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The Research about the Trans-provincial Centralized Bidding Trading Market of East China Power Grid --I: Empirical Analysis

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Abstract

The clearing price and bidding price in electricity market are two key indicators to measure whether it is reasonable or not. Based on the grey incidence analysis, this paper studies the correlation coefficient between the clearing price and bidding price with the generation cost, the supervision and rules of the market, the supply and demand situation, the behavior of market members over the same period, which is based on the actual data of the trans-provincial centralized trading market of East China Power Grid. The results show that the factors affecting the clearing price and bidding price from largest to smallest are generation cost, supervision and rules of the market, the supply and demand situation, the behavior of market members. The conclusion is that the trans-provincial trading platform of East China Power Grid is a reasonable regional market which can discover the market cost, and regulate the market supply and demand balance, and promote healthy competition.

Keywords: East China Power Grid; Trans-provincial Centralized Bidding Trading; Clearing Price; Bidding Price; Grey Incidence Analysis

1. Introduction

In China, the split of power plants and power grids had been completed in 2002[1]-[4], but the electricity market has not been established. In this case, each unit was allocated a certain amount of generating energy during the next year according to the installed capacity of the unit, the unit type and the forecasting load. Then, the power system operation schedules the unit output to meet the actual load and guarantees annual generating energy of the unit equal to the value to be assigned. And electricity is purchased by the grid company with the benchmark price that is validated by the National Development and Reform Commission. This approach is similar to the cost-based economic dispatch, which is called as planned generation in China.

Even so, there is still some effort to adjust power schemes using market competition in China's power industry, the Trans-provincial Centralized Bidding Trading Market of East China Power Grid（TPMECPG） is one of these efforts[5]. East China Power Grid is an interconnected grid, which contains five provinces, and each province is a control zone. Each provincial power grid company is responsible for its own electricity and power balance. But, in order to meet the load demand, about 1% of the total energy needs to be exchanged between these provinces. The TPMECPG is an electricity auction, and its purpose is to form energy exchange programs between provinces.

The market continues to run two and a half years from December 2008 to June 2011.The market prices have been lower than the audited benchmark price of the government. Coal prices rose too fast, the government requires that all wholesale electricity prices must be the benchmark price, the market pause run.

The market shows some interesting phenomenon. For example, the price has been rising from the second half of 2010; however, it has been lower than the government's benchmark price. Even so, the generation companies are still willing to participate in the market competition. What is the true power of electricity price fluctuations? It is because of the market power of generation companies or rising costs? Why power generation companies are willing to participate in market competition, even if the market price is lower than the benchmark price?

This paper is one of the two-part series. This article uses the grey incidence analysis method, based on actual data, to study the correlation coefficient between the clearing price and bidding price with the generation cost, the supervision and rules of the market, the supply and demand situation, the behavior of market members. Another paper explains the cause of the result of the operation of the market.

2. Brief Introduction of the Market

The TPMECPG adopts the two-sides-bidding method and the none-united-clearing method. The doubt is that in this kind of electricity market the clearing price can correctly reflect the cost and the supply and demand situation or not.

The buyers are the provinces that lack electricity in East China region, while the sales are generators that have a surplus of generating capacity [6]. The two sides bid for buying (sale) electricity amount and price, and the traded power will be assigned to each hour on average in the next month. The workflow of the TPMECPG is shown below in figure 1.

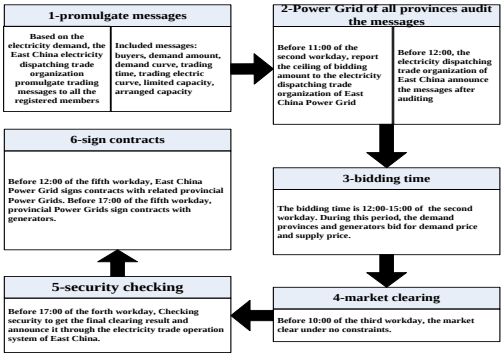

Fig.1 workflow of the TPMECPG

The market clearing mechanism adopts match-clearing mechanism which matches the largest demand bidding price to the smallest supply bidding price, and the clearing price is half of the sum of demand price and supply price except the transmission fee of provincial power grid and trans-provincial trading loss. Figure 2 shows the clearing procedure.

