Research on Spot Trading Model Based on Green Certificate and its Application in New Energy Consumption

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Abstract. In this paper, the spot trading model based on green certificate is fully studied with electricity price and market trading as regulating tools and new energy consumption as the goal. Perfecting the mechanism of mixed electricity price to supplement its scope of action in spot market; Establish a mid - and long-term time-sharing contract market and spot market interface model; The bidding strategy of new energy on demand side and the response method of mobilizing resources on demand side are proposed. The evaluation plan and verification of new energy consumption by the above methods are proposed. This project is an innovative exploration of the current new power market on electricity price and transaction, based on the current medium - and long-term and spot markets have been established in our province, in the face of new factors such as medium - and long-term time-sharing contract, it provides a new research idea for solving the problem of new energy consumption, and has high practical value to promote the development of clean energy. It provides a solid scientific basis for promoting the formulation of new energy development strategies, energy conservation and emission reduction actions, and adjusting the relevant policies of electricity prices.

Keywords: electricity price, market trading, new energy consumption, green certificate, spot trading model, mixed electricity price mechanism, demand side bidding strategy, resource response, evaluation plan, new power market, practical value, clean energy development, energy saving and emission reduction

1. Introduction

1.1 Research background

Liaoning company is the earliest implementation of TOU and new energy consumption province, but there is still a gap from the consumption ratio target[1]. Liaoning company has carried out the pilot power spot market, developed a large power grid, built a large market, accelerated the pace of electric energy marketization, and actively embraced green energy.

At present, due to the short trading time of electricity market in our province, the demand side response is still in the initial stage, and spot trading has also started pilot trading in the near future[2]. How to effectively mobilize demand-side resources, fully understand the characteristics of the new electricity market, make good use of market tools such as price, and improve the proportion of new energy consumption remains to be further studied.

1.2 Research content

This paper aims to promote the consumption of new energy and vigorously develop green electricity is an important task of the new power market. The mismatch between the generating end of new energy is one of the reasons for the phenomenon of abandoning wind and electricity. The power side actively buys new energy and optimizes bidding strategy to promote the grid connection of new energy with fixed generation[3]; In the face of the rapid development of the power market, how to mobilize the response ability of the demand side and sort out the blocking point from the power generation side to the power side needs to carry out the corresponding correlation technology research.

2.   Overview

2.1   Current situation and development trend of domestic and foreign research level

1)Domestic status:

Recently, China's renewable energy development pace accelerated, in the rapid growth of renewable energy installed capacity at the same time, due to the limited local consumption space, inter-provincial transmission channels and inter-provincial barriers and marketization mechanism is not perfect, renewable energy consumption problems are prominent. The quota system effectively fits the strategic needs of the top-level system design of China's energy low-carbon transition, and its implementation is bound to have a positive impact on China's renewable energy generation, Internet access and consumption. However, the quota system still has problems to be solved in the process of promoting the development of renewable energy. The practical experience of Europe and the United States shows that reasonable quota index setting and mature green certificate trading system are the key to play the role of the quota system[4]. However, China has not yet perfected the supporting mechanism policy and determined the mature green certificate trading mechanism supporting the quota system[5].

2)Current situation abroad

New energy consumption has become a research hotspot in the world.

Foreign institutions have also studied the response policy. Washington State University has established the dynamic price simulation and prediction model of green certificate in North America, and studied the influence of green certificate on energy consumption[6]. Statistics Norway's analysis of green energy transactions between EU member states shows that green certificate transactions can reduce the cost of new energy generation[7]. Indian Institute of Technology based on India's new energy market research, it is concluded that green certificate trading has a positive effect on new energy consumption. The green energy trading market in the Flanders region of Belgium summarized the transaction, indicating that the scientific and reasonable setting of green energy quota ratio can promote the growth of new energy power[8].

2.2   Green card spot trading development technology

The development of spot trading technology of green certificate is the technology and mechanism for trading the generation and consumption of green energy[9]. A Green Certificate is a certificate that certifies that electricity comes from renewable sources and can be used for

market transactions and financial subsidies[10]. The following are the key aspects of the development of spot trading technology for green certificates:

Green certificate market platform: Establish a centralized green certificate trading market platform for power generation enterprises, consumers and investors to carry out spot trading of green certificates[11]. This platform can provide functions such as deal making, information release, settlement and clearing, and promote market liquidity and transparency[12].

Trading rules and standards: Develop unified green certificate trading rules and standards, including trading price determination, trading volume measurement and certification verification[13]. This can ensure the fairness, impartiality and reliability of transactions and enhance the trust of market participants.

Trading mechanism innovation: the introduction of more flexible and diversified trading mechanisms, such as bidding trading, bilateral negotiation trading and futures trading[14]. These mechanisms can flexibly determine the price and trading method of green certificates according to market demand and supply and demand.

