

Application and Analysis of PMU Technology on Power System

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Abstract: The PMU-based power system operation monitoring system can be a new wide area measurement system (WAMS), or it can be built by improving the ability to upgrade the SCADA system to process PMU information. Compared to traditional SCADA systems, they can get more Grid operation information. This paper analyzes the technical characteristics of the PMU system. On this basis, it introduces the research and progress made in the monitoring and control technology of power system around PMU at home and abroad, and makes a theoretical analysis of these research results.

1. Introduction

The development of PMU (Synchronous Phasor Measurement Unit) technology is derived from the requirement of phasor measurement values based on symmetric component-based algorithms in relay protection. Since the development of the first prototype in the United States in 1988, with the development of computer, network technology and GPS technology, the performance of the PMU hardware platform has been continuously improved, the cost has been declining, and the application in the power system around the world has been continuously expanded. Based on PMU technology, the emergence of Wide Area Measurement System (WAMS) with network technology as the core has made the concept of power system protection and control leap forward. The traditional protection concept mainly refers to the relay protection of the power system. The essence is to jump off the faulty equipment or overload equipment through the action of the circuit breaker, so that the dangerous power network returns to a safe state, even if there is no fault in the network. The part can continue to function normally. Traditional control is pre-planned control, and control equipment such as on-load tap-changers and frequency-regulating devices operate under pre-set operating conditions to achieve dispatchers' expectations for current and future system operation. WAMS-based wide-area protection and emergency control protect and control the system from a higher level. Traditional relay protection can be used as an integral part of the wide-area protection system. The traditional protection acts when the system finds faulty components, and the wide-area protection is to prevent the system from voltage instability, frequency instability and other major accidents such as crashes caused by series of disturbances caused by local disturbances. It is often possible that there are no faulty components. Similarly, unlike the traditional control method, the emergency control in wide-area protection is a system adaptive control method. When the protection system finds that a system such as voltage instability may cause the system to lose stability, it is taken to prevent the load. Regulate the transformer action or increase the generator excitation to return the system to a safe operating state.

The phasor is the basic tool in AC circuit analysis. The PMU provides the system's voltage, current phasor and frequency, power and other measurements and puts GPS time stamps on these measurements. The key to phasor measurement is phase angle measurement. The key to phase angle measurement is to obtain a system-wide unified synchronous clock, which is provided by GPS. With the help of this synchronous clock, a reference phasor rotating at the power frequency is established at each plant station, and the phasor measured at the plant station is transmitted to the control center in the form of an absolute value relative to the reference phasor, and the control center obtains the data of each station. After using the reference phasor information, the relative phase relationship of each phasor measurement is obtained.

2. PMU-based fault components and fault properties identification

In the event of a single accident in the power grid, especially a line short circuit fault, if the protection action information is correct and the circuit breaker can be normally tripped, the faulty component can be aimed away to form an isolated passive network, so that the faulty component is no longer Connected to a normal power system network. Therefore, the rapid identification of faulty components can be limited to the components included in these areas of the passive network. Thus, the computational speed of searching for faulty areas can be greatly improved, especially for large-scale power networks. For multiple grid faults, the relay protection system often has a malfunction. In this case, if the short-circuiter has error information, it will be more difficult to determine the fault area, and it may not be correctly identified. In combination with the information on the electrical quantity of the PMU, it is not only possible to confirm the status information of the short circuit, but also to detect whether a certain line is faulty in the case of failure of the relay protection. For the identification of the nature of the power system fault, the phase relationship between the voltage phasor and the current phase enthalpy of the line collected by the PMU can be used to easily identify the fault nature of the system.

After the power system fails, the problem of the fault area is determined. The solution process can be as follows: it is simply regarded as a process of solving a problem, and finding a solution problem from the beginning of the solution to the result of the target. From the point of view of professional point of view, the process of solving the problem of solving the fault area is the process of finding this path from the initial state to the target state, that is, the process of solving the problem in the state space search. Since solving the problem process can be seen as solving the state space overriding process with the graph, because of the incompleteness and uncertainty of the initial conditions, there are many branches that can be used to solve the problem, and the path to solve is very large. The process can form a graph, which is the state space. In this paper, the depth-first search and breadth-first search algorithms are used to solve the state space of the power system. In the meantime, the depth-first search algorithm searches for a branch in the power system state space according to a certain search order, and then searches for another branch until the target is found. Breadth-first priority is to search for a layer-by-layer down from an initial state in the power system state space until the target is found.

