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The Impact of New Energy Integration on Traditional Relay Protection Systems and Countermeasures

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Abstract: The increasing penetration of new energy into the power system is accompanied by a series of challenges that traditional relay protection systems face: fast fault detection and decreased protection action time, and decreased system stability. By taking a series of countermeasures, the paper explored the influence of new energy connection on traditional relay protection systems in response to the occurrence of the above phenomenon. These countermeasures include protection logic and settings optimization, fast fault detection technology application, adaptive protection strategy application, and enhancing communication and data processing systems. After the countermeasures were applied, the response time was improved, that is, the speed of fault detection and protection action was improved. The stability of the systems was optimized through implementing protection strategies, enhancing the dynamic response capability, and applying data analysis and intelligent technology. As new energy has impacts on the traditional relay protection system, through applying a series of countermeasures, the fault detection and protection action speed was waned, and the stability of the system was increased.

1. Introduction

As new energy technologies have rapidly developed and been applied more widely, a large quantity of renewable energy is being integrated into traditional electrical power systems. The integration of new energy presents several difficulties for the protection systems of traditional relays, because traditional relay protection systems do not consider and foresee the difficulties new energy integration may present when they are being designed. Therefore, it is imperative to address the issues.

The purpose of this paper is to explore the impact of new energy integration on the traditional relay protection system, and provide effective solutions to achieve integration. The corresponding countermeasures are taken to solve the problem of the impact of new energy integration on the traditional relay protection system, to improve the stability of the traditional relay protection system ability, so as to ensure the safe and reliable operation of the power system.

The structure of this article is as follows: the first part introduces the background and impact of new energy integration on traditional relay protection systems. The second part elaborates on the research methods adopted in this article and their significance. The third part provides a detailed introduction to countermeasures for the challenges of new energy integration and explore their impact on the performance of traditional relay protection systems. Finally, this article summarizes the research results and proposes future directions for further research.

2. Related Work

Many people have studied the introduction of new energy sources. Li Fan used an example to analyze the reliability of relay protection under new energy grid-connected conditions, comparing the relay protection with and without 5G technology, and analyzed the optimization effect of relay protection in new energy grid-connected by using 5G technology [1]. Gao Yan designs a system operation strategy based on time-by-time balancing, combines the feed-in tariff, investment and other influencing factors to put forward the system equivalent tariff calculation method, studies the impact of the new energy power proportion in the system, the installed capacity scale enhancement on the system equivalent tariff, and takes a system as an example for operation simulation, and comes up with the trend of the tariff change [2]. Jiang Zichao discusses the necessity of upgrading the traditional distribution network, and provides comprehensive solutions for upgrading the traditional distribution network through the strategies of microgrid construction and management, intelligent power management system development, and new energy forecasting and scheduling to promote the development of power system in the direction of intelligence, high efficiency, and reliability, and to contribute to the development of sustainable energy [3]. Yang Daye analyzes that reactive power configuration, dynamic reactive power source control strategy, asymmetrical fault form, fault point and fault moment, wind turbine start-up situation, wind turbine control and protection strategy in the transient process, etc. are the main influencing factors of transient overvoltage amplitude and duration in the access system [4]. Qin Wenlong combined with examples to analyze the change rule of power system equivalent inertia constant and the impact on power system frequency inertia under different new energy penetration scenarios, and proposed that the configuration of energy storage is one of the effective measures to enhance the system inertia [5]. Caineng Z O U believes that green hydrogen helps to reduce the carbon emissions [6].Yang X investigated the impact of the implementation of new energy policies on productivity [7]. Khan S A R aims to investigate the potential relationship between renewable energy and ecological sustainability [8]. Adebayo T S reveals a new perspective on the relationship between CO2 emissions and GDP growth in Japan [9]. Majid M A aims to present the significant achievements, prospects, projections, power generation as well as the challenges, investments and employment opportunities for the development of renewable energy in India [10]. This study addressed the impact of new energy access on conventional relay protection system by applying countermeasures.

