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Analysis of the Impact of Distributed PV Integration on the Power Grid Promoted throughout the County

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Abstract. China's power system has always regarded promoting rural revitalization, developing clean energy and building a new power system as an important political, economic and social responsibility. Based on the responsibilities of the power grid, formulate and implement measures to promote renewable energy consumption in the aspects of power grid development environment, power market reform, digital technology application, smart city and Rural Revitalization and development, so as to lay a foundation for promoting the development of renewable energy consumption. Promote the pilot work of distributed photovoltaic development in the county. Promote the construction of roof photovoltaic in the county to realize peak load reduction and valley filling of power grid. Realize the dynamic balance of source load power, reduce the impact of large-scale photovoltaic access on the power grid, and improve the utilization efficiency of distributed photovoltaic. By taking into account the coordination, optimization and matching of distributed photovoltaic and power supply system on different temporal and spatial scales, we can further promote the high proportion of roof photovoltaic consumption and solve the problem of peak shaving and valley filling of power grid. Improve the efficiency of power resource allocation and realize the fine adjustment and compensation of nearby reactive power and power grid output. Improving the quality of line power supply and the flexibility of power grid advantage regulation play an important supporting role in realizing the goal of clean, low-carbon, safe and efficient energy development. We will promote the construction of a new power system with renewable energy as the main body, and implement the national strategy for low-carbon development and Rural Revitalization. Study and analyze the interest needs of multiple subjects such as user side, power grid side, renewable energy supply side and policy supervision side under multiple objectives, maximize the comprehensive interests of multiple parties in the way of coordinated control, form a multi-party joint effort to promote the power system with the construction of new renewable energy as the main body, and implement the important national instructions on the transformation and upgrading of energy industry, take a green and low-carbon path and support the implementation of the national low-carbon development and Rural Revitalization Plan.

Keywords: distributed PV, power grid, evaluate, promoted throughout the county.

1. Introduction

In the context of implementing the "14th Five-Year Plan", implementing the "dual-carbon" strategy, and promoting the transformation of new power systems, in June 2021, the National Energy Administration officially issued the District) “Notice on the Start of Pilot Program for Distributed Rooftop Photovoltaics”. In the notice, it is clear that the roof resources of buildings in China are abundant and widely distributed, and the potential for the development and construction of rooftop distributed PV is huge, and it is proposed to organize and carry out the whole county (city, district) to promote the pilot work of rooftop distributed photovoltaic development throughout the country.

Since 2014, the development of distributed PV has been an important measure to support the path of "rural poverty alleviation to rural revitalization" and has been strongly supported by national policies. Six photovoltaic poverty alleviation policies have been introduced successively: "About the Implementation of the Photovoltaic Poverty Alleviation Project Plan", "The Outline of the Implementation Plan for Photovoltaic Poverty Alleviation (Trial)", "The 13th Five-Year Development Plan for Solar Energy Utilization", "About Printing and Distributing 2016 You Na designated Poverty Alleviation" "Notice on Main Points of Volunteer Work with Counterpart", "Opinions on Implementation of Poverty Alleviation Work by Photovoltaic Power Generation", "Administrative Measures for Photovoltaic Poverty Alleviation Loans of the Agricultural Development Bank of China (Trial)". Following the national photovoltaic poverty alleviation policy, various provinces, cities, and counties have successively introduced relevant preferential policies for photovoltaic

grid-connected in accordance with the special circumstances of the province, city, and county. Through the results of the early distributed photovoltaic poverty alleviation work, we have accumulated rich experience in realizing rural revitalization, promoting the development of the photovoltaic industry, and advancing the county-wide distributed photovoltaic development pilot work.

China's power grid companies earnestly implement the decisions and deployments of the government, and always regard the promotion of rural revitalization, the development of clean energy, and the construction of a new power system as important political, economic, and social responsibilities. Based on the power grid's own duties, formulate and implement measures to promote the consumption of renewable energy in the development environment of the power grid, power market reform, digital technology application, smart city and rural revitalization and development, and lay a development foundation for the promotion of the county's distributed photovoltaic development pilot projects. Promote the construction of rooftop photovoltaics throughout the county to achieve peak reduction and valley filling of the power grid. Realize the dynamic balance of source and load power, reduce the impact of large-scale photovoltaic access on the grid, and improve the utilization efficiency of distributed PV. By taking into account the coordinated optimization and matching of distributed photovoltaic and power supply systems at different time and space scales, it further promotes the high proportion of rooftop photovoltaic consumption and solves the problems of grid peak shaving and valley filling. Improve the efficiency of power resource allocation, and realize the fine-tuning and compensation of nearby reactive power and output on the grid. Improving the power supply quality of the line and improving the flexibility of superior power grid regulation play an important supporting role in achieving clean, low-carbon, safe, and high-efficiency energy development goals. Facilitate the construction of a new power system with renewable energy as the mainstay, and implement the national low-carbon development and rural revitalization strategy. It is very essential to research and analyze the interest needs of multiple entities on the user side, grid side, renewable energy supply side, and policy supervision side under multiple goals, and maximize the comprehensive benefits of multiple parties in a coordinated control manner, forming a multi-party joint effort to promote the construction of a new type of renewable energy as the mainstay. The power system implements the important instructions of the country on the transformation and upgrading of the energy industry and takes a green and low-carbon mode, and supports the implementation of the national low-carbon development and rural revitalization strategy.

