Optimization Model and Settlement Mechanism of Electricity Market in Zhejiang Province under the Form of Diversified and Highly Resilient Grid

Yang Xu [1], Jiahua Hu [1], Tao Shen [2], Cenfeng Wang [1], Jiming Tian [2], Fan Jia [3]

[1]State Grid Zhejiang Economic and Technological Research Institute，Hangzhou 310008，China

[2]Zhejiang Huayun Information Technology Co., Ltd., Hangzhou 310000, China

[3]North China Electric Power University, Beijing 102206, China

Abstract. Taking Zhejiang power market as the research object, this article compares the spot market, medium and long-term market and auxiliary service market models in Zhejiang Province with reference to the theories and practical experiences related to the construction of power market at home and abroad. Combining the situation of Zhejiang Province, the network situation and the current situation of power market construction, a multi-period generation dispatch optimization model based on power contract is proposed, and a day-ahead market clearing model adapted to distributed energy participation is established. Based on the deep learning algorithm using simulation cases of multiple scenarios, the power market model under the multi-fusion high resilience grid form is designed to provide suggestions for the design of generation dispatch optimization model and settlement mechanism for different power market development stages.

Keywords: Market model; Spot market; Medium and long-term trading market; Auxiliary service market.

1. Introduction

Foreign countries have been implementing electricity reforms for more than 20 years, and have accumulated a lot of experience and lessons in market design, optimization, research on renewable energy consumption and environmental market construction. In the UK, after the second round of electricity market reform, the electricity market model has changed from the previous centralized bidding for the entire electricity pool to a trading model based on medium and long-term bilateral contracts with a short-term spot balancing market mechanism [1-4]. Australia does not consider medium-term contract trading and has a spot market in the form of "day-ahead settlement plus real-time market", a unique zonal tariff-approved electricity market model [5-7]. The US electricity market consists of a spot market, a capacity market, an ancillary services market and a financial transmission rights market [8-14]. Currently, most foreign electricity markets have introduced financial derivatives such as electricity futures and electricity options [15-22]. Domestic scholars have also paid much attention to the construction of electricity markets focusing on the actual situation of each province, among which electricity futures and contracts for difference are of great interest [23-31].

The current state of the electricity market in Zhejiang province is characterized by a lack of resources, a predominance of coal-based power and high prices. In order to promote the construction of a clean energy demonstration province and the achievement of the "two 50%" target, Zhejiang power grid has overcome difficulties to ensure the full consumption of clean energy such as photovoltaic and wind power, and to promote the entry of clean power sources from outside the province. However, the high proportion of clean energy and the characteristics of foreign electricity, especially the "explosive" growth of photovoltaic installations, do not match the characteristics of the provincial load, and the peak-to-valley difference in load continues to widen, making the peak regulation contradiction very prominent. According to the 14th Five-Year Plan, the highest load gap and peak-valley difference of Zhejiang's power grid will continue to increase, and the contradiction between the economy and reliability of power grid operation will remain prominent. It is urgent to create a multi-faceted and highly resilient power grid to solve the dilemma of squeezing the four sides of the source network, load and storage, and increasing pressure on clean energy consumption, so as

to better implement the Yangtze River Delta economic. This will enable the implementation of the Yangtze River Delta economic integration strategy. To this end, a market model needs to be designed to match the highly resilient grid.

2. Existing market models

2.1 Electricity spot market

Zhejiang Province has chosen a "centralized" market model. Its electricity market consists mainly of a medium and long-term trading market and a spot market. The provincial medium and long-term trading process is not physically enforced, but uses contracts for difference to manage market risk. In the case of spot trading, all electricity is auctioned centrally, using an all-electricity centralized bidding model. It is clear that the 'centralized' approach is more efficient in resource allocation, less complex in market regulation and requires less maturity from the power seller; in addition, the 'centralized' market is suitable for areas with severe network congestion.