In figure 2, the dashed line divides the trading blocks, and the clearing price is average price of demand and supply side. As trans-provincial trading, the transmission fee and loss must be considered. If the difference between demand price and supply price is less than transmission fee and loss compensation fee, the deal will be cancelled.

The transmission fee and loss compensation fee belongs to demand-side power grid, while the trans-provincial transmission fee and loss compensation fee belongs to the East China Power Grid. The loss compensation fee is 1% of benchmark price, and the transmission fee is the difference between demand price and supply price in principle. But if the sum of transmission fee and loss compensation fee is more than 0.03￥/KWh, then the transmission fee is 0.03￥/KWh.

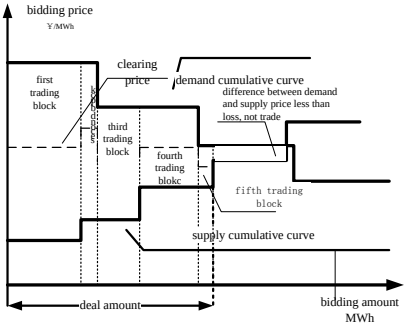

Fig.2 clearing price in the TPMECPG

That is, the sellers' settlement tariffs of accepted quantity is:

$$\rho_{sell} = \frac{1}{2}\left(\rho_{sell}^{bid} + \rho_{buy}^{bid} - \rho_{HD,loss} - \rho_{sell,transmision}\right) \quad (1)$$

Where ρ_{sell}^{bid} denotes the ask price of sellers in the matchmaking, ρ_{buy}^{bid} denotes the bid price of buyers in the matchmaking, $\rho_{sell,loss}, \rho_{HD,loss}$ denote the transmission net loss of power suppliers and the East China Power Grid respectively, which can be calculated as

$$\rho_{sell,loss} = \rho_{HD,loss} = B_{buyer} \times 1\% \quad (2)$$

Where B_{buyer} denotes benchmarking price of power-demand province.

The buyers' settlement tariffs of accepted quantity is

$$\rho_{buy} = \rho_{sell} + \rho_{HD,loss} + \rho_{sell,transimission} \quad (3)$$

Where the transmission payment can be calculated as follows:

$$\rho_{sell,transmision} = \rho_{buy}^{bid} - \rho_{sell}^{bid} - \rho_{HD,loss} - \rho_{sell,loss} \quad (4)$$

Where $\rho_{sell,transmission}$ denotes the payment of trans-provincial transaction with an upper limitation constrain of 0.03 ￥/KWh.

The traded amount of electricity in this trans-provincial centralized bidding platform increases year by year, from 1282 million KWh in 2009 to 3926 million KWh in 2010, and 2200 million KWh in first half of 2011. The average price is shown in Figure 3 where the abscissa represents the 15 trades from Jan. of 2010 to Jun. of 2011, and the ordinate represents the average clearing price. It can be seen from figure 3 that the average price changes over time, and the average price in 2010 is relatively lower while the average price in 2011 is relatively higher. What makes the price fluctuations? The paper utilizes grey incidence analysis method to have empirical analysis for this problem.

Fig.3 average clearing price of the TPMECPG

3. Grey Incidence Analysis

The grey incidence analysis [7] was first mentioned by Professor Deng Julong in the 1980s. This method measures the correlation degree of different factors based on the similar or different degree of its inside factors. And this method avoids the shortage of statistics, for example, the regression analysis method and the variance analysis method. Whether the sample data is more or less or whether the sample data has law or not, this method can get perfect results [8].

The paper makes the price sequence as referential sequence, and chooses generation cost sequence, benchmark price sequence, supply and demand situation sequence and market power sequence as contrasting sequences. Through comparison of grey incidence sort of these contrasting sequences, we can elect the most influential factor of all the factors.

3.1. Grey Incidence Factors of Clearing Price

1). ***Generation Cost***

The coal cost is the main operation cost of coal units. Generally, 70% of generation cost of coal units is coal cost. In the paper, the coal price is utilized to represent the generation cost. Generally speaking, the coal price of different generators is different because of different transmission fee. But grey incidence analysis cares more about the dynamic changes of the data, though different generators indifferent provinces have different coal price, but the change trend is the same. So, this paper uses the price of high-quality-mixed-coal in Shanxi province to represent coal price.