2. Research status and progress

2.1. The impact of connection to the grid and its control

Distributed photovoltaic (PV) power supply is affected by solar irradiance and temperature, and its output power has a certain degree of discontinuity and uncertainty. In addition, the system output power of photovoltaic power generation also has a strong cyclicity. With the large-scale connection of photovoltaic power in the entire county, it will have a relatively severe periodic impact on the grid. Regarding the impact of photovoltaics on the power grid, some cases have been analyzed. For example, the distributed photovoltaic power supply in the Ufes campus network and the distributed photovoltaic power supply in rural Indonesia, etc., the analysis of the impact of large-scale access of distributed photovoltaic power on the system variables of the grid have been done(such as voltage distribution, power flow, line loss and power factor). Some researchers proposed installing voltage regulators, adding energy storage equipment, and reducing the impact of photovoltaics on the power grid. Tonkoski R et al. coordinate the reduction of the photovoltaic active power output of each user by pre-setting the droop coefficient, and finally achieve equal cut-off between users and eliminate the risk of voltage exceeding the upper limit. In addition, countries such as Germany, the United States, and Japan, in order to achieve the full consumption of high-penetration renewable energy power, continue to adapt the renewable energy power market sales mechanism, increase policy subsidies to stimulate the energy market, and adopt market-based incentive trading models.

Regarding the impact of photovoltaics on the power grid, some researchers have carried out relevant researches on power angle stability, short-circuit current, voltage fluctuations and harmonic disturbances. Literature [1-2] studies the impact of photovoltaics on the voltage stability of distribution networks and microgrids; literature [3] proposes to use photovoltaic power generation systems to improve power oscillation damping characteristics. In order to improve the ability of the distribution network to absorb high-

permeability distributed photovoltaics, domestic scholars have proposed some control strategies to reduce the impact of photovoltaics on the grid, which mainly include two types of methods. The first category is from the perspective of power distribution companies, through grid transformation, increase of conductor cross-section, adjustment of transformer ratio, use of energy storage equipment, introduction of demand-side management and other measures. On the other hand, it can be adjusted by adjusting the tap of the on-load voltage regulator, perform voltage control. However, as the penetration rate of photovoltaics continues to increase, the economic costs brought by it have increased substantially. The second category of measures is to maximize the use of photovoltaic inverter control capabilities from the perspective of users to reduce the impact of photovoltaic grid-connected on the distribution network and improve photovoltaic consumption. Active power control adjusts the network voltage level at the cost of sacrificing the economics of photovoltaic power generation, which cannot satisfy the maximum benefit of users. Some researchers use the reactive power capacity of photovoltaics to reduce the impact on the power grid and improve the capacity of photovoltaics.

To sum up, the current domestic and foreign studies on the impact and control of high-permeability photovoltaic power generation on grid access have been considered from different perspectives and the impact on the grid has been analyzed. Some scholars have also conducted in-depth research and proposed corresponding control measures such as the use of reactive power compensation devices, the use of on-load tapping transformers, the addition of energy storage facilities, photovoltaic active power control, and demand side management.

2.2. Grid-connected program and capability evaluation

With the depletion of non-renewable energy, the development of renewable energy has attracted worldwide attention. After many years of research, many researchers have produced lots of achievements in the field of photovoltaic power generation, including the investment evaluation system of distributed photovoltaic access, the capacity evaluation of distributed photovoltaic access to the distribution network, and the analysis of the impact on the power quality of the distribution network.