Information Technology support: Use advanced information technologies such as blockchain, artificial intelligence and big data analytics to provide efficient green card trading and management support[15]. These technologies can realize real-time monitoring of transaction data, secure transmission of transaction information and automatic processing of transaction process[16].

Policy and regulatory support: Formulate relevant policies and regulations, clarify the regulatory bodies and the distribution of powers and responsibilities for green certificate trading[17], and provide a stable policy environment and legal guarantee for the development of the market.

2.3 Research progress of new energy consumption

Smart grid technology: Through smart grid technology, the fine management and control of decentralized new energy power generation equipment can be achieved, and its absorption capacity can be improved[18]. Smart grid technology can also achieve optimal scheduling and flexible distribution of power systems to adapt to the characteristics of high volatility and strong discontinuity of new energy.

Energy storage technology: Energy storage technology plays an important role in the consumption of new energy. Storing excess power generated by new energy sources and then releasing it according to demand can provide a stable power supply. At present, various energy storage technologies such as lithium-ion batteries and pumped storage continue to develop and are widely used.

Cross-regional power transmission: Through the construction of cross-regional high-voltage transmission channels, large-scale new energy power can be transmitted remotely. This can solve the problem of regional new energy consumption and promote the effective use of clean energy.

New energy power market mechanism: In response to the problem of new energy consumption, some local governments and power system operators have launched flexible power market mechanisms. These mechanisms encourage new energy power generation enterprises to

actively participate in market transactions, and provide corresponding incentive policies to improve the capacity of new energy consumption.

Energy Internet: The concept of energy Internet proposes an integrated energy system that integrates energy production, transmission, storage and consumption. Through energy Internet technology, the optimal allocation and flexible scheduling of new energy consumption can be achieved, and the efficiency of energy utilization can be improved.

Multi-energy complementary system: different types of energy complement each other, such as wind and solar energy, water and geothermal energy, etc. The construction of this multi-energy complementary system can effectively use various renewable energy resources and improve energy consumption capacity.

3. Analysis and method

3.1 goal

With the proposal of the "dual carbon" policy, the construction of a new power system and a market that ADAPTS to the development of new energy has become a new national goal. In recent years, the scale of renewable energy generation such as wind energy and solar energy has expanded rapidly, and the electricity consumption structure has also changed. The use of smart meters enables users to participate in source-charge interaction[19]. There is room for improvement in the utilization rate of new energy, so the application of price tools is an economical and effective means to promote the consumption of new energy and alleviate the problems of wind and light abandonment.

3.2 Data acquisition and preprocessing

Generally, the supply(Figure 1) and demand(Figure2) curves required to be declared in practice are in the form of step functions or piecewise linear functions. It is worth noting that the demand curve declared by the market subject should be monotonous and not increasing, and the supply curve should be monotonous and not decreasing, so as to ensure that the clearing model is a convex optimization model.
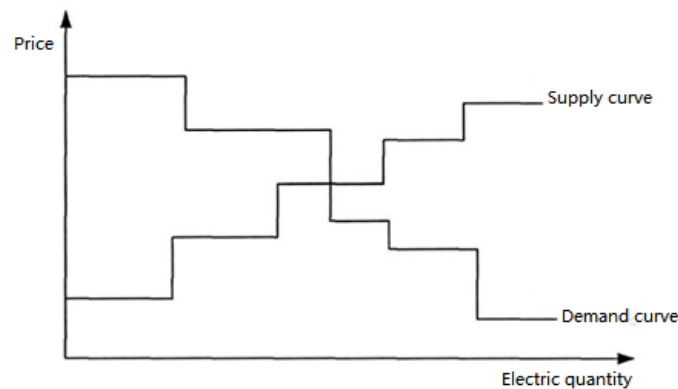

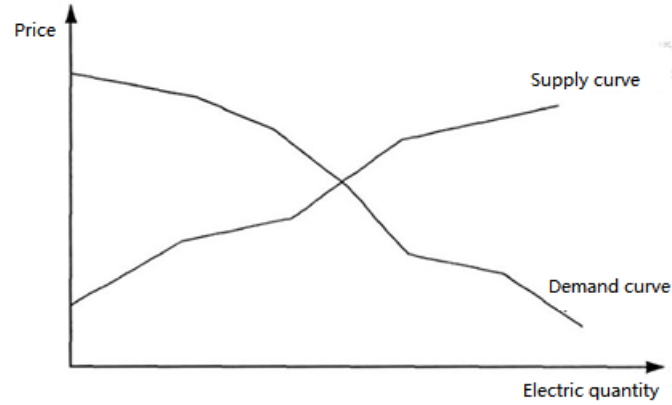**Figure 1:** Supply and demand curve in the form of a step function

Figure 2: Supply and demand curves in the form of piecewise linear functions

Constraints include:

1)Supply and demand balance constraints

$$\sum_{t \in N_D} D_i = \sum_{j \in N_s} S_1$$

2) Upper and lower limit constraints on scalars in

$$D_i^{\min} \leqslant D_i \leqslant D_i^{\max}$$
$$S_j^{\min} \leqslant S_j \leqslant S_j^{\max}$$

Dimx and Dimm respectively represent the upper and lower limits of the medium scalar of the i power purchase quotation, and Smax and Smin respectively represent the upper and lower limits of the medium scalar of the j power purchase quotation.

