Research on Electricity Balance and Measurement Optimization of New Energy Power System Considering Renewable Energy Consumption Mechanism

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Abstract

With the rapid development of renewable energy, the new energy power system is facing the challenge of large-scale grid connection and consumption of renewable energy. In order to achieve efficient utilization and stable power supply of renewable energy, this study proposes a renewable energy consumption mechanism based on optimization methods. By establishing a power and electricity balance model, consider the relationship between different types of renewable energy generation and electricity demand. Various optimization strategies have been proposed for energy consumption issues in different scenarios, including power generation scheduling, energy storage

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optimization, and flexible load management. Validate the effectiveness of the proposed mechanism in terms of electricity balance and metering optimization through a model. The experimental results indicate that this mechanism can effectively enhance the renewable energy consumption capacity of the new energy power system, reduce energy waste, promote energy cleanliness and sustainable development, and has certain theoretical and practical significance for promoting the sustainable development of the new energy power system and responding to energy transformation.

Keywords: Renewable energy, absorption mechanism, new energy power system, balance and metrology optimization.

1 Introduction

In recent years, the global demand and development for renewable energy have continued to grow, and the new energy power system has achieved rapid and sustained development [1, 2]. Renewable energy sources such as solar and wind energy, with their rich, clean, and renewable characteristics, are playing an increasingly important role in the transformation of energy structure [3, 4]. With the continuous innovation and progress of photovoltaic technology, the cost of solar power generation has decreased year by year. Compared with traditional energy sources, solar energy has the advantage of being widely distributed and never exhausted, which occupies an important position in renewable energy. Governments around the world have introduced incentive policies to build large-scale photovoltaic power stations on rooftops of buildings, farmland, and deserts, further promoting the expansion of solar power generation and the improvement of utilization efficiency. Wind energy, as one of the most promising renewable energy sources, has been widely used globally. The construction of efficient wind turbines and wind farms has led to the continuous expansion of the scale of wind power generation. Many countries are increasing investment and policy support in wind energy, encouraging private and corporate participation in the development and operation of wind energy projects [5]. Through effective wind energy development, traditional energy can be replaced, greenhouse gas emissions can be reduced, and energy transformation and sustainable development can be promoted [6, 7]. The rapid development of new energy power systems is thanks to technological innovation and the widespread application of energy storage equipment, which has alleviated the volatility of renewable energy and improved the stability and supply reliability of the power grid. At the same time, the introduction of intelligent control systems can achieve precise scheduling and management of the power system, maximize the utilization of renewable energy, optimize the supply and demand matching of the power system, and improve energy utilization efficiency.

Renewable energy sources such as solar energy and wind energy have the advantages of richness, cleanliness, and renewability, and do not require the consumption of other resources, making them important alternatives to traditional fossil fuels [8, 9]. However, due to the volatility and uncertainty of renewable energy, there are significant fluctuations and differences between supply and demand in the power system, making power and electricity balance more complex and difficult. This poses new challenges to the operational stability and reliability of new energy power systems. In traditional power systems, a constant fuel supply and stable load levels maintain a relative balance between supply and demand [10]. However, in the new energy power system, due to the volatility and seasonality of renewable energy, the electricity supply will constantly change, which may lead to an imbalance between supply and demand in the power system, thereby affecting the stability and reliability of the power grid. In the new energy power system, the proportion of energy storage technology applications is constantly increasing. Although it can alleviate the volatility of renewable energy, the high cost and low energy storage efficiency of energy storage equipment also bring new challenges [11]. In the new energy power system, traditional consumption mechanisms may have certain limitations due to the volatility and uncertainty of renewable energy. For example, the direct absorption method has limited absorption capacity and cannot meet the growing demand for electricity [12]; And due to the volatility of renewable energy, direct consumption may lead to a low degree of supply and demand matching, affecting the stable operation of the power grid. Although energy storage and consumption methods can alleviate the volatility of renewable energy, their high cost and low energy storage efficiency make it difficult to achieve large-scale applications [13]. There are also technical and economic challenges in mechanisms such as power grid dispatch and cross regional consumption, such as power transmission losses, imbalanced cross regional electricity prices, and complex power grid management. Therefore, it is necessary to further explore new consumption mechanisms to improve the stability and reliability of new energy power systems and achieve more sustainable energy development [14].

How to achieve a balance between supply and demand in the new energy power system, improve the stability and reliability of the power grid. From a technical perspective, it is necessary to further strengthen research and innovation in energy storage technology, intelligent control technology, and other aspects of the new energy power system, in order to improve the utilization efficiency of renewable energy and the reliability of the power system. In addition, it is necessary to strengthen the connection between new energy power systems and traditional power systems, achieve smooth transition and interactive supplementation of electricity, and thereby improve the stability and reliability of electricity balance. This article aims to provide valuable insights and decision-making support for the construction and management of new energy power systems through in-depth analysis of key issues in the consumption mechanism of renewable energy, as well as the use of optimization methods and technical means for power balance and metering optimization. Only through continuous innovation and application of advanced technologies can the widespread application of renewable energy in the field of electricity be promoted, achieving the goals of energy transformation and sustainable development.

