Comparison of flexible bidding and hourly bidding in the electricity market

Hechun Wang¹, Gang Chen¹, Kun Fan¹, Kai Wang²ᵃ, Hua Li³, Zijun Guo², Dunnan Liu¹²,
¹Jiangxi Power Trading Center Co., Nanchang, China
²School of Information Engineering, Nanchang University, Nanchang, China
³School of economic and management, North China Electric Power University, Beijing, China
ᵃwk1994@email.ncu.edu.cn, ⁷92316208@qq.com

Abstract. Flexible bidding is an emerging electricity trading product in the Nordic spot market, which is different from hourly bidding and block bidding. It provides electricity generation enterprises and users with flexible and changeable electricity generation and consumption options and can reflect the electricity generation and demand-side behavior and habits of electricity generation and consumption, providing reference value for Chinese market participants to participate in the electricity market and demand-side response. This paper firstly introduces the two bidding models of hourly bidding and flexible block bidding; secondly, it introduces the market clearance model of flexible bidding; finally, it compares the differences between these two bidding approach.

1. Introduction
In August 2017, the Circular on the Pilot Work of Electricity Spot Market Construction¹ selected eight regions, including the South (starting with Guangdong), Mengxi, Zhejiang, Shanxi, Shandong, Fujian, Sichuan, and Gansu, as the first batch of electricity spot market reform pilots. As the pioneer of the exploration of China's electricity market construction, the eight pilot provinces of the market model selection, rule design, and bidding methods have provided an experience for the construction of electricity markets in other regions. At present, most provinces are still in long term electricity trading. A mature electricity market still has a long way to go, and it is necessary to strengthen the learning and reference of the practical experience of foreign spot markets.

Northern Europe is the relatively successful electricity market that was carried out earlier in the world [2]. The United Kingdom established an electricity market model based on a compulsory power pool in 1990 and later developed a trading model based on bilateral contracts. Northern Europe established the world's first relatively complete multinational electricity market and gradually expanded it. Compared with the traditional hourly bidding and block bidding, the flexible block trading varieties and bidding mechanism introduced in the Nordic electricity spot market can better reflect the trading willingness of market entities, meet their actual power generation needs, and stimulate the market the willingness to participate in the competition, promotes the efficient matching of power supply and demand.

[3] shows that hourly bidding promotes the allocation of resources in the electricity market, but it cannot reflect the output characteristics of generating units. On this basis, the concept of block bidding
is proposed. [4] simulates the electricity market of block bidding and analyzes its operating mechanism; [5][6] compares hourly and block bidding, discusses the feasibility of block bidding methods; [7] proposes an hourly and block joint bidding model, which is the basis Load with block bidding, fluctuating load with hourly bidding; [8] summarizes the "block bidding" model of the Nordic electricity spot market, introduces the market model of flexible block trading, and provides market entities with diverse and individual choices.

Based on [7] and [8], this paper introduces flexible hourly bidding and flexible block bidding (referred to as flexible bidding) for hourly bidding and block bidding, respectively. Firstly, it introduces the difference between flexible bidding and traditional bidding methods, and secondly, establishes a bidding model under flexible bidding methods. Finally, compare the difference between flexible bidding and traditional hourly bidding through calculation examples.

2. Flexible bidding and traditional bidding methods

2.1. Hourly bidding

Hourly bidding means that power generators bid for loads of each period (hours, half an hour) of the next day. The power trading center takes the minimum power purchase cost as the goal and determines the power generation of each generator in the order of quotation.

Hourly bidding is cleared by time, and its cleared electricity price can more sensitively track changes in load, provide market signals for market players, guide the electricity market players to adopt more scientific and reasonable electricity generation and consumption strategies according to load and price trends, and promote the reasonable distribution of supply and demand resources.

However, the hourly bidding mechanism of the hourly quotation has severed the intrinsic connection of the load in each period, which contradicts the characteristics of the continuous operation of generating units. The transaction of power generation enterprises and users lacks continuity and can only be financial contracts. When the generator sets are physically executed, it may encounter climbing constraints, which brings challenges to the start and stop of the generator set.

