

Market Experience and Trend of Foreign Countries in Response to Low-carbon Energy Transformation and Development

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Abstract. In response to climate warming, the number of countries planning to implement net zero carbon emissions is increasing worldwide. By analyzing and studying the achievements and experiences of developed countries such as Europe and the United States in formulating and improving relevant policy mechanisms to promote energy, especially in the process of green transformation of electric power, this paper summarizes and judges the development ideas and suggestions applicable to China, which has important reference significance for China to explore and study the policy mechanism and market construction adapted to the new power system.

Keywords: Green transformation; Policy mechanisms; New Power System; Regulation.

1 Introduction

Activities related to energy production and consumption are the main sources of carbon dioxide emissions. Vigorously promoting carbon emission reduction in the energy sector is an important measure to accelerate the construction of a modern energy system and achieve the goal of emission peak and carbon neutrality. However, the existing market mechanism still faces some difficulties and challenges, and it is difficult to meet the needs of promoting green and low-carbon energy transformation under the new situation. By analyzing and studying the cases and trends of foreign countries in response to the development of low-carbon energy transformation, this paper draws important experience suitable for the development of China's energy and power industry, which is of great significance for establishing a sound market system, building a reasonable market mechanism and realizing the optimal allocation of energy resources.

2 Practical experience of international energy transformation

2.1 Promote the construction of carbon market

Carbon emissions trading is considered to be one of the most effective market economic means in many practices of reducing greenhouse gas emissions around the world. The power industry

is not only an important area of carbon emissions and carbon emission reduction, but also a major industry covered by the carbon market. The constantly reforming carbon trading market is becoming an important measure for Europe to reduce carbon emissions and achieve climate goals.

The trading mechanism of the European Union Carbon Trading System (EU-ETS) is mainly based on the trading of carbon emission quotas, which implements mandatory carbon emission limitation quotas for participating countries, and allows trading entities to achieve the trading of carbon emission quotas through the trading platform, so as to ensure the realization of the overall emission reduction targets of the European Union. Up to now, the participants of the EU carbon trading system are not only EU member States, but also non-EU countries such as Iceland and Norway, covering about 13000 emission entities, making it the largest carbon trading market in the world.

The total amount of European quotas is determined by climate targets, which means that the intensity of emission reduction will be further increased, and the total amount of quotas will decrease more annually, thus raising the price of carbon quotas. With the outbreak of the conflict between Russia and Ukraine, the EU benchmark carbon price has soared to about 85 euros per ton by the end of June 2022. At present, the construction of the global carbon market has entered an accelerated period, and its role has become increasingly prominent. The gradual maturity of the carbon market and the rising carbon price have become the main driving force for all walks of life in the world to increase investment in clean technology. With the gradual expansion of industry coverage, the carbon market is expected to become an important driving force for global emission reduction[1].

2.2 Construction of "Voluntary and Quota" Green Electricity Trading Mechanism

Due to the increasingly serious environmental problems caused by the consumption of traditional fossil energy, the U.S. government has issued a series of incentive policies to promote the development of renewable energy, and the green power market has emerged as the times require. There are two main types of green power market in the United States: one is the quota market based on the Renewable Portfolio Standard (RPS), and the other is the voluntary trading market. The quota market is established by the state governments in accordance with the relevant laws and regulations of RPS to help the responsible subjects who undertake the quota obligations to achieve the goal of renewable energy quota. Voluntary market is a market where consumers purchase renewable energy out of their willingness to consume green electricity[2].

2.3 Guarantee the reasonable income of new energy through price mechanism

The recent development trend of renewable energy support mechanisms in European countries is to abandon fixed subsidies. Governments have moved away from the previously adopted fixed feed-in tariffs in favour of premium subsidies and contracts for difference. This allows governments to manage the burden of subsidy budgets through these mechanisms while encouraging new renewable generation capacity. Germany, Spain, Denmark and other countries mainly use premium subsidies, while the United Kingdom uses contracts for difference. At the same time, more and more countries use auctions to implement feed-in tariffs and premium subsidies. Germany fully introduced the premium subsidy mechanism in

2012, that is, to determine the project owner and the winning price through bidding and auction.

The contract for difference mechanism has been implemented in the UK since 2017. Its core is that renewable energy enters the electricity market according to the rules of the electricity market, and the specialized agencies managed by the government sign long-term contracts with renewable energy power generation enterprises at the contract price (the contract price is determined by bidding and must be lower than the government guidance price). During the transaction, if the average market price is lower than the contract price, the power generation enterprise shall be subsidized to the contract price; otherwise, the higher part shall be returned. The contract for difference mechanism adopts the way of bidding to determine the contract price, which not only guarantees the reasonable income of renewable energy enterprises, but also avoids excessive incentives to renewable energy.