2 Renewable Energy Consumption Mechanism

2.1 Emergence of Blockchain Energy Consumption Mechanism

The blockchain energy consumption mechanism is a new type of digital token created through the energy trading process of the blockchain platform, based on the writing of smart contracts. The design purpose of this consumption mechanism is to use a "measurement or counting" carrier to distinguish the contributions and role positioning of various market participants, providing calculation reference for the generation or conversion of different market transactions. The existence of a consumption mechanism can connect products and services related to renewable energy and achieve effective transfer of value to a certain extent, based on green electricity trading and other related transaction markets. Taking the process of participating in green electricity trading in the new energy micro electricity network group system as an example, this article elaborates on the foundation of the blockchain energy consumption mechanism, as shown in Figure 1.

The application of blockchain technology in the energy Internet mainly guarantees the security and authenticity of energy data through distributed ledger and proof of work mechanism. The distributed ledger nature of blockchain technology ensures that data is immutable and secure, with each node keeping a complete copy of the data, and no one can individually tamper with or delete the data. Second, the decentralization and open sharing

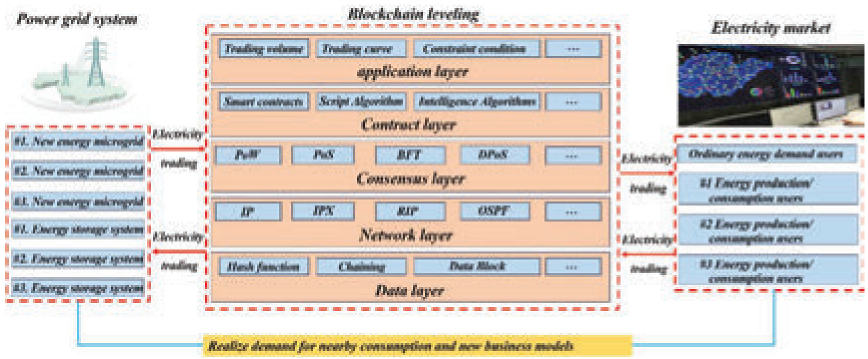

Figure 1 Example of foundation for generating blockchain tokens.

characteristics of blockchain technology can provide a broader sharing platform for energy data, making the flow of data between multiple parties more convenient, fast and transparent.

The production process of the blockchain energy consumption mechanism can be seen as the result of the joint action of PoW (proof of work) and PoS (proof of equity). The joint action of PoW and PoS can make the energy consumption mechanism fairer, safer and more efficient. The parties who obtain access and participate in renewable energy transactions can be considered as various nodes in the blockchain network. There is a certain game relationship between each node. Calculate a random number that meets the rules through mathematical operations. According to the principle of "longest chain win", only the longest blockchain can be recorded as a valid chain, that is, obtain the reward for this accounting right and energy token, send out the data that needs to be recorded in this round, and store it together with other nodes in the entire network after verification. Under this workload proof mechanism, the outcome of the game competition among all parties depends on their computing power and resources.

2.2 Application of Blockchain Technology in the Field of Renewable Energy

With the development of distributed energy and the increasing popularity of green energy concepts, the transformation of traditional energy requires more breakthrough new technologies and mechanisms, and the application of blockchain technology in the field of energy and electricity has also received more attention [15]. The research in this field mainly focuses on three aspects.

(1) Energy Internet. At present, the research hotspot in this field is the issue of data ownership, as the foundation for the operation and development of the energy internet is the incremental benefits brought by data or information [16]. By utilizing the distributed ledger and workload proof mechanism of blockchain technology, the positioning, storage, and value realization of data information can be achieved [17]. The application of blockchain technology in the energy Internet is mainly to ensure the security and authenticity of energy data through distributed ledger and proof of work mechanism. The distributed ledger nature of blockchain technology ensures that data is immutable and secure, with each node keeping a complete copy of the data, and no one can individually tamper with or delete the data. Second, the decentralization and open sharing characteristics of blockchain technology can provide a broader sharing platform for energy data, making the flow of data between multiple parties more convenient, fast and transparent.

(2) Comprehensive energy services. At present, the research content in this direction mainly focuses on energy production management, which combines blockchain technology with production machines to ensure the authenticity, credibility, and security of information generated in various stages of energy production and circulation [18]. The decentralized and open sharing characteristics of blockchain technology can bring new design concepts to regional energy planning, and can also provide new ideas for energy blockchain design that aligns with comprehensive energy services [19].

