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Analysis of "Source-Network-Load-Storage" Integrated Operation Mode for Park Microgrids

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Abstract: This article discusses the concept and characteristics of a park microgrid, as well as the principles and analysis of the integrated operation mode of "generation-network-load-storage". A park microgrid refers to the supply and management of energy within a park through distributed power generation sources, microgrid network architecture, load management, and energy storage technologies. By analyzing distributed power generation sources, optimizing microgrid network architecture, load forecasting and management, as well as the selection and application of energy storage technologies, the energy supply diversification and efficient optimization of the park microgrid can be achieved. This article summarizes the above content and emphasizes the importance of the integrated operation mode for the park microgrid.

Keywords: Campus Microgrids, Source-network-load-storage, Integrated operation.

1. Introduction

With the increasing energy demand and the popularization of renewable energy, park microgrids have become a highly discussed topic. A park microgrid refers to the establishment of a small-scale power network system in a specific area, which integrates distributed generation, load management, and energy storage technologies to achieve efficient energy supply and management. This integrated operation mode can improve energy utilization efficiency, reduce energy consumption, and promote the application of renewable energy. This article will introduce the concept and characteristics of park microgrids, explain the principles of the "generation-network-load-storage" integrated operation mode, and focus on analyzing its application and advantages for park microgrids. Through in-depth research on the operation mode of park microgrids, it can provide reference and inspiration for future energy supply.

2. Overview of Campus Microgrids

2.1. Definition and Characteristics of Park Microgrids

A park microgrid refers to the establishment of a small-scale power network system within a specific area, which integrates distributed generation, load management, and energy storage technologies to achieve efficient energy supply and management. Compared to traditional centralized power systems, park microgrids have the following characteristics:

(1) Distributed energy: Park microgrids utilize distributed generation sources, such as solar photovoltaic, wind power, and small-scale gas generation, to accommodate energy production within the park, reducing transmission losses and improving energy utilization efficiency. The application of distributed energy sources also increases the flexibility of energy supply.

(2) High autonomy: Park microgrids are independent power network systems with the capability for autonomous management and operation. They can operate independently and remain reliable during grid faults or power outages by disconnecting from the main grid. The autonomy of park microgrids enables them to better cope with emergencies and disasters.

(3) Energy diversity: Park microgrids achieve energy diversity by integrating different sources of energy. In addition to conventional fossil fuel generation, park microgrids can utilize renewable energy sources such as solar and wind, as well as other available energy resources like battery storage and fuel cells. This energy diversity helps to reduce reliance on traditional energy sources and promotes the development of sustainable energy [1].

(4) Efficient energy management: Park microgrids can intelligently schedule and manage energy based on real-time load demands and energy supply conditions. Through load forecasting, supply-demand balancing, and energy optimization, efficient distribution and utilization of energy can be achieved, lowering energy costs and reducing reliance on the main grid.

(5) Flexibility and scalability: Park microgrids are flexible and scalable, adapting and expanding according to demand. The size and energy capacity of the microgrid can be adjusted based on the park's development needs and energy scale, meeting the energy requirements of different stages.

By establishing and operating park microgrids, energy independence and sustainable development can be achieved for parks, while providing an innovative example for the transformation of energy supply models.

2.2. Composition and Functions of Microgrids in Industrial Parks

The composition of microgrids in industrial parks includes the following key elements, each providing corresponding functions:

(1) Distributed power sources: Microgrids in industrial parks integrate distributed power generation equipment such as solar photovoltaic panels, wind turbines, and small-scale gas generators. This enhances the reliability and flexibility of energy production and supply. These distributed power sources can provide independent electricity supply to the microgrid, reducing reliance on the traditional power grid.

(2) Microgrid power network architecture: An independent power network architecture is established within the industrial park's microgrid, including transmission lines,

substations, and switchgear. The design and construction of this network architecture enable more controllable and stable energy supply while offering management capabilities for load and power distribution within the industrial park [2].

