Research on the Structure of Distribution Network Voltage Smart Grid Information System Based On Flexible DC

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Abstract. Since the concept of smart grid was defined, it has aroused the interest of many researchers, and many countries have also regarded smart grid as a key research project. Because it is the field of power grid research in the future, the structure of the smart grid becomes more complex with the deepening of research, the scale becomes larger, and the data contained in the system is bound to increase rapidly. Flexible DC grid technology has the characteristics of high reliability, good fault tolerance and good scalability, and can be used to solve some problems encountered in the application of smart grids. Based on the structure of the smart grid information system, this paper studies the characteristics of the smart grid data, as well as some safety issues encountered in the data, applies flexible DC power distribution technology, designs a new smart grid equipment management architecture, and System implementation was carried out. Through experimental verification, the new architecture proposed in this paper has high feasibility and safety. Finally, the realization of the management system function based on the new equipment management architecture and the analysis of the system function effect are given.

Keywords: Flexible DC Technology, Smart Grid, Data Security, Management System

1. Introduction

Both domestic and foreign countries have maintained close attention to flexible DC grid technology. The voltage converter is the key core of the flexible DC grid. The transmission method of electric energy is in the form of DC transmission, and the lines can be connected to each other at will in the DC field [1]. Compared with the AC power system, the flexible DC grid has the advantages of low line loss and low power supply, and can well concentrate the introduction of huge new energy power generation. Compared with the grid commutated converter type grid system, in terms of power quality, the performance of the flexible DC grid is better. Not only does it have no failures that cannot be commutated, but it can also be controlled independently [2]. Therefore, with the rapid development of electronic technology, flexible DC grid technology will occupy a very important position in the field of grid systems in the future. As a new grid system technology, the development of flexible DC grid will also encounter many problems [3].

Chinese scholar Liu Guowei believes that with the development of flexible DC transmission and
modern power distribution systems, the application demand for flexible DC power distribution is increasing [4]. Wu Xueguang and others believe that flexible DC transmission technology based on modular multilevel converters has shown broad application prospects, and accurate and efficient modular multilevel converter simulation technology is the basis for research [5]. Liu Jiachao believes that UHV DC is widely used for long-distance, large-capacity transmission, and more and more DC drop points are concentrated in the load center of our country, which brings excessive short-circuit current to system operation, mutual influence between multiple DCs and large-scale blackout issues such as increased risk. Adjusting the operation mode of the system can relieve the pressure caused by the short-circuit current exceeding the standard to a certain extent, but to fully and effectively solve the problems currently faced by my country's load centers, it is necessary to optimize the grid structure [6].

Smart grid is the inevitable result of today's scientific and technological and economic and social development. The research on smart grid technology is still at a preliminary level. Since this technology was proposed, scientists have not been able to define this technology consistently. Due to the different economic levels and needs of various countries, their views on smart grids are different. The form of research is not very uniform [7]. Simply put, a smart grid is the intelligentization of the grid. By combining the new power grid technology with the traditional power grid technology, it has the characteristics of safety, stability and fast operation, which can improve the resource utilization rate and reduce the damage to the environment.

2. Flexible DC Technology and Distribution Network Voltage Smart Grid System

2.1. Development Status of Flexible DC Distribution Network
With the development of renewable energy and the increasing number of DC loads, the research and engineering applications of DC power distribution have developed accordingly. At present, many scholars at home and abroad have invested in the research of improving power quality, and have achieved certain research results. European and American countries have carried out research and application of DC power distribution earlier, each proposed the concept and technology of DC power distribution, and carried out related engineering practices. Compared with foreign countries, the research in the field of flexible DC power grids has been carried out relatively late in China, but the development speed of this field is still very rapid [8]. There are many important research results in the field of flexible DC grids in China. For example, as early as 2011, China’s first flexible DC grid system was put into use in Shanghai; in 2013, the world’s first multi-terminal flexible DC transmission project was launched in Guangdong, my country, applied the research results of scientific researchers in the field of wind power in the flexible DC grid. In 2015, the real bipolar flexible DC transmission demonstration project with the highest voltage level and the largest transmission capacity in the world was put into operation in Xiamen in 2015, indicating that my country has advanced scientific research results in the field of flexible DC grid [9]. With the introduction of a variety of classic power quality analysis methods and the development and application of compensation devices, the power quality of our country's power system has been improved to a certain extent. Especially in recent years, the rapid development of information technology and digital technology has made various harmonic analysis methods widely used in the field of electric power research, which has greatly promoted the development of power quality analysis and compensation technology.

2.2. Analysis of the Status Quo of Smart Grid
The smart grid is the product of the integration of the power grid and the information network. The information network provides a means for each component in the power network to communicate and dispatch each other, so that the operation of the power network becomes intelligent. Due to the continuous development of the research process in communication and sensing technology, the automation, informatization, and interaction of the smart grid have also been enhanced, and the management of the distribution network is closely integrated with the communication network. The
traditional power grid adds a layer of communication network to form a smart grid. The communication network coordinates the operation of various power departments by collecting status information and measurement information of the power grid, and optimizes the efficiency of grid operation and energy utilization. In the concept of the Internet of Energy, the smart grid is endowed with requirements such as greater connectivity, more interactive user experience, and more secure information architecture. The smart grid is the first step towards the future energy Internet, and it is the key to the rational deployment of power generation, distribution and user power. Smart grid is of great significance for improving energy efficiency, connecting distributed energy to the grid, dynamically adjusting grid load, and enhancing user interaction. It is a key part of the development of the next generation of energy Internet [10].

