Cooperative game of electricity retailers in China's spot electricity market

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Abstract
Chinese electricity market has undergone twice reforms since 2002. However, the current electricity market is still partially irrational in electricity pricing mechanism. Furthermore, the utilization of renewable energy is inefficient in western regions. From the perspective of market participants, electricity retailers are new entrants in deregulated electricity market. In this spot electricity market, they are faced with various challenges and opportunities. Thus, this paper introduces an inter-regional power transaction model based on bottom-up modeling. There are mainly three parts in this paper: (1) It examines the existing problems and achievements in the twice reforms, and introduces the participants of cooperative game in a spot market. (2) It proposes an inter-regional electricity transaction model to illustrate the new pricing mechanism. (3) Based on cooperative game theory, it quantifies how costs, electricity prices and benefits affect the behavior of retailers in a spot market with some reasonable economic assumptions. What is novel about this research is that the proposed transaction model analyzes electricity retailers’ behaviors in a spot market. The cooperative game model improves electricity retailer’s competitiveness in a spot market, and is of great theoretical and practical significance for the reform and development of China’s electricity market.

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1. Introduction

Electricity industries are naturally monopolistic industries all over the world. With the advantage of natural monopoly, the power industry reaps a good deal of benefits [1]. However, it also resulted in the lower operating efficiency, making power companies less competitive in market. A significant restructuring process for power industry has been initiated in many countries since the 1990s [2,3]. In order to enhance operational efficiency and break up monopoly on electricity market, twice important power system reforms have been carried out in China since the 20th century.

The first power industry reform was launched by the Chinese government in 2002 to weaken monopoly interests and liberalize power industry. Power System Reform Plan (No.5 Document) was issued, marking the first round of power industry reform. As a result of this reform, the vertical integration power corporation (State Power Corporation, SPC) was divided into two parts: power generation enterprises and power grids enterprises [4]. To be specific, Big Five power generation companies-China Huaneng Group(CHG), China Power Investment Corporation(CPIC), China Datang Corporation(CDC), China Guodian Corporation(CGC), China Huadian Corporation(CHC)-and two power grid companies-State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG) are established accordingly (See Fig. 1) [3–5]. The original State Power Corporation (SPC), which is not only a state-owned enterprise (SOE) but also a government sector, has been liberalized on the generation side in electricity market [6]. A competitive market is set up on the generation side to improve the operational efficiency. Besides, two auxiliary services companies were separated from power grid companies and then restructured as China Energy Engineering Corporation (EEC) and Power Construction Corporation of China (PCCC) in 2011 [7]. It seems that the No.5 action brought a positive influence by introducing a competitive market on the generation side [8]. However, the few participants (Big 5 power generation companies and two power grid companies) resulted in unfair competition phenomena in the regulated market. As a result, expected results are not achieved through the first electricity market reform in 2002. Many administrative measures are released by the National Energy Board (NEB), National Development and Reform Commission (NDRC) and State Electricity...
Regulatory Commission (SERC) (before 2013) to regulate the operation of electricity market. Thus, electricity market is still completely controlled by the Chinese government [9]. Both on-grid price and transmission and distribution price are decided by National Development and Reform Committee (NDRC). The monopoly pricing mechanism has invisibly increased the cost of users, thus hindering the development of electricity market [10]. Besides, home users (not including large users) do not have the right to negotiate with power plants and power grid corporations, which leads to low operational efficiency and high cost in the end [5,11]. It still needs to increase the competitive capacity of participants in electricity market.

In electricity market, there are several regular patterns for ensuring the soft landing of electricity market reforms [2,12]. Initially, competition mechanism was just introduced to the generation side of vertical integration, for the establishment of the single buyer mode. Subsequently, the competition mechanism was applied to the downstream industry, and developed the electrical wholesale market. In the end, it was introduced to the sell side, for setting up the retail competition mode [4]. This step-by-step process ensured a smooth transition from a vertical integration to a competitive electricity market [13,14]. Electricity market reform in China is similar to these liberalized processes [15].

Prior to 2002, China's power system was operated with a vertical integration mode, meaning that there was only one company to control all processes from the generation side to the sell side. After the first round of electricity market reform, the principle of competition was introduced to the generation side [16]. The power...
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