Generation rights model based on time-division clearing theory

Daoqiang Li 1, Yu Sun 1, Guodong Li 2, Shi Tian 3, * and Xiaochun Zhang 3

1 Zhejiang power exchange center company LTD, Zhejiang, China
2 State Grid Corporation of China, Beijing, China
3 North China Electric Power University, Beijing, China

*Corresponding author e-mail: koryce@163.com

Abstract. China's renewable resources have the characteristics of reverse distribution, under the background of large-scale development of renewable energy consumption, we should break the existing administrative regional barriers of renewable energy electricity consumption across provinces. In order to accelerate the promotion of renewable energy consumption liability mechanism, an effective curve declaration and clearance model should be proposed. Based on the theory of time-division clearing, this paper makes some improvements in declaration and clearing. Two models are proposed, namely the time-division declaration model and the proportional declaration model. In addition, two clearing methods under different curve declaration decomposition methods are proposed, namely time-division matching clearing method and marginal clearing method. Based on the above theory, the organization methods of power grid and power right transferor and transferee are proposed to promote the optimization of power supply structure and the consumption of renewable energy.

Keywords: Renewable energy consumption; Time-division clearing; Generation rights model.

1. Introduction

At present, expanding inter-provincial trading of power generation rights is the key idea to solve the problems such as high abandon wind and light rate and the inability to complete the contracted electricity in some regions.

The common trading modes of inter-provincial power generation rights mainly include the following four types: centralized matching mode, bilateral trading mode, option trading mode and principal-agent mode. Literature [1] focuses on the trans-provincial and trans-regional trading mechanism of power generation rights, designs reasonable trading bidding mechanism according to different regional market models, and puts forward policy suggestions for promoting fair and reasonable trading and promoting market-oriented reform. Literature [2] analyzes and compares the advantages and disadvantages of the existing trading models of power generation rights, constructs a social benefit maximization model that includes network loss cost, and puts forward an improved centralized matching trading model suitable for medium and long-term trading. In the study of centralized bidding trading mode, literature [3] proposes for the first time the power storage mode that can stimulate market competition, and proposes
the pricing mechanism of centralized bidding. Literature [4] introduces the bilateral market bidding mechanism into the electricity market. This mechanism is based on the agency model, and its core idea is to "match the price of high and low" between buyers and sellers. However, the study only considers the unit price of declared electricity, which is far from the actual situation of the electricity market. Literature [5] designs centralized bidding trading rules based on declared price clearing according to local market structure characteristics, and compares and analyzes with common unified price clearing rules at home and abroad, and establishes a monthly centralized bidding trading model applicable to local actual conditions.

This paper proposes improvement methods from three aspects of power declaration, trading settlement and clearing of trading subjects, aiming to promote more flexible generation rights trading and the realization of renewable power consumption guarantee mechanism through the construction of new mode.

2. Centralized Bidding for Power Generation Rights

In the centralized bidding mode of power generation rights based on the decoupling of buyer and seller, the buyers and sellers of power generation rights shall clear the transaction in accordance with the previously provided time period, declare the power, price and other information with the clearing rules of the trading center, forming a contract between the seller and the provincial company or the buyer and the provincial company. In the trading, the buyer and the seller directly trade with the provincial company, which greatly improves the trading efficiency, rather than match one by one [6].

Centralized bidding trading mainly includes information announcement, contract signing and filing, security review, price adjustment, etc. The general steps are as follows:

1. Information Announcement. The trading subject that meets the conditions can publicize the quantity, price and contact information required by bilateral trading on the power trading platform. If the trading is an annual bilateral negotiation trading, then the quantity and price shall be specified in a month.

2. Electricity Declaration. The transferor and transferee declare the trading data according to the requirements of the trading announcement, such as power quantity, power price, etc. The specific parameters to be declared are subject to the trading announcement.

3. Preliminary Trading Contract. After the trading subject of power generation rights negotiates and determines the trading quantity and price, the trading center clears the electricity according to the trading rules.