In terms of the structure of the provincial spot market, Zhejiang Province has adopted the "day-ahead market plus real-time market" model. The day-ahead market and the real-time market have different functions, with the day-ahead market forming trading decisions that are adapted to the system's operating conditions the day before, while for the real-time market, its main role is to provide regulatory measures and economic signals to help manage congestion in the power system and ancillary services markets, to form generation and consumption plans that are highly compatible with the actual performance of the system, and to ensure the safe operation of the grid.

2.2 Electricity medium and long-term market

The medium and long-term electricity market is a safeguard against market risks and a "firewall" for the electricity market. Medium and long-term trading is to meet the access requirements of the power company, power users and other market institutions, the adoption of independent negotiation, centralized bidding and other trading methods, to carry out the annual, monthly power trading. Medium and long-term transactions can be entered into in one or more forms, such as physical contracts, contracts for difference, etc. Under Zhejiang's "centralized" market model, contracts for difference are used for medium and long-term transactions, but the spot market is a full power optimization settlement. The price difference between the current market clearing curve and the medium and long-term trading contracts is calculated using the current market clearing price.

Medium and long-term electricity market transactions in Zhejiang Province are divided into wholesale and retail electricity. Wholesale electricity refers to market-based electricity trading between the offering company and wholesale market users through bilateral negotiations, centralized bidding and platform listing. Retail electricity trading is a transaction between electricity retailers and retail customers. Wholesale market users can not only participate in wholesale electricity trading, i.e. negotiate bilateral annual (monthly) transactions with power generation companies and participate directly in monthly centralized bidding and platform listing transactions; they can also participate in retail electricity trading. For retail customers, they can only purchase electricity through a specific electricity sales company within the same contract period.

2.3 Electricity Ancillary Services Market

Auxiliary services in the electricity market are an important part of the electricity market that should not be underestimated. Specifically, they refer to the services provided by power generation enterprises, power operation enterprises and power users in addition to the production, transmission and normal use of electricity to maintain the stable operation of the power system and guarantee the quality of electricity.

Paid auxiliary services in the Zhejiang electricity market can be participated by independent third-party entities. In the early stage of market development, the offer will be cleared in conjunction with the "two rules" in East China, and power sales enterprises will be encouraged to participate in the

transaction as load aggregators. Under qualified circumstances, independent third-party entities can participate in the spot market offer clearing and cooperate with the progress of the construction of Zhejiang's electricity spot market. The Zhejiang Energy Regulatory Office is responsible for supervising and managing the independent third-party entities involved in electricity auxiliary services, while doing a good job in demand-side management and spot market construction.

3. Market model in the form of highly flexible grid

Faced with the dilemma that grid operation is squeezed by the four sides of the source network, load and storage, and the massive resources are in a dormant state, it is necessary to gradually build a perfect market mechanism for electricity energy, power auxiliary services and demand-side response, formulate scientific and reasonable access rules, trading models and price mechanisms, orderly guide all kinds of power sources, flexible loads and energy storage to participate in market transactions, stimulate potential and vitality, divert invisible costs, and promote grid strength, safety, intelligence and interaction. security, intelligence, interactivity and cleanliness of the grid.

3.1 Electricity spot market

At the initial stage of the spot market, the market is gradually liberalized and developed, and the market players are in the stage of groping from the planning mode to the market mode, with insufficient competition on the generation side and immature quotation strategies that cannot fully reflect the difference in value of electricity energy at different times. On the one hand, it is recommended that the sales-side time-of-use tariff system be maintained, with power users entering the market selectively and still bearing the responsibility for the original peak-to-valley cross-subsidy (peak-to-valley time-of-use tariff - kWh tariff under the market user plan model), which is conducive to "peak-shaving and valley-filling", safe and reliable power supply, and ensuring that the peak-to-valley cross-subsidy source is not lost. The cross-subsidy source will not be lost. On the other hand, it is still necessary to insist that transmission and distribution tariffs do not underwrite market imbalances and that permitted revenues are fully recovered to ensure that investment sources are available for the construction of a diversified and resilient grid.