2). ***Benchmark Price***

In the trans-provincial centralized bidding trading platform, 99% of electricity is on grid through schedule, and the on grid price is the benchmark price of corresponding province; this is actually different from the situation of full electricity competition. So, it becomes an important item that if the clearing price is influenced by the benchmark price.

3) ***Supply and Demand Situation***

In East China region, some provinces have extra electricity, while others are lack of electricity. The electricity surplus and deficiency is defined below: it equals the integrated adjustable capacity minus the reserve capacity and the maximum demand. If it is negative, it means this province is short of electricity, so it has to buy some from other provinces, and conversely vice versa.

In East China region, the provinces that have to buy electricity are Jiangsu province and Zhejiang province, while the provinces that can sale electricity are Anhui province and Fujian province. So, when considering the electricity surplus and deficiency, we only consider these four provinces.

4). ***Market Member Behavior***

The behavior of market members is a key factor in electricity market. The strategic behavior of market members is hard to describe. Overall, the main indicator of market power is HHI (Herfindahl-Hirschman Index) [9], it is a integrating index of measuring the monopolistic degree of a certain industry. The HHI is sum of the square of the percentage of profit for all competitors in this industry. A bigger HHI means a higher monopolistic degree and bigger market power.

The trans-provincial centralized bidding market is an electricity market beside the planned generation; it's not fit to use the unit capacity as HHI indictor. In the paper, the amount of bidding electricity is utilized.

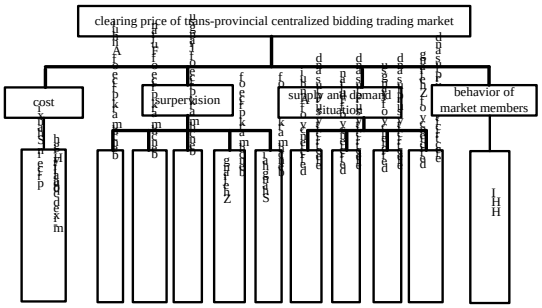

Fig.4 relationships of the correlation factors of the clearing price

Figure 4 shows the relationships of the correlation factors of the clearing price.

3.2. Calculation Steps of Grey Incidence Analysis Method

1). Definition of Grey Incidence

$X_0 = (x_0(1), x_0(2), ..., x_0(n))$ is the referential sequence, for example, the clearing price or bidding price, and n means that the sequence has n numbers. And there are

m correlation factors, $X_i = (x_i(1), x_i(2), ..., x_i(n),), i = 1, 2, ..., m$, which also named contrasting sequences.

Then the grey incidence of the k-th data of X_i and X_0 is defined as below:

$$\xi(x_0(k), x_i(k)) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \times \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \times \max_i \max_k |x_0(k) - x_i(k)|} \quad (1)$$

ρ is the differential coefficient, and $\rho \in [0,1]$. In the paper, $\rho = 0.5$.

The grey incidence of X_i and X_0 is defined below:

$$\gamma(X_0, X_i) = \frac{1}{n} \sum_{k=1}^{n} \xi(x_0(k), x_i(k)) \quad (2)$$

Usually, $\gamma(X_0, X_i)$ is also written as γ_{0i}, and $\xi(x_0(k), x_i(k))$ is also written as ξ_{0i}.

2). Calculation Steps

Step 1: Unitary operation for all data. That is, every data in a certain sequence is divided by the maximum data of this sequence.

$$X_i' = X_i / X_i^{\max} = (x_i'(1), x_i'(2), ..., x_i'(n)); i = 0, 1, 2, ..., m \quad (3)$$

$X_i^{\max}$ is the maximum data of X_i.

