Research on Power Market Stability and Risk Management Based on Heterogeneous Information Sources

Liu Chunxiao¹, Li Zhiyong¹, Zhou Qiang², Zhang Peishen²

¹China Southern Power Grid Power Dispatching and Control Center, Guangzhou, Guangdong, 510663, China
²NARI-TECH Nanjing Control Systems Ltd., Nanjing, Jiangsu, 211106, China

Abstract. The development of power markets in various countries in the world and the gradual formation of China's power market require academic circles to provide research theories related to the power market to support them. In the competitive environment, fundamental changes have taken place in power production, trading and consumption. The operating conditions of the system are harsh and uncertain. The problem of safety and stability is becoming more and more prominent. Judging from the international and domestic development situation, it is a historical necessity for electricity to enter the market. When electric power goes to market, it is necessary to bring electric power industry into the framework of market economy. Stability is the basis for the normal operation and sustainable development of the system, so it is more urgent to promote the healthy development of the power market by the research results of power market stability. The risk analysis method reflects the mathematical expectation of loss by the product of accident probability and accident consequence, so it can effectively unify the stability and economy on the dimension of currency, and realize the analysis and decision-making of technical and economic integration.

1. Introduction

Monopoly system makes power enterprises lack vitality, low management efficiency, high electricity price and poor service quality increasingly prominent. In the competitive environment, fundamental changes have taken place in power production, trading and consumption. The operating conditions of the system are harsh and uncertain. The problem of safety and stability is becoming more and more prominent [1]. The reform goal of the power industry is to improve the efficiency of power production, rationalize the electricity price formation mechanism, and provide high quality and safer power products [2]. Every market participant pursues the maximization of its benefits. The relationship between technology and economy is extremely close, and the traditional relationship of higher reliability than economy no longer exists [3]. Judging from the international and domestic development situation, it is a historical necessity for electricity to enter the market. When electricity goes to the market, it is necessary to bring the electricity industry into the framework of the market economy. At present, our country is in a transitional stage from the monopoly and unified management mode of the traditional power system to the power market. At present, China's electric power enterprises are still implementing "internal simulated electric power markets" with provincial electric power companies as the main body. Monopoly causes the power industry to lack internal development power, production and operation efficiency is not high, and hinders technological progress and even social productivity [4].
As a unified and indivisible system, the power system needs to maintain the stability of voltage and frequency, and ensure that the system's safety requirements are met under various disturbances [5]. The construction of the electricity market has its uniqueness and complexity. There are many problems that countries around the world have not yet solved well, and they are all in the process of exploration and improvement. Provincial power market is the basic market for the optimal allocation of resources at the provincial level and the power supply market directly facing the majority of users. Therefore, it is necessary to standardize and improve the mechanism and promote competition and promote the healthy development of the market through comprehensive opening [6]. The actual operation experience of the power market tells us whether the power reform can be carried out smoothly and achieve good results. The first problem is the design of market models and rules [7]. Under the current circumstances, it is necessary to study the establishment of a simulated power market for regional power companies to improve the power market theory. At present, most of the research on the power market has focused on issues such as bidding on the Internet, ancillary services, and transmission pricing, but few have studied its stability and risk management [8]. Power services are divided into power generation services, power transmission services, power distribution services and electricity sales services, and corresponding transaction methods and pricing mechanisms are determined according to the characteristics of each service. Good market models and rules can meet the requirements of fair competition, improve the production efficiency and service level of power enterprises, reduce production costs and bring huge economic benefits. On the contrary, unreasonable market design hinders the operation and development of the power system, and improper handling may even lead to serious social consequences and economic losses.

2. Architecture of Simulated Electricity Market

Heterogeneous information sources refer to the data sources of power information systems with different structures in the power system. These power information systems are isolated from each other and cannot share information. In this case, various power information systems should be integrated, and different information in various information sources can be used to simulate the power market. Since the data of power demand over the years show obvious characteristics and trends, two time series models with completely different modeling principles are used to model and analyze the same power demand series. When studying the bidding strategies of power generation enterprises, it is necessary to consider the bidding strategies of competitors and the load in each period of the system. The difficulty is to study the bidding strategies of each competitor separately [9]. In a fully competitive market, each generation company will bid at marginal cost to maximize its profit. However, in the incomplete competitive market, the quoted price curve of power generation companies with market power may deviate from the cost curve completely, and the market price can be increased by removing part of the electricity or raising the quoted price. The integration of heterogeneous power information sources does not affect the function and performance of the original systems, on the basis of data fusion of heterogeneous information systems. It not only achieves the purpose of expanding functions to realize data sharing, reducing a large amount of investment and improving the efficiency of equipment, but also lays a good foundation for the integration of heterogeneous power information systems.

