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Article

Optimization model of monthly continuous bidding transaction in electricity market considering risk hedging

Genzhu Li[1,*], Xiaotong Zhang[1], Hanfu Wang[1], Qin Le[2], Jun Wang[2], Dunnan Liu[1]

[1] School of Economics and Management, North China Electric Power University, Beijing 102206, China
[2] State Grid Jiangxi Electric Power Co., Ltd, Nanchang 330077, China
*** Corresponding author:** Genzhu Li, lgz6869532@163.com

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Abstract: In order to further alleviate the problems of large assessment deviations, low efficiency of trading organisation and difficulties in system optimisation in medium- and long-term market trading, the article proposes an optimisation model for continuous intra-month bidding trading in the electricity market that takes into account risk hedging. Firstly, the current situation of market players' participation in medium and long-term trading is analysed; secondly, the impact of contract trading on reducing operational risks is analysed based on the application of hedging theory in the primary and secondary markets; finally, the continuous bidding trading mechanism is designed and its optimisation effect is verified. The proposed model helps to improve the efficiency of contract trading in the secondary market, maintain the stability of market players' returns and accelerate the formation of a unified, open, competitive and well-governed electricity market system.

Keywords: power markets; medium and long-term trading; risk hedging; rolling aggregation; centralised bidding

1. Introduction

The design of the trading mechanism of the electricity market is one of the cores of the market-oriented reform. It plays a decisive role in the distribution of benefits in the electricity market, and has a significant impact on ensuring market fairness and justice, ensuring power supply security, and promoting orderly market competition.

With the deepening of the reform of the electricity market, various trading entities in the market have put forward diversified trading demands for participating in the electricity market according to their own internal and external factors such as power generation and consumption characteristics and market environment changes, including flexible contract adjustment needs, price declaration needs, market organization needs, and balanced adjustment needs. It is urgent to study and design a diversified and standardized electricity market mechanism. The intra-month integrated continuous trading mechanism proposed in this paper, starting from China's national conditions, makes a more systematic, in-depth and detailed design of the intra-month trading mode, trading varieties and trading timing of the medium and long-term electricity market, so that the medium and long-term market can enter the continuous operation stage, ensure the orderly connection with the electricity spot market, and promote the construction of a new power system. It is worth further study and promotion to other provinces to guide the issuance and use of both sides to actively adjust the deviation and reduce the market balance funds through mechanism design.

2. Review of literature

At present, there are some trading mechanism problems in China's electricity market, such as large deviation of market subject assessment, low efficiency of trading organization and difficult system optimization. The reason is that the trading mechanism is not perfect, so China has carried out active exploration. For example, some scholars have proposed a contract power deviation assessment mechanism (Chen et al., 2020), deviation power processing method analysis (Xu et al., 2020), and deviation settlement compensation mechanism in medium and long-term electricity transactions (Liu et al., 2017). With the refinement of time division and the shortening of transaction settlement cycle, the current situation of base rolling as the main deviation adjustment method is not sustainable. In the future, it will gradually transition to a market-oriented approach as the main means of deviation adjustment. Research on monthly deviation power balance mechanism and daily deviation power assessment optimization (Xu et al., 2020; Ma et al., 2019). In the studies of Zhao et al. (2021) and Zhang et al. (2012), the contract transfer mechanism between provinces in the medium and long-term electricity market and the southern electricity market with the participation of energy storage is studied in detail, but the efficiency of contract transfer is not analyzed in detail. The convergence mechanism of transaction organization under the two-level transaction mode (Xu et al., 2022) and the rolling matching transaction mechanism (Xia et al., 2022; Hao et al., 2019; Wang et al., 2018) can effectively improve the problem of large deviation of market subject assessment. The research on the transaction mode design of monthly (Wang et al., 2017) and monthly (Li et al., 2019) and the long-term continuous transaction mechanism (Xu et al., 2020; Yu et al., 2019) can also effectively improve the efficiency of transaction organization. However, in the existing trading mechanism, it is difficult for market players to be familiar with the trading market rules and judge the price trend, and the trading process is complex. In the studies of Shi et al. (2021) proposed a medium and long-term electricity trading model based on standardized futures contracts. In the existing transaction organization model, the above research has certain reference significance for reducing the deviation of medium and long-term transactions under spot conditions, improving organizational efficiency, and optimizing the trading system. However, only one aspect of medium and long-term electricity transactions is considered, and a complete implementation path of medium and long-term continuous electricity transactions in the province coordinated with spot transactions is not proposed.

