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Power System Trading Analysis I: Market Strategies Overview

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Abstract: This is first part of 2 paper series on Power trading, in the first part Power System Trading Strategies (TS) is discussed from viewpoint of Power generation company (GENCO) in auction based (short term) Electrical Power Markets (EPM) while in second paper market design analysis is done to form competitive EPM. Electricity is a particular type of commodity which does not store in large quantities so whenever it is generated it must be consumed immediately. This has made Electrical power status complicated, for both generation and consumption point of view. Usually, electricity generation sources are limited as compared to load. In deregulation environment the GENCOs faces a situation of competition. It is generally seen that market prices (LTP) of power decrease and efficiency of generation increases with the increase in competition but now, many countries faces power LTP much higher than expected by economic considerations. The most probable reason for this LTP is market power and oligopoly, GENCOs having large capacity can impact the LTP by means of their TS. Also, Market Participants having small generation capacity able to manipulate market price in times of stringent supply function. This paper shows the comparative analysis among main strategies GENCOs opt for LTP manipulation to earn more profit.

Keywords: Electrical Power Trading, Pay as Bid, Uniform Price Auction, Market Power, Trading Strategies, & Bid Types.

I. INTRODUCTION

This article discusses the TS of auction based EPM from the perspective of GENCOs. These TS talked about here demonstrates how EPM participants may apply the market rules efficiently, and could maximize their own sales revenues by improvising their status in competitive EPM. The power sector is transforming into a more distributed and cut throat competitive area where demand and supply (DS) will determine the market price of electricity and the expected net cost may be lowered with high competition. Power business restructuring has led to the splitting up of its major hubs: Power generation, power transmission, and its distribution. Surprisingly, the most appropriate use of pro forma tariff & trading is the divorce of ownership of transmission from its control. Now in a restructured power industry there will be a separate operational control over transmission grid that will aid market competition in generation of power. Although, an independent system operator (ISO) is must for the individual functioning of the grid. He should be an independent person and ought not to relate to participants of the market, for instance distribution companies, transmission owners etc. ISO ought to roll out and set some foolproof rules for power energy and its allied firms to efficiently function in the market competition and guarantee the power system reliability.

Over and above, even tiny GENCOs are capable to use their market power during stringent supply function [1], and GENCOs do not get any lucrative push to make a bid at Marginal Cost (MC) [2]. To surmount these difficulties, few alterations are made effected in the EPM, and unique ways have been deliberated in the research done. We have arrived at crucial solutions. Firstly, for escalating competition, market participants are multiplied by breaking large companies into small entities, or new entrants are waited for coming. [3]. Secondly, to control anyone from wielding market power there could be modification in the organization of auction [4] comparison of both auction structures i.e. PAB & the other uniform-price are done and final conclusion in the favour of Pay As Bid (PAB) can be stated by exhibiting few quantitative plus points over the latter [6]. Lastly, the bringing up of price ceilings will Endeavour to somehow maintain the lower price level. Electrical Market Design is discussed in next second part of series of paper in detail.

II. UNDERSTANDING TRADING STRATEGIES CONCEPT IN POWER MARKET

Usually TS are developed by GENCO to increases the profit ‘r’, on their balance sheet but it relies on the LTP, which we denote with ‘p’. Most of the EPXs (Electrical Power Exchange) provide hourly & block bid products. Some new bid structures are also proposed in considering GENCOs start up & shut down cost. But in this section we did not assume start up & shut down bids. Also, the LTP is uncertain, it cannot be predicted with certainty, therefore, and it is considered as a random variable ‘P’. we define ‘P’ as probability density function $G_p(p)dp$ & hence ‘p’ is therefore a sample of P. now for cumulative distribution function of P with ‘$\mathcal{M}_p(x)$’, we have,

$$M_p(x) = \int_{-\infty}^{x} Gp(p)dp \ldots(1)$$

$$\int_{-\infty}^{\infty} Gp(p)dp = 1 \ldots(2)$$

The GENCO under watch have many generators in their portfolio having net capacity of Q & can makes upto N bids on EPM, which we identify by the index 'i'. $1 \leq i \leq N$ are the total number of bids. Usually one bid for one GENCO is taken, but it is not hard and fast rule. Also it perhaps be submitted by making blocks of some defined quantity. b_i is the bid of individual GENCO & p_i is the archived price of bids, therefore net volume of the bids with capacity q_i is given by

