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Planning of Integrated Power Grid Transmission and Distribution System Based on High Proportion of Renewable Energy

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Abstract: In recent years, China's renewable energy has continued to develop rapidly, and the integration of a high proportion of renewable energy into the grid will be an inevitable trend and an important feature of the development of China's power system. A large number of distributed power sources are connected to the power system, which has an impact on the normal operation of the power grid and power quality, and also poses new requirements and challenges for power consumption and storage. This paper aims to study the planning of integrated power grid transmission and distribution system based on high proportion of renewable energy. In order to grasp the change trend of wind power and photovoltaic power and facilitate the formulation of scheduling tasks, this paper introduces a short-term wind and solar power prediction method based on the back-propagation (GSA-BP) neural network optimized by the improved gravitational search algorithm. Firstly, in view of the shortcomings of slow convergence, over-fitting and parameter redundancy in the prediction of wind and solar power by neural network, this paper uses the good global optimization ability of GSA algorithm to determine the optimal weights and thresholds of BP, which enhances the performance of BP neural network.. Then, a new error correction scheme is introduced in this paper, which verifies that there is a certain correlation between forecast errors and specific comprehensive meteorological indicators. The simulation results show that the improved wind and solar power prediction method proposed in this paper can obtain better prediction results, and the error correction method can improve the prediction accuracy and has wide applicability.

1. Introduction

Reasonable and efficient large-capacity storage technology is one of the key research contents to solve the phenomenon of abandoned wind and light. So far, the large-scale energy storage technology is mainly pumped storage. Pumped-storage power stations are mainly composed of upper and lower reservoirs, transmission pipelines, pumps, and turbines. During the trough period of the power load, the pump-turbine unit pumps water into the upper reservoir, uses the potential energy to store energy, and releases the potential energy to generate electricity during the peak

period. The Zurich Power Station in Switzerland is the world's first pumped-storage power station and is now over 100 years old. Pumped storage power station has become the most mature and economical energy storage method with the largest capacity, and the largest single unit capacity has exceeded 450MW. Pumped storage power station has the characteristics of large scale, low operating cost, durability and flexible control. It can quickly respond to the demand of the load, and can stabilize the volatility of wind power and photovoltaics. At present, there are some examples of pumped storage power stations and new energy co-generation in the world. For example, Spain combines wind power and pumped storage for power generation. Pumped storage power stations can store excess power generated by wind power and photovoltaic power generation to reduce the waste of wind and solar energy. This is a very promising way of wind and solar storage [1-2].

In the research of integrated power grid transmission and distribution system planning based on high proportion of renewable energy, many scholars have studied it and achieved good results. For example, Rawat MS uses support vector machine and neural network to combine weather types. However, it is still difficult to deal with multi-classification problems [3]. Melo R's P2P renewable energy trading platform deployed at the headquarters of retail electricity provider American PowerNet in Pennsylvania. These attempts illustrate that the P2P electricity market is a possible future development direction [4].

This paper introduces the concept of peer-to-peer power market and the necessity of developing peer-to-peer power market; introduces the research status of peer-to-peer power market, including existing peer-to-peer market structure, research hotspots and methods, and some industrial projects. This paper designs a day-ahead P2P energy backup combined power market for practical applications. In this market, participants can negotiate with each other to determine the transaction price and transaction volume of energy reserves. First, the uncertainty of renewable energy generation is modeled using a general distribution method, and the required reserve is determined based on a chance-constrained optimization method. On this basis, a market negotiation transaction mechanism based on the consistent alternating direction multiplier method is proposed. Furthermore, to further reduce costs, the correlation and complementarity among generation uncertainties are exploited and a hybrid P2P market based on a group of renewable energy generators is designed. In this market, all renewable energy generators share uncertainty information with managers to calculate the total reserve required.

