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Research on Integrated Optimization of Distributed Distribution Network

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ABSTRACT. *In the early 1990s, there was a simple GPS-based positive-sequence voltage phase angle measuring device. In the late 1990s, PMU monitoring systems were already in operation in the field. For example, the American Electric Power Research Institute installed a number of PMUs across the United States. There are two, more than a dozen, to study the dynamic behavior of the power system under various fault conditions, and to study the real-time transmission and processing of phase angle data. In the mid-1990s, some universities and research institutes began to study phase angle measuring devices (mostly positive phase angles, uploaded once per second), and some were put into trial operation. In February 2003, the National Electric Power Dispatch and Communication Center met in Beijing and formulated the main technical specifications for the real-time dynamic monitoring system project of the power system. For the first time, Spain used PMU information for state estimation. Some grids introduce measurement results into state estimates, improving state estimation accuracy. For example, SDE Power Company of Spain cooperated with SEPSC of the United States to add phase angle measurement to the SCADA system to correct the state estimation. The experimental study was carried out under the conditions of adding 23 phase angle measurements on 100 bus bars. The results show that the estimation accuracy can be improved when the phase angle measurement error is less than 0.12 degrees, and it is not harmful when the phase angle measurement error is large.*

KEYWORDS: *distribution network; comprehensive optimization*

I. Introduction

In the process of reform, due to the continuous updating of power industry technology and the continuous expansion of power grid scale, the current power grid is becoming more and more complex, and it also poses severe challenges for the safe and stable operation of the power grid. The power system is an indispensable part of the national economic development. It is directly related to the national life and the strategic development of the national economy. Therefore, the requirements for the

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scientific management and maintenance of the power system are becoming increasingly urgent. In order to respond to the state's reform of the power grid and ensure the safe and stable operation of the power grid, the implementation of wide-area intelligent real-time analysis and control of the power grid has become the primary task of the power grid reform, making the data of the power grid more accurate, and the scheduling control is scientifically managed. Correct command and complete control of the power system.

At the same time, the smart grid should have the ability to control the large grid of self-perception, self-diagnosis, self-prevention, and self-healing. Self-diagnosis means that when the grid is faulty, it can automatically and quickly diagnose faulty equipment in the power grid, assist the dispatching operation personnel in handling faults, and prevent the fault range from further expanding.

Online fault diagnosis of power grids is a research hotspot at home and abroad. Limited by the level of scheduling automation technology, traditional online fault diagnosis is usually based on a single data source. It is difficult to achieve a good balance between correctness, real-time and comprehensiveness of the analysis results in the online fault diagnosis of the grid, so that it can not be achieved in the dispatch center. practical.

In recent years, with the widespread use of computer communication technology in the field of dispatch automation, the dispatch automation system has gradually formed an integrated data information platform, which realizes the integrated collection, storage and unification of the three-state (steady state, dynamic, transient) data of the power grid. Access provides technical support for the research and implementation of online comprehensive fault diagnosis based on three-state data.

The development of modern information technology provides a good technical platform for the popularization and application of digital protection devices and fault recorders in power grid fault analysis and diagnosis. The effectiveness of information sharing and information utilization has become an important indicator for evaluating modern grid operation technology. First, substantial progress has been made in the research and development, construction and implementation of fault information systems at home and abroad.

In China, since 1977, the theoretical study of grid state estimation has been started, and in 1980, the engineering test of grid state estimation in Beijing power system has opened up a new era of EMS in China's power grid. Later, as the core foundation of EMS, the grid state estimation technology has been continuously developed and matured along with the development of China's power system dispatching automation level. In the late 1980s, China's four major power grids (Northeast, North China, Central China, and East China) introduced EMS including grid state estimation functions. Due to the current situation, it was difficult to exert the performance of state estimation, thus making the function of EMS impossible. Get effective play. Until 1993, the EMS developed by China Electric Power Research Institute was officially put into operation in Hubei Power Grid, marking the practicalization of China's power grid state estimation technology. Subsequently, several major power grids such as Central China, North China and East China began

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the same work. In 1995, the backbone structures of major power grids such as North China, Northeast China, East China, Central China, and South China's interconnected power grids were basically formed. The interconnection of power grids in the region has become an inevitable trend of development. Under the objective conditions, the automation level of China's power system is at In the next five years, the EMS system began to mature into a practical stage. As of 2000, more than half of the province's provincial network allocations have grid state estimation applications. During the fifteenth period (2000-2005), the grid state is estimated to be a mandatory function for the national network. In recent years, most regional dispatching has basically met the requirements for the practical application of state estimation. Especially in some economically developed regions, the grid state estimation has become an important part of the county bureau dispatching automation system.