3.3 Spot trading model based on green certificate

Market clearing model and optimization based on green certificate,The specific work includes the establishment of power generation bidding model, green certificate market trading model, market clearing model and bidding optimization model.

1)Power producer bidding model:

According to the results of medium - and long-term contract signing, the active power output corresponding to the electricity in each period is converted into the power quotation section of the power producer.

2)Green certificate market trading model:

In order to complete the absorption responsibility of new energy for electricity side selling e-commerce, in addition to medium and long-term new energy contracts, green certificates can be purchased in the green certificate market[20]. Generators participating in the spot day market corresponding electricity can be exchanged for the same amount of green certificates. The model can simulate and calculate the number of green certificates between new energy power generators and electricity sellers.

3)Market clearing model:

Market operators clear the electricity day-ahead market with the goal of maximizing social welfare, and adopt a variety of calculation methods to build a clearing model[21].

4)Bidding optimization model:

The bidding model can be divided into two parts for optimization. Some power producers hope to obtain ideal returns in the two parts of electricity trading and green certificate trading, and improve the willingness of new energy grid connection. The other part is the market clearing part, hoping to achieve the ideal power purchase cost[22]. Bilateral optimization to maximize social welfare, the structure is shown in the figure3.
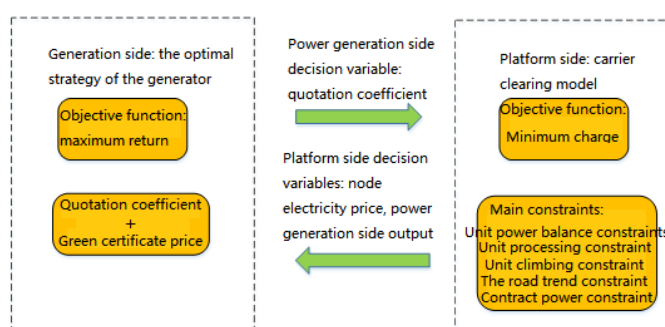

Figure 3: Bilateral optimization analysis frame diagram

4. Research on the correlation technology between new energy consumption effect and electricity consumption pattern

In order to improve the consumption effect of new energy, rationally allocate the electricity consumption mode, establish a new energy power trading model, analyze the new energy quotation strategy in the new energy spot trading process based on green certificates, and maximize the income of power trading. Encourage new energy to increase the proportion of grid-connected, so that electricity customers have more new energy trading power in the market.

The relationship between the power market and the green certificate market is very complicated. As a transmission medium, renewable energy power producers and conventional energy power producers, through the interaction between the price of green certificate, various types of contract electricity price and spot electricity price, the parameter adjustment will have a chain reaction on the entire market and have an important impact on all participants in the market. However, these effects are mostly presented in a non-linear way and contain repeated feedback superposition process, which needs to be analyzed from the perspective of the system[23]. Therefore, this part adopts the system method to simulate the interaction mechanism between the electricity market and the green certificate market, taking the electricity market as the system boundary, including the medium and long-term contract market, the spot market and the green certificate market.

5. Experimental data validation analysis

Using the final model of the second order factor obtained above, the efficiency of the green certificate trading market can be evaluated. This paper uses the correlation weight method to determine the weight of the index system. The correlation weight method is a method to determine the weight by using the correlation between variables [24]. This method is to calculate the correlation coefficient between variables through a large number of sample data, and determine the weight according to the relative importance. The standardized factor load in the fitting result of structural equation model essentially reflects the correlation coefficient between each observed variable and the corresponding latent variable. In view of this, the weight of each index can be obtained by normalizing the standardized factor load.

$$\rho_{ij} = \lambda_{ij} / \sum_{j=1}^{n} \lambda_{ij}$$

See the above formula,， The normalization formula is, ρ_{ij} Is a first-order factor η_i The corresponding weights of the JTH measurement index and the weights of first-order factors are determined by the same method.

$$\xi(\text{Market efficiency}) = \sum_{i=1}^{H} \beta_i \sum_{j=1}^{K} \rho_{ij} y_{ij}$$

See the formula above,ξ Represents the market efficiency of green certificate trading,β Represents a first-order factor η The weight,H represents the number of first-order factors, and K represents the number of indicators corresponding to first-order factors. The weight distribution of the green certificate trading market efficiency index system is shown in the following table. After the implementation of the green certificate trading system, government departments, market supervision departments and market participants can refer to the weight coefficient table of the index system to evaluate the efficiency of the green certificate trading market(Table 1).