3. Methodology

3.1. Current status of market participants in medium and long-term transactions

In China's electricity market, medium and long-term trading is mainly carried out in two modes: bilateral negotiated trading and centralized trading (Tang et al., 2017). In the bilateral negotiated trading mechanism, market players can independently negotiate the price of electricity and the results of electricity trading (Hajimiri et al., 2014). This mechanism has a high degree of market freedom, and for power producers, bilateral negotiations can mitigate the risk of uncertainty about future fluctuations in electricity demand (Garcia et al., 2020; Zhang et al., 2003; Pineda et al., 2012), while for electricity consumers, they can avoid fluctuations in electricity prices and obtain long-term stable electricity supply (Allaz et al., 1993). However, the tedious trading process and high transaction costs of bilateral negotiation have led to a limited scope of application, which is mostly applied to large-scale trading or medium- and long-term contract markets. In the centralised trading mechanism, market players declare electricity and tariffs through a technical support system, trade in a unified manner based on competitive bidding and auctions, and the power trading agency determines the final transaction players, electricity and prices, etc. (Xu et al., 2022). This mechanism has high market organisation efficiency and low transaction costs for market participants, but the final transaction price of electricity is determined by market supply and demand, and the price and quantity of electricity traded is not fixed, which exposes market participants to greater risks.

The market trading relationship with the addition of a continuous bidding (rolling aggregation) session is shown below. The rolling aggregation trading mechanism can enhance the efficiency of contract trading and enable risk hedging. There is a difference in the adaptability of resource allocation efficiency between one-off global centralised optimisation and continuous local optimisation, with rolling continuous allocation being decentralised optimisation and centralised bidding being centralised optimisation. Continuous local optimisation is more flexible, improves the efficiency of contract trading and enables risk hedging. As shown in **Figure 1**.

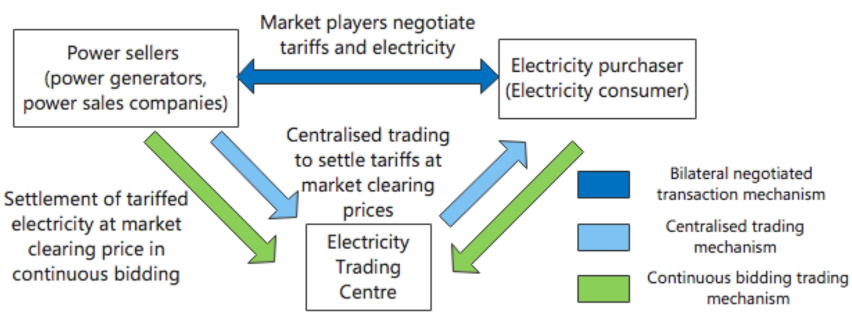

Figure 1. Electricity market trading model diagram.

3.2. Reducing contract deviation rates based on hedging theory

3.2.1. Risk hedging in a two-tier electricity market

Hedging theory means taking advantage of the existence of two different markets, the futures market and the spot market, to carry out two transactions with related quotations, opposite directions, equivalent quantities and offsetting profits and losses. Market participants can apply hedging theory to the electricity market as a means of risk prevention. When hedging risk, it is important to note that: firstly, in a hedging transaction, the buying and selling directions in the futures market and the spot market must be opposite; secondly, the same type of commodity should be bought and sold in the hedging transaction; and thirdly, when a full hedge occurs, the quantity of the commodity in the futures market and the quantity of the commodity to be purchased in the spot market are identical. Hedging theory is widely used in financial markets to hedge risk by operating in the spot market against the futures market. The same theory can be used to hedge market risk in the electricity market, where buyers and sellers buy and sell electricity energy contracts through the secondary market in the opposite direction to that traded in the primary market, hedging risk through contract transfer transactions, ensuring performance rates, reducing deviations and saving costs.