(3) Energy trading. In terms of energy trading, existing research mainly focuses on the discussion of trading mechanisms, trading models, and trading technologies, with less involvement in market behaviour research outside the trading system, especially research on trading incentives [20]. In fact, the establishment of incentive mechanisms for trading market entities is crucial for the implementation and application of trading theory and technology. The prosperity and sustainable development of the trading market cannot be separated from the participation enthusiasm of various market entities. A reasonable incentive mechanism is conducive to activating the energy trading market and ensuring the maximization of the interests of all parties in the trading system.

2.3 Design of Renewable Energy Consumption Mechanism

With the determination of the national "carbon neutrality" target strategy, the issue of renewable energy consumption has attracted much attention.

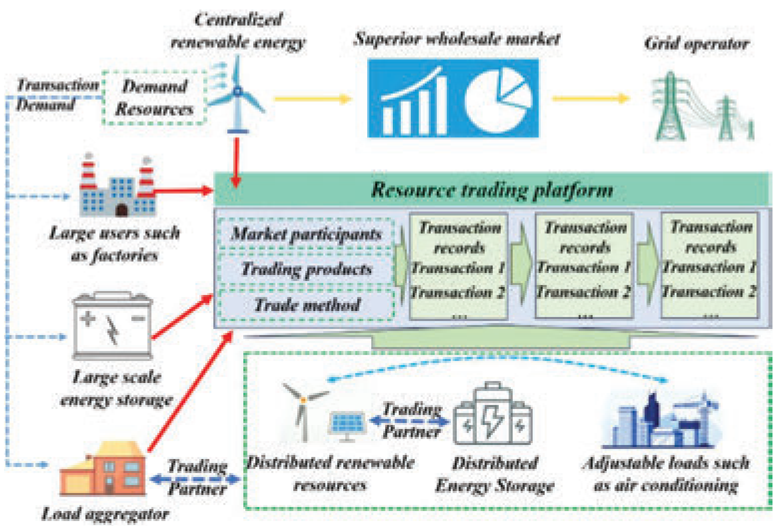

Figure 2 Resource trading market members and trading needs.

Regarding the theme of excess consumption, using blockchain technology [21, 22], the establishment process of voucher trading system is elaborated from multiple perspectives such as concept connotation, trading mechanism, transaction settlement, and transaction settlement, which helps to promote market-oriented consumption of renewable energy; Based on the basic characteristics of blockchain technology, based on the blockchain in the green electricity trading platform, the incentive mechanism of renewable energy consumption is proposed to mobilize the enthusiasm of all parties in the market. Figure 2 shows the membership and transaction requirements of the resource trading market in the context of blockchain technology.

On the blockchain energy trading platform, smart contracts can be created to achieve green electricity trading, carbon trading, energy-saving trading, energy use rights trading, and emission rights trading [23, 24], thereby connecting the consumption of renewable energy with different trading markets; The emergence of blockchain energy tokens can bring more economic benefits, social benefits, and opportunities for green finance to various market entities involved in the consumption of renewable energy, especially investors; With the application of blockchain energy tokens, the renewable energy consumption market is developing rapidly, which can generate more new business models that are conducive to promoting consumption and further promote the consumption of renewable energy [25].

In the model construction stage, Vensim is used as the top layer of simulation to provide basic information on retail electricity prices, green certificate prices, and the scale of renewable energy development, helping users build system dynamics models, determine system structures, define variables, and parameters. The characteristics of Grid Lab-D's fine modeling also make up for the weakness of Vensim's data credibility. By establishing a joint simulation model, the analysis of the blockchain renewable energy consumption mechanism is more in line with the real situation [26]. Vensim's system dynamics model serves as a simulation tool for the external environment, with monthly simulation steps to simulate the evolution of demand side resources. The output is the average retail market electricity price and the scale of DER; DR scheduling strategy developed through MATLAB simulation; In MATLAB, load the DLL library of Vensim DSS and start the simulation, pause, start Grid LAB-D, and pause Grid Lab-D in each simulation step and read the relevant control signal variables of Grid Lab-D; Optimize and solve the control signal variables in MATLAB recently, rewrite the control signal into Grid Lab-D, restart the simulation of Grid Lab-D, and record the simulation data; Analyze the data from Grid Lab-D and write the benefit evaluation indicators into the Vensim model. Start the Vensim model for the next step of simulation. Continuously interact with each other to simulate the three software until the end. as well as the demand side resource evolution simulation process diagram for Vensim, MATLAB, and Grid Lab-D, are shown in Figure 3.