Literature [4] established a more systematic and comprehensive investment evaluation system, formulated investment evaluation standards for various factors affecting such projects, and established an investment evaluation model based on entropy weight method, TOPSIS method and grey relational analysis method. In order to improve the effectiveness of optimized planning, a variety of related factors should be considered comprehensively in DG planning. Literature [5] proposed and studied a DG planning model with voltage deviation, voltage fluctuation and short-circuit capacity constraints. Literature [6] discusses DG optimization planning with voltage deviation, harmonics, and three-phase unbalance as constraints. This type of research obtains optimization conclusions from the perspective of safe operation and comprehensive multi-factor constraints. Literature [7] studies the impact of current harmonics generated by photovoltaic power generation systems on low-voltage distribution grids, as well as the interaction between other nonlinear loads and grid voltage, and analyzes a case study based on the actual grid. Literature [8] proposed methods to suppress harmonics in two aspects: the internal circuit of the photovoltaic grid-connected system and the grid-connected control strategy.

At present, there are many researches on the influence of different access locations and installed capacity of distributed photovoltaics on the distribution of power flow, and there are few researches on the dynamic influence of photovoltaic output fluctuations on the distribution of power flow. After the green development to meet the climate change and enviromental protectiont is proposed, renewable energy power generation has become a research hot point worldwide, among which distributed photovoltaic power generation is particularly prominent. Distributed photovoltaic power generation is connected to a large number of power distribution networks, effectively reducing carbon and polluting gas emissions, and enhancing the environmental friendliness of the power grid. However, the uncertainty of distributed photovoltaic power generation also poses a huge challenge to the operation of the grid. The existing literatures do much study about the influence of distributed photovoltaic grid connection on the distribution network and so on. The research on the coordinated control of distributed photovoltaic and distribution network still needs to be further carried out. Due to the fact that low-voltage power distribution network on-load voltage regulation

equipment and intelligent reactive power compensation equipment are not popularized, energy storage technology is immature, and equipments are expensive and short-lived, many control methods cannot be widely used.

On the whole, there are still many problems in the current research on the evaluation and connection of high-penetration distributed photovoltaic connect capabilities. Research on the participation of distributed photovoltaics in the regulation of distribution network voltage still has problems such as reduced equipment utilization, grid power generation revenue and economic benefits, power factor degradation of the distribution system, and increase in network loss. Therefore, further research is needed on how distributed photovoltaics can better participate in the voltage control of the distribution network. For the distribution network with a high proportion of distributed photovoltaics, the traditional single-ended protection cannot meet the operational requirements. Research on new protection strategies for the distribution network (such as adaptive relay protection, fast protection represented by optical fiber differential) is still need to continue to explore. In the evaluation of photovoltaic power supply systems, researchers and experts have proposed evaluation indicators and evaluation methods through the establishment of various models and various simulation analyses.

3. Technical requirement analysis

3.1. Dynamic model of rooftop photovoltaic array and grid-connected system

In the dynamic model construction of rooftop photovoltaic arrays and grid-connected systems, various factors are comprehensively considered including different seasons, different moments, and different weather conditions, analyzed the changes in the power generation output of the rooftop photovoltaic array, and established an accurate and appropriate mathematical model that simulates the dynamic changes of the photovoltaic output. Based on the technical requirements of distributed power access to the power system, the fault response and dynamic characteristics of distributed photovoltaics under different disturbances are studied. The coupling effect of distributed photovoltaic connection and the transient characteristics of the distribution network. Research on the influence of the grid voltage and frequency changes on the photovoltaic array under the conditions of different rooftop photovoltaic power generation output, connection locations, line parameters and load levels. Study the impact of different fault types of photovoltaic arrays on the transient characteristics of county-level power grids.

3.2. B.Impact of large-scale rooftop distributed photovoltaic access on the safety

Research on the impact of large-scale rooftop distributed photovoltaic access on the security of county-level power grids. Based on the relevant technical requirements of the Power System Stability Guidelines, the leading factors affecting the security of county-level power grids are studied, and the impact of large-scale rooftop photovoltaic access on related leading factors is analyzed. Research on active grid control technology after large-scale rooftop photovoltaic grid connection, and propose measures to improve the security of county-level grids. Research on the impact of large-scale rooftop distributed photovoltaic access on the reliability of county-level power grids. Based on the actual output characteristics of distributed renewable energy with high penetration rate connected to the county-level grid, the impact of distributed photovoltaic multi-mode access on the county-level grid voltage and power flow is analyzed. Based on the technical requirements of the power supply reliability of the county-level power grid, measures to improve the reliability of the county-level power grid are proposed. Research on the impact of large-scale rooftop distributed photovoltaic access on the energy efficiency of county-level power grids. Study the regulation response characteristics of multi-distributed photovoltaics at different time scales, and analyze the impact of large-scale rooftop photovoltaic access on the energy efficiency of county-level grids. Research on the optimal control strategy of power fluctuations with the goal of improving the power quality of the power grid and high-efficiency and reliable power supply.