2. Research on Integrated Power Grid Transmission and Distribution System Planning Based on High Proportion of Renewable Energy

2.1 The Wind and Scenery Prediction Model of Gsa-Bp Algorithm

BP neural network is composed of many weighted connections between neurons. Neurons at various levels are connected to each other with weights. Prepare to find the relationship between input and output and show it. In order to better complete learning, continue Optimization changes connection weights. Usually, a three-layer BP neural network is used to estimate the non-long-term wind power, including the hidden layer, which can be better combined with information such as training speed and data adaptability. Equation (1) gives the input/output relationship of the neural network:

$$Y_i = \phi_i\left(\sum_{i=1}^{n} \omega_{ij} X_j + b_i\right) \tag{1}$$

In the formula: the j-th input neuron is Xj; the i-th output neuron is Yi, represented by i; the

output layer threshold is bi; the activation function is ϕ_i.

For the BP neural network, the initial weights and threshold vectors of each layer are usually randomly defined. There may be abnormal situations of non-convergence or slow speed, or it may fall into the minimum point locally. These problems encountered in learning are easy to cause deviations in prediction. The GSA algorithm has great advantages in optimizing the overall situation. In this paper, the GSA algorithm is used to confirm the optimal value of the BP weight and threshold, and the gravitational search is used to construct a back-propagation (GSA-BP) neural network, and the algorithm is more optimized. And on the basis of GSA-BP, the method of short-term wind and wind forecasting is further studied. In the GSA algorithm, it is necessary to conduct a simulation experiment on gravitation, so as to confirm the optimal one in terms of weights and thresholds among the elements. This algorithm is a population search algorithm inspired by natural rules. The quality and position of the GSA algorithm determine the quality of its elements. Attributes. Under the mutual gravitational force, the element moves towards the more massive element. The positions of the elements correspond one-to-one with the initial solution of the problem, and all have associated applicable values. When the number of elements in the system is N, the position of the element is [5-6] :

$$X_i = \left[x_i, x_i^2, \ldots, x_i^a, \ldots x_i^Q\right] \tag{2}$$

In the formula: i in xi ^{a} is the order of elements, and α is the dimension, that is, the position of the i-th element in the α-th dimension. Q represents the dimension of the search space.

2.2 Design of Supporting Mechanism to Improve the Flexibility of Power System

During the transition period of the electricity market, promoting the nearby consumption of a high proportion of renewable energy is the key to implementing the new quota system based on the weight distribution of consumption responsibilities. The power system regulation ability, which is determined by the power supply structure and power regulation performance, is the key constraint factor for nearby consumption. It is difficult to change an inflexible power supply structure in a short time. Inflexible coal-fired power generation will continue to occupy a central position in the power generation mix at present and for a long time in the future. Therefore, using and improving the peak shaving performance of thermal power units, especially coal-fired power units, has become the most feasible method to promote the nearby consumption of a high proportion of renewable energy. While improving the peak shaving performance of thermal power units to break the physical consumption barriers of the power system, the corresponding market-oriented operation mechanism also needs to be improved. Among them, the trading of power generation rights between self-provided power plants and non-water renewable energy generating units is a representative method in the northwest region, which prompts thermal power units to transfer power generation to renewable energy generation on the basis of the peak shaving capacity of the existing power system. space, so as to achieve excess consumption on the basis of responsible consumption. Different from the method used in this study to assess the nearby consumption potential, other research institutions have also examined similar scenarios, namely, increasing the peak shaving capacity of coal-fired units and increasing the replacement transaction of power generation rights between self-provided power plants and renewable energy units. The consumption increment is calculated, and the results are closer to the operation of the actual power system. The two most representative calculation studies are taken as examples to illustrate the main research ideas and key conclusions [7-8].

2.3 Research on Renewable Energy Quota System

The recently introduced renewable energy consumption guarantee mechanism in China will be implemented in 2020. This renewable energy quota system with Chinese characteristics will have a profound impact on the development of renewable energy in my country. In this context, the following three aspects need to be further studied.

(1) Renewable energy power consumption based on the latest renewable energy quota system policy framework

Since China introduced the power generation side quota system in 2007, as of May 2019, the latest version of the quota system document has been released, and eight editions of policy documents have been released one after another. The newly released renewable energy power consumption guarantee mechanism and consumption responsibility weight assessment Compared with the traditional renewable energy quota system, the method has changed significantly. Therefore, as a strong support policy for China's renewable energy consumption, the optimization of future renewable energy consumption strategies cannot be separated from this basic policy framework, and the optimization of renewable energy consumption based on the latest quota system is in urgent need of in-depth research[9-10].

