Intelligent Optimal Scheduling of Distribution Networks Based on Load Forecasting

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Abstract: The paper provides a detailed introduction to load forecasting in distribution networks, highlighting the importance of load forecasting and the issues encountered. It compares traditional and modern load forecasting methods and explores intelligent optimization scheduling strategies for distribution networks based on load forecasting, such as the use of intelligent algorithms, constraint conditions, and objective optimization. Through case studies, the effectiveness of the intelligent optimization scheduling methods for distribution networks is verified. Based on current research results, the paper looks forward to the future of intelligent optimization scheduling for distribution networks, believing that with the integration and advancement of modern forecasting technologies and intelligent optimization algorithms, distribution network scheduling efficiency will be further improved, while also ensuring reliability. This approach is expected to open a new path for the intelligent development of the power system in China.

Keywords: Load forecasting; Intelligent scheduling of distribution networks; Strategies; Future outlook; Case analysis

1. INTRODUCTION

At present, with the continuous development and advancement of artificial intelligence and big data technologies in China, load forecasting and grid scheduling are becoming increasingly intelligent and modernized. The active integration of machine learning and deep learning techniques has significantly improved the accuracy of load forecasting while providing essential data support for intelligent scheduling. By introducing intelligent optimization algorithms, fundamental solutions are provided for some complex grid scheduling problems, effectively addressing multi-objective and multi-constraint optimization issues. This has propelled the rapid development of China's power industry, helping it stand out in a highly competitive market environment.

2. DISTRIBUTION NETWORK LOAD FORECASTING ANALYSIS DISTRIBUTION NETWORK LOAD FORECASTING ANALYSIS

In the planning and operation stages of the power system, distribution network load forecasting plays a crucial role and is an indispensable fundamental element. Therefore, accurate load forecasting provides an important guarantee for power companies in making reasonable generation plans, optimizes resource allocation, reduces operational costs, and improves power supply reliability and safety. However, load forecasting still faces some unresolved issues, such as being easily affected by weather, load fluctuations, holiday effects, and other factors, which increase the difficulty of forecasting and negatively impact subsequent scheduling tasks.

In the past, commonly used load forecasting methods included time series analysis, grey forecasting, and regression analysis. While these methods met the forecasting requirements, they still faced significant issues and limitations when processing non-stationary load data and nonlinear data. With the continuous development and progress of advanced technologies, modern load forecasting methods are gradually being introduced and applied. For example, machine learning methods, such as support vector machines and random forests, can quickly and accurately capture the complex characteristics of load datasets. Similarly, the use of deep learning techniques, such as convolutional neural networks (CNN) and long short-term memory networks (LSTM), has significantly advanced large-scale and high-dimensional data processing, offering excellent performance. Moreover, hybrid forecasting methods that leverage various advanced algorithms to maximize the strengths and applications of each algorithm have significantly improved the accuracy of load forecasting in distribution networks.

In practice, these intelligent optimized load forecasting methods require selecting appropriate forecasting techniques and considering various influencing factors, such as computational resources, data quality, and forecasting scale. For short-term load forecasting, which is commonly used in daily scheduling, higher accuracy is required. For medium- and long-term load forecasting, it plays an important role in system planning by emphasizing trend forecasting. The gradual widespread use of smart meters and advanced metering infrastructure has made load data acquisition more convenient and efficient, providing great momentum and support for the improvement and intelligent development of forecasting methods, thus facilitating the efficient use of data.

3. LOAD FORECASTING-BASED INTELLIGENT OPTIMIZATION SCHEDULING STRATEGY FOR DISTRIBUTION NETWORKS

3.1 Optimization Data-Driven

The use of data preprocessing methods is a key factor in effectively applying data-driven optimization. Techniques like data standardization and missing value handling are crucial steps. By performing data cleaning, noise and redundant information are removed, ensuring better data quality and improving the accuracy of optimization results. The widespread use of big data technology has led to innovations in preprocessing and cleaning methods, such as machine learning algorithms, which offer automatic recognition and efficient data handling capabilities.

In practical applications, prediction models are built using neural networks and support vector machines, optimizing and improving model parameters during training and validation to significantly enhance prediction accuracy and generalization ability. Moreover, the continued development of deep learning technology has led to efficient solutions for complex intelligent optimization problems in distribution networks.

