Research on the Quantitative Model of Benefit Analysis to Promote the Consumption of New Energy

Jianguang Li[1], Hechun Wang[1]*, Jingjing Gu[1], Dunnan Liu[2], Zhixin Dong[2], Hua Li[2]
Jianguang Li: 3154978636@qq.com
*Wang Hechun: 577980104@qq.com
Jingjing Gu: gujingjing@163.com
Dunnan Liu: 363064079@qq.com
Zhixin Dong: dongzhixin10@163.com
Hua Li: lihua@163.com

[1]Jiangxi Electric Power Trading Centre Co., LTD, Nanchang 330077, Jiangxi Province, China, [2]School of economic and management, North China Electric Power University Beijing, China

Abstract—China has made a solemn commitment to carbon peak by 2030 and carbon neutrality by 2060. The "dual carbon" goal promotes the development of energy transition. At the same time, the “six signings” of medium- and long-term transactions put forward new requirements for the construction of the power market. Therefore, it is necessary to conduct research on the key market mechanisms that increase flexibility in the new situation. Based on the current situation of new energy consumption in China, this paper analyzes the mode of new energy participation in the power market. Then it designs a market mechanism that promotes high-proportion energy consumption. Finally, a quantitative study on the benefits of the flexible market mechanism in promoting new energy consumption was carried out to analyze the contribution of the flexible market mechanism to the promotion of new energy consumption. The analysis of specific calculation examples shows that the proposed model is of great significance to the consumption of new energy. Through relevant research, we hope to lay a solid foundation for the integration of China's high proportion of new energy into the power system.

Keywords-new energy consumption; market mechanism; benefit quantification model

1 INTRODUCTION

At present, China has made a solemn commitment of carbon peaks by 2030 and carbon neutrality by 2060. The ninth meeting of the Central Committee of Finance and Economics emphasized that the "14th Five-Year Plan" is a critical period and window period for carbon peaks. It is necessary to build a clean, low-carbon, safe and efficient energy system, control the total amount of fossil energy, focus on improving utilization efficiency, implement renewable energy alternatives, deepen the reform of the power system, and build a new power system with new energy as the main body. The key to achieving the goal of "carbon peak and carbon neutrality" is to solve the problem of new energy consumption, and to effectively solve the problem of new energy consumption, it is necessary to focus on system adjustment costs. By establishing a transaction mechanism for new energy to bear the cost of system adjustment, it can provide theoretical basis and technical support for the effective transmission of new energy consumption costs, stimulate the system's flexible adjustment capabilities, and promote energy clean and low-carbon transition.

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The new round of power system reform is progressing in full swing. Designing a scientific and rigorous market mechanism, incorporating new energy into the power market, and using a flexible market mechanism to promote the consumption of a high proportion of new energy are key issues currently focused on by all walks of life. In the existing research, literature [1] further explored the contribution of renewable energy power generation in energy, environment, economy and society based on the detailed analysis of the external benefits of renewable energy power. Literature [2] analyzed the benefits of distributed power sources in reducing line loss, environmental benefits, improving power supply reliability, and improving climate, and established a quantitative evaluation model of distributed power benefits. Literature [3] puts forward a linear programming model in which demand-side resources and supply-side resources are equally included in power planning. Different demand-side management measures are distinguished and quantified in the model, which achieves the lowest total system cost and reduces pollution emissions. The above documents all quantify the benefits of a single market mechanism or technology, and have not established a unified quantitative model of the market mechanism.

Therefore, it is necessary to conduct research on the key market mechanisms for enhancing flexibility under the new situation, and to provide new management mechanisms and platforms for exploiting the flexibility potential of technical measures.