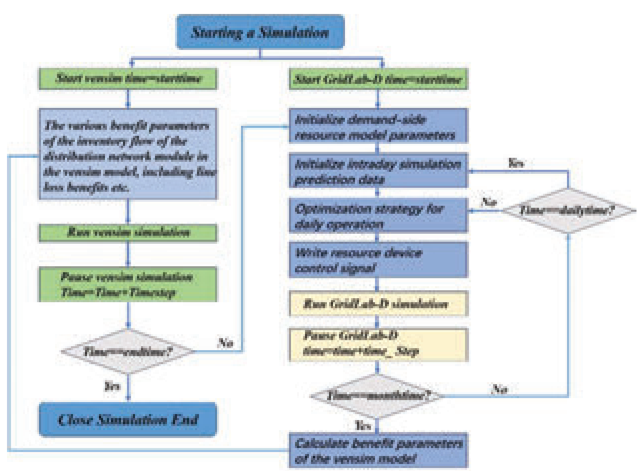

Figure 3 Demand side resource evolution simulation flowchart.

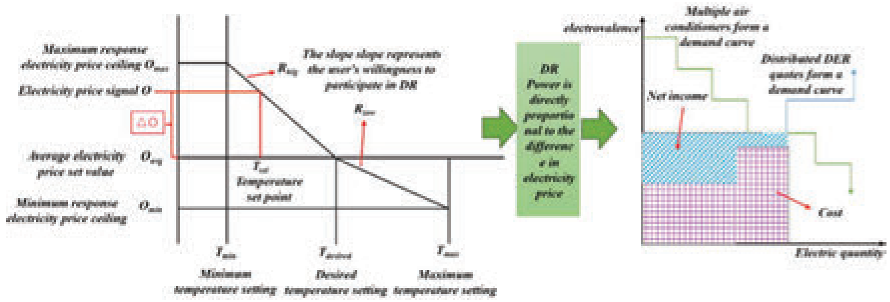

Figure 4 Schematic diagram of market clearance methods for Grid Lab-D.

The auction object accepts bids from both the seller and buyer in the system and clears the market through bilateral auctions. The bid mode of air conditioning load determines the amount of electricity purchased based on the price, and the clearing method for air conditioning load participation in the market is shown in Figure 4. Taking the heating mode as an example, under normal circumstances, the temperature set point of the air conditioning equipment is set to $T_{desired}$; When the electricity price signal O is greater than the average electricity price setting value O_{avg}, the device controller will actively move the temperature setting point T_{set} below $T_{desired}$ to reduce the load; When the electricity price signal O is less than the average electricity price set value O_{avg}, the device controller moves the temperature set point T_{set} higher than $T_{desired}$, increasing the load energy consumption.

3 Quantitative Optimization Method for Renewable Energy Consumption Mechanism System

3.1 Current Status of Metering Optimization in New Energy Power Systems

With the progress of The Times, science and technology are also constantly developing. As an important resource in life and production, the power industry is very necessary to realize system automation and terminal operation and maintenance [27]. The optimization of power metering automation system and terminal operation and maintenance can improve the accuracy, safety and efficiency of power metering automation system to a great extent, and effectively solve the technical problems existing in traditional power metering automation system. Secondly, the work efficiency of the power metering automation system is much higher than the manual operation efficiency, which also solves the problem of human resources to a large extent, but the power metering automation system and terminal operation and maintenance also have certain drawbacks, and technical problems need to be further improved.

3.1.1 Automatic data analysis function of new energy power system

The power metering automation system first collects and stores the user's electricity consumption information in its own system, and then automatically and accurately analyses the user's electricity consumption data. However, in actual system operation, the accuracy of automatic data analysis did not achieve the expected effect. The low accuracy of automatic data analysis has affected the operation of the entire power measurement automation system in the later stage, resulting in information error analysis problems, causing chaos and even economic disputes in the power measurement automation system. Therefore, in the practical application process, system operation researchers should further optimize the automatic data analysis function of the power metering automation system to ensure the accuracy of data analysis. In addition, attention should also be paid to the timeliness of user electricity usage information to avoid serious issues of outdated data. The optimization of automatic data analysis function can ensure the normal operation of the entire power system, accurately collect user electricity information, accurately implement the corresponding user files of the data, accurately locate the source of the data, improve the efficiency of the automatic data analysis function of the power metering system, avoid economic and political disputes between users and power enterprises, and damage the interests of both parties. This is also not conducive to the development and application of the power system.

3.1.2 New energy power system update data function

The power metering automation system needs to regularly update the basic data of users' electricity consumption to ensure the real-time nature of customer data, and also provide information feedback to customers. Electricity customers and power enterprises should develop corresponding transformation plans. Regular updates of data can ensure the stable operation of data analysis functions. Therefore, power system technical operators should establish an update period for power data, regularly update the user electricity information collected by the power system, and detect the data analysis results to determine whether the data results meet the expected goals and the expected requirements for completeness. The regular update of data can lay a solid foundation for the subsequent data analysis of the system, ensure the normal operation of the data analysis function of the power metering automation system, and achieve comprehensive analysis of user electricity consumption information.

