

Design and Simulation Analysis of Green Power Trading Mechanism in Power Market

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Abstract. In order to solve the transaction problems of renewable resources such as wind and solar in the mid-to-long term market and spot market conditions, a corresponding green electricity transaction mechanism and its quantitative analysis model are proposed. This paper analyzes the development and current situation of green power trading in my country, analyzes the green power trading mode and trading process in the medium and long-term power market and spot market, establishes a green power trading model, and simulates the green power trading volume. It also compares and analyzes the relationship with the green certificate and CCER, explains the advantages of the transaction mechanism proposed in this paper, and finally demonstrates it by simulation analysis.

Keywords: Green electricity market, operation evaluation, trade mechanism, block chain.

1. Preface

Green power market-based trading is a green power trading product independently established under the existing medium and long-term trading framework. Green power products refer to the on-grid electricity of photovoltaic and wind power and other renewable energy power generation enterprises that meet the requirements of relevant national policies. At present, it mainly refers to the on-grid electricity of wind power and photovoltaic power generation companies. Green power trading refers to medium and long-term power transactions with green power products as the subject matter, which can meet the needs of market players such as power generation companies, power sales companies, and power users to sell and purchase green power products. demand, and provide green power certificates for power users of green power products. The market-oriented transaction of green power can provide power users with corresponding green power consumption certification, guide green power demand users to conduct transactions directly with power generation companies, explore the environmental value potential of green power in a market-oriented manner, and reflect the role of green power in trading organizations, power grids priority in scheduling, etc. At present, as my country's electricity market-oriented trading platform and coordination mechanism are still in the development stage, further research is needed to realize the standardization of green electricity market-oriented transaction management and promote the effectiveness of transactions.

China's green certificate transactions are earlier than green power transactions, and the voluntary subscription of green certificates is an alternative mechanism for the country to deal with the funding gap of renewable energy grid-connected power generation subsidies. Enterprises can obtain relevant income through green certificate transactions. After wind power and photovoltaic power generation companies sell green certificates, the corresponding electricity will no longer enjoy the subsidies of additional funds for renewable energy electricity prices, which greatly limits the liquidity of green certificates. Under the green electricity trading system, green certificates are issued directly to end users who actually consume green electricity, realizing the unification of green electricity usage instructions and actual consumed electricity, and are easier to be accepted by market players.

At present, there are not many studies on green power trading. Literature [1] analyzes the market mechanism of new energy power trading under the background of "double carbon". Literature [2]

studied the "source-load" coordination and optimization dispatch considering the green power certificate and carbon trading system. Literature [3] proposed a green power certificate transaction mechanism based on blockchain technology. Literature [4] compared China's green electricity, green certificate and CCER policies.

In order to solve the trading problems of renewable resources such as wind and solar in the mid-to-long term market and spot market conditions, this paper proposes a corresponding green power trading mechanism and its quantitative analysis model. This paper analyzes the development and current situation of green power trading in China, analyzes the green power trading mode and trading process in the medium and long-term electric power market and the spot market, establishes a green power trading model, and quantifies the green power trading volume. It also compares and analyzes the relationship with the green certificate and CCER, explains the advantages of the transaction mechanism proposed in this paper, and finally demonstrates it by simulation analysis.

2. Overview of my country's Green Power Market

2.1. Beijing Green Power Market Structure

The establishment of a green power market system needs to fully consider factors such as regional incentive policies, market subject demand, and market subject maturity. According to the current relevant policy requirements, considering the demand of power users for green power in Beijing and the main sources of green power, the green power market in Beijing mainly includes market-based transactions of green power (referred to as "green power transactions") and new energy transactions.

Among the electricity sellers of green power transactions in Beijing, distributed new energy can participate in green power transactions through aggregation, while the main buyers of electricity are electricity consumers who have green electricity consumption and certification needs, and are willing to pay for green environmental rights and interests. Emerging subjects such as electric vehicles and energy storage can be introduced when conditions are met.

The formulation of the electricity market settlement model is also closely related to the maturity of market players and the types of power sources. In order to ensure the reliable and stable operation of the green power market, the Capital Trading Center has formulated specific settlement rules for green power transactions to optimize the settlement process; compiled settlement examples for different scenarios, and steadily developed settlement functions; established a market with multiple business flows such as transaction, marketing, and finance the settlement structure implements the interaction process and operation details between systems, and actively promotes the online settlement of green power transactions in strict accordance with the transaction rules.

2.2. Structure of Southern Regional Power Market

The main body of electricity sales in green power trading in southern China is wind power, photovoltaic and other renewable energy power generation companies that meet the conditions for issuing green certificates. At this stage, the main focus is onshore wind power and photovoltaic power generation. With the needs of market construction, the main body of electricity sales can gradually expand to qualified hydropower enterprises and other renewable energy enterprises. Southern regional power trading can timely introduce market players such as distributed power, electric vehicles, and energy storage.