(2) The coordinated consumption optimization of the game of interests of different market entities is aimed at

There are few studies on the interest game of market players related to renewable energy consumption. Power users - power supply/selling companies - power grid companies - power generation companies - local governments - the central government have different responsibilities for consumption and different motivations for completing consumption, especially The decision-making preferences of relevant market players are quite different from the overall planning direction of government departments. Therefore, it is necessary to comprehensively consider the demands of various stakeholders and explore strategies for coordinated consumption of renewable energy by heterogeneous stakeholders[11-12].

(3) Regional coordinated consumption mechanism of renewable energy

There are few studies on the regional synergistic absorption mechanism. Different regions may have strong complementarities in renewable energy distribution and consumption, dispatching and trading, and grid interconnection. For example, through appropriate mechanism design, regions can be closely Collaboration, mutual benefit and win-win results will greatly increase the space for renewable energy consumption. Therefore, it is necessary to conduct an in-depth analysis of the inter-regional synergy effect, build a multi-regional synergistic consumption mechanism and verify its implementation.

3. Research and Design Experiment of Integrated Power Grid Transmission and Distribution System Planning Based on High Proportion of Renewable Energy

3.1 Pareto Frontier Strategy Based on Reference Points

In these years, the evolution of the algorithm has been affected by historical information. One of the main popular directions of current research is to make the equilibrium dynamic optimization algorithm more balanced in terms of convergence speed, but to ensure the diversity of the population. Historical information is generated with the evolution of the algorithm, such as the historical Pareto optimal frontier and optimal solution. Experts can add some prediction strategies to evolutionary algorithms through historical information. In order to predict the changes of the Pareto frontier in the new environment, it is generally necessary to refer to historical information to form a

time series. In DMOPs, the available information is historical Pareto frontier, and time series cannot be built. According to the current research, the successful research basically selects individuals according to the geometric mean distance in the historical Pareto frontier clusters, but there is no pattern, which reduces the correlation of individuals in the time series, resulting in poor prediction. It will also make the algorithm more complex.

The Pareto frontier forecasting strategy is proposed on this basis. It is based on structured reference points to solve the problem of DMOPs in DMOEAs, and combines current population information to establish a time series. It can also improve the population diversity in an orderly manner. It can improve the convergence speed and also make the population more abundant.

3.2 Experimental Design

This paper explores the market transaction frequency of the electricity market, and mainly analyzes the difference in the transaction frequency between the synchronous market and the asynchronous market. The second is to study the influence of a reasonable integrated transmission and distribution system of the power grid on the regional electricity price.

4. Experimental Analysis of Integrated Power Grid Transmission and Distribution System Planning Based on High Proportion of Renewable Energy

4.1 Market Transaction Frequency

This paper runs synchronous and asynchronous market mechanisms at five different activity rate ranges to study the market transaction frequency-activity rate relationship. The simulation uses the average number of time slots between two market transactions to measure the frequency of market transactions. The time length is still set to 200 time slots, and the simulation is run 50 times under different activity rate ranges, and the parameters are set randomly each time. The data are shown in Table 1.

Table 1: Average number of time slots between transactions by synchronous and asynchronous market mechanisms in different ranges of activity rates

	(0.98, 1)	(0.96, 1)	(0.94, 1)	(0.92, 1)	(0.90, 1)
Synchronous market	2	4	7	12	16
Asynchronous market	1	1	1	1	1

