The New Management Strategy of the Balance Account Based on the Incentive Compatible Theory

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Abstract-- **In the unilateral open electricity market in China, the current management method of the balance account, which is regarded as "regulator" between the bidding price of generation and retail price of electricity, has serious defects and might lead to the huge shortfall of the capital at the account and endanger the operation of market steadily. Based on incentive compatible principle, a new method through reward-punishment for the balance account management is presented in the paper and the optimal bidding strategy of power suppliers considering the new management method of the balance account is also provided. The test results indicate that the bidding strategy proposed can inhibit the market power of the generation, reduce significantly the market clearing price and keep the capital of the balance account fluctuation within a certain range, which ensures the power market to operate steadily and safely.**

Keyword--**electricity market, incentive compatible, balance account, market power**

I. Introduction

In China, the current power markets are unilateral open generation market, in which the linkage mechanism of the retail price of electricity and the bidding pricing of generation is not established. Therefore, there exists a considerable problem for the security and the durative of the market operation. How to ensure the security, reliability and the durative of the power market operation and to lay a solid foundation for the next stage restructure--transmission and distribution also opening up is a big issue needed to be solved imperatively.

[1]Balance account is considered as a “regulator” for the not linkage of the retail price of electricity and the bidding price of generation of the unilateral open generation market, a “reservoir” for the process of mechanism reform from integration system to market system, and also a supplement to the current pricing mechanism [1]. In the northeastern and eastern regional power markets of China, balance accounts have all been established. But in fact, the current balance accounts do not act as "reservoir" and "regulator" as people expected. On the contrary, the Northeastern China power market was stopped urgently by the committee of State Electric Power Supervision and Management in March 2006 because the market clearing price has been very high for a long time and experienced a dramatic shortfall-about three billions RMB in the balance account; and the balance account of the Eastern China regional power market was also stopped in the middle of 1996. This situation indicates that the current management method of the balance account has serious defect, especially when generation companies have the tacit bidding behavior or collusion agreement to make the market clearing price abnormally high, which leads to the sustained deficit of balance account. There is no correspondingly manipulating method at present. The market mechanism which can discover and punish the power plant for the tacit or collusion behavior automatically must be established to keep the security, reliability and sustainability of the market operation. The market design strategy based on the principle of incentive compatibility, on one hand, it could prevent and restrain market participants from market operation mechanism to make use of their market power; and on the other hand, it also encourages market participants to bid at cost, therefore, it is a very effective strategy for balance accounts management.

In Ref. [2-5], the principle of the incentive compatibility was applied for the design of the competitive electricity market mechanism, and an information compensation component was added to the payment of power plant and used by the trading center to award or punish the power companies and encourage them to bid at cost according to the observation of market information. In the financial supervision and management, tax administration, the principle of incentive compatibility is also widely used. Applying the incentive mechanisms to financial regulation and tax administration, the objective function of the regulator achieves the greatest degree of consistency with that of the under-regulator [6-7].

Moreover, the optimal bidding strategy is a hot topic of power market research for a long time, and there are a lot of very interesting and useful methods for it. For example, by taking the reasonable profit as the objective function, the optimal bidding curve is gained through the optimal unit commitment calculation of power plants[8]; by forecasting the market clearing price of the next period, the optimal price that maximizes the profit and at the same time ensures the generation output to be selected is bided accordingly [9]; the optimal bidding strategy is achieved by calculating the aggregated supply curve of the generators of the price recipients and the supply curve of the generators with market power [10]; the Ref. [11] presents the bidding strategies based on the various risk theories; the Ref.[12,15] proposes the optimal bidding strategies based on the estimation of opponents price and behavior.

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Generally, there are many methods and strategies for it, but basically, they did not take the impact of balance account into consideration.

Focusing on the existing defect of the current management method of the balance account, this paper presents a new management method of the balance account based on incentive compatible principle. Its main idea is to give the power suppliers reward or punishment based on the surplus and shortfall of the balance account in order to to keep the fluctuation of fund of the balance account within a range; it further establishes an optimal bidding strategy for power suppliers taking into account of the new management method.

