

Cross-provincial and cross-regional optimization analysis of power auxiliary services for regional power grid construction

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Abstract. In order to improve the optimization level of regional power grid ancillary services, a cross-provincial and cross-regional optimization mechanism for power ancillary services is proposed, taking the southern regional power grid as a representative. The construction and development of typical regional power grids at home and abroad are analyzed, and the characteristics of the construction and development process of the southern regional power grid in the cross-province and cross-region scheme are explained. The direction of regional auxiliary service optimization is proposed, and the connection of electric power and electricity at the current stage is analyzed, an optimized operation model is established, proposing an auxiliary service centered on the regional power grid, with the goal of optimizing the connection and operation system, and combined with specific project pilots, an application analysis is carried out.

Keywords: power auxiliary services; cross-provincial and cross-regional optimization; connection mechanism; power grid construction.

1. Introduction

The southern electric power spot market, which started in Guangdong, has gradually formed and developed into the first batch of domestic electric power spot markets. The construction of the southern regional spot market will become an important beginning of the operation of my country's regional electric power market, and my country is currently in the transition between the medium and long-term electric power market and the spot market. Therefore, there is the problem of the connection of the market mechanism. According to China's national conditions and related policies, we should learn from the successful power market experience at home and abroad, from the market system, market model, trading varieties and other aspects for the development and construction of the power market in southern my country. Provide ideas. This paper studies this content, aiming to provide corresponding solutions and ideas for the construction of regional power market.

At present, for the construction of the southern regional power market, the literature [1] puts forward some thoughts on the construction of the southern regional power market. Reference [2] designed the dispatching business process system under the southern regional power market environment. Reference [3] analyzed the transaction mechanism of the southern regional electricity market. Reference [4] discusses the construction mode of the electricity spot market in the southern region. Reference [5] analyzed an independent settlement system adapted to the southern regional power market.

It can be seen that the current construction of the electricity market in the southern region mainly focuses on the corresponding transaction mechanism and transaction mode, and the market planning under the condition of mature market development in the southern region is proposed respectively. However, in this research process, we should focus on the transition. The content of the above-mentioned documents still needs to be further deepened in order to solve the problem of market connection at the stage.

At present, for the foreign regional power market, the literature [6] analyzes the development process of the EU to promote the integration of the inter-provincial market. Reference [7] analyzed the enlightenment of foreign regional power market to the construction of southern regional power market. The literature [8] analyzed the analysis of the EU's internal power market and its enlightenment to the construction of the southern regional power market in my country. The above

literature analyzes the construction of foreign regional power market and the enlightenment to my country's market, which provides a reference for the development of my country's regional power market to a certain extent.

To this end, the construction process and current situation of the electricity market in the southern region are analyzed. On the basis of the construction ideas of the electric spot market in the southern region, the research on the market connection mechanism based on the spot market is carried out, and the construction ideas of the electric spot market in the southern region are analyzed. It provides ideas and references for the development and reform of the regional market.

1 The Construction History and Current Situation of the Southern Regional Electricity Market

Since the new round of power system reform, the construction of the southern regional power market has been progressing steadily and orderly, covering priority plans and market transactions. At present, the southern region has basically established a power market system with "two-level market synergistic operation, and close connection with spot and auxiliary service markets in the medium and long term". The market adheres to the implementation of the new energy security strategy of "four revolutions and one cooperation". It is committed to the implementation of power transmission from west to east and promotion of clean energy consumption. It is committed to promoting the safe, high-quality and economical operation of the power system in the five southern provinces (regions). It is committed to laws and regulations, fairness and justice, stability and transparency so as to give full play to the decisive role of the market in resource allocation, and better play the role of the government.

1.1. Cross-regional and cross-provincial priority plan

The cross-regional and cross-provincial priority plan includes the framework agreement between the provincial and regional governments, the national mandatory plan for peer-to-peer power plants and other agreements on electricity. The inter-governmental framework agreements between provinces and regions include the inter-governmental agreements on cloud power transmission to Guangdong, Guizhou power transmission to Guangdong and cloud power transmission to Guangxi. The national mandatory plans include Three Gorges to Guangdong, Tianyi to Guangdong and Guangxi, TianEr to Guangdong and Guangxi, and Longtan to Guangdong and Guangxi. Other agreements for electricity include Guangxi to Guangdong for poverty alleviation and Xinjiang electricity to Guangdong priority plan.