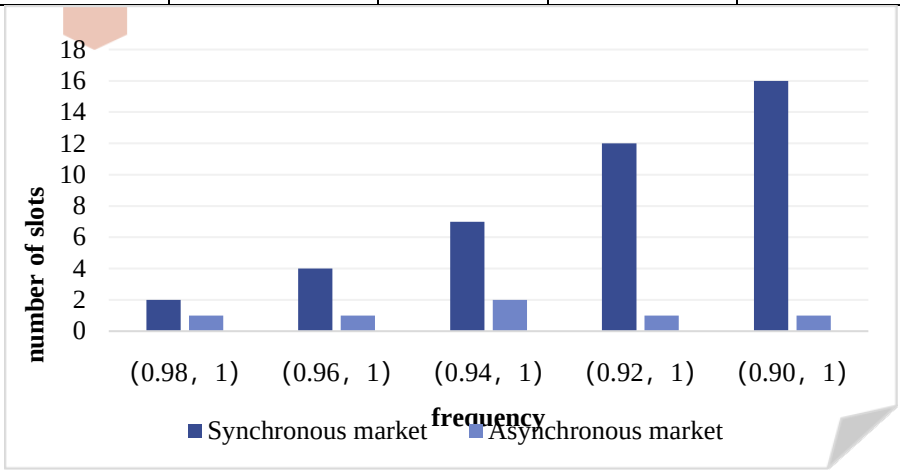

Figure 1: Number of average time slots for two transactions in two different markets under different activity

As can be seen from Figure 1, as the range of activity rates decreases, the average number of time slots between two iterations of the synchronous market mechanism will increase exponentially. And for the asynchronous market, since it can run and trade at any time slot, the result remains at 1. Therefore, the designed asynchronous market mechanism can operate more quickly and frequently and better cope with the uncertainty of renewable energy generation.

4.2 Price Comparison Before and After Power Dispatch

This paper compares the electricity prices in a certain area before and after the application of the integrated power grid transmission and distribution system, and analyzes the optimization of the transmission and distribution system to the electricity consumption in various places. The electricity price changes in the past five years are mainly selected. The experimental data are shown in Table 2.

Table 2: Differences between the electricity price under the two transmission and distribution systems in the same region

	2018	2019	2020	2021
Traditional scheduling	0.05	0.05	0.06	0.05
This article scheduling	0.03	0.03	0.02	0.03

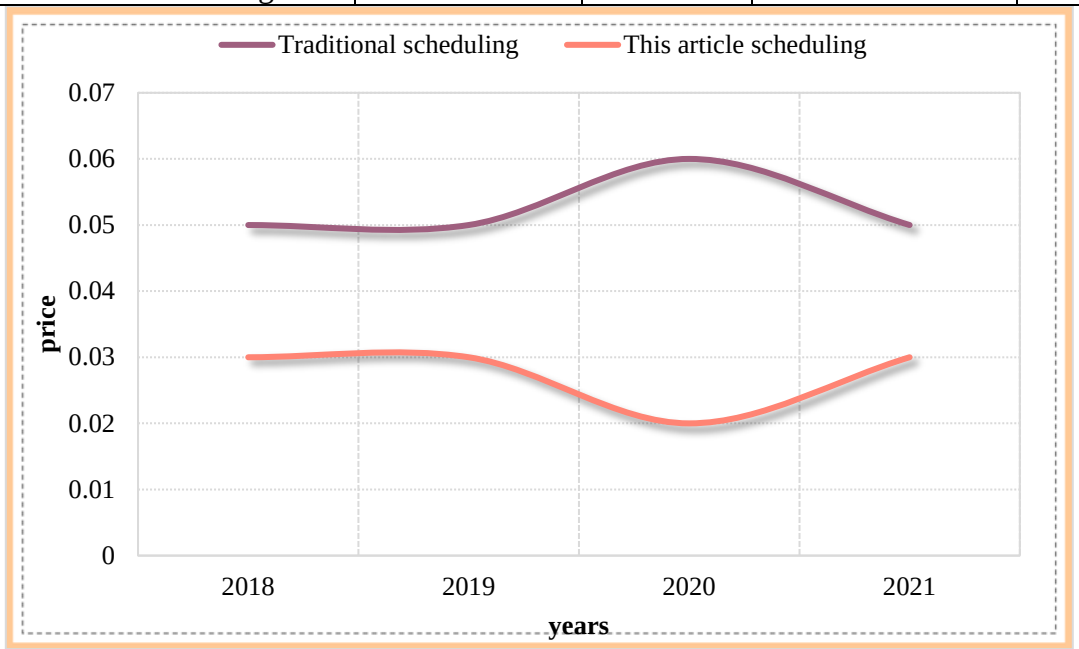

Figure 2: Electricity prices in the two places in the past five years

From Figure 2, we can clearly see the impact of the power transmission and distribution system brought by the algorithm in this paper on the price of electricity. From the perspective of the price of electricity in the past five years, the electricity price of the transmission and distribution system using this paper is significantly lower than that of the traditional transmission and distribution method. It is suggested that the system in this paper be widely promoted.