II. The current management method of the balance account

According to the provisions of " the supervision and management interim procedure of the balance account of Northeastern China regional power market ", when the linkage of the electricity retail price and the market clearing price of generation market is not established, the formula for balance funds is as follows:

The electricity market balance funds = Difference price × The sum of all the electricity power energy output of the successful bidding unit - Expected various surcharges;

Difference price = (The average benchmark price provided by Relevant Price Regulation Departments- The average of the price of the current actual generation output of all the bidding unit)/(1+ The rate of Value-added tax);

The average of the price of the current actual generation output of all the bidding unit = The converting of the capacity price of all the current bidding unit to the electricity power energy tariff + electricity power energy tariff of the current bidding unit;

The converting of the capacity price of all the current bidding unit to the electricity energy tariff = The sum of the capacity fare of all the bidding units / The total electricity energy output of all the bidding unit;

The balance funds are managed by the settlement transition account and special account of the balance capital.

The settlement transition account adopts the quota management; it is paid or shell out monthly. The monthly quota of the settlement transition account will be determined according to the actual needing of the power market; and the excess part over the quota of the settlement transition account is transferred to the special account of the balance capital; for the inadequate part, the application made by the power dispatch center to supplement the quota funds will be checked and approved by the Ministry of Finance, and the Committee of State Electric Power Supervision and Management. The settlement transition account is set at the Northeast Electric Power Dispatch Center and is responsible for its day-to-day manipulation by the center. It is supervised by the Ombudsman from the Office in Liaoning set by Ministry of Finance, and the Northeast sub-Committee of the committee of State Electric Power Supervision and Management.

The fund at the special account of the balance capital comes from the part of the monthly settlement funds over the quota of the settlement transition account and the interest of the fund at the special account of the balance capital, and it is used to balance and stabilize the retail price of electricity. The special account of the balance capital is set at the branch of national treasury in Liaoning province, and is managed and supervised by the officers of the Ministry of Finance working at the Liaoning province finance bureau.

When the funds at the special account of the balance capital falls below a certain amount and is anticipated to go on decreasing or be zero and the funds at the settlement transition account is also predicted to be negative, the Northeast branch office of the committee of State Electric Power Supervision and Management together with the officer of the Ministry of Finance working at the Liaoning province finance bureau, will propose to add or compensate the balance funds, or to raise the retail price of the electricity; they might present the application to be approved by related national department. The additional revenue from the raising of the retail price is used to replenish the balance fund.

When the market clearing price is higher than the benchmark price approved by the relevant state departments, and the difference price by the above formula is negative, the part of the electricity purchasing costs has to be paid by the balance funds, since the electricity tariff paid by the power grid corporation is only the benchmark approved price. Power dispatching centers will report the bidding results to the Northeast branch office of the committee of State Electric Power Supervision and Management to get the approved signatures, the higher part than the benchmark price will be paid using the balance fund. When actual market clearing price is lower than the approved benchmark price, the difference price by the above formula is positive, and the part of the funds paid by the power grid corporation automatically goes to the two balance accounts. In a word, the price paid by the power grid corporation remains unchanged, equal to the benchmark price determined by the relevant state department. This kind of handling approach is consistent with that actual situation of the power market constructing of our country, just at the stage of the simulating of the electricity market, summing up the experience of the market operation, and laying abundant foundation for more comprehensive market reform of the next stage.

Actually, for the current stage power market of our country, the procedure and application of the linkage of the generation bidding price and electricity retail price is very difficult, which should be checked and approved by national price regulation department and many other authority department strictly. Although the northeast regional power market has also set the function, it is never used from the market open to the market stopped urgently. The reason from many analysts for the market urgently stopped is mainly due to the power plants in Liaoning and Jilin province to form the local electricity market by tacit bidding and collusion, which makes the power from Heilongjiang province unable to be transported to southern load center of Liaoning province, and the market clearing price in Liaoning province is very high for a long time (much higher than the approved benchmark price).This event shows that there exists serious management and

operation deficiencies for the current balance accounts; when the linkage of the market clearing price of the generation and the electricity retail price has not built, it is unable to restrain the market power, the tacit action and collusion of the main power plants, which might lead to the generation settlement price to be very high and accumulate huge deficits for the balance fund; and finally the market operation has to be suspended.

III. The new method for balance account management based on incentive compatible principle

The benchmark price for the generation output λ_r approved by the price regulation departments is determined under the consideration of a number of factors and guarantee for the power generation firms to have a certain profit and capability to pay back the loan. According to the current management methods for the balance fund, when the market clearing price is sustained higher than λ_r, it will cause the balance fund at the balance account to decrease or to be greatly negative continuously; the key issue is that for such tacit action or collusion of the power plants, there is no correspondingly handling measure in mechanism for the current management method of the balance account. Focusing on this problem, based on the incentive compatible principle, the paper proposes the following new management method for the balance account:

Set the upper, the lower limit of balance account is $B_{\max}$, $B_{\min}$,respectively, and $B_{\min} \geq 0$.