1.2. Medium and long-term market construction

In terms of medium and long-term markets, the southern region has basically established a medium- and long-term trading mechanism for inter-regional, inter-provincial and intra-provincial cooperation. Inter-regional and inter-provincial medium and long-term transactions are organized by the Guangzhou Electric Power Trading Center and issue market transaction settlement basis. At present, the annual, monthly, and intra-month full-cycle continuous trading mechanism is running smoothly, and the inter-provincial market-based electricity has increased from 13.5 billion kWh in 2016 to 67.3 billion kWh in 2021 (among which, 455 million kWh of market-based electricity for West-to-East Power Transmission 100 million kWh), with an average annual growth rate of 35.7%. The five provinces (regions) have established relatively complete mid- and long-term market systems within the province, and the power trading centers of the provinces (regions) are responsible for organizing and issuing market transaction settlement basis. The market-oriented electricity in the province will increase from 151.9 billion kWh in 2016 to 579.9 billion kWh in 2021, with an average annual growth of 30.7%, and the market-oriented share will reach 47%. As of the end of December 2021, the number of registered market players exceeded 100,000, a year-on-year increase of 51.2%.

1.3. Spot market construction

In the spot market, the Guangdong spot pilot has entered continuous operation, and the southern regional electricity spot market has started trial operation. Combining the characteristics of

Guangdong power grid with large scale, mixed AC and DC connection, and complex security constraints, the Guangdong spot pilot adopts a "centralized" spot market model to achieve the coordination and unity of market-oriented resource optimization and safe and stable operation of the power grid; combined with the competitive atmosphere of the Guangdong market Good, high activity of electricity sellers, establish a complete market structure of "wholesale + retail", achieve effective linkage between the two markets, and ensure that end users enjoy reform dividends; medium and long-term electricity is settled at the contract price, and spot deviation electricity is at the spot price. settlement. Since the start of trial operation in August 2018, the electricity spot market in the south (starting from Guangdong) has successfully completed the trial settlement operation in different time dimensions of day, week and month, and has experienced various scenarios such as loose and tight power supply. It has been in continuous operation since November. The provinces (regions) in the southern region have obvious differences in resource endowments and strong complementarity. In July 2022, the southern regional electricity spot market will start a trial operation without settlement. Through the trial operation, the price of electricity will be discovered, and the complementarity of electricity resources in each province will be brought into play to promote power supply and cleanliness. energy consumption.

1.4. Auxiliary service market construction

In terms of the electric auxiliary service market, the transformation of auxiliary service compensation from a planned system to a market mechanism has been promoted. The FM auxiliary service market in the southern region developed from the FM auxiliary service market in the south (starting from Guangdong). On December 28, 2020, the main network market in the central and eastern regions of the southern region (Guangdong, Guangxi, Hainan) started trial operation, becoming the first in the country. Regional FM Ancillary Services Market. On July 1, 2021, the frequency modulation auxiliary service market in the southern region (including the central and eastern main grid and the Yunnan asynchronous grid) entered official operation. The peak shaving auxiliary service market in Guizhou took the lead to enter into formal operation on January 1, 2021, and the peak shaving auxiliary service market in Hainan and Guangxi entered official operation on May 1 and July 1, 2021. The overall operation of the market is stable and orderly, the power grid is safe and stable, and the peak-shaving capacity of coal-fired power plants is fully exploited through market means to release clean energy consumption space. The inter-provincial backup auxiliary service market in the southern region will start trial operation in April 2022, and encourage various power sources to provide backup auxiliary services through market-oriented means to promote reliable power supply.