3.1.3 Terminal operation and maintenance of new energy power system

The purpose of the optimization of the synchronous establishment of the metering terminal and the file is to strengthen the analysis function of the power metering automation system to the user's electricity consumption information, so that the measurement indicators of the power metering automation system meet the standard requirements, and improve the statistical efficiency of the user's electricity consumption information during the fault period. In addition, the power metering automation system needs to carry out meter reading work, meter reading work needs to first establish user files to ensure the integrity and clarity of information, and the metering terminal needs to achieve the goal of synchronizing the establishment of files and enhancing the correlation between information. The control function of the terminal on the power metering automation system can be applied to the establishment of user files, and the synchronous establishment of system files can cooperate with the terminal to develop a user-related information metering file system to ensure the accuracy and integrity of information [28–30].

3.2 Design of Metrological Optimization Method Considering the Consumption of Renewable Energy

In order to improve transaction processing efficiency and the scalability of blockchain, blockchain developers are currently exploring methods to solve these problems, such as increasing block size or blockchain pruning, as well as utilizing sharding, sidechains, and payment channels to ensure timely completion of transactions. These types of methods mainly focus on accelerating the consensus time of transactions, parallel processing of transactions, or transferring computing tasks on the chain to offline processing. They are mainly divided into parallel processing of transactions and offline processing. In order to improve transaction processing efficiency, in addition to expanding capacity on the blockchain, placing the transaction process offline and only arbitrating or recording the transaction results on the main chain is also a

Table 1 Interaction process and feasible implementation techniques

Interactive Process	Feasible Technology	Technical Description
Information transmission and settlement process between aggregators and customers	Status Channel Plasma	LA needs to frequently transfer information and funds with customers. The state channel can be deployed on the sub chain of Plasma to improve the interaction effect.
Information exchange between aggregators	Cosmos/Polkadot	The blockchain network constructed by interoperability technology facilitates the transmission of information between different entities.
Electricity sales and purchase strategies for power producers, aggregators, and consumers	Smart contracts	Power producers, aggregators, and consumers can write their strategies into smart contracts and deploy them on Plasma side chains, Polkadot based parallel chains, and private chains.

way. Off chain expansion is carried out on the basic layer of blockchain and does not require changes to the underlying protocol. Typical off chain expansion technologies include lightning networks, state channels, Plasma, True bit, and more. State channels and Plasma place interactions off the chain to increase the platform's transaction throughput, while True bit places complex calculations in smart contracts outside the chain, enabling high computational costs and operations that cannot be performed on the chain to be completed.

Before electricity trading begins, aggregators first set up their own private chain, and generators can join the aggregator or sell their own electricity. Aggregators act as agents to write smart contracts based on the proposed interactive offer negotiation process to bid and trade for power users or generators. Participants in the same chain can communicate with each other through state channels. When the price of electricity for all aggregators is agreed, the transaction is determined and verified by a verifier, which is then stored on the main chain [31] (e.g. Ethereum), which guarantees a high degree of security [32]. The verification process is the same as Polka dot's consensus mechanism. relay chains coordinate consensus and power delivery between private chains; Participants in the same chain can communicate with each other through state channels. After the transaction is completed verified by the validator, and then stored on the main chain (such as Ethereum) to ensure high security. Table 1 lists the interaction process and supporting technologies, and the blockchain network is shown in Figure 5.

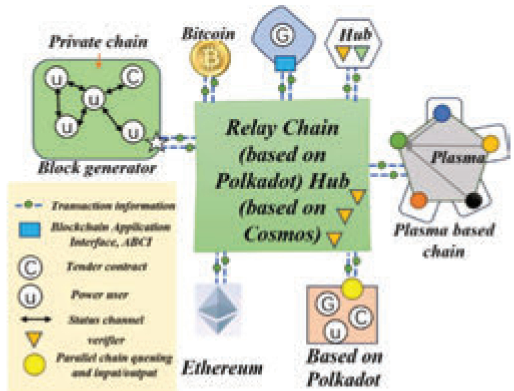

Figure 5 Blockchain technology supporting transaction processes.