2 ANALYSIS OF NEW ENERGY'S PARTICIPATION IN POWER MARKET MODE

2.1 China's Market Mechanism To Promote The Consumption Of New Energy

Since the new round of power system reform in 2015, The National Energy Administration and the National Development and Reform Commission have successively issued a series of policy documents on the development and consumption of new energy [4]. Firstly, starting from the power construction aspect to plan and coordinate the new installed capacity of each province; in terms of market mechanism, encouraging renewable energy to participate in market transactions, and gradually expand the scope and scale of transactions. Implement the renewable energy power green certificate trading mechanism and renewable energy quota system, enhance the development, utilization and guidance of renewable energy, improve the power auxiliary service market, and promote the development of energy storage technology and industry. With the development of the new energy industry, as well as the release of new energy participation in market competition, cross-provincial and cross-regional transactions, parity online and other related policies, new energy consumption will enter a new stage, and more attention will be paid to energy overall planning and market-oriented competition and other factors.

At present, ensuring the consumption of a high proportion of new energy is a difficult problem faced by countries all over the world. Compared with most foreign regions, China's new energy is very concentrated and difficult to absorb locally [5]. Especially in areas where new energy sources are concentrated, the power supply structure is single, and the proportion of flexible power sources such as pumped storage and gas power plants is low. In addition, the economic growth rate has slowed in recent years and the power growth rate has been slow. Under the joint

effect, the contradiction of high proportion of new energy consumption has become more prominent.

2.2 Key Issues for New Energy to Participate in the Power Market

2.2.1The phased marketization of new energy:

Promote the conversion of new energy optimized power generation plans into government authorized contracts. In the initial stage, new energy is still purchased in full in accordance with "quantity and price protection", transforming the new energy priority power generation plan into a government authorized contract, signing factory online purchase and sales contracts, and implementing the price approved by the government. At the same time, a new energy deviation settlement mechanism and a complete deviation adjustment mechanism will be established to provide new energy companies with flexible market-based adjustment methods through continuous opening transactions within a month.

Promote a certain proportion of new energy to enter the market. Comply with the principles of "quantity-guaranteed price" and "quantity-guaranteed bidding". The electricity purchased by new energy is divided into: "quantity and price guarantee" electricity, and "quantity guarantee and bidding" electricity. 1)The guaranteed purchase part is still purchased in full in accordance with the "quantity and price guarantee", the factory online purchase and sale contract is signed, the price approved by the government is implemented, and the market transaction contract is integrated into the unified management. 2)The market-oriented transaction part promotes new energy power generation companies to participate in the time-sharing trading market in the province, and conduct transaction declaration, contract adjustment, transaction execution, deviation and settlement in accordance with market transaction rules.

Increase the proportion of new energy participating in the market in a timely manner. Increase the proportion of market consumption in a timely manner, improve market mechanisms, and explore the development of excess consumption and green certificate transactions.

2.2.2The market model of new energy participation

Promote the participation of new energy in mid- and long-term transactions in time periods, and bilateral transactions can be used to carry out mid- and long-term transactions such as annual, monthly, and multi-day transactions.

Enrich the types of transactions that adapt to the development of new energy, flexibly carry out high-frequency sub-electric energy and contract market integration transactions, and enhance the flexibility of new energy power curve adjustments.

Establish a flexible contract adjustment mechanism to promptly respond to the new energy forecast curve and the adjustment demand under special circumstances such as tight supply and demand periods.

Establish a complete deviation settlement mechanism, settle deviation electricity through the deviation price mechanism, and realize the gradual transition from “monthly settlement” to “weekly settlement” to “daily settlement” for new energy medium and long-term transactions.

Encourage new energy to participate in time-sharing trading through multiple channels

3 PREPARE MARKET MECHANISM DESIGN TO PROMOTE THE CONSUMPTION OF HIGH PROPORTION OF NEW ENERGY

Promote the conversion of new energy priority power generation plans into government-authorized contracts and incorporate them into market-oriented trading contracts for unified management. In order to meet the needs of some users for the consumption of green power, explore the development of green power trading mechanisms, and promote some affordable new energy and emerging market entities to enter the market.