$$\sum_{i=1}^{N} qi = Q \ldots(3)$$

The MC for generation of q_i is denoted with c_i. Here number of bids is chosen in such a way that one bid for each Power Plant (PP), so q_i is equals to the generation capacity of PP i, & c_i is equal to its MC. The GENCOs bids cost are ordered in the following manner

$$c_1 \leq c_2 \leq \ldots \ldots . \leq c_N \quad \ldots(4)$$

& therefore the corresponding bids submitted are ordered as

$$b_1 \leq b_2 \leq \ldots \ldots . \leq b_N \quad \ldots(5)$$

The total profit of all PPs is the sum of individual profit of PPs r_i & given by

$$r = \sum_{i=1}^{N} ri \ldots(6)$$

& hence total PP's net profit is Total Revenue less Total MC

$$r_i = (p_i - c_i)q_i \quad \ldots(7)$$

The inter relation between the LTP 'p' & achieved price p_i of PP's relies on the many factors such as MP, Auction ways, LTP, Peak & Off - Peak time, But here we take only Auction Format manner because of its most dominant factor among all above. The forecasted profit 'r' is given by

$$r' = \int_{-\infty}^{\infty} Gp(p)rdp \quad \ldots(8)$$

This is dependent on the bids b_i. The optimal TS are given set of bids as $\{b_1 \ldots \ldots b_N\}$ which should be maximizes (8). The GENCO we consider in this article does not have access to the retail market (end user market).

III. COMPARISION OF DIFFERENT TRADING STRATEGY

A. Comparison between PAB versus Marginal Pricing Trading

Whether PAB pricing can or should replace the more common marginal pricing (MP) in electricity pool markets is the subject of an ongoing spirited debate. Under both approaches, a centralized system operator (SO) schedules the system generation by minimizing the combined cost of all the generation offers. However, under MP, GENCOs are remunerated at a rate equal to the system MC (SMC), while under PAB pricing the GENCOs are paid the exact cost that they quote to the SO. Thus, to make a profit under PAB, GENCOs must submit offers greater than their true costs, while under MP GENCOs perhaps still earn a profit even if they offer to generate at their true costs.

As per theory of auction, the variant of Ist-price auction that is sealed is PAB whereas the variant of IInd-price auction that is sealed is MP. One statement against to MP is that GENCOs with market dominance perhaps "game" by depositing bids higher than their genuine cost to raise their portion of profits. With such given inputs, a market which decreases the total bidded cost not essentially does full social welfare. However in PAB, regardless to GENCOs game or not, the entailing LTP equilibrium at all times reduces the overall buyer payment. Another opinion which supports PAB pricing is its root in cost accounting, which states that it considers average cost and not MP, so it does not have high fluctuations in response to gaming. Those who criticize PAB argue that it is just MP who conveys an "accurate" far-term economic indication to prospective investors by arriving at the LTP which manifests an excess or gap of capacity generation. As above mentioned statement is too impelling, MP has been made operational as the leading scheme in various kinds of markets. Inspite of it, it has been insisted that in PAB, GENCOs will fast come to know the way of modifying their bids to achieve profits which could be same or surpass the profits gotten in MP. It is disputed that ways like PAB pricing "will be more harming to buyer than doing good" because, in trying to generate standard profits, average cost of power will be triggered high. As the discussion between the ways of PAB & MP is based on subjective or quantitative simulation statements, we have done a thorough comparison of EPM behavior in the approaches of these two pricing.

It acknowledges that GENCOs would modify its profit-maximizing crucial bids to the particular pricing plans, by which it will alter the consequential behavior of the market regarding applicable generation schedule, pertinent system, and MC and buyer bill payments. This study presumes perfect EPM in which no single GENCO bid can affect the system MC. This presumption can be later done away to accommodate oligopolies where few competing groups are market player. The problem in "imperfect market competition" model is that comparison cannot be made without lot of quantitative simulations & many specific assumptions have to be made regarding the reaction of individual competitors to risk. The erstwhile assumption of a perfect competition permits us to make general numerical comparisons which are not based upon EPM artificial set up & assumptions of risk attitude. One important feature of a perfect market is that gaming is not worthwhile to individual GENCOs. Rather if a GENCO resort to game, it will shoot up its own risk of earning low profits.

Under these two methods of pricing, the strategic bids vary, so the relationship between the system MC and the system demand too varies. Therefore, EPMs should function with similar demand conditions, i.e., in resembling probability distribution of demand for above methods of pricing. The outcome which has come tells us that PAB with some shortcomings is better alternative approach than MP.

