Systems Engineering - Theory & Practice
Volume 27, Issue 8, August 2007
Online English edition of the Chinese language journal

Available online at www.sciencedirect.
ScienceDirect

Cite this article as: SETP, 2007, 27(8): 118–126

RESEARCH PAPER

Auction Mechanism Design in Wholesale Electricity Market Considering Impacts of Long-term Contract

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Abstract: In wholesale electricity market, a generator with cost information advantage will submit a bid higher than its true cost, which may reduce the market efficiency. To solve this problem, this article designs an incentive auction mechanism considering the impacts of long-term contract and the variability of marginal cost. The new mechanism includes an extra payment (information compensation) that will make generators submit their true marginal cost, and thus, achieves distribution efficiency. Then, it makes a demonstration based on the data from IEEE-RTS96. The result shows that the new mechanism can control the market power of generator and avoid strategic bidding behaviors.

Key Words: long-term contract; wholesale electricity market; auction mechanism; incentive compatibility

1 Introduction

Electric Power Industry has its own technical particularity; therefore, the market-oriented reform is a gradual process. In the primary stage, competition is only introduced into the generation side, and the demand side is still regulated, that is to say, generators compete with one another in generation market and sell their products to a grid company (just like a centralized or mediated market), which in turn, sells it to final consumers. We usually call it the wholesale electricity market. Since this is not a perfect opening market, all companies will face a huge price risk. To solve this problem, electricity trades can be arranged in two basic ways: the long-term contract and the short-term market, where, long-term refers to future periods of a week or longer, up to several years, in which sellers and large buyers can pair up-and reach agreement on the details of the long-term contract, and short-term refers to a future of a day or less, down to hours or minutes before specific generators are dispatched, which becomes more amenable to mediated market forms run as auctions[1]. Operation of short-term market will determine the stability and efficiency of the wholesale electricity market, and then an appropriate auction mechanism that can achieve economic dispatch is the key issue. Unfortunately, the existing mechanisms (such as MCP or PAB) do not have this function, and an in-depth re-search is indispensable. The design of an auction mechanism that induces an efficient use of generation resources is complicated. Silva, Wollenberg, and Charies proposed solving this problem through a technique in economics, called mechanism design. They designed a mechanism such that when each participant acts in its own best interest, the outcome of the wholesale electricity market is efficient[2]. Shaohua, Yong, and Yuzeng designed an incentive mechanism, which can also re-cover the generators' fixed cost[3]. In this article, we design an incentive mechanism considering the impacts of long-term contract and the variability of marginal cost. Our mechanism can make each generator sub-mit its true cost through appropriate cost compensation, and thus achieve economic dispatch. Our mechanism differs from existing researches in two points. The first one is defining a generator's cost as a quadratic function of its output (power). This can fully describe the feature of power producing. In this article, the marginal cost increases with the quantity of power produced by a generator, whereas it is a constant in relative researches. The second one, also the most important one, is taking the relations between long-term contract and short-term market into account, since once the long-term contract is reached, generators will change their bidding behaviors in short-term market. The impacts of long-tern contract on short-term market have not been included in relative researches. This article is organized as follows. Section 2 describes the two types of electricity trades, generators' cost and the corresponding information assumptions. Section 3 frames the bidding rule in short-term market. Section 4 proposes an electricity dispatch rule in short-term market. Section 5 designs the settlement rule, and it is the core of our auction mechanism. Through simulation, section 6 demonstrates that the mechanism works. Section 7 provides the conclusion.

2 Wholesale electricity market environment

This section describes the environment of wholesale electricity market and the corresponding information assumptions.

Received date: April 17, 2006

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Foundation item: Supported by the National Natural Science Foundation of China (Nos.90510016 and 70071036)

2.1 Two ways of electricity trades

In wholesale market, electricity trades can be arranged in two basic ways, the long-term contract and the short-term market. These two types have their own functions and may affect each other.

2.1.1 Long-term contract

Long-term refers to future periods of a week or longer, up to several years. The quantity of power traded by contract is constant in the primary stage, and accounts for roughly eighty percent of a generator's capacity. The price is regulated by the government initially, and with the opening of the electricity market, sellers and large buyers can pair up and negotiate about it.