The power purchasers mainly refer to power users and electricity sales companies. Grid companies that implement the national guaranteed purchase or agency power purchase policy can also participate in green power market transactions as the main purchaser and seller of electricity. The southern regional trading rules also pointed out that market players such as distributed power supply, electric vehicles, and energy storage can be introduced in a timely manner to participate in green power market transactions.

3. Design of green power trading system based on blockchain

3.1. Design of Green Power Trading Mode

The green power transaction mode is divided into point-to-point transactions between market entities and centralized matching transactions between market entities. The market entities of green power trading mainly include the power generation side and the power consumption side. The former mainly includes renewable energy such as photovoltaics, wind power, and hydropower; the latter mainly includes electricity sales companies, electricity users, electric vehicles, and energy storage. Members participating in the green power market transaction also include market operators, power grid companies responsible for green power transmission, and power trading centers responsible for organizing and trading power energy.

In the point-to-point transaction mode, the two parties agree on the content of the contract before the transaction, and carry out independent price negotiation without the participation of a third party. During the transaction process, the trading platform only plays the role of recording transaction information. Market participants can reach a consensus through various forms of transaction content. This transaction mode is suitable for blockchain-based transactions. It has the characteristics of decentralization and trustlessness. It can use smart contracts to enforce and automatically execute pre-agreed content. Without the basis of mutual trust between the two parties, it can also guarantee the safety and reliability of both parties to the transaction. The centralized matching transaction is mainly used for centralized transactions between large-scale entities, which requires unified price confirmation, and the transaction mechanism is more complicated than peer-to-peer transactions.

3.2. Design of Green Power Trading Mechanism

At present, the green power trading mechanism is divided into two types: intra-provincial trading (direct power trading) and inter-provincial trading, among which:

Intra-provincial transactions: market entities such as electricity users or electricity sales companies and power generation companies directly participate in transactions through bilateral negotiations, centralized matching, and listing. Power generation companies, power users, and electricity sales companies negotiate independently or through market competition to reach transaction volume and electricity prices, and sign bilateral transaction contracts. Electricity users can purchase guaranteed green electricity from grid companies in the province when the direct transaction of green electricity in the province cannot meet their needs. Direct power trading is mainly for the provincial market. The two parties to the transaction can reach a transaction volume and price through bilateral negotiation, centralized matching and listing, and sign a bilateral transaction contract to achieve precise matching of green power supply and demand. In the case that the demand for green power consumption cannot be met, power users can reach a deal by purchasing green power products guaranteed by the power grid company. Price listing) and inter-provincial transactions (grid agency power purchase demand in the province) and other methods.

Inter-provincial transactions: organized in the form of "peer-to-network" at the initial stage. The provincial power trading center finds out the green power demand and intended price of the power users in the province in the early stage, organizes relevant users to participate in the green power bidding in the province through listing transactions, etc., and reaches the green power demand and price in the province, and summarizes it to the provincial level. Grid companies.

3.3. The overall structure of the system

The blockchain-based green electricity trading system is shown in Figure 1. The system is mainly composed of a data layer and a physical layer. The transaction subjects are green power companies, power grid companies, and trading platforms with two-way trends. The subject matter of the transaction is the amount of renewable energy power generation that can be physically executed, and the value of electric energy and the environment can be realized at one time.

The data layer consists of information system, market mechanism, pricing mechanism, energy management system, etc. Among them, the information system relies on blockchain technology, which can effectively break down the information barriers between users, so that information such as market electricity prices, electricity supply and demand, and policies can be safely and efficiently shared among users. In order to build an open, transparent and efficient electricity market environment. In addition, smart contracts have the characteristics of mandatory automatic execution. Using smart contract technology to realize the market mechanism and pricing mechanism can ensure the fairness of the P2P electricity trading market.