3. Methods

3.1 Potential Influencing Factors

One of the potentially most troublesome and most important issues is the impact of new energy integration on traditional protective systems. In the current situation, new energy is directly connected to the traditional energy system. The development speed of wind energy and solar energy in recent years has been the fastest for both power sources. Large-scale new energy integration poses challenges in the operation and protection of the traditional power system [11]. Therefore, evaluating influence factors of traditional protective systems is very important.

The integration of new energy may also cause significant changes to the current and voltage characteristics of power systems. Due to the renewable energy sources' instability, the current and voltage of power systems may have significant fluctuations and interruptions because of such energy sources as winds and lights. This not only affects the monitoring and judgment of current and voltage in the traditional relay protection system, but also poses a threat of relay protection mis-operation and leakage. New energy integration may also apply the reverse flow phenomenon. This is because the traditionally-designed power system has a conventional way of flow, and the current usually flows in one direction, from the power plant to the load. When a multitude of new energy power generation systems are connected to the power system, due to their special operating mode, if the new energy power generation system is in operation, as there is an inversion phenomenon of the power flow (i.e., power flow from the load side to the generation side). This inversion phenomenon may result in the traditional relay protection system being unable to determine the direction of the power flow inaccurately and causing the protection system to make a mistake, leading to the accuracy and reliability of the protection system.

The penetration of renewable energy into the power systems causes variations in the system frequency and power factor because renewable energy is unsteady and has the nature of regenerative. Because of this, there may be issues in the system frequency and power factor, leading the conventional relay protection system to misjudge the changes in frequency and power factor, which in turn have a direct impact on the protection system performance and speed of response. To sum up, the natural power integration causes some voltage stability and power quality problems for the power system. For example, the natural power generation system may cause the transient voltage drops and voltage level fluctuations for the power system, and also may affects the operation of conventional relay protection systems. For example, voltage sag may cause the protection system to operate incorrectly and affect the system stability and reliability [12].

3.2 Problem Identification and Localization

For example, the voltage fluctuation problem caused by photovoltaic power systems is emphasized here. In a certain power system, the power system voltage fluctuation problem is abnormally exacerbated by the connection of a large-scale photovoltaic power generation system. The output power of the photovoltaic power generation system is affected by changes in the intensity of solar radiation and cloudiness, and its balancing influence is no longer simply on the direct-current side, or even on the user side, so that frequent voltage fluctuations at more access points can affect the operation of traditional relay protection systems. Firstly, through real-time monitoring and data analysis of the power system, it is found that after the photovoltaic power generation system is connected [13], there is a significant increase in voltage fluctuations. This issue may lead to deviations in the voltage judgment of traditional relay protection systems, thereby affecting the performance of the protection system. In order to accurately locate the problem, operational data of photovoltaic power generation systems and power systems is collected, including photovoltaic power generation power, power system voltage, load changes, etc. Table 1 shows the collected data.

The relationship between power changes and voltage fluctuations in photovoltaic power generation systems is determined through statistical analysis of data. Using power system simulation software, a power system model that includes photovoltaic power generation systems is established. By simulating the operation of the model, the voltage fluctuations are simulated after the photovoltaic power generation system is connected, further verifying the existence and degree of impact of the problem. Voltage measurement devices are installed at key nodes near the access point of the photovoltaic power generation system to monitor voltage fluctuations in real-time, and compare them with the working data of traditional relay protection systems. Through the process of identifying and locating the above problems, it is possible to clarify the impact of voltage fluctuations caused by photovoltaic power generation systems on traditional relay protection systems, and provide a basis for further measures to solve the problems [14]. To address the issue of voltage fluctuations, the control strategy of photovoltaic power generation systems is optimized, and the impact of power fluctuations on voltage is reduced by adjusting the matching of generation power and grid voltage. Stabilizer devices used in weak voltage nodes of power systems to suppress voltage fluctuations and voltage decision strategies of traditional power system protection devices shall suppress the voltage fluctuations to make more reasonable decisions. The problem of enhanced adaptability of the protection system to voltages variations following the grid connection of the photovoltaic generation system is addressed. By studying and charting the problem and its location, the impact on traditional relay protection from the access of renewable energy is assessed with precision to put forward intra-device relaying technology solutions to guarantee the whole system has safety and stability.