3.3. C.Evaluation of the ability of large-scale distributed photovoltaic access to the distribution network

It includes the following work to study the impact of large-scale distributed photovoltaic grid connection on the distribution network. The first is to sort out the relevant standards for photovoltaic power stations to

connect to the distribution network. Based on this, the next is considering the intermittency and uncertainty of distributed photovoltaic power generation. The next is to carry out research on the impact of large-scale distributed photovoltaic grid connection on the power quality and three-phase imbalance of the distribution network. Considering the uncertainty of power flow caused by distributed photovoltaics connected to the distribution network, it is to carry out research on the impact of large-scale distributed photovoltaic grid connection on the distribution network's relay protection, network loss, line load, etc. Then it is to study the ability evaluation technology of large-scale distributed photovoltaic access to the distribution network and research the comprehensive evaluation index system suitable for large-scale distributed photovoltaic access to the distribution network. Comprehensively considering the constraint conditions such as voltage limit violation, power supply capacity, line current carrying capacity, etc., it is to establish an evaluation model of the carrying capacity of the distribution network system for large-scale distributed photovoltaic access. The last is to research the quantitative evaluation method applicable to the carrying capacity of large-scale distributed photovoltaic access to the distribution network. Based on typical application scenarios, verify and evaluate distribution network access capabilities.

Technical requirement analysis is shown in Figure 1.

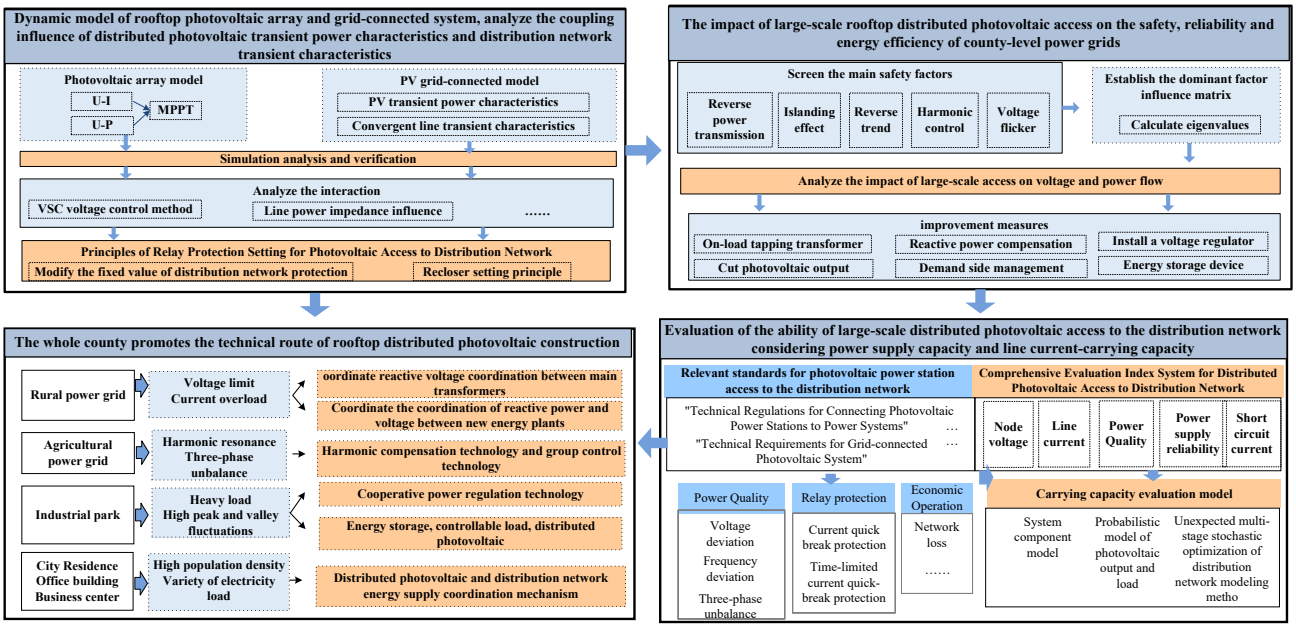

Fig. 1: Technical requirement analysis

4. Conclusion

After the promotion of rooftop photovoltaics, there will be many operation and maintenance management entities, uneven management quality and unmanned management problems, which will threaten the safety of power generation equipment and the safety of power grids. How to innovate the business model, in the initial investment and planning stage of the county's rooftop photovoltaic project construction, comprehensively sort out the rights, interests, and risk relationships of stakeholders, and clarify that all parties are responsible for energy storage and grid power quality governance. And to reasonably allocate costs and benefits, relevant research needs to be carried out. In turn, it reduces the impact of large-scale photovoltaic integration on the grid from the technical and management levels, and provides support for later photovoltaic operation and maintenance and grid security.

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