2.4 Introduce a mechanism to deal with electricity deviation adapted to new energy sources

For conventional units in the United States, deviation penalties will be imposed when the output exceeds 5% or 5MW (whichever is smaller) of the base point command value for consideration of auxiliary service invocation. The base point instruction deviation penalty standard of the wind farm shall be more lenient, and the penalty shall be imposed only when the output of the wind farm is higher than the base point instruction value by more than 10% in the state of wind curtailment. Nordic wind companies are penalized for their output forecast errors in the day-ahead spot market. In a balanced market, if the amount of imbalance is opposite to the amount of system imbalance, wind power enterprises should be punished and settled according to the day-ahead spot market price. If the amount of imbalance is the same as the amount of system imbalance, the enterprise is exempted from punishment and settled at the equilibrium market clearing price[3].

2.5 Ensure adequate generation capacity in the medium and long term through capacity compensation system

In the electricity market with abundant supply and full competition, the market price will be determined by the marginal generation cost of marginal units, which means that fossil energy generation, which often assumes the role of marginal units, can not recover the initial fixed asset investment. Foreign typical electricity markets mainly solve this problem through capacity compensation mechanism, capacity market, scarcity pricing and other mechanisms [4-5].

2.6 Adopt a regulatory policy that pays equal attention to both constraints and incentives

The UK has entered the second regulatory cycle of transmission and gas networks since the adoption of the RIIO regulatory framework. In general, the RIIO regulatory model inherits the essence of the RPI-X model, still implements price cap regulation, and makes some major adjustments to cope with the future of low-carbon energy development and innovation trends in the energy sector. Valid for four years (2021-2024). CRE, its regulator, believes that electricity prices are important for the implementation of national energy policies, and that the new TURPE6 framework will ensure that grid usage fees are in line with the government's

energy development goals. The French TURPE6 regulatory framework considers supporting national energy transformation by fully guaranteeing investment demand, providing differentiated pricing and controlling total costs. The United States mainly uses ROE to stimulate transmission grid investment in line with the government's long-term energy goals, and the fundamental evaluation criterion is whether the investment effect is benefited by users [6-7].

3 Inspiration to China

Firstly, with the gradual increase of the proportion of new energy, the government needs to take comprehensive measures in legislation, planning, market mechanism, taxation and finance.

Secondly, the green and low-carbon characteristics of the new power system are prominent, but the power supply cost of the system has increased substantially, so it is necessary to base on China's resource endowment and rationally alleviate the problem of rising power supply cost through diversified means such as power market, ancillary service market and carbon market.

Thirdly, in the new power system, the safe and stable supply of power is the foundation, and the flexibility of the system is the guarantee. It needs a variety of market mechanisms to cooperate with each other to ensure the safe and stable operation and sustainable development of the power grid and power supply. On the basis of promoting large-scale power grid interconnection, we should give full play to the advantages of large power grids, focus on building a unified national power market, effectively implement the national energy strategy, make full use of regional differences, optimize power generation decisions in different regions, realize seasonal and inter-regional surplus and deficiency adjustment, complement each other's advantages, ensure safe and reliable power supply, and ensure the balance of national power supply and demand.

4 Conclusion

Firstly, with the gradual increase of the proportion of new energy, the government needs to take comprehensive measures in legislation, planning, market mechanism, taxation and finance. In the process of promoting the development of new energy, European and American countries not only stipulate the medium and long-term strategic objectives, but also attach importance to energy legislation and institutional mechanism design. In terms of legislation, Germany pays attention to the policy design of carbon pricing, encourages enterprises to take active measures to reduce carbon emissions through carbon pricing, and incorporates carbon emission reduction into the actual measurement directly related to business performance. In terms of market mechanism, the UK's two-way pay contract for difference system guides low-carbon power investment through contract price signals to protect the profits of renewable energy power generation enterprises. In terms of fiscal incentive policies, Germany has flexibly formulated fiscal incentive policies including fixed feed-in tariff, premium subsidy and power generation bidding system at different stages of renewable energy development. In terms of supporting market system, the United Kingdom has set up carbon tax and supporting

carbon price policies to restrict coal-fired power generation; the United States has established supporting green certificate market based on renewable portfolio standard, and mandatory renewable energy development goals and green certificate market cooperate and coordinate with each other.

In addition, in the process of orderly promoting the transformation of the energy system, the United States has put forward a transformation plan based on the premise of "energy independence", which includes nuclear power, renewable energy, natural gas and clean coal in the category of clean energy, and clearly regards natural gas and nuclear energy as the transitional energy leading to the "renewable and sustainable" energy system. In July 2022, the European Parliament also voted to formally pass the bill on "natural gas and nuclear energy" as green energy.