Step 2: get the difference sequences. The m contrasting sequences minus the referential sequence to get the difference sequences.

$$\Delta_i(k) = | x_0'(k) - x_i'(k) |$$
$$\Delta_i = (\Delta_i(1), \Delta_i(2), ..., \Delta_i(n)); i = 1, 2, ..., m \quad (4)$$

Step 3: get the maximum and minimum difference.

$$Max = \max_i \max_k \Delta_i(k) \quad (5)$$

$$Min = \min_i \min_k \Delta_i(k) \quad (6)$$

Step 4: get the incidence coefficient. According to (1), (5) and (6)

$$\xi_{0i}(k) = \frac{Min + 0.5 \times Max}{\Delta_i(k) + 0.5 \times Max}; k = 1, 2, ..., n; i = 1, 2, ..., m \quad (7)$$

Step 5: get the grey incidence. According to (2) and (6)

$$\gamma_{0i} = \frac{1}{n} \sum_{k=1}^{n} \xi_{0i}(k); i = 1, 2, ..., m \quad (8)$$

3). Data Initialization

Before calculating the grey incidence, there must be initialization to getting rid of the data.

a) Some sequences may be much bigger than the others, it's necessary to have unitary operation before calculation. In the paper, all the data in a certain sequence is divided by the maximum value of this sequence.

b) Due to the use of absolute value of difference between referential sequence and contrasting sequence in definition of grey incidence, it must guarantee that if the contrasting sequence becomes bigger, the referential sequence must also become bigger, and this is called positive operation. The details are shown as below.

Higher coal price turns to higher clearing price, and higher benchmark price turns to higher clearing price, so, they have already met the positive relationship. Bigger electricity surplus and deficiency for generators in supply provinces means a more enough supply which results to a lower clearing price, it must have positive operation before calculating, so the reciprocal of electricity surplus and deficiency is used. The electricity surplus and deficiency in demand provinces is negative, if the absolute value of this negative value is bigger, then it means the demand amount is bigger, and then the

Tab.1 data of clearing price, bidding price, coal price, electricity surplus and deficiency and HHI

year	month	clearing price(￥/MWh)	bidding price (￥/MWh)	coal price (￥/ton)	electricity surplus and deficiency(10^4KWh)				HHI
					Zhejiang	Jiangsu	Anhui	Fujian	
2010	Jan.	387	-	795	-283.8	-91.0	72.0	84.0	0.212
	Mar.	325	299	679	-21.6	402.0	59.0	90.0	0.156
	Apr.(1)	321	311	684	-10.0	511.0	155.0	251.0	0.285
	Apr.(2)	311	277	684	-10.0	511.0	155.0	251.0	0.327
	May	337	233	745	97.2	319.0	150.0	269.0	0.102
	Jul.	383	370	748	-282.9	-179.0	87.0	390.0	0.170
	Aug.	382	370	725	-196.3	-194.0	82.0	311.0	0.153
	Dec.	382	375	789	-191.1	381.0	147.0	257.0	0.174
2011	Jan.	394	385	774	-258.0	-462.0	77.0	195.0	0.095
	Jan.-Feb.	396	-	775	-305.0	-566.0	97.0	334.0	0.250
	Feb.	390	373	765	-305.0	-566.0	97.0	334.0	0.103
	Mar.	396	385	761	-151.0	-613.0	9.0	99.0	0.098
	Apr.	412	-	780	-332.0	-163.0	88.0	97.0	0.167
	May	421	-	817	-181.0	-57.0	20.0	53.0	0.167
	Jun.	417	396	838	-9.0	-222.0	20.0	248.0	0.094

clearing price becomes higher. It has already met the positive relationship. Bigger HHI means higher centralized degree in the industry; the members have more opportunities to force up the clearing price. It has met the positive relationship.

3.3. Overall Design of Grey Incidence Analysis

In order to completely analyze the relationships between the price and the correlation factors, four groups of grey incidence calculation are designed as below:

1) The first group is the calculation based on the data of the 15 exchanges from 2010 to 2011. Figure 2 has shown changes of the clearing price. From these exchange data, we can analyze the grey incidence sort of correlation factors.

2) The second and third group are the calculations based on the data of 2010 and 2011. We can compare the grey incidence sort in the first three groups to make sure whether they are the same and whether they have robustness or not.

3) The fourth group is based on the data of a typical generator in Fujian province. The bidding price is chosen as referential sequence, and the benchmark price and electricity surplus and deficiency are that of Fujian province, while the coal price and HHI are the same as the data above. Based on these data, we can analyze the grey incidence sort between the bidding price and the four correlation factors. If the grey incidence sort in this group is similar to the three groups before, it means that this kind of sort has a considerable credibility.

4. Case Study

The original data is shown in table 1 and 2, using the method provided in part 3, we can get the grey incidence results shown in table 3 and 4.