When the electricity market is very mature, the market structure tends to be perfect, and the market players have the ability to play rationally, a financial transmission rights mechanism can be built, and the financial transmission rights holders can trade the financial transmission rights to achieve the transfer of transmission capacity to more efficient resources, thus using the market mechanism to guide the effective spatial matching of electricity generation and consumption, and achieve the overall improvement of new energy consumption and power system resource utilization.

On the other hand, electricity futures and options trading mechanisms can be gradually introduced. Market players can hedge the risk of price fluctuations in the spot market by purchasing or selling forward contracts, futures and other financial instruments, discover the real market price of electricity, curb the speculative behavior of market institutions on the spot market, stabilize the current market price of electricity, and thus avoid huge fluctuations in the intra-day load on the user side, guide the expected planning of electricity, and enhance the safe and stable operation of the power grid.

3.2 Electricity medium and long-term market

There are two main modes of medium and long-term direct power trading: direct trading for ordinary users and trading in the electricity sales market. From the perspective of facilitating users to enjoy the reform dividends, it is recommended that direct trading by ordinary users be considered as the main mode, with electricity sales market trading as a supplementary mode. All types of direct trading settlement models need to adhere to the user side (including power sales companies) to implement transmission and distribution tariffs and peak and valley time-sharing tariffs, the essence is to shift all the price reduction space on the power generation side to the user side, the grid side does not underwrite the market profit and loss, full recovery of transmission and distribution tariffs

(including line losses, cross-subsidies) and permitted income, to maintain the grid just need investment and operation and maintenance capacity, to ensure the safe and reliable supply of electricity. At the same time, as the power generation side is a single contract price or signed settlement curve peak-valley price difference is small, it is still necessary to continue to maintain the guiding role of the load-side peak-valley tariff signal through the sales-side catalogue time-sharing tariff mechanism, maintain the existing grid "peak and valley reduction" effect, to avoid further widening of the load peak-valley difference, threatening the stable operation of the large power grid.

When the medium and long-term market is mature, the electricity generation and consumption plan is fully liberalized, the source network, load and storage participate in a large number of market players, a variety of types, the market competition is more adequate, non-market user imbalance funds tend to die out. The "day-ahead benchmark, real-time differential, contract differential" settlement model can promote the convergence of contract market prices to day-ahead market prices and day-ahead market prices to real-time market prices, which helps users lock in power in advance in the medium- and long-term contract market, with a smaller proportion of power truly exposed to the real-time market, and to a certain extent reducing the large intra-day load The proportion of real power exposed to the real-time market is smaller, which to a certain extent reduces significant intra-day load fluctuations. At the same time, with reference to the actual trading situation in foreign mature markets such as the US PJM market and the UK electricity market, from a theoretical point of view, the peak-valley price differential of the forward generation-side clearing tariff is larger, and the transmission to market users peak-valley price differential is also larger, so the sales catalogue tariff for operational users can be gradually eliminated, and the electricity balance can be guided by the interactive mechanism between the generation and consumption sides, and incentives for renewable energy sources such as photovoltaics, small hydropower and energy storage can be provided in the high-priced load spike hours to enhance the interaction and coordination of source-grid, load and storage.

3.3 Electricity auxiliary services market

At the initial stage of the spot market, consideration can be given to gradually divesting auxiliary services such as frequency regulation, standby and deep peaking from the "two rules" in East China and participating in auxiliary market transactions. Auxiliary service providers include power generation companies with auxiliary service capabilities, as well as third-party auxiliary service providers, such as energy storage devices and energy storage power plants. Through the establishment of a reasonable and benign bidding and clearing mechanism in the auxiliary service market, the average clearing price of auxiliary services will be increased to enhance the recognition of market players in the auxiliary service market and their enthusiasm to participate in market transactions, and further improve the quality and efficiency of auxiliary service participation by multiple parties from the source, network, load and storage. At the same time, in accordance with the principle of reciprocity of rights, responsibilities and benefits among market players, a mechanism for sharing both sides of auxiliary service generation and consumption will be established, and the costs of the auxiliary service market will be reasonably shared.