Once the long-term electricity price is confirmed, it will not be affected by short-term electricity. Apparently, the contract will intensify the competition and efficiency of short-term market by reducing its demand, when the load is fixed[4], that is, a generator will change its bidding behavior in short-term market after selling a part of its output by contract.

2.1.2 Short-term market

Short-term electricity is dispatched through auction. Usually, a day is divided into 24 or 48 periods, with electricity auction repeated at each period.

A single auction round proceeds as follows. First, each generator submits a bid, and then based on these bids, an agent (grid company or pool operator) assigns the quantity produced by each generator and the corresponding payment[1]. This article provides an explicit formula for such allocations.

2.2 Cost function

A generator's cost can be divided into two parts. One associates with the physical construction of the generating plants, and we usually call it the capacity cost or fixed cost. The other can be called operating cost, which changes with the quantity produced by the generator. Generation units with lower operating cost will have higher capacity cost, and vice versa, those using more-expensive-to-operate technologies will have cheaper fixed cost.

For generator i, if the production function is $Q_i = \sqrt{\alpha_i x_i}$, its cost function will be[5]:

$$C_i = r\alpha_i F_i + (\alpha_i \cdot w)Q_i^2/2 \tag{1}$$

where,
x_i is the quantity of input,
$w/2$ is the price of input,
α_i is the producing scale of generator i,
Q_i is the total quantity of power produced by generator i,
r is the market interest rate,
F_i is the investment cost of generator i,
$r\alpha_i F_i$ is the capacity cost of generator i.

According to Eq.(1), the marginal cost function of generator i is $MC_i = \beta_i Q_i$, where, $\beta_i(\beta_i = w\alpha_i)$ is a coefficient.

The two-step tariff system is applied in the Chinese northeast electricity market at present, that is to say, the price is composed of capacity price and electricity price in the wholesale market. The former is regulated by the government according to each generator's fixed cost. The latter is decided by auction, and our study only proposes an appropriate mechanism for it.

2.3 Information problem

In wholesale electricity market, the grid company wants to achieve economic dispatch, which indicates a minimization of its purchase cost. This requires that the company must know the true cost of each generator. However, the marginal cost of a generator is its private information. The reason is that a generator knows its own inputs (e.g., fuel, boiler efficiency, etc.) better than any other. With generators competing in wholesale electricity market, they are not willing to provide their cost unless given sufficient incentive to do so. This is the information problem to be solved.

We assume that the grid company regards the marginal cost coefficient β_i of generator i as a random variable from a commonly know distribution. This knowledge may be obtained from the publicly available information about a generator's technology and the observed bid data[5].

We further assume that the distribution of a generator's (true) marginal cost coefficient β_i has the following properties:

The domain of possible coefficient β_i is bounded. In other words, the grid company knows that the coefficient β_i of generator i lies between ceiling $\beta_i^{\max}$ and floor $\beta_i^{\min}$ values.

The probability density function of the distribution is continuous and uniform.

The other parameters of an electric system, including transmission line capacities, loads, and the technical limits of the generators, are assumed to be common knowledge among all market participants[2].

3 Bidding rule

In short-term market, each generator submits a bid; based on these bids, an agent (the grid company) assigns the quantity produced by each generator to achieve economic dispatch. This section frames the bidding rule of our mechanism.

Our mechanism, which proposes to make each generator notify its true cost through providing appropriate incentive, sets a bidding rule for all generators in short-term market. It requires that the figure of bidding curve provided by each generator must accord with its marginal cost.