4. Safety Check. Based on the actual operation of the power grid, the CGTC conducts security check on the unbound trading results and returns the security check results to the Beijing power trading center.

5. Release of Trading Results. After the safety check is passed, the trading center will form the restricted trading results and publish them on the power trading platform.

6. Electricity Charge Settlement. After the transferee of the generation rights transmits the power to the grid where the transferor is located, the grid shall settle the electricity charges for both parties of the power right trading according to the response rules.

This paper aims at the three links of centralized bidding curve declaration, clearing and trading settlement of power generation rights, and improves the trading mode to promote the full consumption of renewable energy among provinces.

3. Curve Declaration

Centralized bidding for medium and long-term generation rights trading is mainly carried out by centralized declaration and unified clearing. The trading cycle of participating in spot trading of medium and long-term generation rights trading is divided into annual, quarterly, monthly and multi-day. Market subjects are required to declare trading information during the trading cycle. The trading information declared by both parties of the trading is the power price, while the power quantity is not reported. The specific power quantity is subject to the actual situation of the contract execution.
There are generally two forms of time period division in the process of reporting electricity prices by time period:

First, according to relevant national regulations, the peak hours are from 7:00 to 11:00 and from 19:00 to 23:00; the valley hours are from 23:00-7:00 on the second day; the flat hours are from 11:00 to 19:00. Every day is divided into three periods: peak hour, flat hour and valley hour, and 90 periods are formed every month.

Second, according to the historical data of actual electricity consumption in the province where the power generation rights transferor is located, it takes 30min or 15min as a cycle, and every 30min or 15min is a clearing period, so each operating day contains 48 or 96 clearing periods.

During the above power declaration period, the market subjects declare their respective power curves respectively, and each participant declares different power curves, according to the forecast curve of future output or future load curve. There are two ways to declare the proportion of electricity: The first way is for the power exchange center to uniformly determine the proportion of declared power according to the time period. As shown in Fig. 1, if the electric power trading center determines the electric power ratio as 1:3:2 in the three periods of peak, flat and valley, each participant shall declare the electric power according to this ratio, and the actual delivery shall be conducted according to 1:3:2 in the peak-flat-valley ratio, (The proportion of electric quantity declared can be 0).

The second way is to determine the proportion of trading subjects by themselves according to the division period, and the actual delivery is carried out according to the declared proportion. As shown in Fig. 2, in a certain trading, each trading subject declares the proportion of electricity according to the peak, flat and valley periods: the ratio of the trading subject 1 to the peak, flat and valley is 1:1:1, and the ratio of the trading subject 2 to the peak, flat and valley is 1:2:1.

In order to promote the optimized allocation of power resources and the consumption of clean energy in a larger scope, and to implement the national energy conservation and emission reduction strategy, thermal power and other conventional energy units should actively trade their power generation rights to wind, light and water and other clean energy units [7]. When clean energy units participate in the trading, the power declaration shall be made in the form of annually, quarterly, monthly and multi-daily trading in combination with the current status of the clean energy units.
Taking hydropower units' participation in the annual trading of power generation rights as an example, before the power declaration, the hydropower units determine the future surplus electricity months according to the predicted flood and drought periods. As the transferees of power generation rights, the hydropower units can report the power price and quality in the next month by the way of monthly electricity curve after the publication of the annual trading announcement of power generation rights through centralized bidding. The quoted price of power in each section shall not exceed the upper limit of the declared price. The declaration form for hydropower units is shown in Table. 1.

| Time         | Average power (MW) | Power price (yuan/MW) |
|--------------|--------------------|-----------------------|
| January      | 300                | 357.67                |
| February     | 400                | 367.3                 |
| March        | 475                | 334.55                |
| April        | 580                | 301.76                |
| May          | 710                | 267.19                |
| June         | 850                | 245.03                |
| July         | 970                | 236.20                |
| August       | 1100               | 228.43                |
| September    | 1280               | 200.00                |
| October      | 1150               | 244.50                |
| November     | 860                | 295.31                |
| December     | 550                | 320.49                |

Photovoltaic units can participate in the monthly trading of power generation rights. Before the power declaration, the photovoltaic units predict the next month's volts of power generation, and determine the next month's surplus generation period. As the transferees of the power generation rights, the photovoltaic units report the electricity price and power in the trading cycle according to the peak, flat and valley in the forms of power curve after the announcements of the next month's trading of the power generation rights by centralized bidding. The quoted price of electricity in each section shall not exceed the upper limit of the declared price.