B. PAB Auctions versus uniform price auctions for Generation-Only Company

In this section there is comparison between PAB and uniform price for term sub segment auction market for generation only company. To derive the optimal TS, we calculate the maximum forecasted profit for the two cases of PAB & uniform- price auctions in the following section.

1. PAB Auctions:
In PAB auction format, usually p_i is the achieved price of a PP if it wins the auction by submitting the bid b_i. If b_i is smaller than or equal to the LTP p then only it wins otherwise no trade is executed. Usually auction price is the price of most expensive generator which wins and then it becomes LTP. The profit of a 'i' PP is given by (7). For assuming the perfect competitive EPM we have forecasted profit (9), perfect competitive EPM means GENCOs do not have any impact on the LTP. Now if we consider the random nature of the LTP, the forecasted profit r'_i with probability density function is given by (10)

$$\mathbf{r_i = (b_i - c_i)q_i \quad for\ b_i \le p \ \ \&}$$
$$\mathbf{r_i = 0 \qquad for\ b_i \ge p \quad ...(9)}$$

$$r'i = \int_{bi}^{\infty} Gp(p)(bi - ci)qi\, dp \ \ ...(10)$$

&, it has seen that r_i does not depend on LTP hence LTP p is

$$\mathbf{r'_i = (1 - \mathcal{M}_p(b_i))\,(b_i - c_i)q_i \qquad ...(11)}$$

Ist order for maximize for r'_i for b_i, gives $(dr'_i)/(db_i) = 0$ shows

$$\mathbf{1 - \mathcal{M}_p(b_i) - (b_i - c_i)\, G_p(b_i) = 0 \ ...(12)}$$

Which perhaps find numerical solution for c_i under defined specific distribution. Detail examination of probability distribution is used to understand the methodology of bidding at higher prices than MC. In this analysis two cases are consider, an unbounded distribution & a distribution with a finite maximum price as p^{max} . In the unbounded distribution

$$\mathbf{b_i > c_i \ ...(13)}$$

is the given solution of equation (12), which is independent of c_i, also $1 - \mathcal{M}_p(b_i) > 0$ & $Gp(b_i) > 0$. In the distribution with a finite maximum price p^{max}, $b_i > c_i$; if $c_i <$ distribution upper bound. Under equilibrium conditions $c_i < p^{max}$, & therefore it is assumed that the GENCO cannot impact the LTP in a perfect competitive EPM conditions, but the OB is higher than MC. This phenomenon of PAB auction will cause high prices in EPM, & hence it would not be preferred for EPM design.

2. Uniform-Price Auction:
In this case, the p_i of the PP are equal to the uniform LTP p. $p = p_1 = p_2 \ ..... = p_N$. In other words, LTP is fixed irrespective of MC of PP. if $c_i > p$ then GENCOs makes loss from this strategy, therefore this strategy is not very useful for EPM design perspective.

C. Analyzing pay as bid versus uniform price auction:

We start the calculation of the optimal strategy with the case of a perfect competitive environment. This assumption will be abandoned later on as given below.

1. GENCO Is a Price Taker: when GENCOs do not have impact on the LTP, the total profit r is therefore given as
$r(p) = 0$ for $\quad p < b_1$

$$r(p) = p\sum_{i=1}^{n} qi - \sum_{i=1}^{n} qi\ ci \ \text{ for } b_n \le p \le b_{n+1}$$
$$r(p) = p\sum_{i=1}^{N} qi - \sum_{i=1}^{N} qi\ ci \ \text{ for } b \le p \ \ ...(14)$$

Above shows the indexing of bid for $1 \le n \le N$. The forecasted profit is given as

$$r'i = \sum_{n=0}^{N-1}\int_{bn}^{bn+1} Gp(p)\left(p\sum_{i=1}^{n} qi - \sum_{i=1}^{n} qi\ ci\right) dp + \int_{bN}^{\infty} Gp(p)\left(p\sum_{i=1}^{N} qi - \sum_{i=1}^{N} qi\ ci\right) dp \ \ ...(15)$$

With the first-order condition given by $(dr')/(db_n) = 0$ for $1 \leq n \leq N$, the OBs are $b_n = c_n$ for all N bids. This condition concludes to economic insight which is the main cause of deregulation among power system industry of many countries.