On this basis, this article proposes a monthly integrated trading model based on hedging theory. Market entities can adjust the contracted electricity quantity on an annual and monthly basis, breaking down transaction barriers between the primary and secondary markets, integrating electricity trading in the primary market with contract trading in the secondary market, simplifying transaction organization and settlement work.

Continuous transactions within a month require standardized contracts as the subject matter. Standardized contracts are contracts that pre define and unify transaction codes, targets, and units, and are the basis for conducting monthly comprehensive transactions. Market entities predict the results of spot market prices, based on option pricing theory and arbitrage pricing theory, increase or decrease their holdings of medium- and long-term contract electricity through standardized buying and selling contracts in monthly transactions. This not only provides risk avoidance measures for market entities, but also provides arbitrage for market entities.

3.2.2. Model and analysis of contractual transactions for reducing business risk

Contract trading in the secondary market has the effect of smoothing electricity prices and hedging risks, and can effectively reduce the cost of assessment deviations for customers. For convenience, the single-purchaser, time-of-use electricity market model in the primary market, for example, can be subdivided into 2 market models based on the presence or absence of contractual transactions: model 1 for participation in primary and secondary market transactions, and model 2 for participation in primary market transactions only. For market players, the adoption of mode 1 in the electricity market can reduce deviation assessment costs compared to mode 2. Taking a trading day (assuming 4 trading periods at peak and valley levels) as an example, the revenue from electricity sales by power producer f in trading period t is calculated as follows.

$$R_f^t = Q_{yf}^t P_{yf}^t - \left(Q_{pf}^t - Q_{ef}^t\right) P_{pf}^t - Q_{ef}^t P_{ef}^t \tag{1}$$

$$\tilde{R}_f^t = \tilde{Q}_{yf}^t \tilde{P}_{yf}^t - \tilde{Q}_{pf}^t \tilde{P}_{pf}^t (f = 1,2,\ldots,N; t = 1,2,3,4) \tag{2}$$

In Equations (1) and (2): R_f^t、Q_{yf}^t、P_{yf}^t are the total revenue of the *f*-th power producer in the *t*-th trading session under market model 1 (participation in primary market and secondary market), the quantity of electricity contracted in the primary market and the contracted tariff, respectively; Q_{pf}^t, P_{pf}^t are the quantity of electricity and tariff of the *f*-th power producer in the *t*-th trading session under market model 1 (participation in primary market and secondary market), respectively; Q_{ef}^{t}, P_{ef}^{t} are the deviation assessment quantity and tariff of the *f*-th power producer in the secondary market in the *t*-th trading session under market model 1 (participation in primary market and secondary market), Q_{ef}^{t}, P_{ef}^{t} respectively are the amount of electricity and tariff of the fth power producer in the secondary market in the tth trading session under market mode 1 (participation in primary market and secondary market); *N* is the number of power producers; are the amount of electricity and tariff of the fth power producer in the *t*-th trading session under market mode 2 (participation in primary market only), respectively. $\tilde{R}_{f}^{t}$, $\tilde{Q}_{yf}^{t}$, $\tilde{P}_{yf}^{t}$ are the total revenue, the electricity volume and contracted tariff of the contracted electricity energy contracts in the primary market; $\tilde{Q}_{pf}^{t}$, $\tilde{P}_{pf}^{t}$ are the deviation assessment electricity volume and tariff of the *f*-th power producer in the *t*-th trading session in the case of market model II (participation in primary market trading only), respectively.

Based on the risk hedging theory and its economics, in terms of the volatility of power generation companies' revenue from electricity sales in each time period, the total revenue under market model 1 (participation in primary and secondary market trading) is less volatile than the total revenue under model 2 (participation in primary market trading only), i.e., power generation companies are less exposed to the risk of assessment deviation under the model of participation in primary and secondary market trading. The cost borne by a single power purchaser is the sum of the power purchase cost and the deviation assessment cost. The power purchase cost in a trading session t is the sum of all generators' revenues from electricity sales and is calculated as follows.

$$C_{m}^{t} = \sum_{i=1}^{N}(Q_{yf}^{t}P_{yf}^{t}) + P_{pm}^{t}Q_{pm}^{t} - P_{em}^{t}Q_{em}^{t} \tag{3}$$

$$\tilde{C}_{m}^{t} = \sum_{i=1}^{N}(\tilde{Q}_{yf}^{t}\tilde{P}_{yf}^{t}) + \tilde{P}_{pm}^{t}\tilde{Q}_{pm}^{t} \tag{4}$$