When the fund at the balance account B is $B>0$ and $B > B_{\max}$, all power supplies could bid at reasonable prices and power supplies should be given some rewards; when the market clearing price is much higher than the benchmark price and $B < B_{\min}$,even $B<0$, some power suppliers are making use of their market power and have gained the great amount profit, so they should be penalized. In the uniform pricing strategy, the payment of the power supplies is Γ:

$$\Gamma = \lambda P_i \qquad (1)$$

Where λ is the market clearing price; P_i is the power supply of generator i

The reward or penalty of the power supplies τ_i is :

$$\tau_i = \alpha(\lambda - MC_i(P_i))P_i \qquad (2)$$

Where α is the reward-punishment coefficient, the choice method for the α is as follows:

(1) if $B < 0$ and $B < B_{\min}$,set $\alpha > 0$; after several rounds of bidding and $0 < B \leq B_{\max}$,set α =0;

(2) if $B > B_{\max}$,set $\alpha < 0$; after several rounds of bidding and $0 \leq B < B_{\max}$,set α = 0;

$MC_i(P_i)$ in equation (2) is the average marginal cost for one type of generators; it is assumed that, for the same type of generator, the average marginal cost is public information; it should be noted that the average marginal cost of each type of generators is well known for the market participants and the dispatch center, especially for the changing stage of power market like our country.

The above control strategy is to inhibit the effect of market power of power suppliers, and to encourage them to bid based on their costs. It could be seen that from Equation (2), whether to award or punish power plants is dependent on the difference between marginal price and average marginal cost; when the balance account is seriously deficit, which is resulted from the fact that the market clearing price is much higher than the marginal price, the power supplies should take corresponding penalties; when the balance account is surplus, the power supplies should be awarded according to the difference between marginal price and average marginal cost, which aims to encourage the companies to bid for the generation output based on their marginal cost.

In the uniform pricing condition with balance accounts, the objective for the participations is also how to gain as much as possible profits with the reasonable constraints.

Assume that generators number is n, the generation cost $C_i(P_i)$ for each generator is conic, that is:

$$C_i(P_i) = c_i + b_i P_i + a_i P_i^2 \qquad (3)$$

Where p_i is the output of the generator i.

The income π of the power supplies under the reward-punishment strategy is:

$$\pi_i(P_i) = \lambda P_i - \tau_i - C_i(P_i) \qquad (4)$$

Assume that the bidding curve of generator I is :

$$\lambda_i(P_i) = u_i + v_i P_i \qquad (5)$$

Where u_i and v_i are the bidding coefficients, and they are both above zero.

To maximize the profit of Power companies, it should meet conditions:

$$\frac{\partial \pi_i}{\partial P_i} = 0$$

that is:

$$(\lambda P_i - \alpha(\lambda - MC_i(P_i))P_i - a_i P_i^2 - b_i P_i - c_i)' \mid p_i = 0 \qquad (6)$$

To manipulate the above formula and gain that:

$$(1-\alpha)\lambda - (1-\alpha)\frac{\partial \lambda}{\partial P_i} P_i - 2a_i P_i - b_i + 4a_i P_i + \alpha b_i = 0 \qquad (7)$$

If only the system's load balance is considered, and the power grid security constraints are neglected, the market clearing price is calculated by solving the following linear equations:

$$\begin{cases} u_i + v_i P_i = \lambda \qquad i = 1, 2, \cdots, n \\ \sum_{i=1}^{n} P_i = P_T \end{cases} \qquad (8)$$

And the market clearing price λ and generation output P_i of generator i, is gained as follows, respectively,

$$\lambda = (P_T + \sum_{j \neq i} \frac{u_j}{v_j} + \frac{u_i}{v_i}) / (\sum_{j \neq i} \frac{1}{v_j} + \frac{1}{v_i}) \qquad (9)$$

$$P_i = \frac{\lambda - u_i}{v_i} \qquad (10)$$

To put the formula (9),(10) into formula (7) and gain:

$$(1-\alpha)\lambda - (1-\alpha)P_i/(\sum_{j\neq i} 1/v_j) - (2a_i - 4a_i\alpha) - (1-\alpha)b_i = 0 \qquad (11)$$

To simply formula (11) further and get:

$$\lambda = (1-\alpha)b_i + (2a_i\frac{1-2\alpha}{1-\alpha} + \frac{1}{T_2})P_i \qquad (12)$$

After comparing formula (5) with formula (12), the optimal bidding curve for power generation companies taking into account of reward and punishment approach of the balance account could be achieved by solving the following nonlinear equation group:

$$\begin{cases} u_i = (1-\alpha)b_i \\ v_i = 2a_i\frac{1-2\alpha}{1-\alpha} + 1/(\sum_{j\neq i} 1/v_j) \end{cases} \qquad (13)$$

IV. The sample analysis

The three-machine system is taken as an example to demonstrate the change of balance fund for optimal bidding strategy with or without reward-punishment in balance account. The parameters of the generators are listed in table 1.