2.3. Flexible DC Distribution Network Structure and Control Strategy
The technology used in this paper in the flexible DC distribution network is mainly VCS. One phase of the two-level VCS is connected to two bridge arms, which are formed by IGBTs and diodes in parallel. In order to increase the voltage of the converter, multiple IGBTs and diodes can be connected in series in parallel. The rated voltage of the inverter, the rated current and voltage of the IGBT and diode determine the number of series connected. The two-level VSC has a simple structure and rich operation control experience. Because IGBTs and diodes have limited current tolerance, the increase in the number of series will cause dynamic voltage equalization problems, and the harmonic content of the two-level VSC larger. The output voltage of the three-level VSC is twice that of the two-level VSC, and the rated voltage rises significantly. Because the series connection of switching elements is still used to improve the withstand voltage, the problem of capacitive dynamic and static voltage equalization and harmonics of the output voltage still cannot be solved. NLM uses a discrete step wave to simulate a continuous sine wave. When the number of levels is large enough, the two will be very similar, reducing the waveform distortion of the output voltage, and reducing the switching frequency and loss. Assuming that the DC voltage is stable, the modulating wave is the converter output AC voltage calculated based on the reference value, and each bridge arm has N sub-modules, and then N sub-modules are input to each phase at each moment.

3. The Structure of Distribution Network Voltage Smart Grid Information System Based on Flexible DC Technology

3.1. Significance of Research
Due to the continuous development of power grid technology, more and more smart grid systems will be applied to smart devices in the future. The network equipment that needs to be managed in the smart grid has increased dramatically, which puts an urgent demand for large-scale network equipment management and data collection on the traditional smart grid management system. At present, when the flexible DC grid is used in combination with converters and circuit breakers, there are still many technical problems, which need to be solved by scientific researchers. Especially in the field of flexible DC power grids, how to improve the survivability of the system when encountering DC faults is something that researchers need to focus on. The main research content of this paper is the flexible DC grid and fault isolation. When the flexible DC grid encounters a DC fault, the status analysis is carried out. Based on the analysis of the functional requirements of the networked smart grid equipment management system, the development and testing of the system are realized.

3.2. Multi-terminal Coordinated Control
The DC distribution network can be connected to multiple ports, and coordinated control between multiple ports is required to realize the coordinated and stable operation of the DC distribution network. Drawing lessons from the current multi-terminal coordinated control methods of flexible DC transmission systems, the multi-terminal control methods of flexible DC grids include master-slave control, DC voltage margin control, and droop control. Choose one port with strong regulation ability
in the DC distribution network as the master converter, and the other ports as the slave converters. Through the high-speed and reliable communication system, the operation status of each terminal is monitored, and the operation curve of the port converter is updated in time to maintain. The DC voltage is stable. The main converter dynamically changes the active power output, the DC system power balance and the DC voltage is stable, and the main converter failure and exit from operation may cause the system's DC voltage to collapse. If the master-slave control is adopted, the communication system will send the exit information of the master converter to the slave converter, and the switching mode of the slave converter will be quickly switched to constant DC voltage control, which will replace the original master converter to restore the DC voltage to maintain. The DC system runs stably and the other converter control modes remain unchanged.

3.3. Data Processing During the Experiment
The output error of the DC voltage droop controller is:

\[ e_t = K_p(P_{ref} - P) + K_v(U_{dref} - U_d) \]  (1)

Fault-level current and voltage evaluation formula:

\[ U_{dcp} = -1218e^{-3826t} + 6144e^{-82.2t} \]  (2)
\[ I_{dc} = -9320e^{-3826t} + 1010e^{-82.2t} \]  (3)

4. Experimental Data Analysis
This paper analyzes the detection model and uses simulation software on the terminal to collect different types of data packets, and the normal data packets are collected by the client.

4.1. MLR Classifier Vs. other Classifiers
The training set and test set used are shown in Table 1, and the results obtained are shown in Figure 1.

| Category | Training set | Test set |
|----------|--------------|----------|
| normal   | 5000         | 10000    |
| dos      | 1030         | 2092     |
| probe    | 1000         | 2154     |
| r21      | 1126         | 1997     |
| u2r      | 52           | 500      |

![Figure 1. Comparison results of each classifier](image)

According to Table 1 and Figure 1, it can be concluded that for the training time data, although the training time of the Bayesian classifier is much shorter than the other three classifiers, its accuracy is not High, so this classifier does not match the multi-class classification algorithm. The training time used by the logical classifier is very close to that of other classifiers, the time required is very short,
and the accuracy rate is high, which is relatively reasonable.

4.2. The Impact of Samples on Multi-class Classification Models
To verify the impact of training samples on the multi-class classification model, use the training set with the same distribution as the training data in Table 1, but the number of which is 10 times to predict and classify the multi-class logistic regression classifier and other multi-class classifiers. Experimental results as shown in Figure 2.

![test results](image)

**Figure 2.** Comparison results of each classifier of 10 times sample

According to Figure 2, it can be seen that as the number of training samples increases, the accuracy of the SVM classifier has been greatly improved, but the training time has also increased significantly. Even if the accuracy of the SVM classifier increases significantly, it does not exceed the accuracy of the multi-class logistic regression classifier. In terms of training time, due to the increase in the number of training samples, the training time of the multi-class logistic regression classifier has also increased, but the increase is much smaller than that of the SVM classifier. It can be explained that the multi-class logistic regression classifier is a very stable and accurate classification model.

5. Conclusion
Aiming at the uneven distribution of normal data and abnormal data in a large-scale smart grid, this paper combines the FSVM model and the MLR model. These two models have higher accuracy rates, and a new model is designed. The accuracy of this model is guaranteed. For the processing of offensive data, the MLR model is used to classify, and finally accurate data on the attack type is obtained. Through the experimental results, scientific research has concluded that although the sample distribution of the research is irregular and the scale is small, the accuracy of MLR is still the highest and the time used is the shortest.

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