(3) Load management: The microgrid in the industrial park employs a load management system to monitor and control the electricity demand of various loads in real-time. This includes predicting and adjusting the electricity demand of buildings, equipment, and industrial production within the park, achieving efficient energy utilization and load balancing.

(4) Energy storage technology: The microgrid in the industrial park utilizes energy storage technologies like battery energy storage systems to store surplus energy for future needs. This energy storage technology can provide backup power during energy shortages or emergency situations while playing a key role in power balance and stability.

(5) Intelligent control system: The microgrid in the industrial park is equipped with an intelligent control system that optimizes energy supply and management through real-time monitoring, data analysis, and intelligent scheduling. The intelligent control system can also respond to changes in the main power grid, ensuring coordination and optimized scheduling to guarantee reliable operation of the microgrid.

The main functions of microgrids in industrial parks include providing reliable energy supply, reducing energy costs, decreasing reliance on the main power grid, optimizing energy distribution and load balancing, and promoting the application of renewable energy and sustainable development.

3. The Principle of the "Source-Network-Load-Storage" Integrated Operation Model

3.1. "Source": Access and management of distributed power sources

The "source-network-load-storage" integrated operation model is the core principle of a microgrid in a campus or industrial park. It combines distributed power sources, microgrid network architecture, load management, and energy storage technologies to achieve efficient energy supply and management. In this integrated operation model, "source" refers to the distributed power sources within the microgrid. These can include solar photovoltaic panels, wind turbines, small-scale gas generators, and so on. By accommodating energy production within the campus or industrial park, the model reduces power transmission losses and improves energy utilization efficiency. The intelligent control system enables the monitoring, dispatching, and optimization of distributed power sources. Factors such as the type and capacity of power generation equipment, monitoring and management of power generation data, and coordination between power generation and the electrical network need to be considered for the access and management of distributed power sources. To achieve effective access and management, the microgrid needs to establish corresponding equipment access and data transmission mechanisms to ensure the safe, stable, and efficient operation of distributed power sources. Through the access and management of distributed power sources, the microgrid can achieve diversified energy supply to meet the electricity demands of different loads within the campus or industrial park. Intelligent control and dispatching enable optimized utilization of power sources, reducing energy costs, and improving the reliability of the microgrid's power supply. This innovative operational concept provides a pathway for sustainable development and energy transition in microgrids [3].

3.2. "Network": Electrical network architecture and operational strategies within the microgrid

"Network" refers to the electrical network architecture and operational strategies within the microgrid in the campus or industrial park. A self-contained and controllable electrical network is established within the microgrid, including transmission lines, substations, and switchgear, to enable the distribution and supply of electricity. The design of the electrical network architecture needs to consider factors such as the scale of the campus or industrial park, energy capacity, and load demands. By rationally planning and arranging transmission lines and substations, the transmission and distribution of electricity can meet the electricity demands of various loads within the campus or industrial park. Additionally, the reliability and safety of the electrical network need to be considered, with appropriate protection measures such as overload protection and short circuit protection implemented to prevent power failures from affecting the microgrid. In terms of operational strategies, the microgrid in the campus or industrial park adopts an intelligent energy management system and control strategies to achieve real-time monitoring, dispatching, and optimization of the electrical network. Through the collection and analysis of real-time data, accurate predictions and scheduling of the power condition and load demands within the microgrid can be made to achieve efficient power allocation and load balancing. Additionally, the fluctuation of renewable energy can be intelligently controlled by matching the power supply and demand, fully utilizing renewable energy, improving energy utilization efficiency, and reducing reliance on traditional power grids. Furthermore, technologies such as distributed power management systems, intelligent switches, and monitoring devices can be employed within the microgrid to realize automated control and real-time monitoring of the electrical network. This improves the stability and responsiveness of the electrical network, enhancing the reliability and safety of the microgrid's operation. Through the electrical network architecture and operational strategies within the microgrid, the campus or industrial park can achieve controllable and reliable power supply and improve energy utilization efficiency. This helps to reduce energy costs, improve power quality, and promote the sustainable development and energy transition of the microgrid.

