The Research on Key Technologies of Power Quality Comprehensive Control in Complex Distribution Network

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Abstract. As new types of power sources and loads such as distributed photovoltaic and electric vehicle charging facilities are connected to the distribution network, the distribution network has become more variable and complex, and the simple distribution network has evolved into a complex distribution network. The access of new elements, especially the application of power electronic devices, has a great impact on the power quality of the distribution network. The technical framework of power quality comprehensive management of complex distribution network is proposed, and the corresponding technical route is put forward from three aspects: the influence of power electronic equipment application on power quality of distribution network, power electronic equipment modeling of distribution network, flexible monitoring of power quality and rapid control.

Keywords: complex distribution network; comprehensive control; power quality; power electronic equipment.

1. Introduction

With the rapid development of renewable energy technologies and power electronics technologies, new types of power sources and loads such as distributed photovoltaics and electric vehicle charging piles have been connected to the distribution network. The distribution system has changed from a single power supply radial network to a power supply and load. The multi-power network not only changes the traditional network structure of the distribution network, but also increases the uncertainty of the power flow due to the randomness and intermittence of the output of the distributed power supply, and the distribution network becomes more varied and complex. Simple distribution network has evolved into a complex distribution network.

The access of distributed power supplies, electric vehicle charging facilities, flexible DC equipment and other equipment is inseparable from the application of power electronic equipment. The existence of a large number of power electronic devices brings harmonic interference and imbalance of phase load to the distribution network. Power quality problems such as voltage amplitude fluctuations. Based on the research on the characteristics of power quality of complex distribution network, this paper grasps the influence mechanism and comprehensive treatment technology of a large number of applications of power electronic equipment on the power quality of distribution network, and guarantees the distribution network to provide users with safe, reliable and high-quality electric energy.
2. Summary of Research Status at Home and Abroad

2.1. The Research on Power Quality Characteristics of Complex Distribution Network

D. Perera et al. of the University of Wollongong in Australia proposed a voltage flicker analysis method for a doubly-fed wind turbine to study the attenuation characteristics of various load types of the distribution network. The effect of the fluctuations, the simulation results show that the constant power load and constant current load will increase the voltage flicker of the load node. The Power Electronics Application Center of the Knoxville Electric Power Research Institute studied the effects of single-phase nonlinear loads on power quality and considered the effects of the North American and European low-voltage power system network topologies on harmonic currents. Muhyaddin JHRawa and David WPTThomas of the Department of Electrical Systems and Optics, University of Nottingham, UK, studied the effects of personal computers on power quality by studying the background voltage distortion and the percentage of non-linear load to the total load. Accurately quantify the impact of PC clusters on grid computer quality by the influence of harmonic content in distribution network.

Liu Shuming and Li Qionglin from Henan Electric Power Research Institute conducted detailed analysis, summarization and summary of more than ten typical power quality interference sources such as traction load, electric arc furnace load, intermediate frequency furnace load and electrolytic load in medium and high voltage distribution networks. The power quality data of various nonlinear users is obtained. Pan Shu of Chongqing University studied the influence of distributed power supply access on voltage fluctuation and flicker of distribution network. The paper points out the causes of voltage fluctuation and flicker caused by distributed power supply. The volatility of distributed energy output and distributed power supply. There are two voltage-current harmonics caused by medium power electronic equipment, and the calculation method of voltage flicker attenuation and transmission in distribution network is given. The Electric Power Research Institute of Yunnan Electric Power Research Institute (Group) Co., Ltd. conducted a comprehensive evaluation of the impact of distributed power grid connection, and carefully analyzed the characteristics of power quality of distribution network after distributed energy access. Liu Qing of Guangdong Power Grid Corporation studied the charging mode and the power quality characteristics of the charging station. By measuring the power quality data of a single charging pile, the power quality characteristics of the charging pile were analyzed. Research at home and abroad focuses on the influence of access on the power quality of the distribution network in terms of distributed power supply or load single dimension, and thus derives the power quality characteristics of the distribution network. The research on the characteristics of power quality under the trend of power supply-grid-load three-dimensional analysis, such as nonlinearization of distribution network, frequent network reconstruction, and capacitive system power supply, is still in its infancy.

