energy trading.

2. RELATED STUDIES AND OUTLINE OF THIS CHAPTER

2.1. A Brief Survey of the Related Studies

There have been lots of related studies that investigated the DR mechanism in SG. Based on different techniques used for modeling, we categorize these studies into three groups, namely, the deterministic