2.The status quo and development trend of research level at home and abroad

2.1. Research Status and Development Trend of Traditional Ubiquitous Terminals

1)WAMS research status and development trend

Due to the development of communication and measurement technology, wide-area measurement systems based on synchronous phasor measurement technology have been widely used in power systems at home and abroad. So far, many wide-area measurement systems (WAMS) based on synchronous phasor measurement unit (PMU) have been established at home and abroad, and research on WAMS is also increasing. The United States Western United Power System (WSCC) first adopted the wide-area measurement system, its main purpose is to use the high-precision measurement data of the WAMS terminal PMU to achieve high-precision estimation of the power grid state and carry out corresponding monitoring, control and protection in time. The voltage instability caused by dynamic interference of the system avoids the occurrence of a blackout caused by a voltage collapse. WAMS played an important role in the after-the-fact analysis of the 1996 blackout. The phasor data showed a good indication of the increase in the phase angle difference before the system was disassembled and clearly demonstrated the dynamic process of the power system before and during the blackout. , accurately guide the restoration of power supply to the power system. In order to study the low-frequency oscillation of the system, Japan deployed a PMU device in three main power plants and eight ultra-high voltage substations in the Northeast Power Grid to develop an online global dynamic monitoring system. The system uses the Internet to transmit PMU measurement data, and the oscillation frequency extracted by wavelet transform studies the dynamic characteristics of the system and the generator parameters to improve the system control effect.

With the development of WAMS, the IEEE Power System Relay Protection and Control Committee set up a committee to provide a basis for simultaneous phasor

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measurement technology and drafted the IEEE1344 standard in 1995 and revised it to IEEE Stdpc37.118-2005 in 2005. However, the standard only sets standards for the technical parameters of the steady-state characteristics, and does not set standards for the dynamic performance of the PMU.

China started the synchronous phasor measurement technology and WAMS research relatively late, but according to the document "Requirements for Strengthening the Construction and Practical Work of Wide-Phase Phasor Measurement System" (Guo Tiaoyun [2005] No. 239) and "Distribution of National Grid" The implementation rules of the company during the “Eleventh Five-Year Plan” to strengthen the opinions on power grid dispatching work (Guo Tiaoyun [2006] No. 52), currently China has owned about 20 WAMS main stations and the number of PMU configurations is also nearly 1,000 sets. Regional power grids and some provincial networks have established their own WAMS. China Electric Power Research Institute, Tsinghua University, North China Electric Power University, Hohai University and Beijing Sifang Company, Nanjing NARI Group, Xuji Group and other research institutes are mainly engaged in the research and product development of simultaneous phasor measurement technology and WAMS. For example, the PAC-2000 power system synchronous phasor measurement device developed by China Electric Power Research Institute, the SMU synchronous phasor measurement device developed by Shanghai NARI Group and the CSS-200 system developed by Sifang Jibao Automation Co., Ltd. have been put into practical use. The application of power system data acquisition and monitoring systems. In addition, these major research institutes have cooperated with various power companies and successively launched pilot applications in some regional electric power systems.

2) Research status and development trend of PMU optimization configuration

A reasonable PMU configuration should consider the following six requirements: state observability, that is, the configuration scheme can solve the current state of the system; dynamic observability, that is, the configuration scheme does not lose dynamic mode information about the power angle and voltage; Robustness, which applies to various combinations of operating modes and faults, including cascading failures; economy, that is, the number of PMUs guaranteed to be used is as small as possible; inheritance, premise that PMUs have been installed; operability, That is, the PMU placement is completed step by step according to a certain priority.

According to the starting point, the PMU configuration problem can be divided into: PMU configuration considering system observability, PMU configuration method considering improvement of state estimation accuracy, PMU configuration method considering system coherence, and PMU directly considering power flow equation Configuration method.

a.System-based coherent PMU optimization configuration method

System coherence refers to the characteristic that the difference between the rotor angle of the interconnected generator and the interconnected bus voltage

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remains constant in a certain time scale. According to this feature, to achieve complete monitoring of this group, only one PMU can be installed in a cohort. In the generator coherent PMU optimization configuration method, the homology group is classified into busbars with the same or similar voltage change dynamic trajectories. The PMU position is configured to select the bus node with the smallest voltage safety threshold among the respective groups. In the identification of generator nodes in the power grid where power angle transient instability may occur and to categorize such nodes into different homology groups, the method of extending the dominant mode of Extended Equal Area Criterion (EEAC) is used. Select a generator with a large inertia in a coherent group as the representative of the group to configure the PMU, and monitor the disturbance in the grid with fewer PMUs. Configuring the PMU to be a weaker node in the power grid is the main method for configuring the system to coherent PMU, but the observability of the system may not be realized.

