Simulator for Day-Ahead Electricity Markets

Ashutosh Singh
Department of Computer Engineering
Sinhgad Institute of Technology
ashutosh.singh9215@gmail.com

Bhagyashree N. Jog
Department of Computer Engineering
Sinhgad Institute of Technology
ranijog@gmail.com

Prof. M. S. Chaudhari
Department of Computer Engineering
Sinhgad Institute of Technology
mschaudhari20@gmail.com

***Abstract*— Electricity is a scarce and very important resource. Well matched demand and supply in tenders helps in controlling energy prices. In old non-competitive system, only central authorities setting the prices for maximizing profit of one side, gives rise to energy price fluctuations. This paper presents the simulator that equates the tenders with minimum demand and supply margin using the concept of Market Clearing Price(MCP) thus giving both the Generation Companies (GenCos) and Distribution Companies (DisCos) maximum profit using market clearing price (MCP). Also supporting this system is the decision support system (DSS) of forecasting of day ahead electricity demands. This helps the distribution companies in making an informed decision. Matching the tenders is done using an algorithm based on Nash equilibrium strategy and forecasting is done using linear regression strategy.**

Keywords*— *GenCos;DisCos;demand and supply; forecasting; MCP

I. INTRODUCTION

Electricity is a much needed and demanded resource which has to be used thriftily and wisely. The main and important factor in electricity trading is the demand and supply margin. Demand and Supply must be well matched to avoid wastage and deficit of energy. Also a poorly matched demand and supply causes the distribution companies to be unsure of setting their prices which causes price fluctuations at the consumers' end. Historically demand and supply of tenders is matched using a central dispatching organization. The existing systems for tender management are poorly equipped with demand supply matching and are usually manual. This strategy is usually one sided benefiting only the generators and thus creating price fluctuations at the distributors end. We put forth in this paper an online portal to match tenders having least demand supply margin. This is done on the basis of MCP which is a very important concept in demand and supply management. Also in the portal is a strong decision support system. The DSS is used to forecast the energy load and prices in next 24 hours. Forecasting is used by the distribution companies to view the probable load and prices. Using this forecasting, distribution companies can decide what prices are to be put in their tenders so as to maximize their profits.

II. IMPROVEMENTS IN EXISTING SYSTEMS

A. System functionalities

The existing systems are not transparent enough due to manual tender management. Also there is difficulty in management and aggregation of such a vast amount of data in physical format. Our system addresses these problems by introducing a completely online system which is responsible for the collection, management of tenders and other important data.

B. Auctioning Scheme

There are two types of auctioning schemes, the single and double sided auctions. In single sided auctioning schemes profit of the generation companies alone is taken into account [1]. However in the development of our project we have taken into account the profit of the generation as well as the distribution side. Due to this the margin between demand and supply is also reduced [2].

C. Forecasting of price

Forecasting plays an important role in any decision making problem when it is concerned with profit & loss at large scale. Due to many systems being manually operated they cannot provide a decision support system to the distributors. Our system not only shows them the probable prices of the next twenty four hours but also places a constraint on the prices they are quoting for the tenders. These constraints are also based on the forecasted price.

D. Concept of MCP

The concept of market clearing price (MCP) is an important concept in the demand and supply of any commodity [1]. If the demand and supply is not matched on the basis of MCP there is no solid benchmark for fixing prices. In our system MCP provides this very benchmark for calculating the least margin between demand and supply and then applying this margin to obtain the tenders that provide this least difference.

III. SIMULATOR FOR THE MARKET

A. Architecture of the System

The following figure describes the architecture of the system.

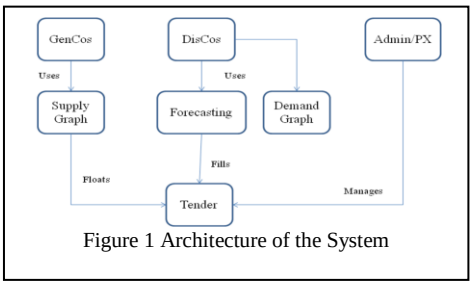

Figure 1 Architecture of the System

As per Fig. 1 the GenCos uses the supply graphs to fill the energy price data for a new tender. The DisCos fills its own energy price data for an existing tender using the demand graphs. The Admin manages the tenders. The DisCos uses the price forecasting system to help in filling the energy price data. The forecasting system also provides

constraints in filling the tender prices. The Admin acts as an interface between the GenCos and DisCos managing the tender.

B. Tender management and the Concept of MCP

Tender management refers to the uploading of a new tender along with all the relevant data. This is followed by filling of tender and its data. The tender management's main module consists of matching those tenders which have the least difference between their prices. For this, the concept of MCP is used which provides a strong benchmark for setting the prices and thus giving the least margin in demand and supply. MCP is the lowest price obtained at the point of intersection of aggregated supply and demand curves [3]. The volume of power at the point of intersection is called MCV (Market Clearing Volume). At this price both supplier's bids & buyer's bids are satisfied. This is also called as an equilibrium price or single clearing price. The primary reason for using MCP to set the single price in electricity markets is the incentives it provides for efficient dispatch and optimal investment [3]. The MCP value allows the matching of tenders such that both the generation and distribution companies are profited. In our system the calculation and implementation of the MCP is done using the Nash equilibrium strategy.