3.3. "Load": Load Forecasting and Management

In the microgrid of the park, "load" refers to the power load demand within the park. Load forecasting and management are essential components of the park's microgrid, as they enable the balance of load and efficient utilization of energy. Load forecasting involves analyzing past load data and considering influencing factors such as seasonal variations, weather, and working hours to predict the load demand for a future period. This helps park microgrid operators understand the changing trends and peak periods of load in the park, optimizing load allocation and scheduling. Load management, on the other hand, involves effective management of loads within the park based on the results of load forecasting. This includes load optimization, distribution, and balancing. By appropriately allocating electrical resources, it ensures meeting the electricity demands of various loads and maintaining system stability. The goal of load forecasting and management is to minimize energy waste, avoid energy surplus or shortage, and reduce energy costs. Accurate load demand forecasting enables the park microgrid to adjust the supply in real-time scheduling to meet the actual requirements of different loads. Additionally, by flexibly scheduling and optimizing loads, it can prevent unstable power caused by excessive load and improve load utilization. Load forecasting and management can also be combined with pricing strategies and energy market conditions to further optimize load management and energy utilization efficiency. For example, during peak periods of power supply, price adjustments can encourage users to reduce electricity consumption, or energy market transactions can be utilized for power adjustment and balancing. In conclusion, load forecasting and management are crucial in the park microgrid as they enable accurate load prediction, efficient load management, improved energy utilization efficiency, and reliable power supply. They make significant contributions to the sustainable development and energy management of the park microgrid [4].

3.4. D. "Storage": Application of Energy Storage Technology in Microgrids

"Storage" refers to the application of energy storage technology in microgrids. Energy storage technology plays a crucial role in microgrids by providing backup power, regulating energy supply and demand balance, and enhancing the reliability and stability of the microgrid. The application of energy storage technology includes battery energy storage systems, pumped storage systems, compressed air energy storage systems, and more. These storage systems can store excess energy and release it when needed to meet the load demands. Among them, battery energy storage systems are the most common and widely used. In a microgrid, the application of energy storage technology has several roles. Firstly, it can serve as a backup power source, providing stable electricity supply to the park. When there is a shortage in grid power supply or emergencies occur, energy storage systems can quickly release stored energy to ensure continuous power supply to the park, reducing reliance on the traditional grid and enhancing power supply reliability. Secondly, energy storage technology can assist in regulating the energy supply and demand balance in the microgrid. When there is an excess supply of renewable energy, the surplus energy can be stored in the energy storage systems. Conversely, when the load exceeds the supply, the energy storage systems can release the stored energy to meet the load demand, balancing the differences between supply and demand. Additionally, the application of energy storage technology can help reduce energy costs through peak shaving. During periods of high power demand, energy storage systems can release stored energy to meet the peak load, reducing the demand from the power market and high electricity bills. During periods of low power demand, energy can be purchased at lower prices to charge the energy storage systems in preparation for the next peak load period. In addition to these roles, the application of energy storage technology also contributes to improving the power quality and stability of the microgrid. By alleviating the peak shaving issues in power transmission and distribution, energy storage technology can reduce energy waste and losses, improving the energy utilization efficiency of the microgrid. In summary, the application of energy storage technology in microgrids provides backup power, regulates energy supply and demand balance, reduces energy costs, and enhances power quality and stability for the park. It provides important support for the reliability and sustainable development of microgrids, driving the energy transition and further development of microgrid technology.