2. The construction ideas and key points of the electricity spot market in the southern region

2.1. Aim of spot market construction

Based on the national power development plan and based on the actual situation in the southern region, by 2023, the southern regional power market system will be basically completed, giving priority to the integrated design of planning, medium and long-term, spot and auxiliary service markets, and joint operation across provinces and within the province. The spot market improves energy participates in market transactions, adapts to the construction of new power systems, improves market-oriented demand response transaction mechanisms, explores transaction mechanisms such as capacity markets, and strengthens the connection with green power transactions. By 2025, the electricity market system in the southern region will be more complete, with more varieties and better mechanisms, and the trading rules and technical standard system will be constantly standardized. The electricity market in the southern part of Inter-provincial transmission price mechanism; coordinated operation with the national market and orderly connection with overseas transactions.

Ultimately, the optimized allocation of resources will be realized in a wider range, which will make the trading varieties more abundant, the trading system more perfect, and the trading mechanism more smooth and flexible, so as to make active explorations for the construction of a unified national electricity market system.

2.2. Status of domestic and foreign regional spot market

The foreign regional power market is mainly represented by the American PJM power market and the European power market. Strictly speaking, they are not exactly the same as the concept of my country's regional power market, but their research content still has reference significance for the development of my country's regional power market. PJM Electricity Market is responsible for the operation and management of the regional electricity market formed by 13 states in the United States and the District of Columbia. It is the only authoritative electricity trading platform in the whole country, and it is used to balance the supply and demand of the power grid, formulate power generation plans and balance in real time. At present, Europe has formed a number of relatively independent regional power markets such as Northern Europe and the United Kingdom, and most of them use the over-the-counter, bilateral transaction mechanism and partition balance mechanism. Similar to the cross-province and cross-regional transactions in the southern region of my country, therefore, the model of the Nordic electricity market has more reference significance for the construction of a cross-regional and inter-provincial electricity market in the southern region.

At present, the southern region has formed a west-to-east power transmission network with "eight crosses and ten straight lines", basically realizing the physical conditions of power interconnection and free flow, and reaching a power transmission capacity of more than 58 million kilowatts. In addition, in response to the new round of power system reform since 2015, the China Southern Power Grid region has made many attempts in market-oriented reform, basically forming a regional power market.

On the basis of fully inheriting the original market-oriented reforms, the southern regional power market has basically formed a market system with two-level market coordinated operation, and has developed into a power market with regional integration and demonstration role. The market players in the southern regional power market mainly include power plants, power transmission companies, and power grid companies. Some of the market players have cross-regional and cross-provincial trading qualifications. The types of transactions in the southern region are mainly agreement plans, direct electricity transactions, contract transactions, incremental transactions, and delivery transactions.

2.3. Key points of the electricity spot market in the southern region

The method of clearing full electricity in the spot market of electricity is adapted to the cross-provincial priority plan and transmission fee in the southern region, adopts the node electricity price according to the cross-provincial transaction component and transmission fee policy approved by the state, and makes full use of the centralized optimization and clearing of all power generation resources in the whole region. The matching model of transaction components and physical gateways is used to reflect the influence of the geographical location of power generation resources in different regions on their clearing, which realizes the effective connection of the provinces in the region and the efficient coupling of the joint clearing of the provinces in the southern region. It can effectively guarantee the implementation of cross-provincial priority plans, realize peer-to-peer transactions and network-to-network transactions, and promote the unification of clean energy consumption and cross-provincial spot transactions.

2.4. Thoughts on the Construction of Electricity Spot Market in Southern Region

On the basis of the experience of the Guangdong pilot, based on the energy resource endowment and the actual situation of economic and social development in the five southern provinces and regions, and following the laws of power operation and market economy, the construction of the

electricity spot market in the southern region will be promoted in stages and steps, and the formation of cross-provincial and provincial power internal time-of-use electricity price and transaction curve, to realize the connection between inter-provincial and intra-provincial spot transactions, and the connection between spot transactions and priority power generation plans and medium and long-term transactions. The flow chart of clearing model is shown in figure 1.