2. GENCOs Impacts the LTP:

The GENCO perhaps try to modify LTP by altering the bid of one generator. If GENCO successes in manipulation, GENCO lose bid for this generator but getting higher MP on others generators in their portfolio. By adopting this kind of strategy GENCOs have very low value of Risk/Reward factor, if the bids of the other generators are low. This can be easily said that by carrying some generator on the hold, GENCOs will easily alter market's supply function or in other words raise LTP of generator. Usually GENCO perhaps decide to bid above the forecasted LTP, rather than shut down & start up the generator again. This behavior of GENCOs helps them for getting higher prices than forecasted one. This cause additional revenue for additional power sale. Fig. 1 illustrates this strategy: bidding low MC generator & Fig 2 at a higher price does raise the LTP.

From the above discussion it can be easily found that GENCOs can easily alter LTP. Above discussion can easily be transform into equation, by splitting LTP into 2 parts, ɗ is price without impact of GENCO, & therefore LTP is presented by ṗ. It is to be noted that price ɗ without the impact of GENCO is not a perfectly competitive, because GENCO still have some generators for selling power. Without loss of generality, this withhold power $\Delta h = \Delta q$ has impact on LTP ṗ which is function of Δh, hence ṗ = $Z(\Delta h, s)$. $Z(\Delta h, s)$ describes the EPM in all its complexity, including competitors & physical constraints.

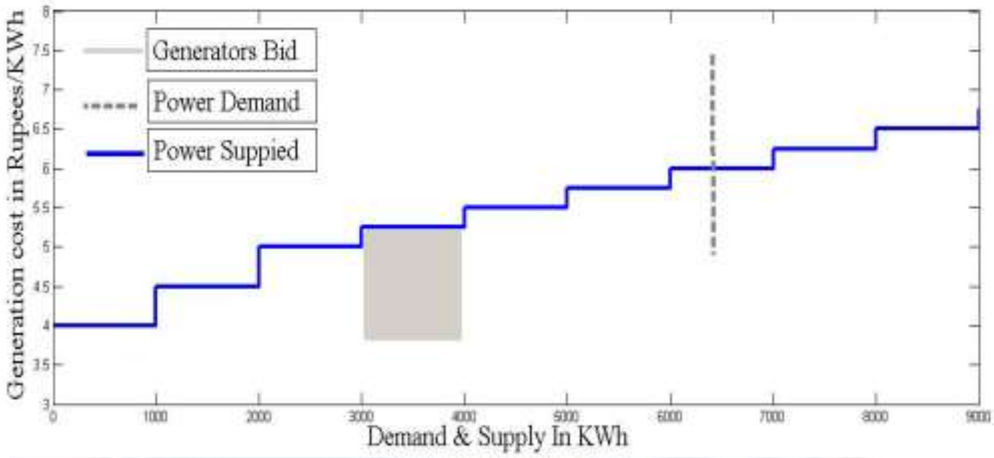

Fig.1 Merit Order Cost curve of generator at MC.

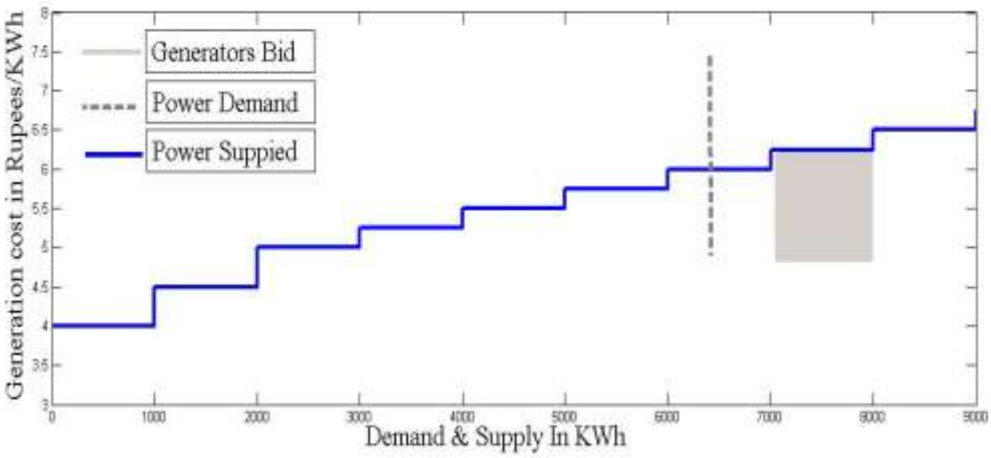

Fig.2 Merit Order Cost curve of generator above LTP.