In Equations (3) and (4): C_{m}^{t} is the total cost of a single power purchaser in the tth trading session in the case of market model one (participation in primary and secondary market trading); P_{pm}^{t}, Q_{pm}^{t} are the deviation assessment power and tariff borne by the *m*-th power producer in the *t*-th trading session in the case of market model one (participation in primary and secondary market trading), respectively; P_{em}^{t}, Q_{em}^{t} are the electricity and tariff of the *m*-th electricity consumer in the secondary market in the *t*-th trading session under market mode I (participation in primary market and secondary market trading); $\tilde{C}_{m}^{t}$ is the total cost of a single electricity purchaser in the tth trading session under market mode II (participation in primary market trading only), $\tilde{P}_{pm}^{t}$, $\tilde{Q}_{pm}^{t}$ are the cost of the *m*-th electricity producer in the *t*-th trading session under market mode II (participation in primary market trading only), respectively. $\tilde{P}_{pm}^{t}$, $\tilde{Q}_{pm}^{t}$ are the deviation assessment power and tariff of the *m*-th power producer in the *t*-th trading session.

Similarly, in terms of the volatility of the total cost per time period, the total cost C_m^t for market model 1 is less volatile than the total cost $\tilde{C}_m^t$ for model 2, i.e., electricity consumers participating in the primary and secondary market trading models are subject to less risk of assessment deviation. Use risk hedging theory to solve this problem. Both power generators and consumers improve the efficiency of conducting sales and purchase transactions of contracts or electricity energy at prices between monthly transaction prices and deviation prices, so that is $\tilde{C}_m^t$ maximised and C_m^t is minimised, achieving the objective of increasing returns and reducing losses. This includes the transfer of contracts [A contract transfer transaction is the sale of a contract when there is a deviation between the contracted quantity and the actual demand by the buyer or seller], incremental [A contract incremental transaction is a transaction between a customer who wants to use more electricity and a power company that wants to generate more electricity, where the two enter into a contract for more electricity], buyback [A contract buyback transaction refers to a transaction between a power plant that wants to generate less and a consumer that wants to use less]. Three types of sale and purchase transactions. The main parties to market transactions are power generators, power users and power sales companies. The buyers and sellers have comparable quantities and opposite directions, and the risk of losses that both parties would have incurred can be offset to form a risk hedge. However, the current trading procedures in the secondary market are cumbersome and the contracts are inefficient, making it difficult to meet the conditions for hedging. It is extremely necessary and important to improve the frequency of secondary market transactions and the efficiency of contract transactions, and how to optimise the primary and secondary market trading mechanisms has become a key issue that needs to be addressed in electricity market transactions.

3.3. Continuous bidding trading mechanism

The continuous bidding mechanism is the mainstream way of futures trading, which is adopted by European and American futures markets, as well as Chinese securities markets. Under the integration of continuous trading mechanisms within the month, a continuous bidding mechanism is introduced. Market entities can declare transactions to the central counterparty at any time during trading hours, and the trading center takes on the role of the central counterparty as the counterparty agent for both buyers and sellers.

3.3.1. Market business organisation

In order to ensure the efficient operation of the intra-month converged continuous trading market, the business process must be reasonably regulated, with buy-side units and sell-side units voluntarily participating in the two phases of information disclosure and continuous bidding for real-time reporting of volume and price. The central counterparty is responsible for the organisation and opening of the market, the rolling aggregation, and the clearing and publication of market results. To ensure the enforceability of trading results, the scheduling agency is responsible for security checks on the trading plans formed by the intra-month fusion continuous trading. As shown in **Figure 2**.