Tab.2 changes of benchmark price of all provinces in East China region

Variable time	Shanghai	Jiangsu	Zhejiang	Anhui	Fujian
2009	456.8	430	457	398	414.3
2011.4.20	457.3	430	457	400	417.4
2011.6.1	457.3	430	457	418	417.4

According to the grey incidence results, we can know that:

1) The coal price has the highest grey incidence with the clearing price under any cases (table 3). Not only in the single calculations in 2010 and 2011, but also in the combine calculation in 2010 and 2011, it always show that the coal price has the highest grey incidence with the clearing price. And even more, in the fourth group, the coal price also has the highest grey incidence with the bidding price (table 4), this means that the generators bid price based on the cost.

2) From table 3, it can be seen that the second grey incidence factor is the benchmark price in all provinces. And there are three levels for the benchmark price, the first highest level is benchmark price in Anhui province, the second one is that of Fujian province, and the third one is that of other provinces. This kind of sort indicates that the trans-provincial centralized bidding trading platform was actually guided by the market supervision. During the observing period, the supply provinces are the Anhui Power to East and Fujian province while the demand provinces are Zhejiang province and Jiangsu province. Form the truth that the grey incidence of Fujian province and Anhui province are higher than others, it can conclude that the supervision of supply side is more powerful than that of demand side.

3) The third highest one is the electricity surplus and deficiency. As demand provinces, the electricity surplus and deficiency of Jiangsu and Zhejiang province are higher than that of others, which means that the trading amount is mainly depending on demand side, if there is a bigger demand, there will be a higher price.

4) The HHI indicator which represents the market power of generators ranks the last. This means that the strategy space of generators is very small; at least, it ranks behind the cost, benchmark price and supply and demand situation.

5) The grey incidence sort between the bidding price of generators and correlation factors is the same as that of clearing price, that is, the highest one is coal price, the second one is benchmark price, the third one is electricity surplus and deficiency, the last one is HHI. The volatility of bidding price is more active than clearing price, but the sort is the same, which means this kind of sort has a strong robustness.

5. Conclusion

Based on the grey incidence analysis, this paper studies the correlation coefficient between the clearing price and bidding price with the generation cost, the supervision and rules of the market, the supply and demand situation, the behavior of market members over the same period based on the actual data of the trans-provincial centralized trading market of East China Power Grid in 2010 and first half of 2011.

The paper designed four groups analysis to confirm the grey incidence sort of all the correlation factors. All the four groups show that the correlation factor with the highest grey incidence is coal price, and the second one is benchmark price, the third one is supply and demand situation, the last one is the HHI.

The conclusion is that this market is a reasonable regional market which can find the cost, and promote healthy competition.

Tab.3 grey incidence results of clearing price in 2010 and first half of 2011

correlation factors	all data		2010		2011	
	grey incidence	sort	grey incidence	sort	grey incidence	sort
high-quality-mixed coal price in Shanxi	0.93	1	0.92	1	0.96	1
benchmark price in Anhui	0.89	2	0.85	3-7	0.96	2
benchmark price in Fujian	0.85	3	0.85		0.93	3
benchmark price in Shanghai	0.84	4-6	0.85		0.92	4-6
benchmark price in Jiangsu	0.84		0.85		0.92	
benchmark price in Zhejiang	0.84		0.85		0.92	
electricity surplus and deficiency in Jiangsu	0.66	7	0.58	9-10	0.68	8
electricity surplus and deficiency in Zhejiang	0.65	8	0.58		0.71	7
electricity surplus and deficiency in Fujian	0.61	9	0.84	8	0.52	10
electricity surplus and deficiency in Anhui	0.59	10	0.88	2	0.47	11
HHI	0.56	11	0.47	11	0.56	9

Tab.4 grey incidence orders of bidding price of generators

correlation factors	all data		2010		2011	
	grey incidence	sort	grey incidence	grey incidence	sort	grey incidence
high-quality-mixed coal price in Shanxi	0.89	1	0.78	0.89	1	0.78
benchmark price in Fujian	0.83	2	0.71	0.83	2	0.71
electricity surplus and deficiency in Fujian	0.63	3	0.66	0.63	3	0.66
HHI	0.58	4	0.47	0.58	4	0.47

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