2.2. Block bidding

The blocking bidding load is auctioned at a level based on the time of continuous production or consumption, creating a clearing tariff for each continuous load segment.

Block bidding can better reflect the electricity generation characteristics of the generator sets. For traditional thermal generator sets, the longer the operating time of the generator set, the lower the electricity generation cost, but for renewables such as solar[9] and wind[10], the start/stop cost and the unit electricity generation cost[11] different.

Under the block bidding mechanism, horizontal sections are divided according to the load duration, the units in the same section operate similarly, and the electricity produced is homogeneous to a certain extent, so the uniform settlement of each section is in line with the fairness principle of the market. The bottom of the load curve has the largest load duration, and the higher the position, the shorter the load duration, the higher the production cost of the unit, and the higher the clearing price should be, so that the contribution of different units to the system can be distinguished. A Block quotation is a continuous feature of electric energy production. The quotation of each segment has a distinctive physical meaning and is easy to be physically executed so that it is convenient for electricity generation enterprises to reasonably arrange the operation mode, reflect the electricity generation characteristics of generating units, and reduce the number of starts and stops of units.

However, the division of load for block bidding is too complicated. For grid operators, the more of the number of blocks, the more refined the electricity supply and demand will be, which helps improve the fairness and efficiency of the market, but also presents new challenges for electricity trading institutions, metering, and settlement.
2.3. Flexible bidding
Flexible bidding includes three different types of trading varieties: hourly order, block order, and flexible order. Electricity generation market players can choose one or more of these to trade according to their actual electricity consumption characteristics.

Hourly trading, means market entities bidding for 24 hours of separate hourly trading intentions; block trading, means market entities bidding for more than 3h (up to 24 hours) of block trading intentions; and flexible trading means market entities allowed to bidding flexible hourly and flexible block trading based on hourly and block trading. For flexible hours, market entities bidding 1h of electricity and price, and the number of hourly blocks that can be accepted (only one of which can be won). Flexible block, similar to flexible hour bidding, where the market entity bidding a combination of block trades, but can only win one of them.

3. The clearing model of flexible bidding
It is assumed that the day-ahead market clearing takes the maximization of social welfare as the optimization goal, including four types of trading varieties: hourly trading, flexible hourly trading, block trading, and flexible block trading. The day-ahead market-clearing model is:

\[ F = \max \left( \sum (\omega_{b,t}^h Q_{b,t}^h \lambda_{b,t}^h + \omega_{b,t}^f Q_{b,t}^f \lambda_{b,t}^f + \omega_{b,t}^h Q_{b,t}^cb \lambda_{b,t}^{cb} + \omega_{b,t}^m Q_{b,t}^mb \lambda_{b,t}^{mb}) - \right) \]

\[ \sum (\omega_{s,t}^h Q_{s,t}^h \lambda_{s,t}^h + \omega_{s,t}^f Q_{s,t}^f \lambda_{s,t}^f + \omega_{s,t}^h Q_{s,t}^cb \lambda_{s,t}^{cb} + \omega_{s,t}^m Q_{s,t}^mb \lambda_{s,t}^{mb})) \]

where \( \omega_{b,t}^h, \omega_{b,t}^f, \omega_{b,t}^h, \omega_{b,t}^f, \omega_{s,t}^h, \omega_{s,t}^f, \omega_{s,t}^h, \omega_{s,t}^f \) are the 0-1 winning variables of the user side and the electricity generation side in hourly transactions, block transactions, flexible hours transactions and flexible blocks transactions; where 0 means unsuccessful and 1 means winning; hourly transactions can partially win the bid, and the winning variable is in [0,1];

\( Q_{b,t}^h, Q_{b,t}^f, Q_{b,t}^cb, Q_{b,t}^mb; Q_{s,t}^h, Q_{s,t}^f, Q_{s,t}^cb, Q_{s,t}^mb \)

are the bidding electric quantity for the user side and the electricity generation side in hourly transactions, block transactions, flexible hours, and flexible blocks; \( \lambda_{b,t}^h, \lambda_{b,t}^f, \lambda_{b,t}^{cb}, \lambda_{b,t}^{mb}; \lambda_{s,t}^h, \lambda_{s,t}^f, \lambda_{s,t}^{cb}, \lambda_{s,t}^{mb} \)

are the bidding price for the user side and the electricity generation side in hourly transactions, block transactions, flexible hours, and flexible blocks.

