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A review of research on the new energy acceptance capacity of high-proportion new energy power grid

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Abstract: This paper mainly studies the impact of high-proportion renewable energy access on the power grid, and discusses the theoretical and engineering application status of the power grid's renewable energy acceptance capacity. With the growth of renewable energy installed capacity, the grid's acceptance capacity has become a key factor restricting the development of renewable energy. This paper first analyzes the impact of renewable energy access on the grid's voltage, frequency and dispatching operations, then reviews the progress in theoretical research and engineering application of renewable energy acceptance capacity at home and abroad, and finally discusses the peak-shaving strategy of renewable energy access to the power grid.

1. Introduction

1.1 Background and significance of the project

1.1.1 Research background

Since traditional fossil energy sources such as coal and oil are non-renewable, improving energy efficiency, developing new energy, and strengthening the comprehensive utilization of renewable energy are inevitable choices for energy development. Wind power and photovoltaics are the new energy sources that are currently being successfully applied worldwide. Because of their wide and reliable sources, they are regarded as the main energy sources for future economic development by countries around the world. China has huge wind and photovoltaic power generation capacity and potential. With the acceleration of the development and utilization of new energy, new energy will occupy an important position in China's energy structure. With the access of a high proportion of new energy, it has brought huge challenges to the distribution network. The huge amount of power generated by new energy needs to be connected to the power grid and transmitted through interconnection lines to achieve large-scale consumption. However, there are still some imbalances and inefficiencies in the development of new energy in China, and the distribution of new energy installed capacity is completely unbalanced. Many new energy bases in China are located in economically underdeveloped areas. For example, the "Three Norths" region composed of Northeast, Northwest, and North China currently accounts for 75% of the country's installed capacity of new

energy. However, the load is concentrated in the economically developed areas of the eastern coastal areas. The distribution of new energy installed capacity is inversely distributed with the load, and it is difficult to match the load and power generation in the region. In addition, the proportion of flexible power sources such as pumped storage and gas turbines in my country is low. The flexible power sources in the "Three Norths" region only account for 17.9% of the installed capacity of new energy. Conventional units have disadvantages in flexibility such as insufficient adjustment depth. When new energy is connected to the grid on a large scale, the grid can only be stabilized by adjusting the output of new energy. New energy has serious problems in absorption. Wind and solar power are seriously abandoned in some areas. The absorption problem has become the biggest bottleneck restricting the further development of new energy.

Carrying out research on the distribution network's acceptance of the gradually increasing proportion of renewable energy installed capacity in the power grid, and studying the optimal ratio and absorption level, will help promote the upgrading and transformation of the distribution network. This will promote the transformation of high-energy-consuming and high-pollution enterprises in the region into energy-saving and environmentally friendly enterprises. It will help improve the planning and operation level of the Liaoning power grid and also facilitate the realization of low-carbon power grid operation in our province.

1.1.2 Research significance

In order to summarize and refine the multi-level acceptance capacity of regional main/distribution networks with a high proportion of renewable energy, form relevant theoretical results, and provide theoretical guidance and technical support for the acceptance of renewable energy in regional main/distribution networks, this project research work is specially carried out.

It aims to lay a theoretical foundation for the construction of smart distribution networks, especially for the construction of distribution networks with a high proportion of renewable energy access.

In view of the increasing proportion of renewable energy installed capacity in the power grid, the widespread access of diversified distributed power generation equipment and the increasing complexity of power system operation, the current research on the coordination and absorption of high-proportion renewable energy access to the power grid lacks macro and holistic thinking. Through the implementation of this project, the study integrates the complementary superposition characteristics of distributed wind, light, and load power into the distribution network. It builds a comprehensive load equivalent model of the distribution network, proposes an analysis method for the wind and light carrying capacity of the distribution network, and quantitatively obtains the optimal ratio and absorption level of wind and light resources access to the regional main/distribution network.

This provides technical support for the multi-level wind and light layout and absorption of the main grid and distribution network in new energy-rich areas.

The increasing penetration of renewable energy generation at all levels of the power grid has made the volatility and uncertainty of the power system increasingly prominent, posing great challenges to the safe and efficient operation of the power system. Researching the load characteristics of distribution networks with a high proportion of renewable energy, the analysis method of the new energy acceptance capacity of distribution networks, taking into account the complementary characteristics of wind and solar power, the typical electric energy substitution load characteristics, and the multi-level new energy cooperative network acceptance strategy of regional power grid main/distribution networks are of great significance. These studies are crucial for promoting the development and consumption of renewable energy.

1.2 Research on the new energy acceptance capacity of high-proportion new energy grid

1.2.1 Overview of the impact of high-proportion new energy access on the grid

In the next few years, the new energy access capacity of Liaoning power grid will usher in rapid development.

The access scale continues to expand, and the penetration rate of new energy in Liaoning's urban distribution network is getting higher and higher, which has brought many challenges and problems to the operation and dispatch of the power system in our province. The main ones are:

(1) Challenges in voltage qualification rate and power fluctuation

(2) Grid frequency operation faces challenges

(3) Challenges faced by power grid dispatching and operation

1.2.2 Current status of research on the capacity of power grids to accept new energy sources

(1) Current status of theoretical research on the capacity of power grids to accept new energy sources Domestic and foreign scholars have conducted extensive research on the capacity of distribution networks to accept distributed power sources. References [1] to [7] proposed calculation methods for the maximum access capacity of distributed power sources in distribution networks considering different constraints. References [8] to [17] established a maximum capacity calculation model for distributed power sources in distribution networks based on the optimal power flow theory, and considered the uncertainty of the output power and load level of distributed power sources.