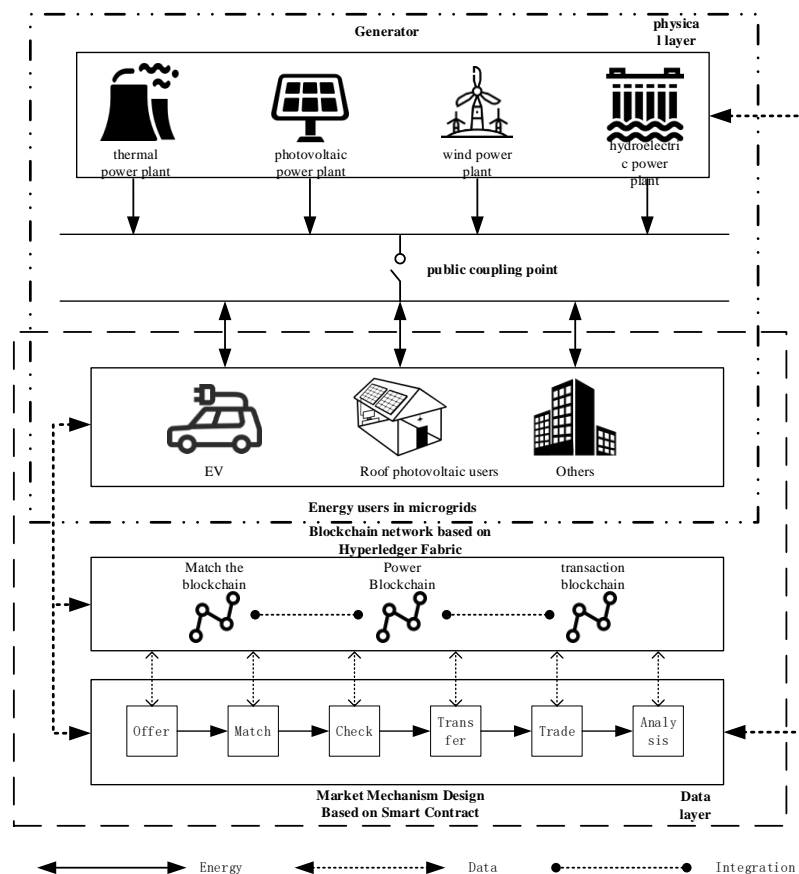


Figure 1. Overall system architecture

The physical layer is mainly composed of distributed power supply, power network, metering equipment, communication infrastructure, etc. To ensure safe and efficient transmission of electric energy between users who have reached P2P green electricity transactions, and to transmit the collected and calculated data such as electricity, electricity charges, and power flows to the data layer in real time for further analysis and processing.

Physical equipment requires relevant network capabilities to perform relevant system upgrades and connect to the blockchain network. The integration of the physical layer and the data layer will build the application layer. By using the application, the user can realize the energy management of the equipment, obtain the blockchain network service, use the proxy system to assist the user in decision-making, and perform data mining on the blockchain ledger.

3.4. Blockchain network design

Blockchain network is the core of the design of the P2P green electricity trading system. Compared with other blockchain development frameworks, Hyperledger Fabric adopts a system architecture that separates automatic contract execution and consensus mechanism, modularly realizes plug-and-play consensus services, member services, etc., and can customize the development of blockchain networks. In addition, compared to Ethereum, the Hyperledger Fabric blockchain network is more

suitable for regional energy transactions. To this end, Hyperledger Fabric is selected to develop the blockchain network.

Build a blockchain network based on Hyperledger Fabric 1.4.3. Each organization includes the relevant components to implement a consortium blockchain network with 3 channels. Channel technology is used to build a one-master-two-slave blockchain storage structure with the transaction blockchain as the main chain and the matching blockchain and the green power blockchain as the slave chains. According to different business needs, the data is stored in the corresponding blockchain to avoid the impact of excessive data volume on the performance of the blockchain network.

3.5. Smart contract

In recent years, smart contract technology has gradually developed due to its characteristics of openness, transparency, and economical efficiency. Facing the four major entities of the electricity retail platform and electricity transactions, smart contracts also have the advantage of being highly adaptable. With the development of the electricity retail platform, the transaction process is bound to move closer to transparency and speediness, especially as time changes, when the platform data shows a big data trend, smart contracts can greatly reduce the load of big data processing, making it more convenient. Complete the transaction contract efficiently, analyze the power consumption habits and patterns of power users, and better understand the data fluctuations of all parties on the platform. At the same time, it can simplify the contract signing and transaction process, which greatly liberates manpower. provide valid information.

In the process of power trading, the power trading package refers to a display that stipulates the power price standard provided by the power sales company to provide power sales services to power users. The electricity package lists electricity in detail with clear quality, energy level, electricity, electricity price and other parameters, so that electricity, a non-traditional commodity, has a value carrier, and through a variety of parameter configurations and business ideas, turning the intangible power that cannot be stored into a variety of online commodities to meet the daily needs of different users. The electricity package needs to specify the available time period, date, quality, and corresponding fees of electricity. The electricity bill of retail users should indicate in detail the basic electricity purchase fees, agency fees of electricity sales companies, transmission network fees and distribution network fees covered by this electricity transaction. For network fees, the platform regulator will supervise the overcharging of unknown fees in electricity transactions.