Wind turbines can participate in multi-day trading of power generation rights. In multi-day trading, the trading subject of power generation right only reports the trading price but not the power quantity in D-3 according to the three periods of peak, flat and valley. The trading price of power shall be the price of the subject matter of the centralized bidding trading of power generation rights, and the maximum and minimum prices shall be implemented according to the provisions.

Before the power declaration, the wind turbines predict the generation situation in the next few days and determine the generation surplus period in the next few days. As the transferees of power generation rights, the wind turbines report the power price and quantity of the next cycle through the power curve with a unit of 30minutes by centralized bidding after the announcement of multi-day trading of power generation rights [8].

4. Clear by Time

The market price of power generation rights trading is cleared by the trading platform according to the method stipulated in the detailed rules of power trading. Similar to the electricity price declaration method, there are two ways to clear in batches. The first method, as shown in Fig. 3, is to divide daily into three periods of peak time, flat time and valley time according to the actual electricity consumption curve of the province where the power generation right transferor is located, forming 90 periods every month. The second method, as shown in Fig. 4, is to declare with a cycle of half an hour or 15 minutes according to the actual electricity consumption curve of the province where the power right transferor is located, and finally form 48 or 96 time periods every day. Then clear according to the matching clearing method or marginal clearing method.
4.1. Matching Clearing Method

The method of clearing the price of the competing trading after matching the declared prices of the two parties in the power generation rights trading is called the matching clearing method. After the deadline for declaration, the power trading agency shall convert the purchase price and sales price declared by the power generation company, power user, electricity sales company and power grid company, taking transmission and distribution prices (including network losses) and government funds and additional into account, to the transaction gate on the landing side in a unified manner to form a converted electricity buyer's quotation and electricity seller's quotation according to the transaction announcement[9].

Sort the converted power buyers' quotations from high to low; in principle, when the prices are the same, sort them in the order of “time priority”; when the above conditions are all the same, allocate the quantity of electricity traded in proportion to the declared quantity. The details are subject to the trading announcement. The converted electricity supplier's quotations are sorted from low to high; when the prices are the same, they are sorted in the order of "renewable energy first, energy conservation and environmental protection first, time first"; when the above conditions are all the same, allocate the quantity of electricity traded in proportion to the declared quantity.

Subsequently subtract the converted electricity buyer's quotation and electricity seller's quotation in order to form a price difference pair $P'_\Delta$.

$$P'_\Delta = P_{bq} - P_{sq}$$

Among them, $P_{bq}$ is the converted power buyer's quotation while $P_{sq}$ is the converted power seller's quotation.

4.2. Marginal Clearing Method

The determination method of marginal electricity price is as follows:

(1) There is an intersection between the power generation rights transferor's declaration curve and the power generation rights transferee's declaration curve, and the price corresponding to the intersection point is the marginal clearing price. The time-share quantity of electricity declared by the power generating right transferee after the price quoted by the transferee of the power generating right is lower than the marginal clearing price and the power generating right transferee after the price quoted by the transferee of the power generating right is higher than the marginal clearing price. If the quantity

\[\text{Figure 3. Schematic diagram of clearing by peak-flat-valley time.}\]

\[\text{Figure 4. Schematic diagram of clearing by time with 15min as a period.}\]
declared by the transferor of the power generation right equal to the marginal clearing price is not the same as the quantity declared by the transferee of the power generation right, the transaction shall be made according to the smaller quantity declared at the time.