For the flexible bidding model, its constraints are as follows.

3.1. Electricity and electricity balance constraints
The total electricity purchased in each period is equal to the total electricity generation, namely:

\[ \sum (\omega_{b,t}^h Q_{b,t}^h + \omega_{b,t}^f Q_{b,t}^f + \omega_{b,t}^h Q_{b,t}^cb + \omega_{b,t}^m Q_{b,t}^mb) - \sum (\omega_{s,t}^h Q_{s,t}^h + \omega_{s,t}^f Q_{s,t}^f + \omega_{s,t}^h Q_{s,t}^cb + \omega_{s,t}^m Q_{s,t}^mb) = 0 \]

3.2. Price constraints
The lowest bid-winning quotation on the user side in each time should be higher than the highest bid-winning quotation on the power sales side, which can be expressed as:

\[ \min \{\omega_{b,t}^h \lambda_{b,t}^h, \omega_{b,t}^f \lambda_{b,t}^f, \omega_{b,t}^h \lambda_{b,t}^{cb}, \omega_{b,t}^m \lambda_{b,t}^{mb}\} \geq \max \{\omega_{s,t}^h \lambda_{s,t}^h, \omega_{s,t}^f \lambda_{s,t}^f, \omega_{s,t}^h \lambda_{s,t}^{cb}, \omega_{s,t}^m \lambda_{s,t}^{mb}\} \]

3.3. Hourly bidding constraints
When the hourly transaction price declared by the power generation side is lower than or equal to the market-clearing marginal price, the hourly transaction will win the bid; otherwise, the bid will not be won. At the same time, the hourly transactions are allowed to bid for part of the electricity.

\[ \omega_{b,t}^h \in [0,1], \quad \omega_{s,t}^h \in [0,1]\]
3.4 Flexible hour bidding constraints

Flexible hourly transactions can be declared for consecutive or discontinuous periods. The clearing period is not fixed, but it can only be cleared once at most. Therefore, the decision variables of flexible hour trading in each time are restricted as:

\[ \sum_{t=1}^{24} \omega_{h,t}^f \in \{0,1\} \quad \sum_{t=1}^{24} \omega_{s,t}^f \in \{0,1\} \]

3.5 Flexible blocks bidding constraints

Compared with the block transaction, the flexible block transaction introduces the flexible constraint of the flexible bid winning time-based on the block transaction, that is, the declared power of the bid block transaction is certain, and the bid winning period is not unique, but it can only win the bid once, which is expressed as:

\[ \sum_{l=1}^{n} \omega_{h,l}^{mb} \in \{0,1\} \quad \sum_{l=1}^{n} \omega_{s,l}^{mb} \in \{0,1\} \]

4. Analysis of actual calculation examples

This paper simulates the situation where 5 power purchase side and 5 power generation side market members participate in the spot market on a typical day. The bidding method adopts the principle of a two-way quotation, high-low matching, and unified marginal clearing. The spot transaction adopts hourly bidding and flexible bidding for simulation. The trading varieties of hourly bidding are hourly trading, and the trading varieties of flexible bidding include hourly bidding, flexible hourly bidding, block trading, and flexible block trading. See Appendix A the bidding options on the power purchase side and power generation side, and Appendix B for the market-clearing results. The Matlab and Cplex toolbox [12] is used to solve the problem.

4.1 Clearing results

Fig.1 shows the marginal electricity price and market clearing results in the 24 trading hours of the electricity market under Hourly bidding conditions.

![Fig.1 Hourly bidding clearing results](image)

Fig.2 shows the marginal electricity price and market clearing results in the 24 trading hours of the electricity market under flexible bidding conditions.

In the flexible trading results of the users, the user’s hourly transactions, block transactions, and flexible block transactions are cleared. Among them, hourly transactions are mostly cleared at peak loads, and the marginal clearing price provides market signals for market entities; In the flexible trading results of the generations, the hourly transaction, flexible transaction, and flexible hourly transaction of the generator are cleared. Among them, the block transaction is mostly cleared in the form of baseload, which avoids the processing adjustment and start-stop of the generators. The diversity of trading varieties provides market entities with multiple choices.
4.2. Comparison of clearing results

The average clearing electricity price for hourly transactions is 12.51MW/euro, and the average clearing electricity price for flexible transactions is 12.54MW/euro, the two clearing electricity prices are the same.