(1) The new energy optimized power generation plan is transformed into a government authorized contract New energy still follows the principle of full purchase of "quantity and price protection", transforming the new energy priority power generation plan into a government-authorized contract, signing factory online purchase and sales contracts, and implementing the government-approved price. Incorporate into market-oriented transaction contracts for unified management, and implement "take or pay, deviation settlement, monthly settlement, and compensation for thermal power companies with difference funds."

(2) Annual transactions: New energy power generation companies predict the annual power generation capacity of the following year, and declare the total amount of peak, flat, valley, and peak periods of the following year on the trading platform, as well as monthly and weekly plans. New energy power generation companies can agree on their own monthly plans and weekly plans for annual electricity with grid companies, or form annual monthly plans and weekly plans according to the typical decomposition method provided by the trading center.

Monthly transactions: new energy power generation companies predict the monthly time-of-use power of the next month, combined with the annual contract power, declare on the trading platform the standard contract power of the energy block for each period of the next month's peak, flat, valley, and tip, and decompose it to the power grid. The enterprise signs the corresponding time-sharing power purchase and sale contract, and implements the government approved price.

(3) Intra-month transactions: In order to meet the needs of new energy companies for flexible adjustment of deviations, organize and carry out intra-month transactions involving new energy companies. New energy companies can flexibly adjust contract positions and contracts according to the actual power generation situation during the month through the purchase and sale of standard energy block contracts. The price is the government approved price.

(4) Contract adjustment and execution: Allow the electricity trading platform to adjust the monthly contract plan for each subsequent month (the total contract amount remains unchanged) before the execution of the next month's transaction. According to their own forecasts, new energy companies can declare on the trading platform a month ago to adjust their annual contract monthly plans.

(5) Deviation settlement: Settling the deviation electricity through the deviation price, and gradually realize the "weekly settlement and monthly settlement" of the transaction contract in time periods to ensure the performance of medium and long-term contracts.

4 QUANTITATIVE MODEL OF MARKET MECHANISM BENEFIT TO PROMOTE THE CONSUMPTION OF NEW ENERGY

4.1Environmental Benefit Quantitative Model

Fossil energy generating sets will produce a large amount of polluting gases such as sulfur dioxide and carbon dioxide during the power production process, which is very unfriendly to the environment. However, new energy power generation does not produce these pollutants during the production process, so these pollution can be avoided. By implementing a flexible market mechanism to promote a high proportion of new energy consumption, environmental pollution can be effectively improved. Previous studies have summarized the data of environmentally unfriendly gas emissions in the production process of various power sources as shown in the table 1.

TABLE 1. POLLUTION EMISSION DATA OF VARIOUS POWER GENERATION TECHNOLOGIES

Type of power supply	**NOx (kg/MWh)**	**CO_2 (kg/MWh)**	**SO_2 (kg/MWh)**
Photovoltaic power generation	0	0	0
Wind power	0	0	0
Natural gas power generation	0.008—1.547	49.037	0.464
Micro gas turbine	0.619	184.083	0.001
Internal combustion engine (gas turbine)	4.795	170.161	0.023
Coal-fired power generation	0.154—3.194	86.473	0.108—3.945

When fossil fuel power generation is replaced by new energy due to the flexible market mechanism, the reduced ith environmentally unfriendly gas emissions can be expressed as:

$$e_c^i = P_N \cdot k \cdot 8760 \cdot D_i \tag{1}$$

P_N is the active power of new energy power generation; k is the average capacity coefficient of the new energy generator set, D_i is the ith environmentally unfriendly gas volume that the replaced fossil energy power generation would produce.

Through the implementation of a flexible market mechanism, the power generation capacity of new energy can be increased, and the flexibility to promote the consumption of new energy resources. The reduction of the i-th environmentally unfriendly gas after the implementation of resources is:

$$e_m^i = P_V \cdot k_p \cdot 8760 \cdot D_i \tag{2}$$

k_p is the average capacity coefficient of new energy power generation after the implementation of the flexible market mechanism.