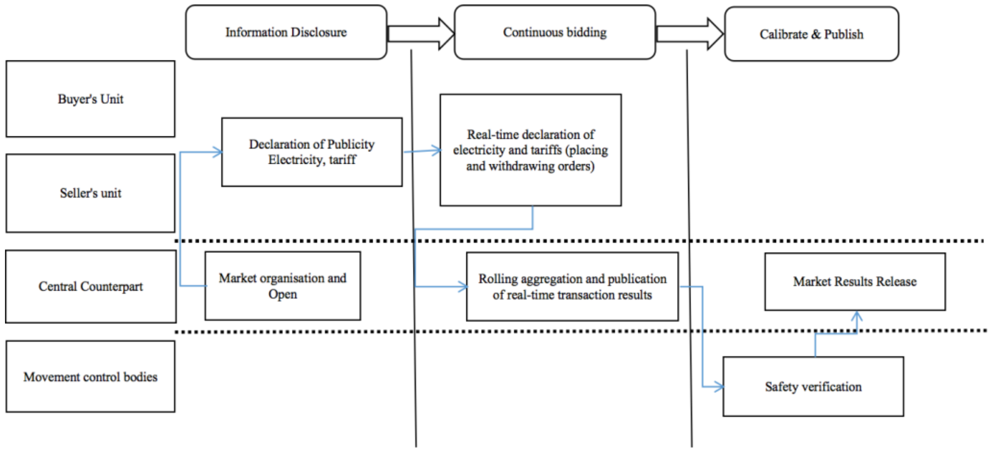

Figure 2. Continuous trading business flow chart.

3.3.2. Rolling aggregated trading process

The rolling aggregation trading method of "independent listing, free removal, instant transaction" is established for all kinds of market players in the power trading platform according to their own needs, forming real-time prices for time periods, reasonably reflecting the peak-valley price difference and reflecting the time-sharing value of electricity. A standardised and reasonable trading system is the key to ensuring that the two stages of information disclosure and continuous bidding are carried out in an orderly manner. See **Figure 3** for a diagram of the rolling aggregation trading system with a central counterparty.

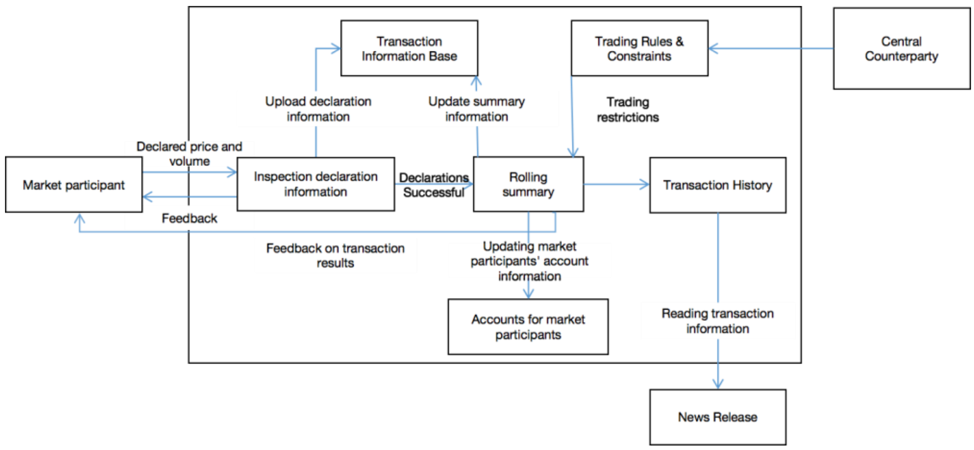

Figure 3. Flowchart of rolling aggregated transactions.

1) Information disclosure stage. Before the start of the continuous bidding phase, the market purchase and sale of electricity mains declare their own willingness to transact the price volume, the central counterparty will test the information according to the system specified good trading power limit and price limit, invalid orders will be withdrawn, valid orders will be uploaded to the trading information database, and the trading information database will be publicized as market reference information.

2) Continuous bidding stage. The system matches and aggregates orders according to the principle of price priority and time priority, and trades are aggregated in equal proportions according to the declared electricity at the same price and time. Through the rolling aggregation method, the time period price is

formed, reasonably reflecting the price difference between peak and valley and reflecting the time-sharing value of electricity. Real-time anonymous display of the highest ten tariffs for buyers and the corresponding total declared power and the lowest ten tariffs for sellers and the corresponding total declared power for each time period, as well as the tariffs for each market entity that have been and are not traded. The trading system automatically reads the transaction records, updates the market players' account information and publishes the final trading results at the same time.