2.2. Research on Modeling Technology of New Power Electronic Equipment in Distribution Network

Foroozan Ghassemi and others of the British National Transmission Company proposed a simplified method for harmonic analysis model to simplify the calculation of harmonic analysis. The model of the low-voltage wind farm is simplified according to the two-port network theory. The accuracy of the wave analysis. Danish East Energy has designed a harmonic analysis model for offshore wind farms that considers the effects of high-voltage submarine cables used to connect the coast on harmonic propagation. Walker Geoff of Queensland University of Technology in Australia takes the inverter of photovoltaic power plant as the core, and simplifies the components such as photovoltaic modules, filters and step-up transformers according to the requirements of the inverter topology, and obtains a simplified model of the photovoltaic power plant. For simple harmonic analysis, but does not reflect dynamic harmonic variation processes.

Mi Fuli of Harbin Institute of Technology conducted an in-depth analysis of the harmonic problems of direct-drive wind farms. The components of the wind farm were mainly modeled and analyzed by grid-connected converters. From the working principle of the converters, different frequencies were used. The harmonic characteristics of the downconverter are established, and the high frequency harmonic model and the low frequency harmonic model are respectively established. Zhu Yongqiang.
of the State Key Laboratory of New Energy Power System and others considered the impact of multiple PV inverters on power quality after parallel connection, and further considered the influence of collectors, filters and other collector systems on the harmonic transmission of the power grid, and established a large-scale photovoltaic power station. Harmonic transfer network model. Zhao Wei and others of Guangdong Electric Power Company Electric Power Research Institute established a single three-phase uncontrollable rectification charger model. Furthermore, the harmonic characteristics of multiple charging piles are further analyzed, and the harmonic propagation in the distribution network is analyzed by establishing the harmonic current model of the distribution network and the harmonic impedance accurate model of the transmission line. The State Key Laboratory of Power Transmission Equipment and System Security and New Technology of Chongqing University uses the established single charger and charging station simulation models to analyze their impact on power quality, focusing on current harmonic content and current total harmonics. The distortion rate varies with the charging power of electric vehicles and the variation law with the number of charging machines. The research of domestic and foreign scientific research institutions focuses on the establishment of distributed energy-related power electronic equipment models, and the research methods of new power electronic equipments for complex distribution networks such as electric vehicle charging equipment, charging facilities, and multi-port flexible equipment are at The starting stage.

2.3. Research on Flexible Monitoring and Rapid Control Technology of Power Quality in Complex Distribution Network

Kansas State University uses DSP chips for power system power quality monitoring, highlights the unique features of DSP chips, discusses the issues involved in adopting system architecture, selecting DSPs, and developing application software, making it ideal for real-time applications. RPK Lee of the City University of London in the United Kingdom used the power quality database provided by the American Academy of Electric Power as a benchmark to improve the designed power quality detection system. Finally, the Web-based large-grid multi-channel power quality monitoring system was designed to be available to users in the power grid. Together with the grid company to obtain monitored data to jointly address power quality issues. L.Xu et al. of the University of Glasgow in the UK designed a quality management system that focuses on two- and multi-stage pulse width modulation (PWM) controlled voltage source inverters (VSIs) with embedded control software. On the DSP board, flexibility and reliability are improved, and experimental results verify the effectiveness of the system.

Sun Yi, Tang Liangrui and Gong Gangjun of North China Electric Power University followed the trend of network monitoring of power monitoring, and proposed a design scheme of online monitoring system for power quality. The system monitors each monitoring point online through the virtual instrument-based power meter and passes the data. Real-time display, local display and web display give the power department access to real-time detailed data. A number of units such as State Grid Electric Power Research Institute and Naval Engineering University have jointly developed a power quality monitoring system based on ARM+DSP dual system and software based on multi-agent technology. The model of this system is well adapted to the distribution of power system. The development trend of the structure and power market, and can meet the current power grid quality monitoring needs, has a preliminary application in Zhejiang and Hubei power grids. In terms of comprehensive management of power quality, Hunan University, Wei Wei, Tu Chunming, and Cheng Ying proposed a comprehensive power quality control system for harmonics and reactive power in high-voltage distribution networks. The system consists of injection hybrid active power filtering. The device (IHAPF) and the thyristor control reactor (TCR) are composed, and a control method based on the system for comprehensive dynamic control of harmonics and reactive power is proposed. Researches at home and abroad have focused on the development of power quality parameters. However, there are few studies on the coordinated control methods for multi-power quality control devices in complex distribution networks.
3. Research on Comprehensive Quality Control Technology of Complex Distribution Network Power Quality

3.1. The Overall Framework of Research on Comprehensive Control of Power Quality
The overall framework of the comprehensive control of power quality in complex distribution networks is shown in Figure 1.