Therefore, after the implementation of the market flexibility mechanism to promote the consumption of new energy, the increase in the reduction of the i-th environmentally unfriendly gas in the system is:

$$\Delta e^i = e_m^i - e_c^i \tag{3}$$

Based on the above formula, the environmental cost and benefit resulting from the increased consumption of new energy can be expressed as:

$$E = \sum_{i=1}^{n} (W_i + V_i) \Delta e^i \tag{4}$$

Among them, 1 is the environmental value of the i-th environmentally unfriendly gas; 2 is the environmental cost of the i-th environmentally unfriendly gas to reduce emissions.

4.2 Quantitative model of benefits for saving electricity costs

With the continuous improvement of new energy power generation technology, the cost of new energy power generation continues to decrease. New energy power generation in regions with rich new energy resources has a very large cost advantage. Through flexible market mechanisms such as inter-provincial new energy bundled delivery transactions, The implementation of inter-provincial new energy and thermal power generation rights transactions, etc., can greatly reduce the power purchase cost of power purchasers, thereby saving considerable power purchase costs.

Let Q_i^S be the total purchased power of the ith power purchase company; $Q_{i,j}^P$ represent the transaction power completed by the jth province with outsourcing capacity and the ith power purchase company; $Q_{i,l}^M$ represent the first power plant and the ith The amount of transaction electricity completed by the purchasing company. According to the balance of supply and demand, the following expression holds:

$$Q_i^S = \sum_{j=1}^{N_1} Q_{i,j}^P + \sum_{l=1}^{N_2} Q_{i,l}^M \tag{5}$$

According to the above description, the power purchase cost model can be described by the following expression:

$$C_s = \sum_{i=1}^{M} \sum_{j=1}^{N_1} Q_{i,j}^P (P_{cj} W_{ci} + N_{cj} W_{N_{cj}}) + \sum_{i=1}^{M} \sum_{j=1}^{N_1} P_l Q_{i,l}^M \tag{6}$$

In the formula, P_{cj} represents the average purchase price of thermal power generation in the j-th province participating in the power transaction, N_{cj} represents the average purchase price of the new energy power generation in the j-th province participating in the power transaction, and W_{ci}, $W_{N_{cj}}$ indicate that these two types of units are in the transaction power The proportion, and the sum of the two is 1, P_l represents the average power purchase price of the lth power plant. Before and after the implementation of the market mechanism, the difference in electricity purchase costs is the benefit of saving electricity purchase costs.

4.3 Figures and Tables Quantification model for increasing income from electricity sales

$$E_{sale} = \sum_{i \in N_{sale}} Q_i P_i \tag{7}$$

In the formula, E_{sale} is the set of market mechanisms that promote the cross-provincial transactions of new new energy, and Q_i, P_i are respectively the new external power delivered and the corresponding price under the market mechanism i.

4.4 Quantitative model of benefits for improving power supply reliability

$$E_{re} = (P_{tup,peak} + P_{re}) \cdot k_{re} \cdot t \cdot W \tag{8}$$

In the formula: $P_{tup,peak}$ is the peak load reduced by the time-of-use electricity price, P_{re} is the new peak reserve capacity in the reserve auxiliary service market, k_{re} is the average capacity coefficient of the peak reserve capacity, t is the average annual outage time; W is the power generation ratio.

4.5 Quantitative model of benefits of delaying transmission and distribution network construction

$$r = \frac{c}{1 + c \cdot n} \tag{9}$$

$$V_d = Z \cdot [1 - \frac{1}{(1+r)^n}] \tag{10}$$

In the formula: c is the interest rate; n is the number of years that the transmission and distribution network project has been postponed; r is the industry discount rate; Z is the originally planned capital injection for the transmission and distribution project.

4.6 Improve transmission line utilization

$$E_{tr} = \frac{E_{net}}{8760} (\frac{1}{P_{DK}} - \frac{1}{P_{DK}^{'}}) \tag{11}$$

In the formula, E_{net} is the accounting annual permitted income of the transmission line, P_{DK} is the guaranteed capacity of the new energy base under the reliability requirements before bundling of new energy thermal power, and $P_{DK}^{'}$ is the capacity corresponding to the combined power generation guarantee rate of 95% after bundling.