According to load forecast, maintenance plan of power generation, transmission and transformation equipment, operation constraints of generator sets, constraints on the operation of hydropower plants and reservoirs, constraints on optimal scheduling of hydropower, constraints on safe operation of power grids, output arrangements for non-market units, priority consumption of clean energy, and priority plans across provinces, power balance and other boundary conditions, with the goal of maximizing social welfare, using the Safety Constrained Unit Combination (SCUC) and Safety Constrained Economic Dispatching (SCED) methods to conduct cross-provincial and intra-provincial joint full power optimization calculations, and get the Unit start-up combination, unit output curve, cross-provincial power transmission and reception plan curve and node electricity price. According to the results of market transaction clearing, each province shall formulate and issue the dispatching plan of its own province and organize its implementation.

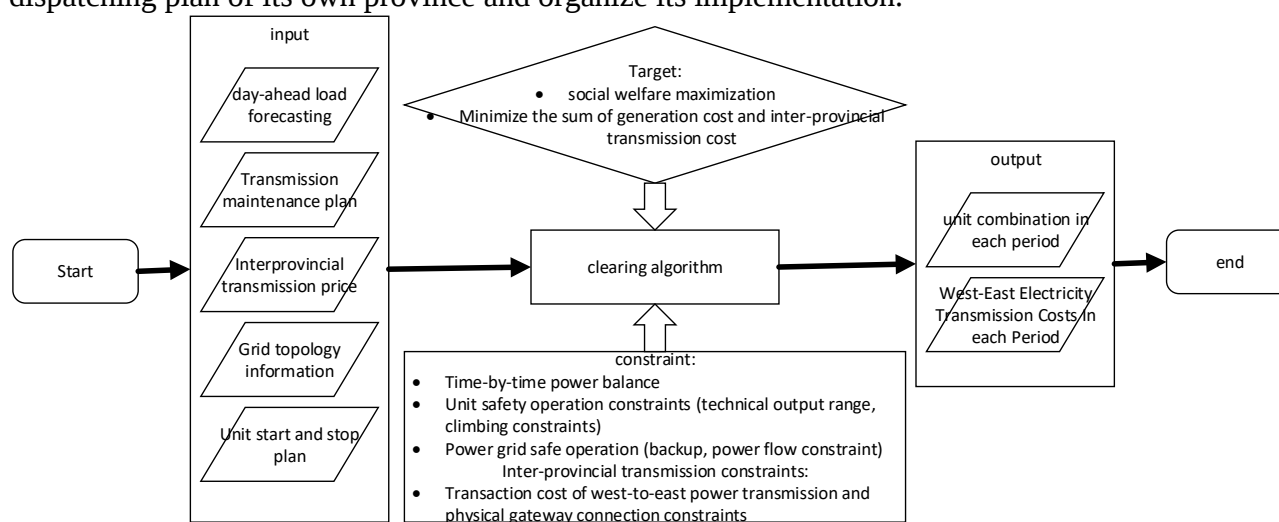


Fig.1 Flow Chart of Clearing Model

3. Research on market connection mechanism based on spot market

3.1. Connection to priority programs

On the basis of implementing the power grid security and power supply to support the power supply, a cross-provincial priority power generation plan curve decomposition mechanism is established, and the cross-provincial priority power generation plan curve is decomposed to the corresponding market players through independent negotiation or typical decomposition of market players. It is to establish a cross-provincial priority power generation plan adjustment mechanism to play the role of the southern regional platform. According to the energy and power supply conditions of each province, the priority plan can be adjusted by consensus.

It is to orderly promote cross-provincial priority power generation to carry out market-based bidding through "network-to-network" and "point-to-network" methods, and promote long-term medium and long-term transactions; gradually promote "point-to-point" transactions. The cross-provincial priority power generation plan shall be liberalized by category, and the national power transmission plan and local government power transmission agreement shall be transformed into medium and long-term contracts authorized by the government.

The priority power generation plan in the province will be liberalized in an orderly manner. Low-price priority power generation will be used to ensure electricity consumption for residents and

agriculture, and priority generators such as new energy and nuclear power will be promoted to participate in the market by category, so as to promote priority power generation and full production.