![Figure 1. The overall Research framework.](image)

There are three key technologies involved: 1) studying the power quality characteristics of complex distribution networks; 2) studying the modeling techniques of distributed power grid-connected equipment, multi-port flexible lines and other new power electronic equipments in distribution networks; 3) research complex Flexible monitoring and rapid management of power quality in distribution networks. It is the basis of mastering the influence mechanism of distributed energy and diversity load on the power quality of distribution network. It is the key to accurately model new power electronic equipment such as multi-port soft and straight, and master the power quality parameters of complex distribution network. Based on the rapid detection method, a power quality coordinated control technology and a comprehensive management method based on the operational data of the power system are proposed.

3.2. Technical Route for Comprehensive Research on Power Quality

3.2.1. Technical Research Route on Power Quality Characteristics of Complex Distribution Networks.
Firstly, combined with the development characteristics of nonlinear distribution of complex distribution network, the power quality characteristics of nonlinear distribution network are analyzed from the three dimensions of power supply-grid-load. Among them, non-linear power supply such as photovoltaic power generation and gas turbine power generation is analyzed from the power supply angle. From the perspective of power grid, the characteristics of power quality of AC/DC hybrid distribution network, especially DC distribution network, are analyzed. From the perspective of load, the access of equipment such as subway and electric vehicle charging load is analyzed. The power quality characteristics of the distribution network; secondly, analyze the power quality characteristics of the distribution network when the distribution network topology changes frequently in the scenarios of distribution network load transfer, transformer economic operation, distribution automation fault handling, etc.; again, from the urban power grid Power supply cable, DC side capacitor, AC side filter capacitor, etc. make the distribution network parameters capacitive analysis of the power quality characteristics of the distribution network; Finally, summarize the power quality characteristics of the complex distribution network.

3.2.2. Technology Route for Modeling New power Electronic Equipment in Distribution Network.
The research technology of modeling technology for new power electronic equipment in distribution network is shown in Figure 3. Firstly, combing the working characteristics of representative power electronic equipment in complex distribution networks, such as distributed photovoltaic on the power supply side, multi-port soft on the grid side, and electric vehicle charging facilities on the load side; secondly, from the power electronic
equipment pair Research on the influence mechanism of voltage quality of distribution network, the influence of access location on voltage, and the influence of working mode on voltage quality of distribution network. The impact of power electronic equipment on voltage quality of complex distribution network is studied. The influence of position on the current quality of distribution network, the influence of working mode change on current quality and the influence of power electronic equipment interaction on current quality. Three dimensions analyze the influence of power electronic equipment on the current quality of complex distribution network; The research and analysis of power grid electronic equipment modeling technology, the modeling method of electric power vehicle charging facilities, multi-port flexible equipment and other complex power grid new power electronic equipment is proposed, and the rationality of the model is guaranteed by simulation.

**Figure 2.** Technical route on power quality characteristics of complex distribution network.

**Figure 3.** Technical route of modeling technology for new power electronic equipment.

3.2.3. *Research Route for Flexible Monitoring and Rapid Control Technology of Power Quality in Complex Distribution Network*. The research route of flexible monitoring and rapid management of power quality in complex distribution network is shown in Figure 4.

Firstly, based on the theory of instantaneous harmonic detection and instantaneous reactive power detection, a fast detection method for power quality parameters of complex distribution network is proposed, and the harmonic components of the power grid and the reactive current of three-phase fundamental are analyzed. Then, the power quality is obtained. The optimal configuration method of power quality equipment for regional distribution network is proposed in terms of configuration principle, type, number of devices and location of device access. Thirdly, considering the actual situation of power grid and the equipment configuration of power quality equipment, multi-electric
energy of complex distribution network is proposed. The coordinated control method of the quality device; Finally, from the aspects of data acquisition module design, communication module design, decision analysis module design, etc., the intelligent coordination control device based on the regional power distribution network power quality management device is developed.

![Diagram](image)

**Figure 4.** Technical route for flexible monitoring and rapid management of power quality in distribution network.

### 4. Conclusion

This paper analyzes the solutions proposed by domestic and foreign experts and scholars in the face of the impact of large-scale access of power electronic devices on power quality of distribution network, and proposes a research framework and detailed technical route for comprehensive management of power quality in complex distribution networks. The feasibility, relevant research ideas and technical methods can effectively guide scientific research institutions and colleges and universities to carry out research work on power quality comprehensive management technology of modern distribution network.

### Acknowledgments

This work was financially supported by “National Key Research and Development Program of China” (2018YFB0905000).

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