TABLE 1 .THE PARAMETERS OF THREE GENERATORS SYSTEM

NUM	a_i	b_i	c_i	P_{imin}(MW)	P_{imam}(MW)
1	2.5	200	1000	15	200
2	2	100	1000	10	100
3	1	110	1000	30	300

To facilitate the explanation, assuming that: the load demand for each time bidding is all the same 300 MW, the upper limit and the lower limit of the balance fund is $B_{\max} = 75000$, $B_{\min} = 0$, respectively; when $B < 0$, α =0.15;when $B > 0$, α =-0.05.

The fluctuation of the balance fund with or without reward -punishment approach for many rounds of competitive bidding is calculated as follows:

The change of the balance capital of the optimal bidding without reward-punishment is shown at Table 2; and its curve is presented at Fig. 1.

The changes of balanced capital for optimal bidding with reward-punishment: initial balance account fund -30000 and 100000, are shown at Table 3, 4 respectively; and its curves are presented at Fig.2.

The curves of market clearing price with and without reward-punishment of balance account are shown at Fig.3

TABLE2: THE CHANGE OF THE BALANCE CAPITAL OF THE OPTIMAL BIDDING STRATEGY WITHOUT REWARD-PUNISHMENT

Round of bidding	P_1(MW)	P_2 (MW)	P_3 (MW)	λ (RMB)	The fund at balance
0					-30000
1	62.10	95.86	142	551.9	-45570
2	62.10	95.86	142	551.9	-61140
3	62.10	95.86	142	551.9	-76710
4	62.10	95.86	142	551.9	-92280
5	62.10	95.86	142	551.9	-107850

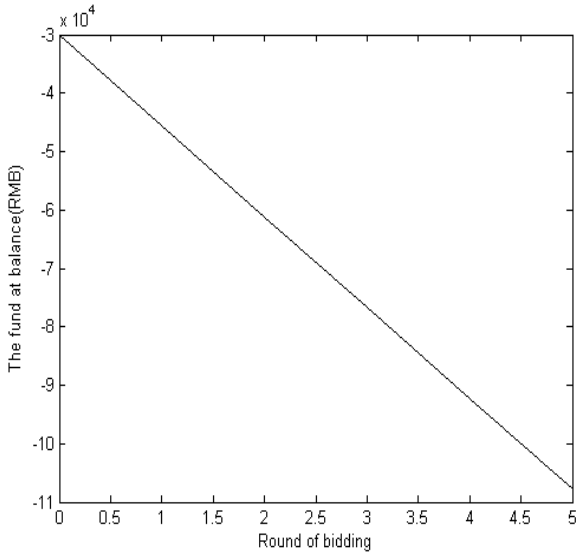

Fig 1 The curve of the change of the balanced capital without reward-punishment

TABLE 3 THE CHANGE OF THE BALANCED CAPITAL FOR OPTIMAL BIDDING WITH REWARD-PUNISHMENT (INITIAL BALANCE ACCOUNT FUND -30000RMB)

Round of bidding	P_1 (MW)	P_2 (MW)	P_3 (MW)	λ (RMB)	The fund at balance
0					-30000
1	61.5	93.6	144.9	471.22	-20190.5
2	61.5	93.6	144.9	471.22	-10381
3	61.5	93.6	144.9	471.22	-571.5
4	61.5	93.6	144.9	471.22	9238
5	62.10	95.86	142	551.9	-6332
6	61.5	93.6	144.9	471.22	3477.5
7	62.10	95.86	142	551.9	-12092.5
8	61.5	93.6	144.9	471.22	-2283
9	61.5	93.6	144.9	471.22	7526.5
10	62.10	95.86	142	551.9	-8043.5
11	61.5	93.6	144.9	471.22	1766

TABLE 4: THE CHANGE OF BALANCED CAPITAL FOR OPTIMAL BIDDING WITH REWARD-PUNISHMENT (INITIAL BALANCE ACCOUNT FUND 100000)