3.3.3. Trading out principles

The transaction is settled on a monthly basis, without negotiation, and the cumulative value of the electricity generated during each day of the month is used as the measurement value. The boundary conditions of the trade calibration are formed according to the latest grid constraints provided by the dispatching agency before the trade is organised, and the results are adjusted according to the specific clearing rules to form the trade clearing results with security constraints.

3.3.4. Trading price restrictions

Specify the offer caps for each of the four time periods: peak, flat, valley and peak. Taking into account factors such as the electricity consumption structure of customers and the cost of electricity, cooperate with the provincial energy authorities to measure and publish the upper limit of the trading price for each time slot in the annual market-based programme for time-sharing transactions. The relationship between the annual, monthly and deviation assessment tariffs is expressed as follows.

$$P_Y < P_M < P_m < P_d \tag{5}$$

In Equation (5): P_Y, P_M, P_m and P_d are the annual tariff, monthly tariff, intra-month tariff and deviation tariff respectively.

4. Findings (also called results)

In order to verify the effectiveness of the monthly continuous trading mechanism designed in this paper, the actual results of monthly transactions in the medium and long-term power market of Jiangxi Province, China, were taken as an example, and six different purchasers and sellers were selected to analyze their adjusted electricity, deviate electricity, and contract completion rate before and after integrated continuous trading within the month, as shown in **Table 1**.

Three typical scenarios are constructed. Scenario one adopts traditional monthly periodic trading, while scenario two adopts monthly comprehensive continuous trading, as shown in **Table 2** below.

According to the principle of "price priority, credit priority and time priority", the rolling matching transaction was carried out. The results showed that the market activity of fusion continuous trading within the first month was high, the price signal at each moment was obvious, and the positive and negative deviation power was significantly reduced, which minimized the medium and long-term contract deviation, as shown in **Table 3** below.

Table 1. Basic data for six market players.

Market participants		Actual electricity generated (used)/MWh	Contracted electricity/MWh	Initial deviation of power/MWh	Contract completion rate
Before conducting in-month trading	P1	1289.34	800	489.34	161.2%
	P2	509.21	600	−90.79	84.9%
	P3	292.91	400	−107.09	73.2%
	P4	199.21	260	−60.79	76.6%
	P5	98.56	150	−51.44	65.7%
	P6	190.06	150	40.06	126.7%
After conducting in-month transactions	S1	1200.34	830	370.34	144.6%
	S2	529.21	600	−70.79	88.2%
	S3	282.91	380	−97.09	74.5%
	S4	219.21	250	−30.79	87.7%
	S5	89.56	130	−40.44	68.9%
	S6	210.06	160	50.06	131.3%

Table 2. Sets two trading scenarios.

Serial number	Parameter	Period division	Net load division	Transaction timing
Scenario one	Medium and long-term market	Peak flat valley peak 4 periods	4 session load	Open regularly during the year, month, month
Scenario two	Medium- and long-term markets and spot markets	Peak flat valley peak 4 periods	4 session load	Annual, monthly, monthly integration of continuous transactions

Table 3. Comparison of trading results in two scenarios.

Scenario	Scenario one	Scenario two
Average annual transaction price (CNY/MWh)	372.50	372.50
Average monthly transaction price (CNY/MWh)	530.00	530.00
Average trading price during the month (CNY/MWh)	618.00	625.00
Price signals by moment	Not obvious	More obvious
Positive deviation charge (MWh)	4070	1192
Negative deviation charge (MWh)	1129	293
Number of transactions per cycle	Once a year, 12 times a month, regular opening day within a month	Once a year, 12 times a month, the market continues to open within a month

In this example, in order to avoid bias assessment, market subject 1 and market subject 6 need to increase their contract positions through monthly transactions, and the remaining market subjects need to reduce their contract positions. Under the traditional medium and long term trading mechanism, the main way for market players to adjust the contract is bilateral negotiation, the adjustment amount is small, and the transaction is not flexible, which often leads to a large deviation between the contract electricity and the actual electricity consumption. The monthly continuous transactions designed in this paper can effectively improve the flexibility of contract adjustment and promote the contract completion rate to close to 100%, as shown in **Table 4** below.