Table 1: Collected data

Time	Photovoltaic Generation Power (MW)	Power System Voltage (kV)	Load Variation (MW)
08:00 AM	10	220	100
09:00 AM	12	218	110
10:00 AM	11	215	95
11:00 AM	9	212	105
12:00 PM	8	210	120
01:00 PM	9	215	115
02:00 PM	11	216	90
03:00 PM	12	218	105
04:00 PM	10	220	100
05:00 PM	8	217	95

3.3 Countermeasure Design

To address the impact of the integration of new energy sources on traditional relay protection systems, a number of coping strategies should be advanced. Firstly, traditional relay protection systems need to be optimized and updated to adapt to the new energy integration, which involves corresponding changes in protection logic and the new protection devices, in order to ensure the accurate diagnosis and rapid treatment in the face of changes in faults of new energy equipment. Secondly, this study uses intelligent technologies (such as artificial intelligence and big data) to realize real-time monitoring and analysis of system operation data as well as predictive diagnosis and maintenance. Moreover, the review of new energy equipment and standardization requirements can be enhanced, which can probably lead to new energy equipment meeting the safety and stability needs of the power system. Further, by reinforcing new energy equipment's control and balance, for instance as to the power generation system [15], by operating the grid voltage match, it is possible to lessen the function of traditional relay protection systems. Finally, the efficiency of new energy technologies and integration requirements training and education for bulk power operators can be enhanced to ensure the system operates reliably and securely. By addressing the design and implementation of the above actions, it is able to correctly address new energy access's effect on traditional relay protection systems, ensuring the power system operates safely and reliably.

4. Results and Discussion

4.1 Experimental Design

Experiments are designed to evaluate the changes in the impact of new energy integration on traditional relay protection systems under the influence of countermeasures. In order to achieve this goal, it is first necessary to accurately measure and record the performance indicators of traditional relay protection systems before and after new energy integration, including the accuracy of protection component actions, fault detection and positioning accuracy, etc. By comparing the data before and after implementing the countermeasures, it can be determined whether the traditional relay protection system is affected after the integration of new energy, and understand which aspects need improvement. In the experiment, a simulation experimental environment is established to simulate a power system with photovoltaic power generation system connection, and set up the experimental group and control group. The experimental group applies the designed countermeasures for system optimization, while the control group maintains the original configuration and parameters of the traditional relay protection system. By comparing the performance differences between the experimental group and the control group, the effectiveness of the designed countermeasures can be evaluated and the degree of improvement on system performance can be determined. The fault detection accuracy, response time, and system stability are selected as evaluation indicators, and multiple experimental repetitions are conducted to obtain reliable experimental results; the comparative analysis between the experimental group and the control group is conducted to reduce errors caused by system changes or other factors.

4.2 Experimental Results

The integration of new energy may lead to changes or increases in the fault transmission path, which may increase the difficulty of fault localization. The accuracy of fault detection can reflect the accuracy of the relay protection system in locating faults, that is, determining the location and scope of the fault occurrence. Figure 1 shows the comparison results:

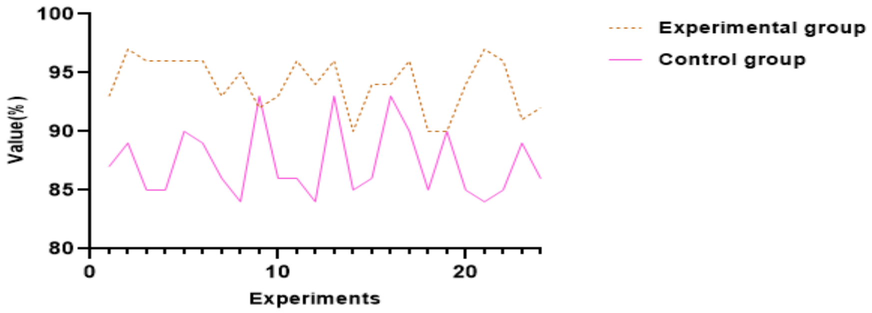

Figure 1: Fault detection accuracy

In the testing of fault detection accuracy, 24 repeated tests are conducted. The accuracy of the experimental group is 89%-97%, while the accuracy of the control group is between 84%-93%.