's' is an arbitrary vector which shows present state of the EPM. $Z(\Delta h, s)$ has three conditions:

(a) If the GENCO don't carry some generators for production then, $\Delta h = 0$, therefore there is no alter in LTP ṗ = ɗ, & hence, $Z(0, s)$ = ɗ.
(b) Otherwise, $Z(\Delta h, s)$ must increase as Δh increases, therefore $dZ(\Delta h, s)/d\Delta h \geq 0$.
(c) If $dZ(\Delta h, s)/d\Delta h = 0$ for all Δh, then the EPM is perfectly competitive.

These condition of $Z(\Delta h, s)$ shows approx. linearization at point $\Delta h = 0$. Taking the slope of $Z(\Delta h, s)$ at $\Delta h = 0$, $dZ(\Delta h, s)/d\Delta h|_{\Delta h=0} = k$, we get

ṗ = ɗ + kΔh …(16)

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k shows the impact of single GENCO on LTP in EPM. Similarly we divide bids into two parts bid without price impact $đ_n$ & GENCO's price impact, therefore price impact is $k\Delta h_n$. hence alteration in price ṗ - ƈ = kΔh. Δh_n is power capacity which GENCO carry if corresponding bid is highest winning bid of GENCO. The new impacted bid is given by $ƀ_n$, is $ƀ_n = đ_n + k\Delta h$.

Understanding the above situation, we say $ƀ_n \leq ṗ \leq ƀ_{n+1}$ the PPs with bids $ƀ_{n+1}$ & above is costly therefore does not wins the auction, & perhaps impact the LTP. It is clear that from above equations that only those PPs contribute to Δh_n, which could have won the auction under not impacted conditions. In other words, PPs with comply with given conditions $đ_n$ < ƈ & $ƀ_n$ > ṗ is responsible for alteration of LTP. This can be seen as demand for electrical energy is constant but quantity of bids successful in auction is small i.e. in other words there is some remaining generator capacity carry by GENCO, which can be sold on later stages. This cause impact in the LTPs. It perhaps even be subject to strategic action of the competitors. The bids represent a step-wise bidding function that is bound to the number of PPs & their respective quantities.

3. Bids which Impact on the LTP:

Let us consider GENCO in having five generators. Here generator quantity and its MC are given in Table 1. The Impact factor k on OBs is given in fourth block. Due to MPR generator it is seen that weighted average MC is equal to 4.692 Rs/kWh while weighted average OB is 7.5 percent high of 5.044 Rs/kWh. In other words GENCO can alter price to about 7.5 percent. Econometric estimation of DS allows to derive a value of k. The value of k is estimated from the California EPM data [5]. A linear regression of LTP on EPM volume, results in a value of k = 0.143Rs/KWh/MWh. Physical constraints such as generation limits, ramp rates, down times, MC function don't impact k. Fig. 3 shows that Marginal cost of generators is less than its bidding price.

TABLE 1 :Example of TS for a given generators of single GENCO

Quantity (kWh)	MC (Rs/ kWh)	Calculation (k = 0.143Rs/KWh/MWh)	Bid (Rs/ kWh)
$h_1 = 2000$	$c_1 = 4$	$ƀ_1 = c_1$	$ƀ_1 = 4.000$
$h_2 = 2000$	$c_2 = 4.5$	$ƀ_2 = c_2 + kh_1$	$ƀ_2 = 4.786$
$h_3 = 1000$	$c_3 = 5$	$ƀ_3 = c_3 + k(h_1 + h_2)$	$ƀ_3 = 5.572$
$h_4 = 1000$	$c_4 = 5.5$	$ƀ_4 = c_4 + k(h_1 + h_2 + h_3)$	$ƀ_4 = 6.215$
$h_5 = 500$	$c_5 = 6.0$	$ƀ_4 = c_4 + k(h_1 + h_2 + h_3 + h_4)$	$ƀ_5 = 6.858$
Total =6500	Weighted Average MC = 30500/6500 = 4.692 Rs/kWh		Weighted Average Bid price =32788/6500 = 5.044 Rs/kWh