The marginal cost function of generator i is $MC_i = \beta_i Q_i$. When a generator submits a bid for an auction period in short-term market, it has already produced a quantity of long-tern electricity q_i^0 at this period. Let q_i and $Q_i^{\max}$denote its quantity of power produced in short-term market and its maximal output; then, the marginal cost of short-term electricity is $mc_i = \beta_i q_i^0 + \beta_i q_i$ for $q_i + q_i^0 = Q_i \leq Q_i^{\max}$. This marginal cost curve is illustrated by Figure 1(a). We believe that the disposal describes one impact of the long-term contract. In our mechanism, each generator must submit a linear bidding curve formed as $b_i = \hat{\beta}_i q_i^0 + \hat{\beta}_i q_i$. The bidding curve is shown in Figure 1(b). A generator simply needs to submit its bidding coefficient $\hat{\beta}_i$ and maximal output $Q_i^{\max}$ in short-

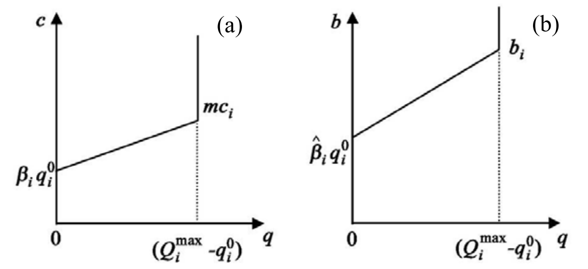

Figure 1. Marginal cost and bidding curve in short-term market (a) Marginal cost curve; (b) Bidding curve

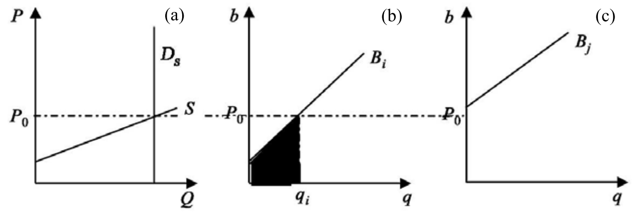

Figure 2. Electricity distribution in our mechanism (a) Market clearing price; (b) Generator i that wins; (c) Generator j

term market, because its quantity of long-term electricity q_i^0 is a common knowledge.

4 Electricity dispatch rule

In wholesale electricity market, generators compete with one another and sell their products to the grid company, which in turn, sells it to the final consumers at a fixed price. To maximize its profit, the grid company will dispatch electricity in an economic way. This section interprets the basic rule of electricity dispatch.

The economic dispatch can be described as a minimization of the total purchase cost in short-term market subject to 1) generation limits, and 2) short-term electricity balance limits, i.e.,

$$\min \sum_{i=1}^{n} \Gamma_i^S(q_i) \tag{2}$$

$$\text{s.t. } q_i \le Q_i^{\max} - q_i^0 \text{ (i = 1,2,} \cdots n) \tag{3}$$

$$\sum_{i=1}^{n} q_i = D - \sum_{i=1}^{n} q_i^0 \tag{4}$$

where:

$\Gamma_i^S(q_i)$ is the total purchase cost of the grid company. It is also the total income of all generators in short-term market

D is the total quantity of demand

$D - \sum\limits_{i=1}^{n} q_i^0$ is the demand in short-term market. It is equal to the total demand subtract the quantity of electricity traded by long-term contract.

The demand side is still regulated, and the price elasticity of the demand is zero in wholesale electricity market, and thus, the total quantity of demand D is a given constant in our study. Eqs.(3) and (4) describe the physical constraints.

The solution of this problem is just the dispatch rule. When the bidding curve is linear, we can simplify it. By adding all generators' bidding curves together, we can get the supply curve of short-term market, and then make the market supply equal to its demand, and thus find the economic dispatch. In brief, determine the clearing price b that solves equation (5)

$$S = \sum_{i=1}^{n} \frac{b - \hat{\beta}_i q_i^0}{\hat{\beta}_i} = D - \sum_{i=1}^{n} q_i^0 \tag{5}$$

We can illustrate the above solution. In Figure 2(a), the intersection between supply curve S and demand curve D in short-term market denotes the equilibrium, and the market clearing price is P_0.

The quantity that a generator is assigned to produce depends on its own bidding and the market clearing price. According to its bidding curve, a generator's bid b_i is increasing with its quantity q_i. There is a quantity q_i , which makes the bid b_i equal to the market clearing price, and this quantity satisfies the solution of economic dispatch, that is to say, we need to find a quantity q_i, which solves the equation $b_i = \hat{\beta}_i q_i^0 + \hat{\beta}_i q_i = P_0$. If $q_i > 0$, generator i wins the auction, otherwise, it loses. As seen in Figure 2(b), the bidding curve of generator i intersects the price curve at a positive quantity, therefore, it can sell the corresponding quantity of power in short-term market. Generator j in Figure 2(c) loses.