The green power package is mainly to provide users with green power from wind power and photovoltaics, and its cost depends on the user's energy plan or agreement. It is also possible to negotiate with the electricity sales company and the user to formulate a personalized green package.

Table 1. Green Power Package

Proportion of green electricity	5% green electricity	50 % green electricity	1 00 % green electricity
cost	Additional P ₁ per week	Extra P ₃ per kWh	Extra P ₆ per kWh
Estimated additional costs	₁ per week or additional P ₂ per quarter	₄ per week or P ₅ per quarter	Additional P ₇ per week or P ₈ per quarter

P_t is the electricity cost, which is determined by the electricity sales company.

3.6. Quantitative calculation of green power transaction price

The transaction price of green electricity is equivalent to the price of a bundled online parity hotel, which includes energy value and environmental value. The energy value is reflected by the transaction price of the hotel project in the electricity market, and the environmental value is reflected by the part that exceeds the mid- and long-term transaction price of local electricity.

Take carbon dioxide emission reduction benefits as an example for analysis.

The grid baseline emissions are:

$$E_B^y = c_1 E_G^y$$

$$c_1 = \alpha F_p + \beta F_E$$

Among them, E_B^y is the baseline emission; E_G^y is the on-grid electricity of green power projects; c_1 is the emission factor, F_p and F_E are the emission factors of unit electricity and unit capacity.

The carbon emission reduction of green power trading is:

$$E_R^y = E_B^y - E_V^y$$

Among them, E_V^y is the carbon emission reduction of green power enterprises.

The carbon emission reduction benefits of green power enterprises are:

$$R_C^y = pE_R^y$$

Among them, p is the transaction price of green electricity.

Carbon emission reduction value per unit of electricity is:

$$p_C = \frac{R_C^y}{Q^y}$$

Among them, Q^y is the on-grid electricity in the y th year.

Taking a power plant as an example, after adopting green power trading, the average annual CO2 emission reduction is 6.2 million tons. The transaction price is based on the minimum $p=20$ yuan/t, the annual emission reduction benefit is 106.981 million yuan, and the emission reduction benefit per unit of electricity is 0.0147 yuan/kWh, that is, the carbon emission price is obtained.

Considering that the coal consumption of thermal power is 0.315kg/kWh, the power plant will reduce the use of coal by about 2.282 million tons per year, and the CO2 emission reduction will be 29,200 tons, and the corresponding emission reduction benefit will be 135.538 million yuan.

4. Green electricity, green certificate, CCER relationship

Table 2. Content comparison

	C CER	Green certificate	Green electricity
Purpose	Provide key emission units with performance methods other than quota trading to help enterprises complete energy conservation and emission reduction; encourage entities not included in the carbon trading market to actively participate in energy conservation and emission reduction; at the same time provide offset sources for voluntary carbon neutral enterprises and organizations	Alleviate the pressure of the government subsidy funding gap, cooperate with the renewable energy power consumption responsibility weight target, and help enterprises complete the green certificate quota target	Provide the realization of the environmental value of renewable energy power, encourage the development of renewable energy power companies, and complete the consumption of green power
project source	Including new energy projects, forestry carbon sequestration and methane utilization projects, meeting relevant methodology, additionality and environmental integrity requirements	Onshore wind and photovoltaic power generation, except for distributed projects and water resource projects	Green power, currently wind power, photovoltaic, can be expanded to hydropower and other renewable energy power generation projects in the future
Trading places	Recorded carbon emission rights exchange	China Green Power Certificate Subscription Trading Platform	Power Trading Center
trading variety	Certified Voluntary Emission Reductions	Green Power Certificate	Green Electricity Consumption Certificate and Green Electricity Certificate
transaction target	Emission reduction corresponding to renewable energy electricity	Environmental value of electricity generated by renewable energy power generation projects included in the subsidy catalog and other parity items	Renewable energy power generation that can be physically executed, realizing the value of electric energy and the environment at one time

Green power trading, green certificate trading, and CCER are all voluntary market trading behaviors, and are relatively independent in terms of rules. However, at present, China is still in the

stage where the three market mechanisms are parallel. Here is a summary of the three market mechanisms in terms of purpose, project source, and trading variety, differences in trading venues.

5. Conclusion

This paper analyzes the mechanism and quantitative model of green power trading under the conditions of the power market, compares and summarizes the relationship between green power, green certificates, and CC E R, and builds the overall architecture of the green power trading system based on blockchain. The design is carried out, the point-to-point green electricity transaction is proposed, and the green electricity package is proposed for the smart contract in the block chain technology, and the price of the green electricity transaction is explained. This paper provides a new idea for the development of the mechanism of green power trading under market conditions, and has guiding significance for market development.

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