After the application of countermeasures, the accuracy is significantly improved. The design of countermeasures includes updating the protection logic to adapt to the characteristics and fault modes of new energy equipment. These optimized protection logics can improve the accuracy of fault detection, enabling the relay protection system to better identify and respond to faults applied by new energy equipment.

The integration of new energy may apply new types or characteristics of faults, and traditional relay protection systems need to detect faults in the shortest possible time. The response time can reflect the ability of the relay protection system to detect faults quickly, that is, the time interval from the occurrence of a fault to the detection of a fault by the relay protection system. Figure 2 shows the comparison situation:

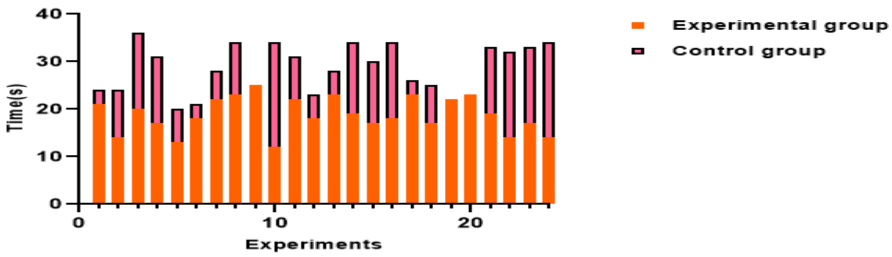

Figure 2: Response time

In the response time test, the performance of the experimental group in this article is between 12-25 seconds, while the performance of the control group is between 20-36 seconds. The response time of the experimental group is shorter, because the application of countermeasures adopt fast fault detection technology, which can quickly detect faults when they occur and trigger protection actions, thereby shortening the response time. Figure 3 shows the system stability test:

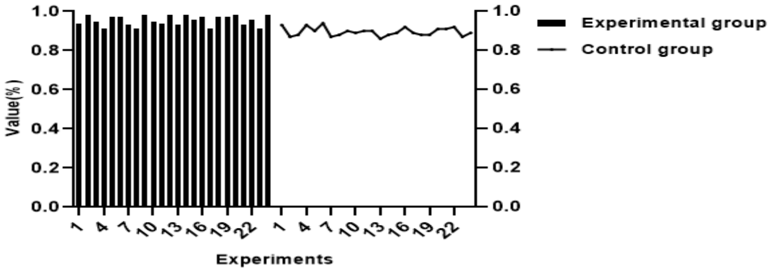

Figure 3: Stability

The stability test in Figure 3 indicates that after the application of countermeasures, the stability of the system is 91% -98%, while before the introduction of countermeasures, the stability of the system is 86%-94%, indicating that the application of countermeasures can significantly improve the stability of the system. The application of countermeasures strengthens the system's fault isolation and recovery capabilities. When a fault occurs, countermeasures can provide a faster and more accurate fault isolation and recovery plan to minimize the impact of the fault on other parts of the system and maintain the overall stability of the system.

4.3 Contribution of This Article

By optimizing protection logic and settings, adopting fast fault detection technology, applying adaptive protection strategies, and improving communication and data processing systems, response time can be shortened, and fault detection and protection action speed can be improved. At the same time, applying countermeasures can also enhance the stability of the system. By optimizing protection strategies, improving dynamic response capabilities, applying data analysis and intelligent technologies, and strengthening fault isolation and system recovery capabilities, the stability of the system can be improved.

5. Conclusions

The arrival of renewable energy has brought a great impact on the traditional relay protection. The right process can effectively solve all the problems. Relay protection for renewable energy access systems can then be solved by a specific process. Through this specific process, the performance of the relay protection system can be optimized; the response time of relay protection can be shortened; the stability of the system can be improved. At the same time, the safety of the system can be ensured, and the system reliability and protection requirements of renewable energy power generation can also be met.

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