Dynamic optimization algorithms, such as genetic algorithms and differential evolution algorithms, are particularly suitable for use in dynamic and rapidly changing grid environments. These algorithms offer real-time adjustment and optimization functions. To maximize the optimization effect, the application of these algorithms requires analyzing their real-world operational conditions, especially constraints and computation speed.

Multi-objective optimization and decision support are closely linked to smart grid optimization tasks, including goals such as maximizing reliability, minimizing costs, and optimizing the environment. Therefore, the use of multi-objective optimization methods generally includes techniques like weighted sum and Pareto methods. By actively building decision support systems and integrating them with optimization algorithms, valuable references for load forecasting and distribution network scheduling can be provided.

To maintain network security and enhance data protection, data-driven optimization must incorporate encryption technologies, along with anonymization and access control measures, to prevent data leakage or misuse by malicious entities. Additionally, the widespread use of IoT and cloud computing technologies has provided significant support for network security and data protection efforts.

3.2 Modern Intelligent Optimization Methods

When analyzing the intelligent optimization scheduling strategy for distribution networks with load forecasting, it is essential to emphasize the optimization of scheduling goals. The key directions are reducing operating costs, improving power supply reliability, and minimizing network losses. However, conflicts exist between these objectives, which require the use of multi-objective optimization methods to balance them.

Energy Saving and Consumption Reduction: By optimizing scheduling strategies, the efficiency of energy use in the power system can be maximized, which helps reduce excessive energy consumption. In the context of global energy shortages, improving energy utilization is one of the main objectives of load forecasting and intelligent optimization scheduling in distribution networks. Advanced data analysis and forecasting technologies can be applied to scientifically and accurately predict load demands and rationally design generation plans, avoiding waste of electricity resources during the generation process, thus reducing operational costs. During this process, integrating renewable energy into scheduling plans allows for continuous optimization, ensuring that renewable energy has good absorption capacity while reducing reliance on traditional fossil resources, contributing to a more refined energy structure.

Power Supply Reliability: Smart grid real-time monitoring and quick-response measures can ensure that the grid restores power quickly in the event of a fault, minimizing the impact on user service and stabilizing power supply. Distributed generation and energy storage systems play a crucial role in

improving grid flexibility and resistance to disturbances, preventing long-term power outages caused by natural disasters, equipment failures, and other factors. Additionally, the use of artificial intelligence technologies enables real-time analysis of operational data, accurately predicting hidden fault locations and preventing accidents through early intervention and control, reducing the occurrence of incidents.

Optimal Resource Allocation: New big data technologies and artificial intelligence significantly enhance the rationality and efficiency of resource allocation. By analyzing electricity demand for each region and time period, scheduling plans can be adjusted in a rational and targeted way, ensuring that the grid remains stable and meets the diverse needs of different users. The intelligent optimization model for distribution networks also involves innovative forms, such as encouraging power companies to engage in cross-regional electricity trading. This optimizes resource allocation and helps control operating costs, creating more profit opportunities for power companies.

Meeting User Demand: The installation of smart meters and user-side devices allows for comprehensive data collection of daily electricity consumption, providing valuable reference data for subsequent scheduling optimization. Encouraging users to actively participate in grid scheduling and establishing a demand response mechanism helps regulate electricity usage efficiently, improving the overall operation speed of the grid. Additionally, improving the efficiency of user energy storage devices is crucial for maintaining dynamic balance in the power system, meeting users' personalized energy needs.

Environmental Protection: Adjusting scheduling plans to control carbon emissions helps eliminate the negative impact on the ecological environment. Emphasizing energy conservation, environmental protection, and green development, the promotion and use of clean energy, such as solar, geothermal, and wind energy, are key measures for environmental protection. These actions reduce pollution and damage to the surrounding environment, contributing to sustainable development.

3.3 Optimization Algorithm Design

The algorithm design and optimization, based on heuristic algorithms, significantly accelerated the scheduling speed and reduced operational costs when applied. The application principle of this algorithm is to simulate the biological evolution process in nature. Heuristic algorithms, such as Particle Swarm Optimization and Genetic Algorithms, are forms of such algorithms, playing an important role in optimizing the operational parameters of the power grid. When designing heuristic algorithms, it is important to analyze the uncertainties, complexities, and intricacies of the smart grid itself. After integrating adaptive control mechanisms, the effectiveness of the algorithm has become increasingly significant.