In the power market, the power generation company has the autonomy of production and operation, and becomes the main body of market competition. It will adopt different bidding strategies and adjust the bidding curve to maximize profits. As shown in Fig. 1, the scanning speed modulation architecture of the power prediction model.
After integrating all the data into the table, the program will read them uniformly, and then the program will make different appraisals for different units according to different unit types. During the construction of the risk assessment system, the role of the integration server as an information integration center was fully utilized, various required data were directly called, frequent transfer of various data was avoided, the validity and non-modifiability of the original data were guaranteed, and users were not allowed to modify directly in the whole process [10]. The coordinated operation of carbon capture power plant and electric power can make full use of surplus electric power and increase the energy consumption of capture to treat stored rich liquid at low ebb time. The coordinated operation of carbon capture power plant and electric power can improve the system's ability to absorb electric power and obtain certain carbon emission reduction benefits. For example, Table 1 shows the optimized operation results of the system before and after the carbon capture power plant is configured. Fig. 2 shows system stability and power output.

Table 1 Results of system optimization operation before and after carbon capture power plant configuration

|                                      | Including carbon capture power plants | Carbon-free capture power plant |
|--------------------------------------|--------------------------------------|---------------------------------|
| Power generation cost                | 317.58                               | 329.84                          |
| Carbon emission cost                 | 244.62                               | 211.68                          |
| Power wind rejection rate            | 5.65                                 | 0                               |
| Capture benefit                      | 1.27                                 | 18.49                           |
| Comprehensive cost                   | 543.85                               | 538.73                          |
When the appraisal result already exists, the appraisal data will not be saved to maintain the validity of the data. The trend cycle component can reflect the overall trend change direction of the time series, which is mainly influenced by long-term factors and assumes that the influence will run through the sequence. Under the environment of continuous reform of the power enterprise market, ensuring the demand of power load is the premise of implementing the strategy of power market strategy, ensuring the harmonious development of power enterprises and the national economy is the important guarantee of the power market, and ensuring the optimal allocation of power resources and the reliability of power grid operation are the power supply foundation of the power market. The whole stability prediction system should realize the automation of data processing, meet the prediction conditions of power demand, and automatically integrate and analyze a large amount of input information [11]. During risk assessment, the assessment program directly obtains the unit’s declared load data and historical actual load data from the integration server, then reads the planned load data from the load control server, and calculates the reward and punishment data for each unit through a special algorithm.

3. Power Market Stability and Risk Management Measures

3.1 Firm the Development Direction of Risk Management

At the present stage, safety risk management is carried out in the company system, hazard source identification, risk analysis, risk assessment and risk control are implemented, and a safety risk management system based on closed-loop process management is gradually established. The establishment of this system is not only an inevitable direction for the development of safety management in modern enterprises, but also an objective requirement for realizing safety control. The comprehensive prediction model optimized by the mixed penalty function method is also in line with the urban development. No matter in what area, the hybrid penalty function optimization synthesis model has better fitting precision and prediction precision.

Since the power station does not need to consume fuel, the power company should first dispatch all the electricity. The goal of dynamic economic dispatch of the power market including the power station is to minimize the generation cost of the traditional generator set. The objective function can be written as follows:

\[ dR_i = \chi \cdot a(t) \cdot dt + \delta \cdot a(t) \cdot dw_i \]  

(1)

Power balance constraint:

\[ R_i^e = x + \int \xi a(R_i^e) \cdot ds + \int \xi a(R_i^e) \cdot dw_i - U_i^e \]  

(2)
When the operation cost is not considered, based on the original startup and shutdown state, due to the randomness of wind power, the power generation cost of conventional units is also a random variable, so the objective function is the minimum expected value of power generation cost:

$$dR^* = \zeta \cdot a_1(t) \, dt + \zeta \cdot a_2(t) \cdot dw - dU^*$$

(3)

In an incomplete competitive electricity market, power generation companies can use strategic quotations to maximize profits. The database server is the data layer. It mainly installs large-scale relational database software and stores data, feeds back requests from application servers and performs budget operations. Under the condition of incomplete information, quotation strategies developed based on the estimation of competitors’ costs or quotations generally have certain risks. For example, the power generation capacity that has not been scheduled due to too high an offer or that has been scheduled is significantly less than expected. Adjust the price of electricity supply timely and appropriately so that the price of electricity changes with the fluctuation of energy price and supply and demand. Timely maintenance of failed power generation equipment shall be carried out to ensure orderly power supply order and safe operation of the power grid, and an electricity saving mechanism shall be established.