There are also many examples in China where the ability to accept new energy is used in engineering construction. For example, Chengdu Power Supply Company cooperated with many groups to create an integrated demonstration project of "fishery, light, load, storage and charging" in order to improve the existing distribution network's ability to accept new energy. It integrated electrochemical energy storage technology, new energy photovoltaic grid-connected technology, Tongwei digital breeding technology, and Internet energy management technology. Photovoltaic power generation gives priority to digital breeding and electric vehicle charging, and the surplus photovoltaic power is stored in energy storage equipment for use during peak hours, forming a source-grid-load-storage model of "photovoltaic power generation-breeding, electric vehicle charging load consumption-storage flexible regulation-data application". Shandong Power Supply Company carried out the construction of a green energy development benchmark village demonstration in Yishui County, and piloted it in 5 towns and 37 villages in the county, combining distributed photovoltaic with the comprehensive utilization of agricultural and forestry biomass and the construction of rural biogas facilities, promoting the local consumption of new energy in the distribution network and improving the distribution network's ability to accept new energy. The Qingyuan Pumped Storage Power Station Project in Fushun, Liaoning Province is an important clean energy supporting delivery project in Liaoning Province during the "14th Five-Year Plan" period, supporting the power transmission of 5 wind farms in Liaoning and improving the grid's ability to accept new energy power generation. For the first time, a 10 million kilowatt-level wind and photovoltaic power cluster source-grid coordination control system demonstration project was built in the Hexi Corridor, covering 84 wind farms (12.82 million kilowatts), 154 photovoltaic power stations (8.07 million kilowatts), 4 thermal power plants (2.4 million kilowatts) and 1 ultra-high voltage DC converter station in the Hexi Corridor. A real-time monitoring network and data platform for wind and photovoltaic resources including 44 wind towers and 18 photometric stations has been built. Since the system was put into operation in 2015, there has been no large-scale wind and photovoltaic power disconnection accident in the Gansu power grid. At the same time, the AC and DC transmission capacity of the Hexi wind and photovoltaic base has been increased by more than 2 million kilowatts, and the wind and

photovoltaic abandonment rates have been reduced from 39% and 31% to 18.9% and 10.1%, respectively, which has promoted the advancement of grid-connected dispatching and management technology for wind and photovoltaic power stations. The State Grid Corporation of China has proposed a policy of "integrating as many distributed renewable energy sources as possible" in rural areas to promote the continued increase in the proportion of renewable energy power generation in rural energy consumption. In this way, it will carry out the transformation and upgrading of the distribution network infrastructure. For example, Lingyun County, Baise City, Guangxi Zhuang Autonomous Region, has invested a total of 608 million yuan in grid transformation, which has significantly improved the local distributed renewable energy acceptance capacity.

(2) Current status of research on peak load regulation strategies for renewable energy access to the power grid

Wind and solar power generation is constrained by environmental factors and natural conditions, and its output power is random and intermittent. When it is connected to the grid in large capacity, the peak-shaving pressure and standby demand of the system will increase significantly, which will reduce the economic efficiency of the system to a certain extent and threaten the stable operation of the system. Due to the anti-peaking characteristics shown by the difference between wind power and the system load change law, the voltage and frequency inside the system will change significantly when the wind speed is greatly disturbed. At this time, the system will abandon wind to maintain the safety and stable operation of the grid. Therefore, it is very necessary to evaluate the wind power absorption capacity from the perspective of the system peak-shaving capacity.

At present, the mainstream peak-shaving mode at home and abroad is still concentrated on the power supply side of the power system, using the peak-shaving resources on the power supply side to meet the needs of peak loads and valley loads. The peak-shaving technologies used are mainly thermal power peak-shaving and hydropower peak-shaving. In addition, gas turbine peak-shaving occupies a certain position. With the access of various new energy sources to the power grid, new energy joint peak-shaving is also developing rapidly.

Pumped storage has been rapidly developed as a way of peak load regulation of new energy. Pumped storage is to pump water to the upper reservoir during low electricity consumption, convert the surplus electricity into potential energy, and release water to the lower reservoir during peak electricity consumption, converting the stored potential energy back into electricity, thus playing the role of peak load reduction and valley load filling. Its main features are large energy storage capacity (generally 100-2000MW), long continuous response time (up to 4-10 hours), and extremely low cost per kilowatt-hour, but it has high requirements for geographical location. Pumped storage is currently the most widely used energy storage mode and occupies a dominant position in energy storage projects. As of 2018, the world's cumulative installed capacity of pumped storage is about 184.20GW, accounting for 94% of the total installed capacity of global energy storage projects. China's installed capacity of pumped storage power stations in operation is about 26.69GW, ranking first in the world in terms of installed capacity, but in terms of installed capacity ratio, China (about 1.6%) is still far behind developed countries such as Britain and France (more than 4%) and Japan (more than 10%). The future development trend of pumped storage is to increase installed capacity and increase environmental adaptability. The Basconti Pumped Storage Power Station built by the United States is the largest pumped storage power station in the world, with an installed capacity of up to 3 million kW, while the Hebei Fengning Pumped Storage Power Station under construction in China has reached 3.6 million kW. In addition, the United States, Germany, Japan and other countries are also exploring how to transform abandoned mines and oceans into pumped storage reservoirs.

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