b.PMU optimization configuration method based on system state estimation

The system state estimation refers to the method of estimating the internal state of the dynamic system according to the quantity of the state in the available power grid. The state quantity of the power system measured directly can only reflect a part of the characteristics of the power system, which can be called external characteristics, and the internal state of the system. Variables are usually not directly measurable by measuring available dynamic laws. In the development of technology, that is, the emergence of PMU becomes a reality for dynamic real-time measurement in the system, because the traditional SCADA system can only measure data with large delay. In the hybrid measurement system, it is necessary to consider the high-precision data obtained by linear estimation of WAMS and the inaccurate data obtained from SCADA state estimation, and the SCADA data can be extracted and synchronized with the measured PMU. The time coordinate data is called synchronous data, which forms dynamic monitoring of the power grid. Based on the wide-area dynamic real-time state estimation method of SCADA and PMU hybrid measurement, it is impossible to install PMU in multiple nodes at this stage. The wide-area measurement system is also in the pilot operation state, so the nodes that are not monitored by PMU are estimated by SCADA static estimation. The data is supplemented to achieve monitoring of the grid.

c.PMU optimization configuration method based on complete observability of system

The essence of PMU's optimal configuration problem is a discontinuous, nonlinear, high-dimensional optimization combination problem. The shoulder-sending algorithm, search algorithm and enumeration algorithm are the three main methods to solve such problems. Heuristic algorithms require different rules to deal with different problems, so they are used in a small range, but they are highly efficient. The characteristic of the search algorithm is also to use a certain rule to carry out the random search optimal solution. It has the advantages of high efficiency, fast search speed and ideal solution. The disadvantage of this type of algorithm is that when the system scale is large, it is often searched. The global

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optimal solution is to the local optimal solution. At present, many mathematicians use a combination of search algorithm and heuristic algorithm to achieve network observability, which has a good effect on the optimal configuration combination of nonlinear and complex optimized PMU. The PMU optimization configuration for the complete observability of the grid is first proposed by Baldwin. A certain number of PMUs are installed on some nodes of the power network to achieve network observability. To solve the PMU installation location, a binary search method can be used (Bisecting Search, BS). A double-choosan algorithm combined with Simulated Annealing (SA). In the application of larger scale systems, the algorithm has obvious deficiencies, and the amount of calculation will increase dramatically. Genetic Algorithm (GA) is a global optimization algorithm. The solution process is not dependent on specific problems and has been widely used in many fields. It has fewer restrictions on constraints and objective functions, and has a strong search ability. In order to meet the needs of the actual situation, solving the PMU configuration problem should have multiple feasible solutions in integer programming. An improved adaptive genetic algorithm can be used to solve the PMU optimization configuration problem. In the optimization configuration model of the observable PMU, considering the factors that add stability to the stability of the grid node, the sensitivity of the instability is preferred [1].

High nodes perform PMU configuration, but the grid must be fully observable as a prerequisite. For the PMU configuration, a two-stage configuration can be implemented: pre-processing and dynamic online processing. The PMU configuration phase is pre-processed to determine the grid nodes in the system that do not need to be configured with PMUs and the grid nodes that must be configured with PMUs. Dynamically process the PMU configuration phase, and determine the next need to configure the next grid node of the PMU; use the simulated annealing method to verify the configuration scheme. This method may not get all feasible global solutions, and the convergence speed of this method is related to the range of optimization.

d.PMU optimization configuration considering direct calculation of power flow calculation

If all nodes in the grid are equipped with PMU devices, the power system does not need to perform power flow calculations, and the voltage amplitude and phase angle of each node in the grid can be directly measured.

In the related literature [2], an algorithm combining adaptive genetic algorithm and tabu search algorithm (IAGA-TS) is proposed in the configuration of PMU. Due to the advantages of the two algorithms, IAGA-TS becomes an algorithm with global search characteristics, which not only effectively improves the computational efficiency of the optimization algorithm, but also enhances its original characteristics and proposes redundancy based on measurement. The PMU optimization configuration method of redundancy. Combined with the concept of measurement redundancy when the system is fully observable, the tabu search (TS) is utilized by analyzing the augmented matrix in the system.

