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A Literature Review on Bidding Strategy in a Deregulated Electricity Market

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***Abstract* - In an open competitive electricity market generators (suppliers) and large consumers (buyers) need a suitable bidding strategy to maximize their own profit. Therefore, each generator (supplier) and large consumer (buyers) will have to bid strategically under incomplete information of other rival generators. This initiated a significant research effort by the researchers and practitioners in deregulated electricity market throughout the world. As a part of this, many authors have presented different methodologies and tools to solve the bidding strategy problem in a competitive electricity market. The purpose of this paper is to provide an overview of optimal bidding strategy for GENCOs and Large consumers in deregulated electricity market. This paper also presents a literature review based on optimal bidding strategy applied so far in the area of power system deregulation.**

***Keywords*: Deregulated Electricity Market, Rivals, Oligopoly Market, Bidding Strategy, Market Clearing Price (MCP).**

I. INTRODUCTION

The Indian power market has change significantly over the past few years. This is mainly due to three factors, emergence of competitive bidding, growth of bilateral trading and introduction of power exchange. Restructuring of the power industry mainly aims to abolishing the monopoly in the generation and trading sectors. There by, introducing competition at various levels wherever it is possible. But the sudden changes in the electricity markets have a variety of new issues such as oligopolistic nature of the market, supplier's strategic bidding, market power misuse, price demand elasticity and so on.

Before deregulation a traditional monopoly structure was exist in the power sector market. But After deregulation process the Large consumers (buyers) and generators (suppliers) starts to interact regarding power transaction and maintain system security through Independent system operator (ISO). Competitive electricity market consist of several Generating Companies, Transmission Companies and Distribution Companies along with the ISO. However, the emergent electricity market structure is more akin to oligopoly than perfect market competition. This is due to special features of the electricity supply industry such as, a limited number of producers, larger investment size (barrier to entry), transmission constraints which isolate consumers from effective reach of many generators, and transmission losses which discourage consumers from purchasing power from distant suppliers. All these make it practicable for only a few generating companies to service a given geographic region and in this setting each supplier can maximize profit through strategic bidding.

Theoretically, in a perfectly competitive market, supplier should bid at their marginal production cost to maximize their profit. However, practically the electricity markets are oligopolistic nature, and power suppliers may seek to increase their profit by bidding a price higher than marginal production cost. Knowing their own costs, technical constraints and their expectation of rival and market behaviour, suppliers face the problem of constructing the best optimal bid. This is known as a **strategic bidding problem**. In general, strategic bidding is an optimization problem that can be solved by various conventional and non-conventional (heuristic) methods. Depending on the bidding models, objective functions and constraints may not be differentiable and then conventional method can't be applied. Heuristic methods such as GA, Simulated Annealing (SA), Evolutionary Programming (EP), and PSO have main limitations of their sensitivity to the choice of parameters, such as the crossover and mutation probabilities in GA, temperature in SA, scaling factor in EP, etc.

II. LITERATURE SURVEY

A complete review of optimal bidding strategies in Electricity Market (EM) has been published in [1]. In [2] David proposed Dynamic Programming (DP) based approach to solve strategic bidding problem. A Lagrangian relaxation-based approach for strategic bidding in England-Wales pool type electricity market has been adopted in [3]. The same approach for daily bidding and self-scheduling decision in New England market has been suggested by Zhang et al. in [4]. A considerable amount of work has also been reported on the game theory applications in the competitive electricity markets. In non-cooperative game theory approach [5, 6], strategic bidding problem was solved using Nash equilibrium. Genetic Algorithm (GA) has been proposed by David and Wen in [7] to develop an overall bidding strategy using two different bidding schemes for a day-ahead market. The same methodology has been extended for spinning reserve market coordinated with energy market in [8]. Ugedo et al. in [9] have proposed a stochastic-optimization approach for submitting the block bids in sequential energy and ancillary services markets, and uncertainty in demand and rival's bidding behaviour is estimated by stochastic residual demand curves based on decision trees. In [10], A stochastic programming model has been used to construct linear bid curves in the Nord-pool market for price-taking retailer whose customers' load is price flexible. Opponents' bidding behaviours are represented as a discrete probability distribution function in [11] and as a continuous probability distribution function in [12] for a supplier's bid decision-making problem. In [13], affect of selection of mutation parameter in GA for bidding strategies is explained. In [14] considering risk constraint, the bidding for single sided and double sided was modelled and solved using GA. Optimal bidding strategy problem using PSO has been applied in [15, 16]. Recently bi-level programming and swarm algorithm have been applied to model the competitive strategic bidding decision making in the electricity markets [17].