When the ancillary services market is more complete, it will cover more trading varieties such as frequency regulation, standby and deep peak regulation, black start, etc., with more scientific setting of trading parameters, more reasonable clearing prices, more number of trading subjects, more complex types and stronger trading aspirations. Further improve the capital sharing mechanism of the auxiliary services market, with market users first sharing the corresponding costs in proportion to their actual electricity consumption, and the remainder being shared by the units securing guaranteed users in proportion to their priority generation capacity. On the other hand, exploring the construction of a capacity market will increase the certainty of future income for power generation companies, guide rational investment and construction of power sources with capacity price signals, reduce grid blockages, significantly improve power supply reliability, and help reduce electricity prices during peak hours and improve energy economy. Through scientific planning of the total demand and structure of the capacity market, it can provide support for intermittent low-carbon energy to be

connected to the grid, guide the transformation of power supply to green and low-carbon development, and actively serve the construction of a clean energy demonstration province.

3.4 Demand-side response market

In recent years, the province's demand-side response pilot has adopted a fixed amount of invitations, determining in advance the total demand response load such as peak shaving and valley filling, and issuing response invitations to eligible customers. With reference to the experience of Jiangsu, Tianjin and other provinces and cities, an interruptible load tariff mechanism has been constructed, and economic leverage has been used to improve the lean management of electricity by users. Gradually lower the conditions and thresholds for user-side participation, introduce and cultivate load integrators, tap the potential of the user side and awaken more social resources; refine from a single subsidy standard to a graded subsidy according to response time and rate for different types of varieties, and strengthen the price incentive and guidance for response efficiency, so as to better ensure the safe and stable operation of the power system and enhance the capacity of clean energy consumption. At the beginning stage, it is recommended that the following order of priority be adopted for the funding sources of interruptible load subsidies: first, user-side sources, for example, unifying the proceeds from peak tariff increases into a special pool of funds to be managed to reward users participating in electricity demand-side response; second, special government financial sources, for example, financial allocations and grid enterprise funds together to form a special pool of funds for demand-side management; third, undertaken by grid enterprises. For example, using the surplus of the price difference from the inter-provincial over-purchase of surplus renewable energy as a source of subsidy funds.

When the demand-side response market is mature, real-time market price signals can more accurately reflect supply and demand, effectively incentivizing users to respond actively. A small part of the load gap that cannot be regulated by the electricity energy price signal during the day can be incorporated into the load regulation market in real time. Under a shorter trading frequency, a larger range of load integrators or users can independently declare the required response load, response time and incentive price for bidding according to the rules, better awakening the resources of the whole society to participate in electricity power balancing, delaying grid investment and reducing the cost of the whole power system. The funds required for the load regulation market should all be shared by the market players in proportion to the degree of benefit.

3.5 Pumped storage market

Pumped storage power stations are safe, reliable, responsive and flexible, and are a memory, regulator and regulator for the stable operation of the power system, as well as an important tool for guaranteeing the full consumption of clean energy such as scenery and promoting the development of new energy. The pricing power of pumped storage power stations is at the national level, and a unified national pricing policy is required. However, if no pricing policy is introduced at the national level in the short term, it is recommended that the provincial governments be pushed to pilot a quota sharing mechanism in order to alleviate the difficulties of cost recovery for pumped storage. Nuclear and hydropower units that do not perform peak and frequency regulation functions should bear the cost of pumped storage capacity electricity; small and medium-sized pumped storage power stations can be considered to have nearby wind power, photovoltaic and other clean energy projects bear the cost of capacity electricity and operate jointly with them. It is recommended that the provincial government should be encouraged to implement a provincial subsidy for photovoltaics, which is currently more than RMB 1 billion per year.

When the pumped storage market is perfected, the pumped storage capacity tariff and pumped generation losses should be shared and transmitted to market-based users, with market players fairly bearing the sunk costs of market reform; market users should first share the corresponding costs according to their actual share of electricity consumption, and the remaining portion can be reasonably shared by the beneficiary units. On the other hand, with a large peak-to-valley price

difference for market users in the long term, pumped storage can take advantage of the load-side peak-to-valley price difference arbitrage, and can also widely participate in auxiliary service transactions such as frequency regulation for profit, and no longer need special subsidies for energy storage.