5 Market settlement rule

There is an information problem in the wholesale electricity market. When firms compete with one another in short-term market, a generator generally will not be willing to provide its true production costs. Consequently, the marginal cost of generator i becomes its private information. Therefore, if the grid company still dispatches electric power production according to economic dispatch, then the outcomes are likely to be inefficient, because the marginal costs may be misrepresented[2].

To solve this problem, in this section, we design a payment scheme that makes our mechanism incentive compatible, i.e., induces each participant to submit its true marginal cost. The payment consists of two parts. One is cost compensation, and the other is information compensation.

The cost compensation is according to the marginal cost claimed by the generator. It can be illustrated by the area with blue shadow in Figure 2(b). Let A_i denote it,

$$A_i = \int_0^{q_i} (\hat{\beta}_i q_i^0 + \hat{\beta}_i q)\mathrm{d}q = \hat{\beta}_i q_i^0 q_i + \frac{1}{2}\hat{\beta}_i (q_i)^2 \tag{6}$$

The information compensation, which is indispensable owing to the information structure, is a compensation for the information advantage of the generator. This part is precisely tuned so that each generator is willing to provide the true marginal cost. Let τ_i denote it; we have $\tau_i = \tau_i(\hat{\beta}_i)$. Therefore, the core of our payment scheme is to find an appropriate information compensation τ_i, which satisfies the individual rationality condition and makes our mechanism incentive compatible and feasible[2]. Such a desirable part of payment is presented below.

A mechanism is said to be feasible if its allocations satisfy all physical constraints. In our study, this indicates that the electricity production dispatched by the mechanism needs to satisfy all the feasibility constraints given by the generation limits (3) and the short-term electricity balance limits (4).

5.1 Incentive compatibility

According to our payment scheme, the income received by generator i in short-term market will be:

$$\Gamma_i^S = \int_0^{q_i} (\hat{\beta}_i q_i^0 + \hat{\beta}_i q)\mathrm{d}q + \tau_i(\hat{\beta}_i) \tag{7}$$

In our setting, there is a different viewpoint on a generator's bidding behavior. A generator tries to maximize its expected profit from selling all outputs but not the part in short-term market. This is a description of the fact that long-term contract will affect the behavior of a generator in short-term market. Let ρ_i denote the price of long-term electricity sell by contract; then, the total income received by generator i will be:

$$\Gamma_i = \int_0^{q_i} (\hat{\beta}_i q_i^0 + \hat{\beta}_i q)\mathrm{d}q + \tau_i(\hat{\beta}_i) + \rho_i q_i^0 \tag{8}$$

The expression for the expected profit function, depending on the true cost, and the bid, will be:

$$\pi_i = \int_0^{q_i} (\hat{\beta}_i q_i^0 + \hat{\beta}_i q)\mathrm{d}q + \tau_i(\hat{\beta}_i) \ + \rho_i q_i^0 - \frac{\beta_i (q_i^0 + q_i)^2}{2} \tag{9}$$

If we take the first derivative of π_i with respect to $\hat{\beta}_i$, we get,

$$\frac{\partial \pi_i}{\partial \hat{\beta}_i} = q_i^0 q_i(\hat{\beta}_i) + \hat{\beta}_i q_i^0 [q_i(\hat{\beta}_i)]' \ + \hat{\beta}_i q_i(\hat{\beta}_i)[q_i(\hat{\beta}_i)]' + \frac{1}{2}[q_i(\hat{\beta}_i)]^2 + [\tau_i(\hat{\beta}_i)]' \ - \beta_i [q_i^0 + q_i(\hat{\beta}_i)] \cdot [q_i(\hat{\beta}_i)]' \tag{10}$$