Table 1: Variable weight coefficient table of green certificate trading market efficiency evaluation model

Primary index	Weighted weight	Secondary index	Secondary index	Three-level index
Green certificate trading market efficiency	0.207	Market stability	0.299	Market supply and demand ratio
			0.322	torage ratio
			0.379	Average selling price of green certificate
	0.249	Market competition	0.311	Relative concentration HHI
			0.317	Barriers to entry and exit
			0.372	The degree of competition in the market
	0.173	Market efficiency	0.407	Market efficiency
			0.291	Inter-provincial and inter-regional

			transaction rate
		0.302	Total social welfare
0.203	Market economy	0.352	Bain index
		0.375	Market order index
		0.273	Good economies of scale
0.168	Market coordination and development	0.202	Transaction cost
		0.244	Proportion of electricity generation from renewable sources
		0.290	Rate of change of emissions of carbon, nitrogen, sulfur and other pollutants
		0.264	Growth rate of installed renewable energy capacity

6. Experimental data validation analysis

6.1 Summary of research results

1)We will increase the proportion of new energy consumption and reduce the cost of consumption

Based on the analysis of the spot market trading model based on green certificate, the paper puts forward the mixed electricity price based on time-sharing capacity, which fully considers the cost of new energy generation and the mobilization cost of flexible resources[25]. Optimize the bidding method, improve the new energy grid connection capacity, increase the supply. In the analysis of the correlation between long-term time-sharing contract and spot market transactions, the unbalanced funds are estimated, the delivery method is optimized, and the new energy trading mechanism is clarified. Finally, the new energy bidding strategy is optimized on the demand side, and the demand-side response ability is actively mobilized through the form of power package, so as to increase the proportion of new energy consumption. To achieve a win-win situation for power users, power grid enterprises and new energy power generation enterprises.

2)Participate in the revision of electricity price policy and strive for favorable price policy

Through the participation of the power grid company in the revision of the TOU tariff policy of the local government, a favorable price policy can be obtained. The bidding strategy and optimization method based on green certificate studied in this project can effectively improve the consumption ratio of new energy. Increase the willingness of new energy power generation enterprises to connect to the grid. To maintain the overall stability of electricity prices, and improve the supply and demand of electricity through market means. It can provide a scientific decision-making basis for local governments to make power spot market policies, and also create a scientific basis for power grid enterprises to strive for favorable pricing policies.

6.2 The direct and indirect benefits after the results are popularized

Our province has excellent green energy rich conditions, backed by large-scale wind power base, photovoltaic resources are extremely rich. By improving the design of mixed electricity

price, this project makes it more suitable for spot market new energy trading and improves the grid-connected proportion of new energy on the power generation side. Analyze the relationship between medium - and long-term time-sharing contract method and spot market trading, optimize delivery mode, and actively mobilize demand-side resources to increase the proportion of new energy consumption. Economically, increase the proportion of new energy power generation connected to the grid, so that the cost advantage of new energy is fully reflected, and the comprehensive cost of energy use tends to be reasonable; For power grid enterprises, medium - and long-term and spot market means are fully used to make the load relatively uniform distribution effectively improve the life of power grid facilities, reduce power grid losses, and slow down peak load investment; For new energy power generation enterprises, the return on investment of new energy has been improved. In terms of environmental protection, the use of new energy will significantly reduce carbon emissions, and make practical contributions to the early realization of China's "double carbon" goal. In terms of social benefits, the reasonable cost of comprehensive energy use will improve social satisfaction, and the reasonable setting of electricity price strategy will improve the comprehensive efficiency of energy use, and make due contributions to the transformation and upgrading of China's industry.

7. Conclusion

*A.*The bidding strategy and optimization method based on green certificate can effectively improve the proportion of new energy consumption. Increase the willingness of new energy power generation enterprises to connect to the grid. To maintain the overall stability of electricity prices, and improve the supply and demand of electricity through market means. It can provide a scientific decision-making basis for local governments to make power spot market policies, and also create a scientific basis for power grid enterprises to strive for favorable pricing policies.

*B.*Promoting innovative exploration of new energy consumption has become an important and ongoing challenge. Combine the green certificate market, medium and long-term market and spot market effectively; Mobilizing demand-side resources and giving full play to the role of price system tools is a new way to realize the absorption of new energy and ensure the balance of market transactions.

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