The single element single fault has a higher probability of occurrence in the actual power system. If the circuit breaker and the relay protection are both correct, the fault can be easily diagnosed in this case. However, when the power system has multiple faults and is accompanied by malfunction or refusal of the circuit breaker and relay protection, the fault area includes multiple faulty components, and the fault area is enlarged due to malfunction. In the traditional system, in this case, it is usually combined with the operation dispatcher, the control experience and the fault diagnosis system to complete the fault diagnosis. However, the entire diagnostic process is laborious, and the time spent may be longer. In order to make it easier for the dispatcher to fully utilize the resources of the information in the complex power failure, we use a hierarchical diagnosis method, which can improve the efficiency and accuracy of the diagnosis. The basic idea of the fault diagnosis method of hierarchical is to divide the fault diagnosis process into two levels, namely, the fault area is quickly determined and the faulty component is identified, as shown in Figure 4.2. The main function of the first level is to determine the fault area. In this process, after the fault occurs, the information of the electrical quantity measured by the circuit breaker and the electrical quantity measured by the PMU are used to judge the possible fault area of the formed power outage. Through this layer of processing, when a single component failure occurs in the system and the circuit breaker and protection are correctly operated, the component can be directly diagnosed; if a complex fault is encountered, the process can be used to determine the fault power failure area. All possible fault elements are accurately located through the second level. The main function of the second level is to identify the faulty component. In this process, the multi-source information such as circuit breaker, relay protection and electrical quantity can be comprehensively used to diagnose the faulty component accurately and quickly, and the alarm information, protection action and circuit breaker status are correct.

3. PMU application in system stable operation monitoring

Now, the regional power grid is equipped with a SCADA system. The control center estimates the system status based on SCADA data and monitors the stable operation of the system. From the time the RTU obtains the data to the control center to obtain the system state estimation results, the time is in minutes, such data acquisition rate is unable to monitor the transient or even dynamic behavior of the system in real time; and the data obtained in this way is lacking Continuity, even for post-accident simulation analysis, is difficult to produce accurate results. The PMU transforms the state estimation work that takes a few minutes into a state measurement work that takes only a few tenths of a second. The data is large and continuous, and such data provides a good basis for real-time monitoring of the dynamic behavior of the system. It makes it possible to identify the online parameters of the system and even the online dynamic equivalent of the system. These device characteristics plus PMU data distinguishes one of the most important features of traditional RTU measurements—high-precision time synchronization—making research into a new technology for real-time monitoring of power system operations.

In order to test the dynamic recording capability and accuracy of the PMU system, several major power companies in North America jointly conducted an important field practice using the PMU to record the transient process triggered by the line switching of the cross-region system. The WAMS system records the PMU data at a data acquisition speed of less than 10 ms. The results (especially the phase angle measurement results) prove that the system state that can only be calculated by the power flow and voltage data for a long time to obtain the state estimation value can be quickly measured by the PMU. Got it. The transient process and simulation results of the PMU record are in good agreement, indicating that the PMU-based monitoring system does have the ability to perform real-time online monitoring of the dynamic behavior of the system. The experiment also proved that the PMU has sufficient measurement accuracy, and the PMU data can be used to adjust the model parameters to obtain more accurate results in the failure analysis than before. The PMU can get the phase difference between different locations in the system at any time. This feature makes it easy to monitor some system stability problems related to the power angle. Literature used FFT and wavelet analysis to analyze the dynamic phase angle difference data of PMU records installed in different locations, and identified the characteristics of system oscillations, and obtained the results consistent with the theoretical estimation. The PMU is used to measure the voltage and current positive sequence phasors of the system generator nodes and calculate the phase angle of the generator end point. The system angle center (COA) is determined by using all generator phase angles. The phase difference between the generator phase and the angle center is used to judge the coherent unit and the equivalent coherent unit, and the phase angle of the coherent unit is predicted to finally predict whether the system will lose the step.

The study of voltage stability is relatively immature compared to the problem of power angle stability. The mechanism of voltage instability has not been as clear as the power angle instability. Similarly, the development of voltage stability indicators is still in a relatively imperfect stage. Although the conclusion that voltage instability is a dynamic process has been recognized, the indicators that are applied now are static indicators, and the calculation volume is slow. The scope of application is limited. The emergence of PMU and WAMS has made people see the hope of solving problems, so many scholars have done a lot of research recently. In the published literature, the voltage stability indicators constructed by using PMU information are basically static static voltage stability indicators, because most of these indicators use the power transmission limit as the critical point of voltage stability, and the critical solution around the PV curve and the tidal current. The nature of the point is coming up. The method is basically based on impedance analysis. It mainly studies how to equip the system into the Thevenin circuit, that is, how to determine the parameters of the equivalent circuit, how to deal with the node load, and then analyze the relationship between the equivalent power supply internal resistance and the node load impedance. .

4. Conclusion

The PMU system is able to obtain more data than the traditional data acquisition system of the power system at a higher data acquisition rate, and this data also has a time scale with high synchronization accuracy. This means that the control center (the center must be equipped with WAMS or upgrade SCADA to process PMU data) can get richer real-time information, making it possible for some tasks that were previously difficult to accomplish, such as real-time online monitoring system to stabilize. More accurate and rapid monitoring of grid operating conditions, timely control response, can increase grid operation safety, compression safety margin during operation, and improve grid transmission power. These attractive features of PMU-based surveillance systems have made them the focus of attention of major companies and scholars, and deserve our attention.

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