The total amount of the electricity in the hourly transaction was 2946MW, and the total amount of the electricity in the flexible transaction was 3116MW; the total transaction amount of the hourly transaction was 36855 euros, and the total transaction amount of the flexible transaction was 39088.5 euros.

5. Conclusion

Hourly bidding ignores the internal coupling of continuous electric energy production and cannot reflect the output characteristics of different units. Flexible bidding is a new bidding method. Compared with hourly bidding, flexible bidding has the following advantages:

(1) Respect the willingness of market entities. Inflexible block transactions, different block transactions have their physical characteristics in actual power transactions. Market entities can choose appropriate transaction varieties according to their characteristics to promote the maximization of benefits.
(2) Compared with hourly bidding, the amount of power and transaction volume of the flexible bidding has been increased, and the market-clearing price is the same as the hourly bidding price, which strengthens the liquidity of electricity trading and provides more choices for market entities.

(3) Promoting renewables investment and sending positive signals for renewables construction. Flexible bidding methods are more in line with the output characteristics of renewables units, provide more bidding options for renewables to participate in the electricity market, and help market entities participate in new energy investment.

Acknowledgments
This work was financially supported by the Electricity Market Mechanism Design Consulting Project to Adapt to Medium and Long-Term Convergence with Spot Trading of Jiangxi.

References
[1] The National Development and Reform Commission and the National Energy Administration issued the "Notice on Carrying out the Pilot Work for the Construction of Electric Spot Market" [J]. China Electric Power, 2017 (17): 4-4. (in Chinese)

[2] Bao Minglei, Ding Yi, Shao Changzheng, et al. A review of the Nordic electricity market and its experience for my country [J]. Proceedings of the Chinese Society of Electrical Engineering, 2017 (17): 4881-4892. (in Chinese)

[3] Wang Xifan. An electricity market with block bidding [J]. Proceedings of the Chinese Society for Electrical Engineering, 2001, 21 (12): 1-6. (in Chinese)

[4] Geng Jian, Wang Xifan, Chen Haoyong, et al. Simulation, analysis, and comparison of block bidding electricity market [J]. Journal of Xi'an Jiaotong University, 2003, 37 (10): 1043-1047. (in Chinese)

[5] Wang Xifan, Geng Jian. Comparison between block bidding and time-sharing bidding [J]. Automation of Electric Power Systems, 2003, 27 (7): 22-26. (in Chinese)

[6] Geng Jian, Wang Xifan, Ding Xiaoying, et al. Comparison of block bidding model and time-sharing bidding in electricity market [D], 2003. (in Chinese)

[7] Wang Jianxue, Zhang Chenggang, Wang Xiuli, et al. Hybrid bidding mode and its clearing algorithm on the electricity market [J]. Automation of Electric Power Systems, 2011, 35 (7): 28G33. (in Chinese)

[8] Zhang Xinyu, Chen Qixin, Ge Rui, etc. Electricity spot market-clearing model considering flexible block trading [J]. Automation of Electric Power Systems, 2017, 41 (24): 35-41. (in Chinese)

[9] Chi Xiukai. Research on Cost Control of Wind Power Enterprises [D]. North China Electric Power University, 2011. (in Chinese)

[10] Zhao Hang, Liu Guangbin, Guo Liyuan, et al. Analysis and prediction of solar power cost based on the learning curve [J]. Journal of Shanxi University of Finance and Economics, 2014 (S1): 89-90. (in Chinese)

[11] Zhang Wei, Wang Xiuli. Demand response strategy on the retail side based on block bidding [J]. Automation of Electric Power Systems, 2017 (14): 24-29. (in Chinese)

[12] Xiong Wentao, Yong Longquan. Integer programming model solution method based on the Yalmip toolbox [J]. Journal of Hubei Institute of Technology, 2014, 34 (003): P.41-45. (in Chinese)