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An improved binary particle swarm optimization algorithm is proposed in related literature [3]. In this paper, the shortcomings of the traditional binary particle swarm optimization algorithm are improved. The concept of probability offset factor is proposed. The probability of node installation PMU is re-set according to the number of outgoing lines in the topology of the system, and the system is configured in the system. The redundancy is analyzed, and the feasibility of the algorithm is proved by verification. The improved algorithm has better convergence performance.

In the related literature [4], the premise of complete observability and measurement redundancy is proposed. The hybrid algorithm of adaptive genetic algorithm and tabu search algorithm is used to optimize the configuration of PMU in power system. The hybrid algorithm of this paper for the global optimal algorithm, the hybrid algorithm is improved by using the elite individual retention strategy. The verification shows that the algorithm is effective and feasible.

3) Research on optimization configuration of FTU

In the 1960s and 1970s, some developed countries such as Japan have proposed the concept of distribution network automation, and at the same time have achieved different degrees of application results. Its development has probably gone through three stages: the first stage is the 60th century, and the automatic isolation of faults is realized. The second stage starts from the 1970s, and the automatic load control of feeders is carried out on the basis of automatic fault isolation. Pilot work and distribution automation pilot work, but most of the automatic control systems work independently; the third phase began in the 1980s, due to the rapid development of computers and current communication technologies, began to use computer technology to form substation local optimization control, In the event of grid failure, automatic fault location, isolation, power restoration or load transfer can greatly shorten the power outage time. By the end of the 1980s, 86.5% of the lines in Japan's national distribution network had realized feeder automation, and the Japanese distribution network feeder automation technology was very Advance. After the mid-1970s, the United States began to research feeder automation technology. With the rapid development of computer and communication technology, the development of feeder automation technology in the United States in 80 years is also very rapid. In the 1990s, its feeder automation technology level has reached the forefront of the world, which also benefits. In the United States, many high-tech companies demand for power supply reliability, the United States attaches great importance to the development of feeder automation has quickly solved the grid power failure, improve the grid's public service level to mention customer satisfaction. For example, the United States

Most of the feeder lines of LILCO (Long Island Lighting Company) are overhead lines. The bad weather often leads to short-circuit faults. Therefore, it is especially important to realize the rapid removal of faults and load transfer. In 1994, LILCO launched 120 feeders for distribution lines. The automation transformation project has built the first batch of distribution network automation system in the

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United States and reached the international leading level. Within 43 seconds, the system can complete the rapid resection of the fault and restore the normal power supply in the non-faulty area, which is very powerful. Later, the United States Progress Energy, Alabama, Edison, Southern California Edison, Texas Oncer and other companies have also begun to build distribution network automation systems. The development of distribution network automation in the London area of the United Kingdom was mainly concentrated in the five years from 1998 to 2002. The first phase of the distribution automation system for the radiation emission lines in the suburbs was completed in London. The medium-voltage distribution network automation system built in the London area has realized online monitoring of 861 medium-voltage lines in London, and the reliability of power supply for 1.8 million users has been guaranteed. After the construction of the project, more than half of the grid faults can automatically remove the faulty line and restore the normal power supply in the non-faulty area within 3 minutes. The proportion of automatic fault recovery has risen sharply, from 25% at the beginning of construction to 75%. The average power outage time of residents in the London area has decreased by 33.2%, and the application effect of distribution network automation technology is very obvious [5-6].

2.2.Research on Optimized Configuration of Distributed Power Detection

Because distributed power sources (DGs) have the advantages of low energy consumption and low pollution, and China's GDP continues to develop steadily and rapidly, and the scale of the formed power system is getting larger and larger, distributed power sources are rapidly being promoted. At the end of the 2020s, distributed power supply capacity is expected to exceed 187 million kWh, which is expected to account for 10% of total installed capacity.

Although distributed power access to the distribution network brings various benefits such as economic benefits and environmental improvement, the safe operation of the distribution system is also threatened. Due to the access of more and more random DGs, the traditional radial distribution network becomes a multi-terminal power supply network. In the traditional distribution network, the power flow calculation and protection will be interfered by the distributed power access, which will ensure the safe operation of the power grid. Bring hidden dangers.