III. MARKET STRUCTURE AND OPERATION

In Deregulated Electricity market Electric power sellers and buyers submit bids to the pool for the amounts of power that they are willing to trade in the market. Sellers in a power market would compete for the right to supply energy to the grid, and not for specific customers. If a market participant bids too high, it may not be able to sell. On the other hand, buyers compete for buying power, and if their bids are too low, they may not be able to purchase. In this market, low cost generators would essentially be rewarded. An ISO within a Pool Co would implement the economic dispatch and produce a spot price for electricity, giving participants a clear signal for consumption and investment decisions. The market dynamics in the electricity market would drive the spot price to a competitive level.

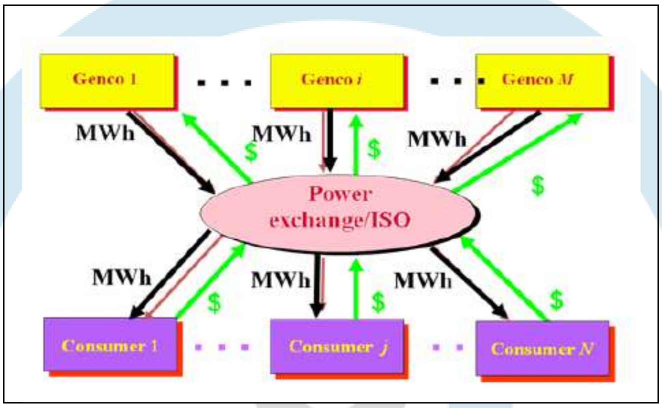

Fig.1. Market structure

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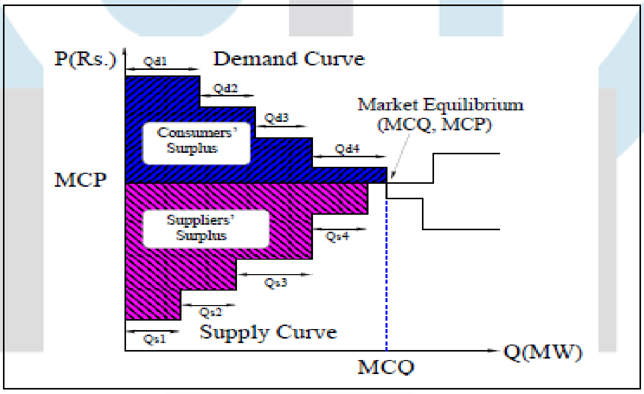

Fig.2. Market equilibrium point and social welfare

Power exchange (PX) accepts supply and demand bids to determine a MCP for each of the 24 hours period in the trading day. MCP is determined at the intersection of the supply and demand bid curve, and all trades are executed at the MCP. In other words MCP is the balance price at the market equilibrium for the aggregate supply and demand graphs.

The main function of PX is to determine a generation/demand schedule that meets security and reliability constraints using transparent dispatch procedures, with the objective of maximizing **social welfare**. Here the Sum of *Consumer's surplus* and *Supplier's surplus* is called ***Social Welfare*** (Fig. 2).

IV. NEED OF BIDDING MODEL

After restructuring the electricity market as deregulated the monopoly in generating sector is abolish. Now any generator (supplier) and large consumer (buyer) is free to sell or buy the electricity from anywhere. In most of the country they have energy exchange, which provides a platform for such transactions between suppliers and buyers. In India such transactions are carried out by **IEX (Indian Energy Exchange).** To participate in energy exchange, supplier or buyer should have a strategic bidding model which depends on past bidding history, rivals bidding behaviour etc.

There are mainly four types of bidding models exist in electricity market around the world. The classification of each is discussed below.

