Chapter 5
Game Theory for Smart Grid

ABSTRACT

A smart grid is a modernized electrical grid that uses analog or digital information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. Therefore, smart grid is an evolved grid system that manages electricity demand in a sustainable, reliable, and economic manner, built on advanced infrastructure and tuned to facilitate the integration of all involved. Roll-out of smart grid technology also implies a fundamental re-engineering of the electricity services industry, although typical usage of the term is focused on the technical infrastructure. This chapter explores this idea.

INTRODUCTION

The traditional power grids are generally used to carry power from a few central generators to a large number of users or customers. In contrast, the Smart Grid (SG), regarded as the next generation power grid, uses two-way flows of electricity and information to create a widely distributed automated energy delivery network. By utilizing modern information technologies, the SG is capable of delivering power in more efficient ways and responding to wide ranging conditions and events. Broadly stated, the SG could respond to events that occur anywhere in the grid. Usually, the term *grid* is used for an electricity system that may support all or some of the following operations: electricity generation, electricity transmission, electricity distribution, electricity control, consumption, and adopt the corresponding strategies. And, the term *smart* in SG implies that the grid has the intelligence to realize advanced management objectives and functionalities. Most of such objectives are related to energy efficiency improvement, supply and demand balance, emission control, operation cost reduction, and utility maximization. Therefore, SG covers the entire spectrum of the energy system from the generation to the end points of consumption of the electricity (Fang, Misra, Xue, & Yang, 2012).

In this chapter, we provide a number of game theoretic approaches to solve a wide variety of problems in SG. The proliferation of advanced technologies and services in SG systems implies that disciplines such as game theory will naturally become a prominent tool in the design and analysis of SG. In particular, game theoretic approach

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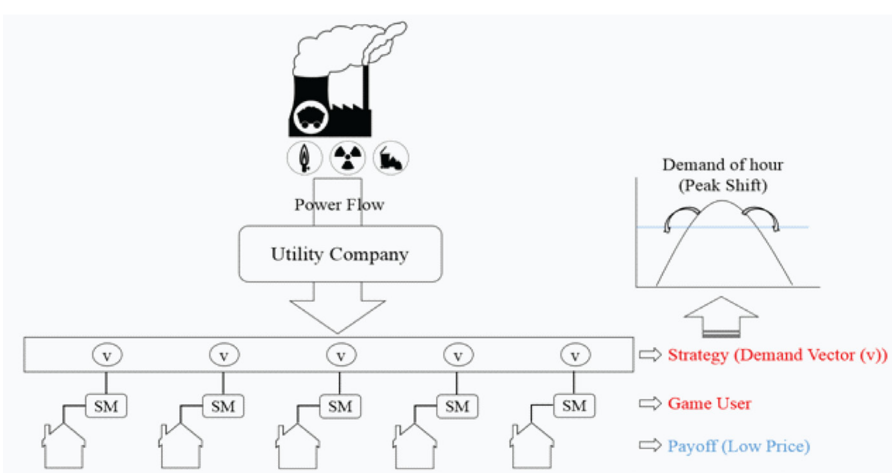
focuses on the design of micro-grid systems, demand-side management, and communications in order to support the distributed nature of the SG. In the past few years, distributed game approach is taken into account to improved scalability and efficiency of the game-based solutions (Fadlullah, Nozaki, Takeuchi, & Kato, 2011). The advantages of applying distributed game-theoretic techniques in any complex system such as the SG are accompanied by key technical challenges. Usually, non-cooperative games can be used to perform distributed demand-side management and real-time monitoring or to deploy and control micro-grids. On the other hand, economical factors such as markets and dynamic pricing are an essential part of the SG. In this respect, non-cooperative games provide several frameworks ranging from classical non-cooperative Nash games to advanced dynamic games, which enable to optimize and devise pricing strategies that adapt to the nature of the grid (Saad, Han, Poor, & Başar, 2012).

GAME MODELS FOR DEMAND SIDE MANAGEMENT

Controlling and influencing energy demand can reduce the overall peak load demand, reshape the demand profile, and increase the grid sustainability by reducing the overall cost and carbon emission levels. Therefore, demand side management is an important function in energy management of the future smart grid. Efficient demand side management can potentially avoid the construction of an under-utilized electrical infrastructure in terms of generation capacity, transmission lines and distribution networks (Figure 1). Most conventional demand-side management approaches for SG mainly focus on the interactions between a utility company and its customers (Fadlullah, 2011).

Recently, a lot of researches carried out to present an autonomous and distributed demand-side energy management system based on game theory. The essence of demand-side management revolves around the interactions between various entities with specific objectives which are reminiscent of the players' interactions in game theory. Since lowering peak demand and smoothing demand profile shaping reduces overall plant and capital cost requirements, the electric utility can use real-time pricing to convince some users to reduce their power demands, so that the total demand profile full of peaks can be shaped to a nicely smoothed demand profile. In fact, game theory provides a plethora of tools that can be applied for pricing and incentive mechanisms, scheduling of appliances, and efficient interconnection of heterogeneous nodes.

Figure 1. Demand side management



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