According to the relevant industry assessment, it can be seen that more than 90% of the user side encounters power outages is caused by the failure of the distribution network. To ensure the safety and reliability of the distribution network operation, it is necessary to quickly find the fault after the line fails. Go to the fault location, then cut off the fault and restore the power supply of the non-faulty feeder in time to shorten the power outage time. Therefore, the rapid and accurate identification of the fault direction of the distribution network is of great significance for the reliable operation of the distribution network, and the access of the distributed power source may cause the traditional fault protection method to be invalid and malfunction or even no action, resulting in unstable operation of the grid. According to IEEE

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std.1547, after the distributed power supply is connected to the distribution network, when a fault occurs, the distributed power supply must be cut off, and the purpose of cutting off the distributed power supply is to reduce the distributed power supply access to the distribution network automation system. The impact of the accuracy of the fault information. Because the access of the distributed power source transforms the traditional distribution network from a radiated network to a multi-terminal power supply network interconnected by the power supply and the user, the accuracy of the current fault location identification method applied to the conventional distribution network is reduced. However, by removing the distributed power supply to cope with the failure, the utilization of the distributed power supply is reduced. Therefore, research on a fault direction identification algorithm for distribution network with DGs can effectively deal with the impact of low utilization of distributed power supply after distribution network, and it is of great significance for improving fault direction identification efficiency and sustainable development strategy.

2.3.Research on Optimized Configuration of Intelligent Distribution Terminals

At present, the rapid development of smart grids has made China's requirements for the safety and reliability of power supply increasingly high. In this context, intelligent distributed feeder automation (FA) systems have emerged. The intelligent distributed FA system refers to the information exchange, protection or timing coordination through the power distribution terminal without the control of the power distribution master station. When the distribution network fails, the system can automatically realize the positioning and isolate the fault area according to the preset conditions. The power supply is restored in the non-faulty area, and the information about the fault is reported to the power distribution main station, which improves the reliability of power supply. The intelligent distributed FA system is widely used in 10KV distribution lines because of its fault location, accurate isolation, high self-reliance, independent distribution of power stations, and ease of maintenance. However, although the intelligent distributed FA system has many advantages, it also has the following shortcomings that restrict its promotion and development: (1) The adaptability is weak. Intelligent distributed is only suitable for fixed network topology. When the system is debugged, the topology will be fixed and it is difficult to modify it. (2) The debugging workload is large, and the professional level of the debugging personnel is high. It is difficult for ordinary debugging personnel to complete. (3) The maintenance and configuration process is complicated, and the maintenance and configuration parameters are highly coupled, so that the later maintenance requires the cooperation of equipment manufacturers to achieve, which seriously reduces the work efficiency.

3. Research by foreign research institutions on this project

Due to the development of communication and measurement technology, wide-area measurement systems based on synchronous phasor measurement

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technology have been widely used in power systems at home and abroad. So far, many wide-area measurement systems (WAMS) based on synchronous phasor measurement unit (PMU) have been established at home and abroad, and research on WAMS is also increasing. The United States Western United Power System (WSCC) first adopted the wide-area measurement system, its main purpose is to use the high-precision measurement data of the WAMS terminal PMU to achieve high-precision estimation of the power grid state and carry out corresponding monitoring, control and protection in time. The voltage instability caused by dynamic interference of the system avoids the occurrence of a blackout caused by a voltage collapse. WAMS played an important role in the after-the-fact analysis of the 1996 blackout. The phasor data showed a good indication of the increase in the phase angle difference before the system was disassembled and clearly demonstrated the dynamic process of the power system before and during the blackout. , accurately guide the restoration of power supply to the power system. In order to study the low-frequency oscillation of the system, Japan deployed a PMU device in three main power plants and eight ultra-high voltage substations in the Northeast Power Grid to develop an online global dynamic monitoring system. The system uses the Internet to transmit PMU measurement data, and the oscillation frequency extracted by wavelet transform studies the dynamic characteristics of the system and the generator parameters to improve the system control effect.

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4. Research by the domestic research institutions on the project

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developed by Sifang Jibao Automation Co., Ltd. have been put into practical use. The application of power system data acquisition and monitoring systems. In addition, these major research institutes have cooperated with various power companies and successively launched pilot applications in some regional electric power systems.

The first domestic distribution automation system equipment was born in Pudong, Shanghai in 1996, which is also a historical change in domestic distribution automation. In the early days, due to the late start of research on intelligent terminals and backward technology, it was basically imported from abroad. At that time, the representative products with mature technology were DART from the United States and Talus-200FTU from France. However, with the deepening of China's research on intelligent automation and the enhancement of China's comprehensive national strength, many manufacturers in China have invested in the research and development of DTU products. According to incomplete statistics, the number of manufacturers producing power distribution terminals in the country has reached at least 50. Has accumulated a lot of mature DTU products. At present, the domestic mature technology and representative DTU products are PDZ800 from Shenzhen NARI Group and WPZD-16 from Henan Xuji Group, and these products also have relay protection, phase synchronization detection, voltage feeder automation, Bluetooth wireless. Maintenance and many other additional features.

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