By the first order necessary condition of the maximization in $\hat{\beta}_i$, the first derivative of π_i with respect to $\hat{\beta}_i$ is zero, and the incentive compatibility property implies that for any true cost coefficient β_i, the optimal bid equals the true value. Therefore, let $\partial \pi_i \big/ \partial \hat{\beta}_i = 0$, and by replacing $\hat{\beta}_i$ with β_i, we get,

$$[\tau_i(\beta_i)]' = -q_i^0 q_i(\beta_i) - \frac{1}{2}[q_i(\beta_i)]^2 \tag{11}$$

Applying the integral operator between the upper bound of the probability distribution, $\beta_i^{\max}$, and a generic β_i, we get,

$$\tau_i(\beta_i^{\max}) - \tau_i(\beta_i) \ = \int_{\beta_i}^{\beta_i^{\max}} \left[-q_i^0 q_i(\beta) - \frac{1}{2}[q_i(\beta)]^2 \right] \mathrm{d}\beta$$

The generic function$\tau_i(\beta_i)$that solves the above is,

$$\tau_i(\beta_i) = \int_{\beta_i}^{\beta_i^{\max}} \left[q_i^0 q_i(\beta) + \frac{1}{2}[q_i(\beta)]^2 \right] \mathrm{d}\beta + K_i \tag{12}$$

In Eq. (12), the value of $\tau_i(\beta_i^{\max})$ is replaced by the symbol K_i.

When generator i submits its bid $\hat{\beta}_i$, it will get information compensation

$$\tau_i(\hat{\beta}_i) = \int_{\hat{\beta}_i}^{\beta_i^{\max}} \left[q_i^0 q_i(x) + \frac{1}{2}[q_i(x)]^2 \right] \mathrm{d}x + K_i \tag{13}$$

The information compensation in Eq.(13), which depends on the degree of information advantage, can make our mechanism incentive compatible under the fact that $q_i(\cdot)$ is a decreasing function. If a generator has more private information of its marginal cost, it will get considerable compensation from the grid company. The compensation will be equal to zero, in case a generator's marginal cost is a common knowledge.

5.2 Individual rationality

A mechanism is said to be individually rational if no participant will lose profit at the truth-telling equilibrium. This condition is required because participants usually have an outside option of quitting[2]. For example, a generator company can turn off its plant and get zero profit. For one period of electricity auction, the above payment will satisfy the individual rationality condition.

In wholesale electricity market, a generator can negotiate with the grid company and sell its product through long-term contract, or submit a bid and compete with one another in short-term market to gain a part of profit. A rational generator company will drop out of the auction and sell its product through long-term contract, if the payment is lower in short-term market. In our study, we take this fact into account, and make our mechanism individually rational at multi-periods. To do this, we make the payment of per unit higher than the average price of long-term electricity. At this point, our mechanism differs from the existing ones. The reason is that we descript the relation between long-term contract and short-term market. Let $\bar{\rho}_i$ denote the average price of long-term electricity; the individual rationality condition can be written as,

$$\hat{\beta}_i q_i^0 q_i(\hat{\beta}_i) + \frac{1}{2}\hat{\beta}_i [q_i(\hat{\beta}_i)]^2 + K_i + \int_{\hat{\beta}_i}^{\beta_i^{\max}} \left[q_i^0 q_i(x) + \frac{1}{2}[q_i(x)]^2 \right] \mathrm{d}x \geq \bar{\rho}_i q_i(\hat{\beta}_i) \tag{14}$$

Regrouping,

$$K_i \ \geq \ (\bar{\rho}_i - \hat{\beta}_i q_i^0) q_i(\hat{\beta}_i) - \frac{1}{2}\hat{\beta}_i [q_i(\hat{\beta}_i)]^2 - \int_{\hat{\beta}_i}^{\beta_i^{\max}} \left[q_i^0 q_i(x) + \frac{1}{2}[q_i(x)]^2 \right] \mathrm{d}x \tag{15}$$