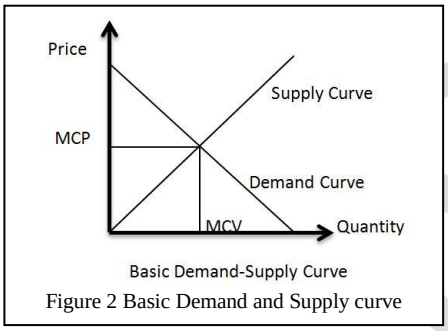

Figure 2 Basic Demand and Supply curve

C. Concept of Forecasting

Forecasting plays an important role in any decision making problem when it is concerned with profit & loss at large scale. But the factors vary depending upon the usage. Forecasting may not provide accurate solutions but can give a range of values from which resulting decision can be taken. In this paper we have used forecasting to predict the energy prices of the next twenty four hours, which will be then used by DisCos in order to take decision on their quoted price. This is done with the help of various factors including last week's price of the same time span, previous day's price of the same time span. Our system employs the simple linear regression strategy to calculate the next day prices for forecasting.

IV. PROPOSED ALGORITHMS

A. Shorlisting of DisCos using Nash Equillibrium strategy

We have used an important concept of Game Theory known as Nash equilibrium. Nash equilibrium is a concept in noncooperative game theory. Nash equilibrium since its introduction has been widely used for matching demand and supply and coordinating profits of both sides [4]. According to this concept, it involves two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy [4]. In this paper we have applied Nash equilibrium for balancing the supply-price & demand-price such that the tenders with the least demand supply price margins are chosen. The algorithm that we have designed for this purpose is stated below. Calculating MCP

- Initially for each DisCos its demand data is aggregated with the supply data of the particular GenCos.
- Note the MCP for each DisCos, GenCos combination
- Now we have MCPs for each DisCos, which will be compared with each other.
- This gives us the final MCP and the apt DisCos for that tender
- Populate list of DisCos having least difference with final MCP on the basis of quoted price & send it GenCos.
- This list contains the first DisCos which has the least difference and the DisCos having the second least difference. This list is then forwarded to GenCos.

B. Forecasting of energy prices, the Decision Support system

The system provides a strong decision support system to the DisCos for the filling of energy prices in the tender. The system uses a simple linear regression strategy to compute the probable next twenty four hour prices. There are six slots representing twenty four hours and their approximate average prices. Various factors affect the prices of energy prices and various models like Neural Networks, Genetic Algorithms are available [6]. The parameters that affect these prices are [5]:

- Price of K hour of previous day
- Price of k hour of previous week
- Price of K-1 hour of previous day

The simple linear regression equation is of the form

$$Y = a + \beta_0 X_1 + \beta_1 X_2 + \beta_2 X \qquad (1)$$

Here

- Y is the probable price of k hour of current day
- X_1, X_2, X_3 are the price of K-1 hour of previous day, K hour of previous day, K hour of previous week respectively
- β_0 , β_1 , β_2 are regression coefficients and a is the constant coefficient

V. ADVANTAGES, APPLICATIONS, DISADVANTAGES OF THE SYSTEM

A. Advantages of the System

The advantages of the system are as following:

- Easy calculation of energy prices
- Minimum margin between supply and demand
- Best strategy for calculation of MCP
- Easy collection and aggregation of data
- Best deals offered to both parties
- Constant monitoring of incoming tenders and bids

- Strong decision support system for DisCos

B. Applications of the System

Application areas are:

- Government regulated power supply and consumption
- Privately owned power distribution
- Price forecasting and energy load forecasting for private and government organization
- Constant demand and supply monitoring groups
- Power industry

C. Disadvantages of the System

The disadvantages of the system are

- No negotiation between GenCos and DisCos after the bidding is complete
- The DisCos does not have the choice of tenders

VI. EXPECTED RESULTS

A. Result of shortlisting of DisCos

The following table shows the data given by one GenCos and two DisCos. The capacity is in MW and the price is in Thousand Rupees.

TABLE I. TENDER DATA

Capacity(in MW)	GenCos Price	DisCos 1 Price	DisCos 2 Price
225	62.5	60.0	59.9
300	80.9	79.8	78.1
350	100.2	98.7	99.3
420	122.6	112.2	114.5
500	147.9	130.4	128.2
550	160.0	150.6	155.4

Given, Table 1. And the algorithm proposed the DisCos 2 has least demand supply margin at capacity 350

B. Forecasting Results

The forecasting results are expected as follows.

TABLE II. EXPECTED FORECASTING RESULTS

Previous week K hour price	Previous day K hour price	Current K hour price(predicted)
60.5	78.1	68.5
92.3	99.3	108.7
90.0	98.7	96.5
75.6	80.9	77.7
103.4	100.2	104.8
80.5	79.9	79.2

The coefficients here are calculated using the simple linear regression model and they are then applied to the two parameters previous week K hour price and previous day K hour price [5].

VII. FUTURE WORK

For the future improvements in the system, we have negotiation between GenCos and DisCos after selection of DisCos and forwarding of list to GenCos, which is to be done at runtime. We also have a nationwide, integrated, centralized system which will have highest level of required transparency and security. Forecasting system can be better developed taking more factors like Season, Temperature, Area, Population and Weather.

VIII. CONCLUSION

A system has been designed for the demand and supply matching in electricity markets and tender management. The algorithm for demand and supply price matching is based on Nash equilibrium. The Demand and Supply module is supported by the decision support system of energy load and price forecasting which makes the system stronger. This is based on the Simple Linear Regression Model. The system provides a very good strategy for demand and supply management and provides forecasting not only for DisCos but also other companies that map the increase and decrease price and load of energy in day-ahead markets.

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