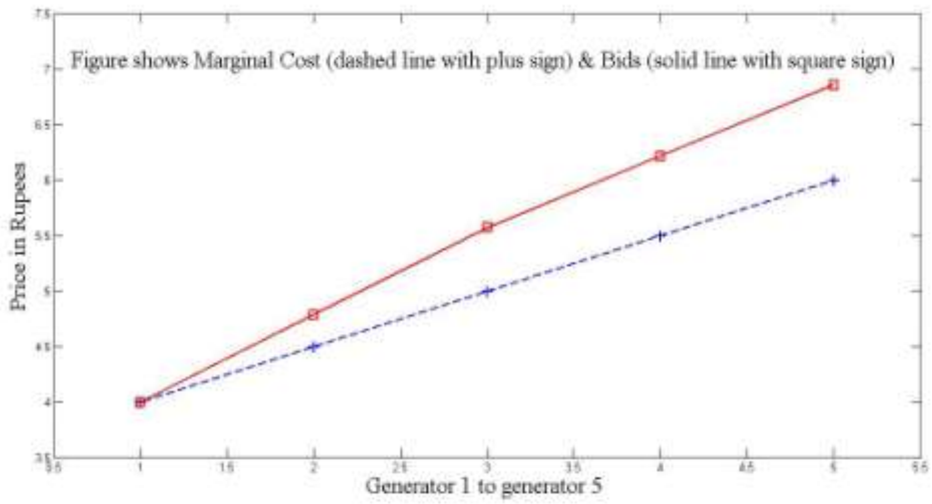

Fig. 3: Marginal cost is less than bid price

D. Trading Strategy Analysis

In the above sections, auction-based EPM strategy is thoroughly examined from the viewpoint of a GENCO. It is proved above that trading strategies can easily manipulate the LTP, it is also seen that single company carrying large portfolio of generator has impact on the EPM price. These inefficiencies & noncompetitive in the EPM can be rectified by proper EPM design with alert EPM regulator which keep close watch on the trades done in the EPM. Existence of Oligopoly can be found out from above discussion. Among various Commodities, excellent instances under perfect competition are seen in Agriculture products because there is no segmentation in its market. In case of other products, few producer firms and few large consumer influence market share and thus wield dominance in market. They are known as key participants. As it has been past proven; that price manipulation is possible by hoarding or by increasing the selling price.

IV. CONCLUSION

After detailed analysis shows/found that EPM is noncompetitive and inefficient because GENCOs easily manipulate LTP. It is seen that GENCOs has the ability to alter the LTP through its Strategic bids. This assumption is true until number of GENCOs is not enough or in other words less number of market participants with small generator capacity. Usually LTP is set by the interactions of the bidder and auctioneer. An EPM in which all GENECOs & power purchase act as price takers is said to have perfect competition. MC of production is equal to the marginal value of the goods to the consumers is general economic goal to achieve. Such a behavior encourages efficiency on both sides. This Article describes in one image about perceptions and observations of recent research of Market power in EPM. The presence of market power shows one assumption of non competitiveness among market participant in EPM. For GENCOs, this research paper demonstrates on best & optimal TS that permit us, distinctly from famous theories of collusion, to delineate the reactions of companies, showing in market power with steep LTP fluctuations. But, suiting itself to the specified parameter k the method illustrated in the paper corresponds to traditional approaches, which is directly pertinent in monopoly markets, game theory, supply equilibrium, & the perfect market competition. Full deregulation , without imposing any conditions, appears to entail survival of the fittest case, that, opposite to old beliefs in economics, never result in perfect competition because LTP = MC. Contrary to above it provides fittest with essential toolkit to enhance its dominant market position. So, perfect competition has to be brought up by a cautiously planned market and business environment. In the second part of the paper market design is discussed in detail for perfect competitive market.

REFERENCES

[1]. S. Borenstein, "The trouble with electricity markets: Understanding California's restructuring disaster," J. Econ. Perspect., vol. 16, no. 1, pp. 191–211, 2002.
[2]. S. Hao, "A study of basic bidding strategy in clearing pricing auctions," IEEE Trans. Power Syst., vol. 15, no. 3, pp. 975–980, Aug. 2000.
[3]. R. Green, "Increasing competition in the British electricity spot market," J. Ind. Econ., vol. 44, no. 2, pp. 205–216, Jun. 1996.
[4]. A. R. Kian, J. B. Cruz, Jr., and R. J. Thomas, "Bidding strategies in oligopolistic dynamic electricity double-sided auctions," IEEE Trans. Power Syst., vol. 20, no. 1, pp. 50–58, Feb. 2005.
[5]. California Electricity Market Data The University of California Energy Institute, 2003 [Online]. Available: http://www.ucei.berkeley.edu/
[6]. R. Wilson, "Architecture of power markets," Econometrica, vol. 70, no. 4, pp. 1299–1340, Jul. 2002.