3.3 Current Status of Metering Optimization in New Energy Power Systems

During each trading period, DEGs broadcast their supply (represented by PG), and the power consumed by power users is represented by P Li. The centralized scheduling model is shown in formula (1).

$$max \sum_{i=1}^{N_L} U(P_{Li}) - \sum_{i=1}^{N_G} C(P_{Gi}) \tag{1}$$

This equation is equivalent to formula (2):

$$min \sum_{i=1}^{N_L} U(P_{Li}) + \sum_{i=1}^{N_G} C(P_{Gi}) \quad Li \in L \; Gi \in G \tag{2}$$

$$s.t. \sum_{i=1}^{N_L} P_{Li} - \sum_{i=1}^{N_G} P_{Gi} = 0 \tag{3}$$

$$P_{Li}^{min} \leq P_{Li}(K) \leq P_{Li}^{max} \tag{4}$$

$$P_{Gi}^{min} \leq P_{Gi}(K) \leq P_{Gi}^{max} \tag{5}$$

In the formula, P_{Di} is the power purchased by power user *Li*, while N_L and N_G are the quantities of power users and distributed energy producers, respectively. $U(\cdot)$ is the user's benefit function, and $C(\cdot)$ is the cost function of DEGs. Equation (3) is the energy balance formula. At transaction stage k, the electricity purchased by users and the electricity output by DEGs are limited by inequalities (4) and (5). The functions $U(P_{Li})$ and $C(P_{Gi})$ are quadratic functions, and the equality constraints are also linear, so the optimization model conforms to the characteristics of LASSO (Least Absolute Shrinkage and Selection Operator).

Considering the low marginal cost of renewable energy generation units, it can be expressed as formulas (6), (7) and (8). Among them, x_{Li} is the electricity required by user i managed by aggregator L; x_{Gi} is the output provided by power producer i managed by aggregator G. For the convenience of display $P_{RE} = \sum_{L=1}^{M} x_{Gi}\; i \in G_{res},\; f_{Li}(\mathrm{x_{Li}}) = -\mathrm{U}(\mathrm{x_{Li}}) f_{Gi}(\mathrm{x_{Gi}}) = \mathrm{C}(\mathrm{x_{Gi}})$.

$$min \sum_{L=1}^{N_L} f_L(P_L) + \sum_{L=1}^{N_G} f_G(P_G) \tag{6}$$

$$P_L = (x_{L1}, x_{L2}, \ldots x_{LD_L}) \tag{7}$$

$$P_G = (x_{G1}, x_{G2}, \ldots x_{GD_G}) \tag{8}$$

$$s.t.\; \|y\| \le \sigma$$

$$y = \sum_{L=1}^{N_L} \sum_{k=1}^{D_L} f x_{Lk} - \sum_{G=1}^{N_G} \sum_{i=1}^{D_G} x_{Gi} - P_{RE} i \notin G_{res} \tag{9}$$

In the formula, N_L and N_G respectively represent the number of load aggregators and power generation aggregators; P_L is the purchasing power matrix of aggregator L; D_L and D_G represent the number of users of load aggregator L and power generation aggregator G. The difference between demand response resources and DEGs output should be less than a normal amount, as shown in formula (9). Using $f_p(x_p)$ to represent $f_L(P_L)$ and $f_G(P_G)$, the problem can be expressed as formulas (10)–(13) and (14):

$$min \sum_{L=1}^{N_L} f_L(P_L) + \sum_{G=1}^{N_G} f_G(P_G) \Rightarrow min \sum_{p=1}^{N_p} f_p(P_p) \tag{10}$$

$$s.t.\; y = \sum_{p=1}^{N} A_p P_p - P_{RE} \tag{11}$$

$$\|y\| \le \sigma \tag{12}$$

$$x_p = [x_{L1}, x_{L2}, \dots x_{LD_L}]^T \quad if\ aggregator\ p \in L \tag{13}$$

$$x_p = [x_{G1}, x_{G2}, \dots x_{GD_G}]^T \quad if\ aggregator\ p \in G \tag{14}$$

The Lagrange function is shown in formula (15):

$$L(x, \lambda) = \sum_{p=1}^{N} f_p(x_p) + \lambda^T \left(\left\| \sum_{p=1}^{N} A_p x_p - P_{RE} \right\| \right) - \sigma \tag{15}$$

The objective function is shown in formula (16):

$$min \sum_{p=1}^{N} f_p(x_p) = min\ max\ L(x_p, \lambda) \tag{16}$$

The dual function is shown in formula (17):

$$\begin{aligned} \max_{\lambda} \min_{x_p} L(x_p, \lambda) &= \max_{\lambda} \min_{x_p} \sum_{p=1}^{N} f_p(x_p) \\ &\quad + \lambda^T \left(\left\| \sum_{p=1}^{N} A_p x_p - P_{RE} \right\| \right) - \sigma \\ &= \max_{x_p} \sum_{p=1}^{N} f_p(x_p + (A_p^T \lambda_p)^T x_p) - \frac{1}{N}(p_{RE} + \sigma)\|\lambda_p\| \end{aligned} \tag{17}$$