4. Analysis of the "Generation-Grid-Load-Storage" Integrated Operation Mode for Park Microgrids

4.1. Achieving Energy Supply Diversification through Distributed Generation Sources

The "Generation-Grid-Load-Storage" integrated operation mode for park microgrids aims to achieve energy supply diversification and efficient operation. A key step in achieving diversified energy supply is through the utilization of distributed generation sources. These sources include renewable energy such as solar photovoltaic, wind energy, biomass, as well as traditional energy sources like gas power generation. By distributing these generation sources within the park, energy supply points can be decentralized, reducing energy transmission losses and improving the stability and reliability of electricity. The utilization of distributed generation sources for diversified energy supply has the following advantages: utilization of renewable energy, diversified energy supply, energy security and reliability, and reduction of energy costs. By utilizing distributed generation sources, park microgrids can achieve diversified energy supply and efficient operation. This provides parks with a more sustainable, stable, and cost-effective energy solution, serving as an important reference for future energy transition and microgrid development [5].

4.2. Optimizing the power network architecture and operation strategies within microgrids

Optimizing the power network architecture and operation strategies within microgrids is a crucial measure for achieving efficient microgrid operation. In terms of optimizing the power network architecture, the introduction of smart distribution grid technologies can be considered. These technologies enable monitoring, control, and dispatching of various nodes within the microgrid. Through smart distribution grids, real-time power data can be collected from each node, allowing for data analysis and algorithm optimization to achieve efficient power network operation and load management. Additionally, establishing a microgrid energy management system that integrates monitoring, analysis, and control functions can comprehensively manage and schedule energy flow within the microgrid. This helps improve energy utilization efficiency and reduce energy waste. Furthermore, it is important to properly configure hybrid energy systems based on the characteristics and supply-demand relationships of different energy sources within the microgrid, aiming to optimize energy utilization. By optimizing the power network architecture and operation strategies within microgrids, the reliability and economic viability of energy supply can be enhanced, thereby promoting the sustainable development of microgrids.

4.3. Optimizing load management based on load forecasting

Optimizing load management based on load forecasting is an effective way to achieve efficient energy utilization and optimize supply-demand balance within microgrids. By accurately predicting future load conditions, microgrids can adjust their energy supply strategies to provide sufficient energy while avoiding energy waste. Load forecasting involves analyzing historical load data and considering external factors such as seasonality, weather conditions, weekdays vs. weekends, etc., to predict future energy demand. These models can utilize algorithms such as machine learning and artificial intelligence for modeling and training, continuously improving the accuracy of load forecasting. Based on load forecasting results, corresponding load management strategies can be developed. There are several key strategies that can be applied in load management. Firstly, load optimization and dispatching involve rational scheduling and dispatching of various energy sources based on load forecasting results, aiming to achieve supply-demand balance without compromising electricity demand. By incentivizing users to participate in load regulation, it is possible to minimize the peak load and energy waste within the microgrid while ensuring user comfort. Furthermore, combining energy storage technologies is also a significant load management strategy. Energy storage devices can be charged during low load periods and discharge stored energy during high load periods to balance supply-demand differences within the microgrid. For example, utilizing battery energy storage systems to store surplus energy generated by solar photovoltaic systems during the day and supply energy during nighttime or high load periods.

5. Conclusion

Analysis of the integrated "generation-network-load-storage" operation mode for the microgrid in the park is an important research direction to promote the sustainable development of microgrids. By integrating the various processes of energy generation, transmission, utilization, and storage, this integrated operation mode can achieve efficient flow and optimal utilization of energy within the microgrid, improving the reliability and cost-effectiveness of energy supply. By comprehensively analyzing the relationship and coordination mechanisms between generation, network, load, and storage, efficient integration and flow of energy within the microgrid can be realized. This integrated operation mode not only improves the energy self-sufficiency of the microgrid but also adapts to diversified energy supply and demand and optimizes energy utilization efficiency. At the same time, combining intelligent technologies and data analysis methods can enable intelligent scheduling and management of energy within the microgrid, further enhancing the automation and intelligence level of operations. In conclusion, the analysis of the integrated "generation-network-load-storage" operation mode for the microgrid in the park is a key research area that provides guidance for achieving sustainable development of microgrids. Through the synergy of each process, efficient configuration of energy, supply-demand balance, and stable operation of the microgrid can be achieved, promoting the microgrid to move towards a more reliable, intelligent, and sustainable energy supply system.

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