Table 4. The adjustment result of market main body contract under continuous operation mode.

Market participants	Initial power deviation/MWh	Secondary adjusted power/MWh	Adjusted deviation/MWh	Contract completion rate before adjustments	Adjusted contract completion rate
S1	370.34	370	0.34	144.60%	100.03%
S2	−70.79	−70	−0.79	88.20%	99.85%
S3	−97.09	−97	−0.09	74.50%	99.97%
S4	−30.79	−30	−0.79	87.70%	99.64%
S5	−40.44	−40	−0.44	68.90%	99.51%
S6	50.06	50	0.06	131.30%	100.03%

5. Discussion

Taking the actual settlement results of bilateral market entities participating in monthly transactions in Jiangxi from January to April 2020 and from January to April 2021 as an example, the analysis was carried out. From January to April 2021 in Jiangxi, 20.153 billion kWh of electricity was settled in the market by the integrated thermal power generation enterprises, accounting for 62.02% of the online electricity of the integrated thermal power generation enterprises, an increase of 37.04% year-on-year, with an average settlement price of RMB 404.86/MWh (RMB 403.3/MWh in the same period last year). The power generation side was adjusted upwards by 268 million kWh, with an average settlement price of RMB 407.3/MWh, while the power generation side was adjusted downwards by 426 million kWh, with an average settlement price of RMB 406.57/MWh. This mechanism significantly increased the market-based trading activity of power generation companies, raised the upward and downward power adjustments and reduced deviation assessment costs. The overall situation of the selling company’s January–April 2020 and 2021 time period trading settlement is shown in **Tables 5** and **6** respectively.

Table 5. January–April 2020 electricity sales company settlement.

Monthly	Contracted electricity	Settlement of electricity	Deviation power	Deviation rate	Differential tariff
January	6.02	4.91	−1.11	−18.4%	218,539.26
February	4.3	3.72	−0.58	−13.49%	235,882.26
March	6.21	6.89	0.68	10.95%	139,317.57
April	35.98	33.17	−2.81	−7.81%	350,022.48

Unit: billion kWh, RMB/MWh, Yuan.

Table 6. January–April 2021 electricity sales company settlement.

Monthly	Contracted electricity	Settlement of electricity	Deviation power	Deviation rate	Differential tariff	Cost reduction	Reduced deviations in electricity costs
January	5.59	5.51	−0.09	−1.57%	72,846.42	3,348,280.12	145,692.84
February	4.20	4.16	−0.04	−0.97%	78,627.42	7,943,840.7	157,254.84
March	6.04	6.30	0.26	4.32%	46,439.19	11,966,305.7	928,78.38
April	34.23	33.89	−0.35	−1.02%	116,674.16	65,915,825.3	233,348.32

Unit: billion kWh, RMB/MWh, Yuan.

From the user's perspective, four large power users participated in the session trading, settling for 904 million kWh of electricity at an average settlement price of $400.11/MWh. The difference in electricity costs totaled RMB 2292.69. According to the statistics, only one customer participated in the market-based transactions from January to March, and the average contract price for this customer was RMB 401.07/MWh in January–April 2021, reducing electricity costs by RMB 128,773,000. The overall situation of the settlement of the session trading for January–April 2020 and 2021 for large electricity users is shown in **Tables 7** and **8** respectively.

Table 7. Overall table for the settlement of transactions for the January–April period for large electricity consumers in 2020.

Monthly	Contracted electricity	Settlement of electricity	Deviation power	Deviation rate	Differential tariff
January	2.1	2.4	0.3	14.29%	1789.38
February	1.8	1.96	0.16	8.89%	1322.76
March	1.98	2.29	0.31	15.66%	1002.99
April	3.24	3.47	0.23	7.1%	2762.94

Unit: billion kWh, RMB/MWh, Yuan.

Table 8. Overall table for the settlement of transactions for the January–April period for large electricity consumers in 2021.

Monthly	Contracted electricity	Settlement of electricity	Deviation power	Deviation rate	Differential tariff	Cost reduction	Reduced deviations in electricity costs
January	1.86	1.93	0.06	3.20%	596.46	1,127,884.15	1192.92
February	1.60	1.64	0.04	2.76%	440.92	3,834,713.06	881.84
March	2.02	2.05	0.03	1.66%	334.33	4,295,608.04	668.66
April	3.42	3.42	0.0014	0.04%	920.98	7,851,401.43	1841.96

Unit: billion kWh, RMB/MWh, Yuan.