3.2 Clarify the Work Ideas of Risk Management

The premise of stable operation and sustainable development of power market is that there must be sufficient stability of power plant supply system. In recent years, the shortage of power supply and demand in China has been eased to a certain extent, but investment in the power industry cannot be relaxed. It is necessary to promote the development of the power industry in a predictable manner and to resolve the imbalance between supply and demand. According to their respective management responsibilities and work characteristics, different management levels should be responsible for controlling different levels and types of security risks and implementing security responsibilities step by step. The risks associated with bidding strategies that expect large profits are also large. Therefore, for power generation enterprises, the risks associated with bidding strategies need to be analyzed and evaluated [12]. Or construct a compromise bidding strategy that takes into account the two contradictory objectives of maximum expected profit and minimum risk. In reality, different decision-makers have different attitudes towards risk, which also determines their different priorities in decision-making. In the peak load period, in order to meet the load demand and obtain the power generation benefit, the power plant needs to reduce the capture energy consumption to improve the net output. At this time, the waste gas discharged by the power plant is continuously absorbed, the rich liquid produced is sent to the rich liquid storage for storage, the energy consumed by the regeneration tower is reduced to a lower level, and the energy consumption of the power system is reduced as a whole, and vice versa. The risk of power market is an objective matter. As long as it is an objective matter, people have the ability to understand it and control it. This requires us to strengthen the study of security theory and understand the basic methods of risk management.

4. Summary

The architecture of regional power simulation market based on heterogeneous information sources takes into account the actual hardware conditions of regional power grid, makes full use of existing resources, and integrates the data of heterogeneous systems, so that the application system of simulation power market can obtain the required data from the information sources of heterogeneous systems and complete its basic functions. With the continuous promotion of power market reform, the gradual formation of large regional power market, and the growing scale of power system, the demand for power market stability is higher and higher, and the risk coordination between security and economy is more urgent. The problem of power market stability is essentially a risk management problem that needs coordinated control in the short and long term. The quantitative analysis method of power market stability based on risk can realize the optimal balance between stability and economy. Since the power market reform is still in its infancy in China, there is no precedent for regional power market. Therefore,
there are still many aspects of the theory is still in the research stage, the overall structure is still insufficient, the transition between the simulated market and the actual market is still not fully understood. In China's power system, it is impossible to complete the power market reform in a short period of time, and the theoretical research on the power market reform will continue gradually.

References

[1] Liu Jun, Zhang Jiani, Li Wenxuan. Comparison and Enlightenment of Credit System Construction in International Mature Power Markets [J]. Price Theory and Practice, 2018 (2): 71-74.

[2] Zhou Xiaojin, Zhao Yan, Liu Hua. Impact of Power Market on Power Grid Dispatching and Operation [J]. Theoretical Research on Urban Construction: Electronic Edition, 2016 (10): 112-113.

[3] Cui Jinzhu. Discussion on Zhangye Power Market Forecasting System [J]. Guangdong Science and Technology, 2014 (24): 36-37.

[4] Wang Guodong. Impulse delayed feedback control method for a class of game models in the electricity market [J]. Journal of Chongqing University of Arts and Sciences (Social Science Edition), 2014, 33 (5): 32-35.

[5] Su Kai, Guangdong Power Grid Co., Ltd., Su Kai, et al. Design and Implementation of Guangdong Electric Power Market Trading System [J]. China Southern Power Grid Technology, 2015, 9 (8): 52-56.

[6] Wang Zhaohua, Su Yongzhang. Structural Design and Stability Analysis of ETS EMUs in Malaysia [J]. Technology and Market, 2014, 21 (5): 58-59.

[7] Qi Hongzhong, Du Weijun. Power System Stability Analysis and Research [J]. Inner Mongolia Petrochemical Industry, 2014 (12): 15-17.

[8] Zhang Xinde, Xu Huang, Zhou Liangsong. Research on Power Delivery Stability of Large Power Plants [J]. Journal of East China Normal University: Educational Science Edition, 2015, 37 (6): 9-12.

[9] Zhang R, Dong Z Y, Xu Y, et al. Short-term load forecasting of Australian National Electricity Market by an ensemble model of extreme learning machine[J]. IET Generation Transmission & Distribution, 2013, 102(9):391-397.

[10] Cifter, Atilla. Forecasting electricity price volatility with the Markov-switching GARCH;model: Evidence from the Nordic electric power market[J]. Electric Power Systems Research, 2013, 102(9):61-67.

[11] Xu N, Dang Y, Gong Y. Novel grey prediction model with nonlinear optimized time response method for forecasting of electricity consumption in China[J]. Energy, 2017, 118:473-480.

[12] Wang J, Liu F, Song Y, et al. A novel model: Dynamic choice artificial neural network (DCANN) for an electricity price forecasting system[J]. Applied Soft Computing, 2016, 48:281-297.