Round of	P_1 (MW)	P_2 (MW)	P_3 (MW)	λ (RMB)	The fund at balance
0					100000
1	58.48	89.17	152.34	564.14	78931.09
2	58.48	89.17	152.34	564.14	57862.18
3	62.10	95.86	142	551.9	42292.18
4	62.10	95.86	142	551.9	26722.18
5	62.10	95.86	142	551.9	11152.18
6	62.10	95.86	142	551.9	-4417.82
7	61.5	93.6	144.9	471.22	5391.68
8	62.10	95.86	142	551.9	-10178.32
9	61.5	93.6	144.9	471.22	-368.82
10	61.5	93.6	144.9	471.22	9440．68
11	62.10	95.86	142	551.9	-6129.32
12	61.5	93.6	144.9	471.22	3680.18

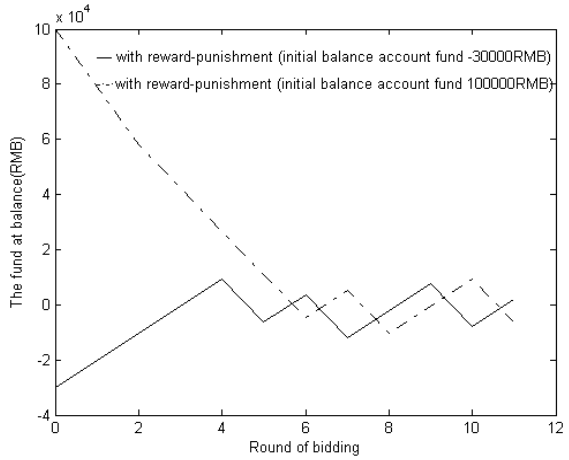

Fig 2 The curves of the change of balanced capital for optimal bidding with reward-punishment

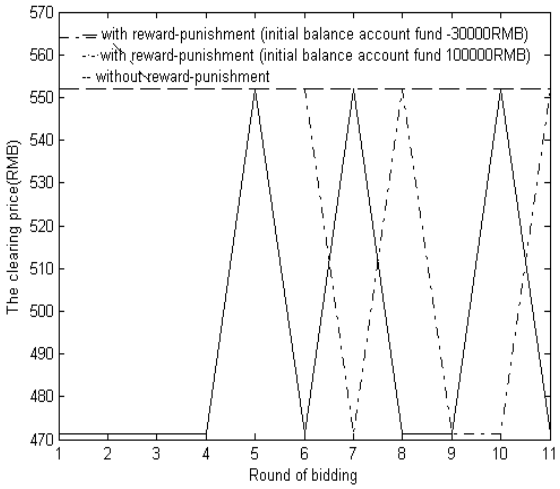

Fig 3 The curves of marginal clearing price with and without reward-punishment

From the change of balance fund at balance account in above tables and the curves at the Fig. 1,2,3, it could be seen that without reward-punishment for the balance account, the market clearing price is raised quite high, and the fund at the balance account declines sharply, and it can even be greatly negative, which results in the dramatic shortfall of balance account and the inability of the power market to continue operating. While bidding on the optimal strategy with reward-punishment and the initial balance funds being negative, the reward and punishment coefficient α is selected to be positive, which means to punish the power supplies and lower the market clearing price, the fund of balance account changes from negative to positive after several rounds of bidding; when the initial balance funds is over the upper limit, the reward and punishment coefficient α is selected to be negative, which means to reward the power companies for their bidding based on the cost, part of the fund of balance account is used for rewarding power plants. The above situation is repeated and the funds of the balance account are ensured to change between the upper and lower limits, avoiding to be in continuously large negative or positive; therefore, the security, reliability and durative of the operation of power market at the current stage of our country could be achieved. The curves of marginal clearing price at Fig 3 make it clear that the market clearing price with the reward-punishment approach is much lower than that without the approach for most cases, which at some extent restrains the effect of the market power of the main power supplies, and even their tacit action and collusion.

V. CONCLUDING

In the unilateral open electricity market, based on the principle of incentive compatibility, reward-punishment measure is introduced into the management of balance account in the paper. In this new management approach, to award or punish power supplies according to surplus or shortfall of the balance account, and an optimal bidding strategy with the reward-punishment in the balance account management is also established. This new method could significantly inhibit market power, the tacit action and

collusion of generation companies, and keep the change of the funds of balance account between the lower limit and upper limit and avoid the balance account to be continuously deficit; therefore, the security, reliability and durative of the unilateral open generation market is ensured.

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