If $g_p(\lambda_p) = \frac{1}{P}(P_{RE} + \sigma)\|\lambda_p\| - inf_{x_p}(x_p) + (A_p^T \lambda_p)^T x_p$, then formula (18) can be obtained:

$$\max_{\lambda} \min_{x_p} L(x_p, \lambda) = \max_{x_p} \sum_{p=1}^{N} -g_p(\lambda_p) = \min_{x_p} \sum_{p=1}^{N} g_p(\lambda_p) \tag{18}$$

The original problem can be expressed as a dual problem, as shown in formulas (19) and (20):

$$\max_{\lambda} \sum_{p=1}^{N_p} g_p(\lambda) \tag{19}$$

$$g_p(\lambda) = \frac{1}{N}(p_{RE}\|\lambda_p\| + \sigma\|\lambda_p\|) - inf_{x_p}(f_p x_p) + (A_p^T \lambda_p)^T x_p) \tag{20}$$

In the formula: $N_p = N_L + N_G$. Is the total number of aggregators; *Ap* is the row matrix, with all values being 1 for loads and -1 for DEGs.

4 Model Experiment and Result Analysis

In order to analyse the research model for electricity balance and metering optimization in new energy power systems considering renewable energy consumption mechanisms proposed in this article.

In order to analyze the power balance and metering optimization research model of new energy power system considering the consumption mechanism of renewable energy proposed in this paper, the user benefits under the scenario where the users participating in the demand response (DR) load trading also have energy storage equipment when there is a grid power limit and the optimization control method proposed in this paper is adopted are mainly investigated. The comparison of 24-hour decision-making between this scenario and a single demand response resource transaction and a single configuration of energy storage equipment is shown in Figure 6. After accessing energy storage, users can trade with demand response resources in a more flexible form, resulting in changes in market transaction clearance results, such as at the 9th and 11th to 14th moments; Moreover, trading with demand response resources can also affect the charging and discharging arrangements for energy storage. The clearing price advantage in the demand response exchange market is very cheap, which is due to the fact that the retail price given by the distribution system operator (DSO) is very cheap at this time, and no demand response resource is willing to trade with blockchain renewable energy (RES).

Due to the high similarity in the adaptability analysis of various faults, this paper analyzes only two situations to verify the adaptability of the proposed blockchain transaction clearing algorithm. The first is in the negotiation process, assuming that the No.1 aggregator fails to communicate at the 10th iteration, resulting in offline (CAF). The second scenario is that on the 10th iteration, the No.1 aggregator has 1 user offline (CUF) due to a device failure. The simulation results of the fault resolution process are shown in Figure 7, which shows the data of three aggregators or users, as the data results of normal participants are similar. In CAF, after a communication failure occurs, smart contract C cannot receive data sent by smart contract B of the No.1 aggregator. Due to the dual variable containing information from all market participants (calculated from the bidding prices of all aggregators), this variable should be set as the initial value to exclude the

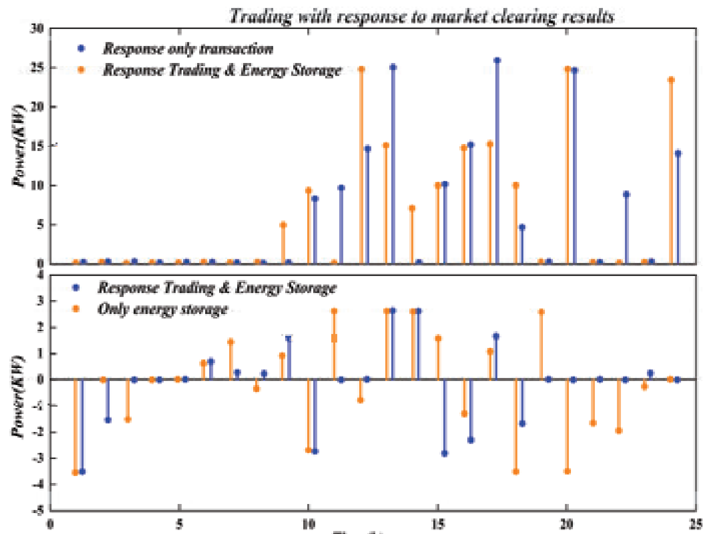

Figure 6 Impact of multiple consumption measures on a single consumption measure.