In the connection with the priority plan, the curve of the cross-provincial priority power generation plan is guaranteed to be executed, and the priority is cleared. The units that do not participate in the market shall arrange the daily output plan according to the current method, as the boundary condition of the day-ahead and real-time spot market.

3.2. Connection to medium and long-term transactions

Inter-provincial mid- and long-term market transactions form transaction electricity, time-sharing transaction curves, transaction prices and settlement reference points.

The medium and long-term market transactions in the province form transaction electricity, time-sharing transaction curves, transaction prices and settlement reference points.

The medium and long-term trading results are connected with the spot market through the CFD settlement mechanism.

3.3. Connection of inter-provincial and intra-provincial operations

The mid- and long-term markets in the southern region are two-tier markets, including the inter-provincial mid- and long-term markets and the intra-provincial mid- and long-term markets. The way to carry out the order is to give priority to the intra-provincial market transaction of the sending-end power grid (preferentially to ensure the transaction and power balance), then to carry out the inter-provincial transaction, and finally to carry out the intra-provincial transaction of the receiving-end power grid; or to give priority to the intra-provincial market transaction of the sending-end power grid, and then Carry out joint transactions of inter-provincial and receiving-end power grids within the province.

The spot market in the southern region is the primary market, and the inter-provincial and intra-provincial connection is reflected in all aspects of organizing transactions. The general dispatcher of China Southern Network is responsible for joint clearing, and each dispatching agency forms market boundary conditions according to the dispatching jurisdiction, executes dispatching plans and monitors and monitors according to the clearing results. Without changing the balance area, the power balance of each province is the constraint of market clearing. The deviation between the intraday clearing plan and the real-time operation is adjusted by the winning unit in the frequency regulation market, and each balance area will adjust and intervene when the real-time operation accident is abnormal.

3.4. Connection to the Ancillary Services Market

The connection with the auxiliary service market is divided into the connection with the auxiliary service market for frequency regulation, the auxiliary service market for backup and the connection with the auxiliary service market for peak regulation.

(1) Connect with the FM auxiliary service market. The start-up combination determined by the spot market clearing is used as the boundary condition for the frequency regulation auxiliary service market clearing, and the frequency regulation auxiliary service market clearing result is used as the boundary condition for calculating the power generation plan and node electricity price in the spot market clearing.

(2) Connect with the backup auxiliary service market. The inter-provincial backup auxiliary service market and the southern regional spot market are cleared step by step, and the clearing result is the boundary condition for the clearing of the spot market.

(3) Connect with the market of peak shaving auxiliary services. According to the progress of the spot market in the southern region, the peak shaving auxiliary service market in each province is gradually integrated into the spot market.

3.5. Connection with out-of-area electricity

Overseas power plants integrated into China Southern Power Grid or overseas entities connected with China Southern Power Grid (including overseas power grid companies, overseas power plants, etc.), in compliance with national laws and regulations, can participate in transactions in accordance with the rules of the southern regional power market.

3.6. Connection with the national unified electricity market system

In accordance with the requirements of guiding the coordinated operation of the national, regional and other power markets, the southern regional market participates in national market transactions as an independent organic whole. According to the structural characteristics of the power grid, medium and long-term transactions will be carried out in the initial stage; after conditions are met, the scope of market transactions will be gradually expanded to integrate with the national market.

4. Conclusion

The key mechanism and connection mechanism of the southern regional market is designed, taking the typical market situation at home and abroad as the breakthrough point, the corresponding mechanism based on the characteristics of the southern region is designed, including the clearing mechanism of the regional spot market and its connection with the priority plan, The connection with medium and long-term transactions, the connection between inter-provincial and intra-provincial operations, the connection with the auxiliary service market, the connection with the power outside the district, and the connection with the national unified electricity market system, etc are analyzed. The market mechanism proposed in this paper can give full play to the role of market players, implement the new energy security strategy of "four revolutions and one cooperation", implement west-east power transmission and promote clean energy consumption, and ensure that the power systems of the five southern provinces (regions) are safe and high-quality economic operation, and give full play to the decisive role of the market in resource allocation.

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