The application of linear programming methods is also a key point in algorithm optimization design. Considering that the objective functions and constraints in smart grid scheduling are very clear, linear programming can improve the effectiveness and scientific nature of power resource allocation. For example, the use of slack variables and penalty functions fundamentally solves non-linear constraint issues, and this approach has high self-applicability value. Moreover, the various data generated during the operation of the smart grid can be improved by linear programming methods,

ensuring that this scheduling strategy is implemented more timely and efficiently.

The application of dynamic programming primarily involves breaking down the problem into multiple sub-problems. By solving each one individually, the overall solution to the problem is found, which allows for comprehensive optimization and improvement in complex power grid scheduling tasks. However, this planning approach is particularly effective in handling power grid operation issues, especially when dealing with uncertainties and responding to emergencies such as load fluctuations and equipment failures. After fully recognizing the importance of this scheduling optimization strategy, machine learning algorithms are integrated to ensure that dynamic programming methods exhibit high accuracy in load forecasting and, to a certain extent, accelerate the intelligent scheduling speed of the smart grid.

4. THE FUTURE OUTLOOK OF INTELLIGENT OPTIMIZATION SCHEDULING FOR DISTRIBUTION NETWORKS BASED ON LOAD FORECASTING

4.1 The Application of Advanced Forecasting Technologies

By utilizing technologies such as machine learning and deep learning, the accuracy of data in load forecasting results can be significantly improved. At the same time, innovations in big data and Internet of Things (IoT) technologies can help explore potential factors that impact load, enhancing the effectiveness of scheduling work. Through the active development and use of adaptive forecasting models, and by analyzing factors such as grid conditions and related changes, dynamic improvements and adjustments can be made.

4.2 The application of integrating renewable energy.

Against the backdrop of continuous research and innovation in science and technology in China, the load forecasting and intelligent optimization scheduling of distribution networks will become more refined and diversified. By integrating renewable energy, real-time monitoring and dynamic forecasting of renewable energy output can optimize the scheduling strategy and provide a good balancing effect for intermittent energy sources. Incorporating energy storage systems and distributed generation into scheduling work can make the grid more flexible and reliable. Through the active development of collaborative optimization algorithms and combining the characteristics of renewable energy, the stability and safety of grid operations will continue to improve.

4.3 The Application of Distributed Energy Optimization Technology

With the support of demand response technology and distributed generation, the penetration rate of distributed energy in the distribution network has significantly increased. By building distributed energy aggregators, the scheduling work has been greatly optimized, while also improving the coordination and control of some decentralized resources. Therefore, the development of optimization algorithms is mainly moving towards flexibility and effectiveness, and,

based on the actual location and technical characteristics of the energy, it is driving the modernization and intelligent development of the power industry.

4.4 The application of smart grid architecture.

Improving the smart grid architecture is a key direction for the future development of the industry. By introducing advanced sensor equipment and integrating it with cutting-edge control and communication technologies, the aim is to optimize real-time monitoring and automated control of the distribution network. At the same time, with the support of emerging technologies such as the Internet of Things (IoT) and big data, the development of smart grid platforms brings new opportunities for the use, processing, and storage of vast amounts of data. Additionally, technologies such as blockchain and edge computing play a crucial role in ensuring the security and stable operation of the power grid system.

5. CONCLUSION

In conclusion, under the diverse social development trends, the research on intelligent optimization scheduling strategies for distribution networks is highly necessary. The application of various new intelligent collaborative scheduling methods for distribution networks makes load forecasting data more accurate, complete, and real, facilitating the accurate identification of user demand. By utilizing multiple intelligent grid scheduling methods and approaches, the forecasting work is enhanced, actively responding to the multifaceted electricity resource usage requirements of users. The introduction of the intelligent grid scheduling concept fundamentally addresses many issues in distribution network scheduling, improving the feasibility, reliability, and professionalism of scheduling plans. It not only aligns with energy-saving, environmental protection, and green development concepts but also brings new insights for the transformation, upgrading, and innovative development of the power industry. This opens up a new pattern for social development and enhances the overall benefits of enterprise development.

6. REFERENCES

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