(2) When there is no crossover between the power generation rights transferor's declaration curve and the power generation rights transferee's declaration curve, and the converted power generation rights transferor's quotation curve is larger than the power generation rights transferee's quotation curve, the total amount of electricity quantity by period is the smaller of the total amount of electricity declared by the power generation right transferor and the power generation transferee corresponding to the power generation right transferor's declaration curve. At this point, the marginal clearing price is determined according to the difference coefficient \( k \) between the price quoted by the transferor of power generation rights and the transferee of power generation rights.

(3) When there is no cross between the buyer's declaration curve and the seller's declaration curve and the quoted price of the buyer is always lower than the quoted price of the seller, there is no trading period of electricity quantity by time division.

When the buyer's quotation is always lower than the seller's quotation, there is the following relationship:

\[
D_{bdc}(P_0) < S_{sdc}(P_0)
\]  

The final electricity quantity by period \( Q_0 \) is:

\[
Q_0 = 0
\]  

After comprehensively considering the marginal clearing price and the conversion to the landing-side transaction mark, transmission and distribution prices (including network losses), government funds and surcharges, the final price of the power purchaser and the price of the power seller are finally formed [10].

5. Trading Settlement

The current settlement method of power generation rights trading is mainly that the substitute party directly pays the substituted party after the substituted party transfers the power generation rights to the substitute party, without the participation and supervision of a third party. In practice, the payment process is often in arrears after the transfer of power generation rights, which will definitely affect the enthusiasm of the substituted party to participate in the trading as the market subject in the long run and further affect the expansion of the power generation rights trading market, hindering the construction of the power generation rights trading market and the development of inter-provincial power generation rights trading.

5.1. Electricity Quantity Settlement of Power Generation Right

The power quantity calculated by the transferor and transferee of the power generation right is as follows:

(1) Electricity quantity settled by the transferor: Electricity quantity received by the power grid enterprise to which the transferor belongs.

(2) The settlement quantity between the power grid enterprise to which the transferor belongs: The results of the above power consumption after the actual line loss of each transmission link is converted as the settlement power of each party.

(3) Electricity quantity settled by the transferee: Combined with the actual line loss rate of the corresponding transmission line, the above power is converted into the power on the grid side of the transferee.
5.2. Electricity charge Settlement of Power Generation Right

As shown in Fig. 5, after the deadline of the declaration, the power trading agency will consider the transmission and distribution prices (including network losses), government funds and surcharges based on the transaction announcement, and uniformly convert the electricity purchase price declared by the power generation right transferor and the electricity sales price declared by the power generation right transferee to landing side trading gate, and eventually form a converted quotation for the power generation right transferor and a quotation for the power generation right transferee.

The price of the transferor of power generation rights after conversion is sorted from high to low and the declaration curve of the transferor of power generation rights is formed. In principle, when the price is the same, distribute the quantity of electricity in order of "time priority"; when the above conditions are all same, distribute trading power in equal proportion according to declared quantity. The details are subject to the trading announcement.

The price of the transferee of power generation rights after conversion is sorted from low to high and the declaration curve of the transferee of power generation rights is formed. In principle, when the price is the same, order according to the principle of "renewable energy priority, energy conservation and environmental protection priority (low energy consumption priority, the same below), time priority "; when the above conditions are all same, distribute trading power in equal proportion according to declared quantity.

The electricity charge settlement method of power generation rights is as follows:

1) The on-grid electricity price of the unit of the transferor is based on the price agreed in the trading contract between the original provinces.

2) The power grid enterprises of the transferee pay the electricity charge to the transferee according to the received electricity quantity and the trading price agreed between the transferee and the transferor. That is: The transferee's settlement electricity charge is equal to the product of the transferee's settlement electricity quantity and the trading price agreed between the transferee and the transferor.

3) The power grid enterprise to which the transferee belongs and the power transmission party at the next higher level settle the account according to the transfer price agreed by the transferee and the transferor.