5 CASE ANALYSIS

According to the benefit quantification model, the implementation benefits of typical market mechanisms in A and B are calculated. The detailed calculation results are shown in Table 2:

TABLE 2. ENVIRONMENTAL COSTS OF GASEOUS EMISSIONS

Gaseous emissions	**Cost of abatement / (yuan/kg)**	**Environmental value/ (yuan/kg)**
Nitrogen oxides	2.003	7.995
SO_2	1.258	5.997
CO_2	0.764	0.023

(1) Time-of-use electricity price The time-of-use electricity prices are implemented in places A and B respectively, and the average electricity prices in the markets of A and B are 498.3 yuan/MWh and 620 yuan/MWh respectively. The peak and valley load electricity of A are -1.3 and -0.6, the flat-segment electricity price and the peak and valley price of electricity are 498.3 yuan/MWh, 549.3 yuan/MW, 298.3 yuan/MWh, respectively; B's peak and valley load electricity are respectively -1 and -0.8, the flat-segment electricity price and the peak and valley electricity prices are 670 yuan/MWh, 620 yuan/MWh, and 420 yuan/MWh, respectively.

(2) The calculation shows that for A, the direct benefits of the implementation of the time-of-use electricity price include environmental benefits and improved power supply reliability. According to the calculation of the benefit quantification model, the environmental benefit obtained by Site A is 78,900 yuan/day, and the revenue of improving power supply reliability is 864,100 yuan/day. For land B, the direct transactions obtained through the implementation of the time-of-use electricity price include environmental benefits, improvement of power supply reliability, and reduction of power purchase expenditures. According to the calculation of the benefit quantitative model, the environmental benefits obtained by land B are 213,300 yuan per day, which improves the reliability of power supply. The income is 4,123,900 yuan/day, and the income from reducing electricity purchase expenditure is 452,300 yuan/day.

(3) Wind and fire bundling transactions For site A, the direct benefits from the implementation of wind-fire bundling transactions are mainly to increase the revenue from electricity sales and increase the efficiency of transmission line utilization. According to the calculation of the benefit quantification model, the increase in revenue from electricity sales is 4,544,500 per day, which improves the utilization of transmission lines. The rate benefit is 76 yuan/MWh. For site B, the direct benefits obtained from the implementation of wind-fire bundling transactions are mainly environmental benefits, reduction of power purchase costs, and improvement of transmission line utilization benefits. According to the calculation of the benefit quantitative model, the environmental benefits are 998,600 yuan per day, reducing purchases. The electricity

revenue is 1,110,100 yuan/day, and the benefit of improving the utilization rate of transmission lines is 76 yuan/MWh.

(4) Reserve ancillary service market Carry out backup ancillary services in places A and B, increase the reserve capacity during peak hours, increase the consumption of new energy, improve the reliability of the new energy power system with a high proportion of power supply, and obtain the benefits of reducing load loss. In the standby ancillary service market, the participation of flexible power supplies in areas A and B in providing standby services increased by 2% and 4%, respectively. According to the calculation of the benefit quantification model, the benefits of improving power supply reliability for A and B are 402,600 yuan/day and 1,59,400 yuan/day respectively. Based on the above calculation results, it can be seen that market mechanisms such as time-of-use electricity price, transfer of power generation rights of captive power plants, bundling of new energy thermal power, and auxiliary service market can bring about the effect of promoting the consumption of a high proportion of renewable energy in the system, and bring significant Economic, environmental, and social benefits.

6 CONCLUSION

This article analyzes the necessity of establishing a flexible market mechanism to promote the consumption of new energy based on the current status of consumption of new energy in China. Firstly, it summarizes the existing market mechanism to promote the consumption of new energy, and then designs the market mechanism to promote the high proportion of new energy consumption in China in the short and long term. Finally, a quantitative study on the benefits of the flexible market mechanism in promoting new energy consumption was carried out to analyze the contribution of the flexible market mechanism to the promotion of new energy consumption.

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