4. Policy Suggestions

In the dual background of low-carbon power transformation and power market reform, Zhejiang power market construction should not only learn from mature foreign experience, but also fully integrate the characteristics of China's resource layout, new energy development, extra-high voltage transmission channels and grid digitalization, and take the development path with Chinese characteristics.

4.1 Constantly reduce the cost of electricity for enterprises

Around the provincial party committee and the provincial government to win the battle against the new crown pneumonia epidemic, make every effort to stabilize enterprises, stabilize the economic work construction, fully implement the national phased price reduction and reduction of electricity tariff policy of two parts. Enhance the monitoring of the charging behavior of sub-power supply links such as shopping malls, industrial parks and office buildings to ensure that the profits from electricity prices are passed on to end users, thus increasing the sense of achievement of enterprises. Expand electricity market transactions. By establishing a market platform, creating a market environment, organizing market bidding, regulating market order, and improving the pricing mechanism for power trading, we will seize the current opportunity to reduce fuel costs and lower electricity costs. Eliminate the electricity price difference between Zhejiang Province and the provinces of the Yangtze River Delta. Give full play to the comparative advantages and reduce the final electricity price level in Zhejiang through the electricity market reform and cost reduction policies.

4.2 Continuously promote the improvement of electricity sales market

Improve the electricity market system in Zhejiang Province with medium- and long-term trading as the main body and spot trading as a supplement, and implement electricity demand management with Zhejiang characteristics. Improve the supervision and regulation capacity of the electric power system, carry out green energy business and promote the consumption of renewable energy and clean energy. Further enhance the power security guarantee capacity, vigorously develop renewable energy, safely and efficiently develop nuclear energy, encourage the development of natural gas distributed energy, distributed photovoltaic energy, regularly upgrade pumped storage power plants and offshore wind power, and accelerate the development of energy storage and hydrogen energy. Promote the construction of diversified and highly resilient power systems, and build a comprehensive power supply network with reasonable layout, complete functions and priority for people's livelihood.

4.3 Comprehensively speed up the construction of electricity spot market

Further upgrade the spot market settlement system. Take a problem-oriented approach, continuously summarize experience, and summarize the speed of foreign points, power sales companies, and power consumers entering the cash market settlement system. Improve the auxiliary service market mechanism. The spot market provides a variety of market-based trading auxiliary services, such as frequency regulation services and standby services, introduces new market units such as load integrators, virtual power plants, pumped storage and energy storage, actively participates in the power market, and guides the power side, load side and energy storage side to deepen market transactions. Standardize the construction and operation of technical support system, optimize and modify the functions related to technical support system, and ensure the compatibility of contract design and technical system.

4.4 Orderly build the electricity trading pattern

Promote the reform of the shareholding system of Zhejiang trading center. Develop and propose the implementation plan for standardized and independent operation of the trading center, and accelerate the construction of an open and transparent power trading platform. In accordance with the principle of "multi-party review and multi-party weighing", continue to promote the share reform of the trading center. Give full play to the role of the market management committee. Further clarify the business positioning of the power market management committee, trading agencies and dispatching agencies, and give full play to the role of the market management committee in the construction of the power market, the formulation of regulations and supervision of market operation, and strengthen the role of distribution agencies in the current market to ensure that the supply market operates in a safe and sustainable manner.

4.5 Further improve the work guarantee mechanism

Strengthen organizational safeguards. Strengthen the leadership of the energy working group on power reform, improve the working mechanism of power system reform, enrich the staffing, reduce the main responsibility of each unit, and coordinate the power market pricing power, transmission to mechanism, transmission and distribution pricing and incremental distribution. Establish a comprehensive coordination mechanism system to ensure that the reform work is carried out in an orderly manner and the benefits are complementary. Improve the market release mechanism, do a good job of policy publicity and training, release risk warnings, guide the agencies to efficiently carry out market operations, improve market players' understanding and mastery of policies, and avoid instability of reforms. Accelerate the establishment of industry and credit supervision system to create a standardized, orderly and fair competitive environment in the electricity market.

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