Let us define the function $\Phi_i(\hat{\beta}_i)$:

$$\Phi_i(\hat{\beta}_i) \ = \ (\bar{\rho}_i - \hat{\beta}_i q_i^0) \cdot q_i(\hat{\beta}_i) - \frac{1}{2}\hat{\beta}_i [q_i(\hat{\beta}_i)]^2 \ - \int_{\hat{\beta}_i}^{\beta_i^{\max}} \left[q_i^0 q_i(x) + \frac{1}{2}[q_i(x)]^2 \right] \mathrm{d}x \tag{16}$$

Setting $K_i \geq 0$, simplifying Eq.(15), and replacing the value of $\Phi_i(\hat{\beta}_i)$ from Eq.(16), we get,

$$K_i = \begin{cases} 0 & \Phi_i(\hat{\beta}_i) \leq 0 \\ \Phi_i(\hat{\beta}_i) & \Phi_i(\hat{\beta}_i) > 0 \end{cases} \tag{17}$$

The payment generator i received in short-term market is,

$$\Gamma_i^S(\hat{\beta}_i) = \begin{cases} \hat{\beta}_i q_i^0 q_i(\hat{\beta}_i) + \dfrac{1}{2}\hat{\beta}_i[q_i(\hat{\beta}_i)]^2 + \\ \displaystyle\int_{\hat{\beta}_i}^{\beta_i^{\max}} \left[q_i^0 q_i(x) + \frac{1}{2}[q_i(x)]^2\right] \mathrm{d}x & K_i = 0 \\ \bar{\rho}_i q_i(\hat{\beta}_i) & K_i > 0 \end{cases} \tag{18}$$

Therefore, the information compensation of per unit is,

$$f_i = \frac{\int_{\hat{\beta}_i}^{\beta_i^{\max}} [q_i^0 q_i(x) + \frac{1}{2}[q_i(x)]^2]\mathrm{d}x + K_i}{q_i(\hat{\beta}_i)} \tag{19}$$

Our payment consists of two parts, the cost compensation given by Eq. (6), and the information compensation given by Eq. (13). When designing the mechanism, we consider the impacts of long-term contract, and our mechanism also achieves all of the following:

It induces every generator to provide its true marginal cost (incentive compatibility).

It dispatches electricity production efficiently (feasibility and efficiency).

It guarantees that no generator will lose profit if it submits its true marginal cost (individual rationality).

6 Simulations

This section demonstrates the merits of our mechanism by simulation, and the data is based on the IEEE-RTS96. Our simulation first describes the power system and defines the market structure of generation. With the selected data, we calculate market outcomes of different mechanisms. From these results, we compare the traditional mechanisms (MCP and PAB) with our mechanism. The simulation results show that our mechanism is incentive compatible and excels traditional ones. Our mechanism can control market power of generator and avoid strategic bidding behaviors, and thus produces the lowest market clearing price and payment.

6.1 Description of the system

In this subsection, we define the market structure and load data.

6.1.1 Market structure and generation parameters

On the basis of the fact that there are five large companies in the Chinese generation market, we frame a market with five firms in this simulation. To analyze the impacts of strategic bidding behavior and the differences resulting from market structure; we take two cases into account. One is that all generators have almost the same capacity. The other is that there are huge capacity differences among generators. To do this, we select the entire thirty-two units in IEEE-RTS96[6], and then put these units into five companies at each case. Thus, the total capacity is 3497MW[7]. The data is shown in Table 1.

In Table 2 we can see the market share, the true marginal cost coefficient, and its probability distribution of each generator. In our study, every generator company, while knowing its true cost, assumes that the costs coefficients of its competitors are drawn from a truncated normal distribution (between $\beta^{\min}$ and $\beta^{\max}$).

6.1.2 Load at each period

The load data is included in Table 3. The maximum

Table 1. Unit number and its owner

Generator	Unit number
Case 1	
1	U400 U400
2	U20 U20 U76 U76 U12 U197 U100 U12 U155
3	U76 U20 U20 U12 U197 U76 U155 U100
4	U76 U76 U76 U12 U100 U350
5	U12 U76 U76 U12 U197 U155 U155
Case 2	
1	U400 U400
2	U20 U20 U76 U20 U12 U12 U12
3	U76 U20 U76 U76 U197 U100 U155 U100 U197 U155
4	U76 U76 U76 U100 U350 U197 U155 U155
5	U76 U76 U12 U12 U12