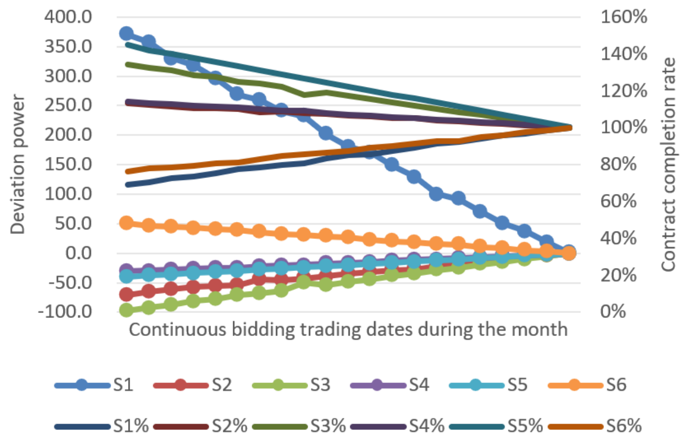

Figure 4. Comparison of electricity deviations in January–April 2020 and 2021 for electricity sales companies.

After the intra-month fusion continuous trading is carried out, as shown in **Figure 4**, curves S1–S6 represent the change of deviated electricity of market players in 1–20 trading days, and curves S1–S6% represent the change of contract completion rate. During the 1–20 trading days of continuous market opening, the deviated electricity of each market player gradually converges to 0, and the progress of contract execution gradually converges to 100% contract completion rate, and finally the deviation of contract completion rate of each market player is very small close to 100%.

6. Conclusion

Firstly, an optimised model for continuous intra-month bidding in the electricity market, which takes into account risk hedging, can effectively improve contract completion rates and hedge the risk of deviations in assessments, providing a means for market participants of all types to proactively correct deviations.The implementation of continuous operation in the Jiangxi market in 2021 has demonstrated the importance of continuous intra-month operation in safeguarding the physical execution of medium- and long-term contracts in non-spot provinces, significantly reducing the amount of electricity settled in deviation. Medium- and long-term continuous operation does not change the current operational management mode of grid dispatch. At the same time, continuous bidding allows market players to align their medium- and long-term contract curves more closely with the actually executed generation and consumption curves, making it easier to arrange and execute contract plans, and providing an important boost to reducing deviations from the spot transaction curve and reducing imbalance funds.

Second, decoupling the identities of buyers and sellers greatly enhances the trading autonomy and flexibility of market participants. The original medium and long-term contract adjustment, transfer and buy-back model can only be carried out between contract buyers and sellers, between power generation enterprises and between the electricity consumption side, and none of the flexibility can meet the needs of market participants, making it difficult to adapt to the new situation under the enhanced diversity of cycles and time periods. The continuous bidding trading optimization model breaks the boundary between the primary and secondary markets in the medium and long term, and effectively integrates direct trading, contract trading and contract curve adjustment, allowing market participants to buy and sell electricity in one market for different time periods and adjust their medium and long term positions, which not only enhances the flexibility of trading, but also avoids the contradiction of interests caused by off-site negotiations and solves the disadvantages of balancing the distribution of interests caused by medium and long term contract curve adjustment.

Thirdly, in markets where annual and monthly trading is mature, an optimised model for intra-month continuous bidding trading can help to further optimise the conduct of annual and monthly trading. There is a complementary relationship between intra-month continuous trading and annual and monthly trading, which allows for more orderly and smooth annual and monthly trading. There is also a substitution relationship between continuous intra-month trading and annual and monthly trading, which can foster market awareness and improve cost control efficiency among market participants. The continuous intra-month trading mechanism is an effective solution to connect the medium and long term with the spot. By shortening the trading cycle to promote medium to long-term continuous operation to intra-month, and even D-2 day rolling trading, it will achieve stepless variable speed and seamless integration with D-1 day trading of spot, and the optimised model of intra-month continuous bidding trading can lay a solid foundation for the development of future spot trading mechanism.

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