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Electric power bidding model for practical utility system

M. Prabavathi *, R. Gnanadass

Department of Electrical and Electronics Engineering, Pondicherry Engineering College, Pondicherry 605 014, India

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Intermediate value theorem

Abstract A competitive open market environment has been created due to the restructuring in the electricity market. In the new competitive market, mostly a centrally operated pool with a power exchange has been introduced to meet the offers from the competing suppliers with the bids of the customers. In such an open access environment, the formation of bidding strategy is one of the most challenging and important tasks for electricity participants to maximize their profit. To build bidding strategies for power suppliers and consumers in the restructured electricity market, a new mathematical framework is proposed in this paper. It is assumed that each participant submits several blocks of real power quantities along with their bidding prices. The effectiveness of the proposed method is tested on Indian Utility-62 bus system and IEEE-118 bus system.

1. Introduction

The electricity industry around the world has been undergoing through a change from regulated to restructuring market structure and the government owned utilities have become privatized. In this environment, introduction of competitive energy market, unbundling electricity services and open access to the network have been created. In order to have the competitive market, market operator and policy makers need to study, analyze and monitor the behavior of market participants. In a competitive electricity market, both power suppliers and consumers are allowed to participate in the market. Due to limited number of power producers, long period of power plant construction, large size of capital investment, transmission constraints and transmission losses, the restructured power market behaves more like an imperfect competition. In such oligopolistic markets, an individual generator can exercise market power and manipulate the market price via its strategic bidding behavior and generating companies may achieve benefits by bidding at a price higher than their marginal production cost. This is called as a strategic bidding problem. In order to maximize the profit for suppliers and minimize the payments of customers, the building of bidding strategies is a major concern in the restructured power market because their profits depend on their bids.

In recent years, a number of strategic bidding models have been proposed by many researchers. There are three main methods to model the strategic bidding problems based on the estimation of market clearing price, probability of rival's bidding behavior and game theory approach [1]. The market clearing price (MCP) plays a significant role in the strategic bidding problem since it determines what blocks will be nom-

* Corresponding author.
E-mail addresses: mpraba21@gmail.com (M. Prabavathi), gnanadass@pec.edu (R. Gnanadass).
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inated by the market clearing mechanism. The MCP is determined by the following process. In the competitive electricity market, the sellers submit the offers to sell the energy and the buyers submit the bids to buy the energy. After accepting the offers and bids from the sellers and buyers, the market operator ranks the selling offers with buying bids. The stacked supply curve for seller and demand curve for buyer are formed by market operator. The point of intersection of the two curves sets the MCP. The determination of market clearing price is main operating function for a market operator in energy trading market.

Still now, a wide research work has been done on developing bidding strategies for generation side market participant only and little work on demand side participants. The problem of developing optimal bidding strategies for competitive generation companies was first introduced by David [2] and then surveyed by several researchers. Most of the researchers have used a linear bid function or quadratic bid function to build the bidding strategy for the electricity market participant. In [3,4], a linear bid function is assumed to build the bidding strategies for participant and the system is dispatched to maximize the social welfare. In [5], Market clearing price with and without wind power has been evaluated in double sided bidding for linear bid and block bid trading model. Using Graphical analysis, the MCP and schedules are determined under different market conditions in which quadratic bid function from both generating side and consumer side is considered [6]. In [7], a conceptual study is carried out on optimal bidding strategies of power suppliers in the operating Zhejiang provincial electricity market in which the step-wise bidding protocol is used. A normal probability distribution function is used to describe the bidding behaviors of rivals. The problem of building optimal bidding strategies for GENCOs is formulated as stochastic optimization problem which is solved by Monte-Carlo simulation method and the optimal bidding block price of GENCO is searched by Genetic Algorithm. Based on the stepwise bidding protocol in electricity markets, the impact of different numbers of bidding segments on the bidding strategies of generation companies is calculated in [8].

The published research work regarding solution methodology for bidding strategies can be grouped as optimization method, game theory based and evolutionary based model. In [9,10], strategic bidding problem has been formulated as an optimization problem in which producers try to maximize their profit based on the market clearing price. An analytical formulation was developed for building the optimal bidding strategy in England and Wales type electricity markets under an assumption that the MCP is independent of the bid of any supplier [11]. Some mathematical programming models [12] such as linear and nonlinear integer programming models were established to build optimal building problem for power producers in day ahead electricity auction markets. In [13], the bidding decision problem is formulated for GENCO with considering risk management and unit commitment. Using Graphical analysis, MCP and schedules are determined under different market conditions in double sided auction [14]. Li et al. [15] have presented a mathematical model to find out MCP in the electricity markets. In [16], a strategic bidding procedure based on stochastic programming is decomposed using the Benders technique. Zou [17] has designed bidding strategy model to maximize social welfare in the spot market. In [18], the supply function models of various bidding strategies with forward contracts are employed to simulate the bidding strategy of suppliers in the power pool. An improved PSO algorithm is proposed to solve the optimal bidding problem for GENCO's in a uniform price spot market [19]. Richter and Sheble have applied GA [20] and GP - Automata [21] to evolve appropriate bidding strategies in double auctions for electric utilities which trade electricity competitively.

Strategic bidding has been addressed by many researchers for a wide variety of market players. Researchers utilized many different modeling approaches and different solution methods. By analyzing the strategic bidding behavior of generating companies, a specific MLNB decision model for day-ahead electricity markets is created in [22]. Soleymani [23] has proposed a new method that was the combination of PSO and simulated annealing to predict the bidding strategy of generating companies in an electricity market where they have incomplete information about their opponents and market mechanism of payment is pay as bid. In [24], discrete cosine transforms based neural network approach is used to classify the electricity markets of Mainland Spain and New York. Agent based simulation is employed to study the power market operation under different pricing methods in [25]. The JAVA based power trading simulator is proposed to find out the market clearing price in single sided auction market in [26]. For the price-maker hydro-electric producers bidding problem, the most recent developments and a path for future efforts are illuminated in [27]. Jain et al. [28] have developed an optimal bidding strategy for a supplier considering double sided bidding, rivals bidding behavior, and unconstrained and constrained market scenario.

A number of strategic bidding models have been proposed by different researchers in recent years. In this paper, a mathematical model is developed for step bidding function for a day ahead market in the competitive environment. In most of the research work, a linear supply function model was presented to investigate strategic bidding behavior. However actual implementation of electricity markets requires the representation of supply offers and demand bids that aggregated into distinct steps. This paper presents mathematical model for stepwise bidding protocol for both supplier offer functions and customer bid functions of real power. Conventional method is used to solve this mathematical model for step bidding function. This proposed method is tested on Indian Utility-62 bus system and IEEE-118 bus system.

The Indian Energy Exchange actually uses piecewise-linear bids that are strict functions from price to quantity. Bidders in practice use these functions almost exclusively to closely approximate step functions with constant quantities for a range of prices. In this paper, bids to be assumed of a true step form throughout and do not use the linear interpolation of the exchange.

In the developing electricity markets, a suitable trading mechanism is required for all participants in order to achieve the profit. This paper employs conventional method to solve the bidding function of both suppliers and customers. The pricing mechanism in double side auction is uniform pricing method. The social welfare generated by the double auction will be improved greatly. The different case studies with block bids models are illustrated. It has been found that MCP may be higher when demand is increased. Case studies show that

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