5. Conclusions

With the massive increase of distributed energy resources and the rapid development of demand-side response management technology, the electricity market will develop towards a more

decentralized mechanism, and participants in the market will become more proactive, hoping to decide on their own trading objects and trading results. These technological developments have promoted the application of the P2P market mechanism in the electricity market, which is considered to be the development direction of the electricity market in the future. The P2P market mechanism is based on the principle of cooperative economy and facilitates the exchange of goods among all peers. Using the P2P trading mechanism can encourage participants to participate in the market while improving the reliability and privacy protection of the power system. To this end, based on the two-stage clearing structure commonly used in the power market, this paper establishes a day-ahead P2P power market and a real-time P2P power market respectively, and studies how to solve the uncertainty of a high proportion of renewable energy. In this paper, a market model is established, a negotiated transaction mechanism is designed, the ideal nature of the market is analyzed, and the performance of the algorithm is verified by simulation.

References

[1] Brinkerink M, Gallachoir B O, Deane P. A comprehensive review on the benefits and challenges of global power grids and intercontinental interconnectors[J]. Renewable and Sustainable Energy Reviews, 2019, 107(JUN.):274-287.

[2] Gomes P V, Saraiva J T, Carvalho L, et al. Impact of decision-making models in Transmission Expansion Planning considering large shares of renewable energy sources[J]. Electric Power Systems Research, 2019, 174(SEP.):105852.1-105852.13.

[3] Rawat M S, Vadhera S. A Comprehensive Review on Impact of Wind and Solar Photovoltaic Energy Sources on Voltage Stability of Power Grid[J]. Journal of Engineering Research, 2020, 7(4):178-202.

[4] Melo R, Torres C, Borba B, et al. Multi-year two-stage generation and transmission expansion planning: intermittent renewable energy sources integration for Brazilian interconnected power system[J]. Electrical Engineering, 2022, 104(4):2689-2701.

[5] Adrees A, Milanovic J V, Mancarella P. Effect of inertia heterogeneity on frequency dynamics of low-inertia power systems[J]. Generation, Transmission & Distribution, IET, 2019, 13(14):2951-2958.

[6] Chelumala N, Patra P. Power Quality Issues of Wind and Solar Energy Systems Integrated into the Grid[J]. Advanced Science Letters, 2020, 26(5):514-523.

[7] Javadi M S, Nezhad A E. Multi-objective, multi-year dynamic generation and transmission expansion planning-renewable energy sources integration for Iran's National Power Grid[J]. European transactions on electrical power engineering, 2019, 29(4):e2810.1-e2810.21.

[8] Gbadamosi S L, Nwulu N I. Reliability assessment of composite generation and transmission expansion planning incorporating renewable energy sources[J]. Journal of Renewable and Sustainable Energy, 2020, 12(2):026301.

[9] Siala K, Mahfouz M Y. Impact of the choice of regions on energy system models[J]. Energy Strategy Reviews, 2019, 25(August 2019):75-85.

[10] Hannoon N M S, Vijayakumar V, Vengatesan K, et al. Small Signal Fault Analysis for Renewable Energy (Wind) Power System Distributed Generation by Using MATLAB Software (Simulink)[J]. Journal of Computational and Theoretical Nanoscience, 2019, 16(2):537-543.

[11] Mojumder M, Hasanuzzaman M, Cuce E. Prospects and challenges of renewable energy-based microgrid system in Bangladesh: a comprehensive review[J]. Clean Technologies and Environmental Policy, 2022, 24(7):1987-2009.

[12] Liu S C, Zhang J, Wang H B, et al. Analysis of the Influence of AVC Reactive Power Optimization on Line Loss in High Proportion New Energy Area[J]. Journal of Physics: Conference Series, 2022, 2158(1):012003.