Table 2. Marginal cost and probability distribution data

Generator	Total output (MWh)	Market share	True marginal cost coefficient (yuan/kWh)	$\beta^{\min}$	$\beta^{\max}$
Case 1					
1	800	0.23	0.379	0.35	0.41
2	668	0.19	0.479	0.45	0.51
3	656	1.19	0.486	0.45	0.52
4	690	0.20	0.469	0.44	0.50
5	683	0.19	0.469	0.44	0.50
Case 2					
1	800	0.23	0.379	0.35	0.41
2	172	0.05	2.155	2.00	2.31
3	1152	0.33	0.272	0.25	0.29
4	1185	0.34	0.261	0.24	0.28
5	188	0.05	2.083	1.93	2.23

Table 3. Load data at each period

Period	Total demand (MWh)	Quantity of long-term electricity (MWh)	Demand in short-term market (MWh)
1	2100.45	1680.36	420.09
2	1975.05	1508.04	395.01
3	1881.00	1504.80	376.20
4	1849.65	1479.72	369.93
5	1849.65	1479.72	369.93
6	1881.00	1504.80	376.20
7	2319.90	1855.92	463.98
8	2696.10	2156.88	539.22
9	2978.25	2382.60	595.65
10	3009.60	2407.68	601.92
11	3009.60	2407.68	601.92
12	2978.25	2382.60	595.65
13	2978.25	2382.60	595.65
14	2978.25	2382.60	595.65
15	2915.55	2332.44	583.11
16	2946.90	2357.52	589.38
17	3103.65	2482.92	620.73
18	3135.00	2508.00	627.00
19	3135.00	2508.00	627.00
20	3009.60	2407.68	601.92
21	2852.85	2282.28	570.57
22	2602.05	2081.64	520.41
23	2288.55	1830.84	457.71
24	1975.05	1580.04	359.01