1. Single-Part Bidding

In this type of bidding, generators (suppliers) bid for independent prices at each hour and MCP varies accordingly. In this case the market operator does not make unit commitment decision. Hence, generators (suppliers) need to consider all involved costs and physical limit in constructing their bid. Since this type of bidding structure does not guarantee to redeem total cost, Hence not feasible.

2. Multi part bidding

A multipart bid, is also known as complex bid. It consist separate prices for ramps, start-up costs, shut-down costs, no-load operation, and energy. It can be considered as ideal bid as it shows accurate cost structure and technical parameter limit of generators (suppliers). The market clearing procedure is based on an optimization technique that optimizes the winning bid. It leads to a centralization of the unit commitment decisions at the market operator level, It means market operator is decision taking body. All bidders are required to submit the relevant information and the market operator makes optimal decisions. The technical feasibility is guaranteed in this bidding.

3. Iterative Bidding

In this type of bidding generator (supplier) and large consumer (buyer) are allowed to change or modify their bid according to some rules. But their costs must be appropriately allocated and their technical constraints should considered. This method may have vast computational burden and may not be practical. There are some contradiction that a single bid is not sufficient mechanism for market to run efficiently, and then introduced a new technique known as asynchronous iterative bidding scheme. The difference between these two iterative methods is a feedback. It works such that when it receiving generation levels from the first round of market clearing, generators (suppliers) are allowed to change or modify their bid one more time if they want.

4. Demand Side Bidding

Demand side bidding is for large consumers to react to electricity pricing. Earlier only generating unit are allowed to determine the price of electricity but, on introducing demand side bidding, In the market that leads to maximization of social welfare. Now this approach should be employed for bid clearing, and the market using minimum price approach with supply side bidding is no longer exist and that is not fair to the sellers. To maximize the social welfare in this case both the generator (seller) and large consumer (buyers) are bidder, and the buyers are no longer passive in this scheme. Earlier the demand side bidding was not permitted, the minimum price approach was employed, and in this case the large consumers (buyers) are passive and their profit are protected by regulations. Till today research work on strategic bidding is focused on the supply side, but now many electricity market start this scheme due to its impact on social welfare and profit.

V. BIDDING SCENARIO IN INDIA

Power exchanges in India was commence in 2008. There was a need for a market place in India, where large consumer (buyers) and generators (sellers) could meet and buy or sell power with genuine price discovery. The motivation for establishing such market place in India comes from the Electricity Act 2003, which is the first act to introduced the concept of non-discriminatory open access of power through rules and regulation for promoting competition in the electricity market. As the major step taken by the Electricity Act 2003, the country's power markets have been witnessing significant innovation. Further efforts are positive regulatory that create a competitive market and supported by the efforts of market operators to introduce new products and solutions that benefit consumers, suppliers and the power sector as a whole. Before the functioning of power exchanges in India, an alternatives method was used for purchasing short-term power that consist the unscheduled interchange (UI) market (where prices were volatile) and over the-counter (OTC) trading mechanisms (which typically have high transaction costs). Only the OTC mechanisms continue to serve an important function, earlier consumers wanted a platform that allowed them to enter standardized contracts, take care of counterparty risks, and provided fixed acceptable future electricity price signals. The customer demand for such contracts led to the evolution of power exchanges in India. At present, the power exchanges of India account for 30 percent of the power transacted in the short-term market, so serving as a valuable link in bridging the power demand supply gap.

The **Indian Energy Exchange (IEX)** is the leading energy trading platform of India. Earlier it started operations with a few of participants. But at present, the number of participants registered on the exchange has increased to 6238 comprising 29 states, 5 union territories (UTs). Over 4,500 registered participants were eligible to trade electricity contracts and over 4,100 registered participants were eligible to trade RECs, as of March 2018. Out of participants registered to trade electricity contracts include 54 distribution companies, over 450 electricity generators and over 3,900 open access consumers [18].

The IEX provides a platform for trading power in two type of market first is the day-ahead market (DAM) and second is the term-ahead market (TAM). IEX also started Renewable Energy Certificate (REC).

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