4) The power transmission parties settle in accordance with the transmission price and line loss issued by the State Grid Corporation of China (including branches) on the power trading platform of the Beijing Power Trading Center.

5) The power grid company to which the transferor belongs is based on the transferor 's electricity trading and pays the transferee the electricity charge. That is: The electricity charge obtained by the transferor equals to the product of the amount of electricity settled by the transferor and the price of the transferor; the price of the transferor is the difference between the price agreed in the inter-provincial trading contract minus the trading price between the transferee and the transferor, the transmission price of each transmission party and the net loss discount.

6) The transferor bears the compensation fee for the power grid enterprise approved by the relevant government department, and pay the power grid enterprise for the loss compensation fee.

Figure 5. Schematic diagram of electricity charge settlement for the new model of power generation rights.
6. Conclusion

On the basis of the original centralized bidding trading of power generation rights, the paper improves its supporting links of trading declaration, clearing and electricity charge settlement. This paper first proposes two kinds of proportions of trading declaration to declare the trading power curve and corresponding electricity price: dividing by peak, flat and valley time and dividing by every 15min. Then, it proposes to match the clearing and marginal clearing in the clearing process according to the above two proportions. Third, in the trading settlement, it improves the way in which the original power generation transferor’s power grid pays the power generation transferee to the power generation company so that the power grid company directly pays the due electricity charges to both parties, which avoids the problem of late payment of electricity charge. The improvement of these links will further optimize the inter-provincial power generation rights market to adapt to the future spot market.

Acknowledgments

This work was supported by the project: Research on New Model and Supporting Technology of Inter-provincial Power Generation Market Promoting Power Structure Optimization. (5108-201919044A-0-0-00).

References

[1] Hao Cuitian. Study on Optimization Model of Different Bidding Mechanism in Power Market [D]. North China Electric Power University (Beijing), 2019.
[2] Huang Dawei, Liu Jianyan, Yang Chunyu, Sun Wensheng, Cai Guowei, Wang Jianyuan. Power Generation Rights Trading Model with Network Loss Cost [J]. Automation of Electric Power Systems, 2010, 34(05): 38-42.
[3] Daniel, S.K, Goran Starbac. Fundamentals of Power System Electronics, [M].
[4] Nicolaisen J, Petrov V, Tesfatsion L. Market Power and Efficiency in a Computational Electricity Market with Discriminatory Double-auction Pricing [J]. IEEE Transactions on Evolutionary Computation, 2002, 5(5): 504-523.
[5] Wang Ruichen, Zhang Maolin, Huang Songbo, Xing Yuhui, Liu Xiangrui, Chen Qinggui. Design of centralized bidding trading rules in Yunnan power market [J]. Yunnan Power Technology, 2017, 45(06): 115-119.
[6] Fan Jie, Yang Libing, Li Xiaogang, Zou Bin. Simulation analysis of inter-provincial centralized trading platform based on intelligent agent model [J]. Automation of Electric Power Systems, 2013, 37(09): 60-65.
[7] Shi Lianjun, Zhou Lin, Pang Bo, Yan Yu, Zhang Fan, Liu Jun. Market mechanism design ideas for promoting clean energy consumption in China [J]. Automation of Electric Power Systems, 2017, 41(24): 83-89.
[8] Zheng Xiangyu, Jia Rong, Wen Dong, Xu Hui, Guo Jun, Li Juan. Research on the new trading mode of trans-provincial and trans-regional power generation rights considering new energy consumption [J]. High Voltage Apparatus, 2017, 53(05): 121-126.
[9] He Yang, Huang Long, Chen Haoyong, Shang Jincheng, Li Peng, Liu Yumeng. Simulation analysis of centralized bidding market based on coevolutionary algorithm [J]. Zhejiang Electric Power, 2019, 38(07): 7-13.
[10] Wei Luo, Ying Cai, etc.: Day-ahead market clearing strategy in transaction to electricity spot market based on locational marginal price [J]. Electrotechnical Application, 2020, 39(03): 38-43.