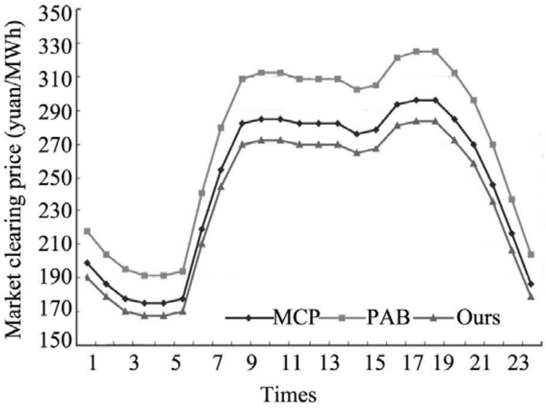

Figure 3. **Market clearing prices using different mechanisms in Case 1**

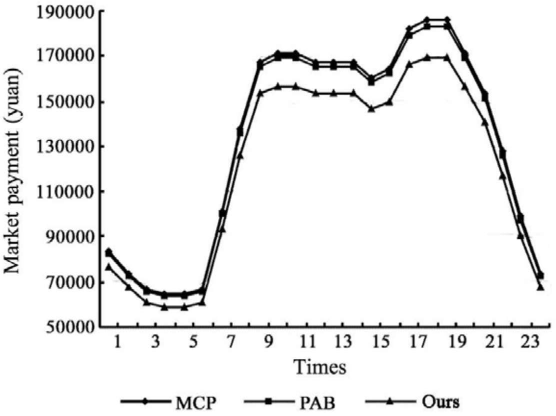

Figure 5. **Market payments of different Mechanisms in Case 1**

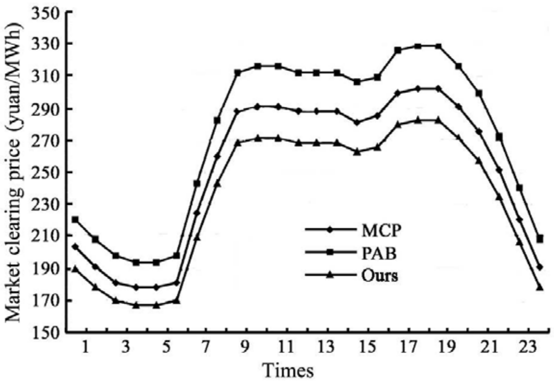

Figure 4. **Market clearing prices using different mechanisms in Case 2**

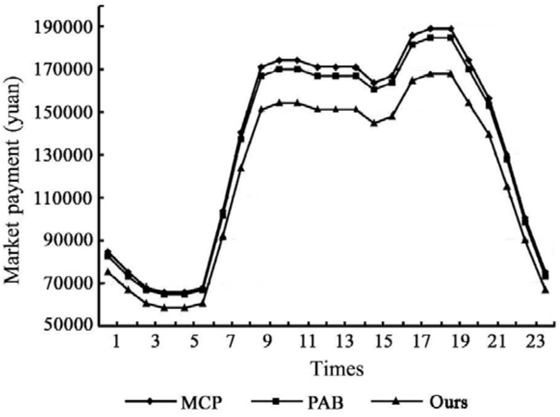

Figure 6. **Market payments of different Mechanisms in Case 2**

load equals 3135 MW. To simplify the simulation, this section assumes that the quantity of long-term electricity accounts for eighty percent of the total demand at each period, and the long-term electricity of generator i depends on its market share.

6.2 Comparison between our mechanism and traditional ones (PAB and MCP)

In this subsection, we compare our mechanism with the traditional ones. Two types of auction mechanisms have been widely used in electricity market. The MCP (market clearing price) mechanism was applied early, and the PAB (pay-as-bid) was a replacement of the former. In this article, we refer to these as the traditional mechanisms.

With the above data, we can make simulations to demonstrate the merits of our mechanism. First, we compute the market outcomes of different mechanisms, and then compare them. The result shows that the market outcome in case1 differs from that in case 2. This indicates that the changing market structure will affect the efficiency of auction mechanism. The market clearing price increases by nearly 5.3 Yuan when we use the MCP mechanism. In the same way, the market clearing and average price increase 3.56 and 2.97 Yuan, respectively, when we use the PAB mechanism. These figures prove that a generator will take strategic bidding behavior in the market using traditional mechanisms, and thus reduce market efficiency. On the other hand, the mechanism described in this article can control the market power of generator and avoid strategic bidding behaviors. The evidence is that market clearing and average price have almost no changes.

In the following, we contrast the traditional mechanisms and our mechanism in detail.

6.2.1 Market clearing price

As seen in Figures 3 and 4, in the two cases, the PAB mechanism produces the highest market clearing price and our mechanism produces the lowest. The reason is that a generator will submit a bid higher than its true cost when we use traditional mechanisms, and the market supply curve becomes steeper. Therefore, the price is higher than normal. The result in this subsection also proves that a shift from MCP to PAB mechanism will not provide power purchasers substantial relief from soaring prices. In a word, our mechanism is incentive compatible and excels the traditional ones.

6.2.2 Market payment

In Figures 5 and 6, we can see the market payments of different mechanisms in both cases. These figures show that the market payments of our mechanism are quite lower than that of traditional ones. The reason is that the PAB mechanism produces the highest market clearing price, and our mechanism produces the lowest one.

7 Conclusions

This article designs an incentive auction mechanism considering the impacts of long-term contract and the variability of marginal cost. Our mechanism includes an extra payment (information compensation) that will make generators submit their true marginal cost, and thus achieves economic dispatch. Our study differs from the existing researches in two points. The first one is defining a generator's cost as a quadratic function of its output (power). This can fully describe the feature of power producing. In this article, the marginal cost increases with the quantity of power produced by a generator, whereas it is a constant in relative researches. The second one, also the most important one, is taking the relations between long-term contract and short-term market into account, since once the long-term contract is reached, generators will change their bidding behaviors in short-term market. The impacts of long-term contract on short-term market have not been included in relative researches.

Simulations have demonstrated the desirable properties of our mechanism. Compared with traditional mechanisms, our mechanism can control the market power of generator and avoid strategic bidding behaviors. Our mechanism produces the lowest market clearing price and payment.

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