Building a new power system is a complex project and a long-term task. If the gradual withdrawal of traditional energy is not based on the safe and reliable substitution of new energy, it will have an impact on economic development and social stability. Therefore, the realization of the goal can not be separated from the strong policy guarantee. The energy transformation plan should not only ensure the premise of energy independence and energy security, but also conform to China's realistic resource conditions and long-term development strategy.

Secondly, the green and low-carbon characteristics of the new power system are prominent, but the power supply cost of the system has increased substantially, so it is necessary to base on China's resource endowment and rationally alleviate the problem of rising power supply cost through diversified means such as power market, ancillary service market and carbon market. Affected by the development of renewable energy, electricity prices in Germany and Britain have risen rapidly. With the rapid development of renewable energy such as wind power and photovoltaic power in Germany, the proportion of wind power generation has increased from about 3% in 2002 to more than 17% in 2020, and the proportion of photovoltaic power generation has increased from less than 1% in 2002 to about 16% in 2020. Coal-fired power generation in the UK declined rapidly, from 30% in 2007 to less than 2% in 2019; the proportion of wind power and photovoltaic power generation continued to rise, accounting for more than 20% in 2019. Affected by this, the price of residential electricity in Germany has risen by more than 90% in the past 18 years, and that in Britain has risen by nearly 60% in the past 12 years. If it is not reasonably dredged, it will cause difficulties in the operation of power enterprises, resulting in the system can not operate safely and stably.

Foreign experience shows that the increase of the proportion of wind and solar renewable energy with random output will increase the demand for flexible regulation resources such as ancillary services, which requires a rich variety of ancillary services. The development of foreign ancillary service mechanisms is characterized by the gradual subdivision of products and the addition of new categories such as flexibility climbing and moment of inertia, the gradual diversification of trading mechanisms, the more reliance on the user side for resource sources, and the transmission of ancillary service costs to users, which is worth learning from in China.

In addition, as the carbon price will account for an increasing proportion of the cost of electricity, the high proportion of renewable energy access also makes the supply of electricity commodities itself more complex, so it is necessary to strengthen the synergy between

multiple markets. Strengthen the coordination between electricity and carbon markets, reasonably allocate carbon quotas to the power system, so that the transmission of carbon costs to electricity prices is reasonable and controllable; strengthen the coordination between primary energy markets such as coal and gas and electricity markets, set price limits for fuel and electricity markets according to fuel supply, and support fossil energy units to play a basic role; Strengthen the coordination of sub-markets in the electricity market, such as electric energy, ancillary services and capacity, enhance the resource allocation capacity of the electricity market, and better balance the objectives of security, emission reduction and economy.

Thirdly, in the new power system, the safe and stable supply of electricity is the foundation, and the flexibility of the system is the guarantee. It needs a variety of price mechanisms to coordinate with each other to ensure the safe and stable operation and sustainable development of the power grid and power supply. On the one hand, China needs to explore the relevant mechanisms to ensure capacity adequacy in the market environment. In the process of rapid development of new energy, many foreign countries are also facing challenges such as the reduction of power space of traditional power sources such as thermal power, the reduction of market price due to zero marginal cost of wind and solar units (I. E. Priority effect), and the operation is very difficult. Capacity mechanism plays an important role in ensuring the smooth operation of the electricity spot market and the normal development of medium and long-term transactions. In order to ensure that the controllable generation capacity of the system is reasonable and abundant, countries have established market-oriented mechanisms such as capacity market, strategic reserve, decentralized obligations, scarcity pricing and reliability options to slow down the withdrawal of traditional power generation capacity and avoid excessive capacity gaps. Adverse effects on system safety. China is promoting the construction of power market in an all-round way, and it is necessary to select the appropriate capacity guarantee mechanism on the basis of fully considering the security of power supply.

On the other hand, transmission pricing should be aligned with energy policy goals and establish incentive and constraint mechanisms for power grid enterprises. Countries such as the UK, France, and the US have gradually established and improved transmission and distribution electricity price regulatory mechanisms to incentivize investment in the power grid, and provided support for net zero emission project investment in the power grid. In the UK, before 2013, the RPI-X model was used to regulate transmission and distribution electricity prices. However, due to the unstable output of renewable and distributed energy connected to the grid, as well as severe aging of grid facilities, regulatory agencies began to adopt the RIIO framework, incorporating efficiency incentives, uncertainty adjustments, innovation incentives, etc. into the pricing process, and gradually increasing policy support to achieve the net zero emissions target of the network. The United States has also actively proposed to accelerate the connection between transmission pricing and energy policy goals, and proposed using the method of increasing ROE to incentivize transmission network investment that meets the government's long-term energy goals. The fundamental evaluation criterion is whether the investment effectiveness benefits users.

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