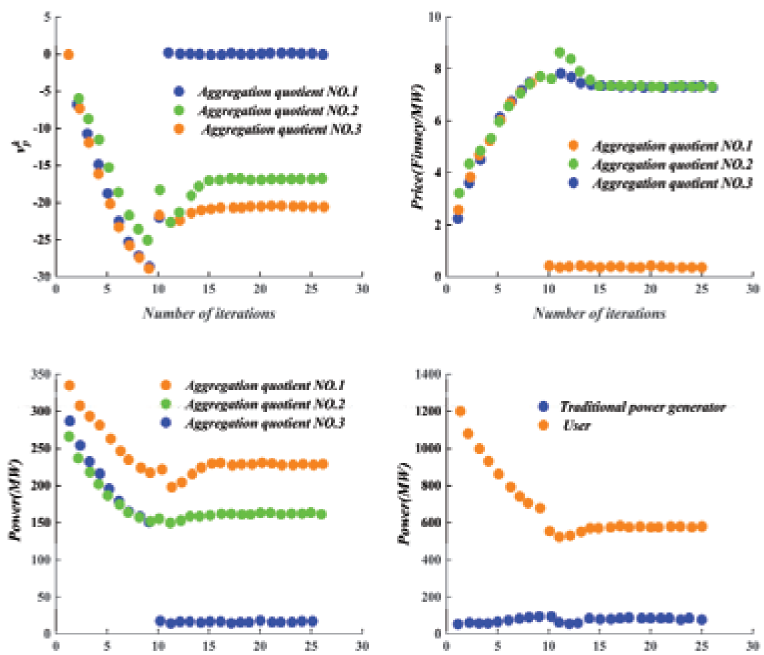

Figure 7 Performance of CAF decentralized market clearing algorithm.

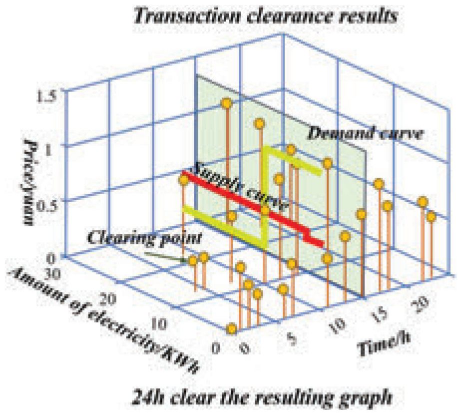

Figure 8 24-hour clearance results on a certain day.

impact of communication failures on aggregators. Therefore, the price signal transmitted to each normal aggregator will undergo a significant change in a short period of time. However, through several rounds of negotiations, this algorithm can eliminate the impact of faults and make the price signal normal and achieve market clearance.

The photovoltaic panel area of solar users with surplus electricity connected to the grid is 50 m^2, the efficiency parameter is 0.2, the rated capacity is 10 kW, and the measured maximum active power output is approximately 9.2 kW. Most power selling companies set higher electricity fees for users who participate in transactions, as they play a backup role. Therefore, flexible loads such as air conditioning and water heaters are set to participate in market transactions, while the fixed load portion is still set to purchase electricity from the power selling company. Set the maximum power injected into the grid by blockchain renewable energy to 5 kW. Blockchain renewable energy generators use max (0.4, 0.9 * LMP) as a quote calculation formula, with the aim of balancing market supply and demand and preventing market prices from being too high or too low. Where 0.4 is a fixed minimum quotation value, ensuring that market participants receive at least some profit margin. 0.9 * LMP is a quotation ratio based on LMP, so that the quotation can be adjusted with the change of the market price. In this way, market participants can reasonably adjust their offers according to market conditions to achieve a balance between supply and demand and economic benefits. The green certificate price is set to 0.1 yuan/kWh. Figure 8 shows the market clearance results on a certain day, and two virtual quotation providers can be seen, namely distributed generation companies and power sales companies, providing guaranteed services. The two form a stepped supply curve and a stepped demand curve formed by users. The intersection of the two is the inventory of the distributed generation market.

5 Conclusions

After studying the mechanism of renewable energy consumption, the main conclusions are as follows:

(1) With the rapid development of renewable energy and large-scale integration into power systems, such as wind power and solar energy, traditional power systems are facing challenges of renewable energy volatility and instability. The renewable energy consumption mechanism can balance supply and demand differences and improve the reliability and stability of the power system through flexible scheduling and energy storage technologies.

(2) Traditional measurement methods cannot accurately reflect the generation and consumption of renewable energy, so it is necessary to optimize measurement based on the characteristics of the new energy power system. Based on intelligent measurement equipment, data collection and analysis technology, and artificial intelligence algorithms, it is possible to monitor and analyse the energy flow in the power system in real-time, improving the accuracy and precision of measurement. Energy storage technology can store energy when there is an excess supply of renewable energy, release energy during peak demand periods, and achieve supply-demand balance. At present, commonly used energy storage technologies include battery energy storage, pumped storage, compressed air energy storage, etc. By properly designing and optimizing energy storage systems, the efficiency and flexibility of power utilization in new energy power systems can be improved.

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