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Overview of Analysis on State Evaluation of Relaying Protection System

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Abstract

With the rapid development of the smart grid, it is necessary to do good corresponding work in relaying protection so as to meet the overall requirements of the smart grid better. So we must focus on the state division, risk analysis and fault diagnosis methods in the relaying protection system, in the basis of fully understanding the advantages and disadvantages of relaying protection system, and then improve the problems existing of relaying protection system at this stage according to the actual situation. This paper aims at the overview of analysis on state evaluation of relaying protection systems.

Keywords

Relaying Protection System, State Evaluation, Research Overview

1. Introduction

At this stage, the construction and development of smart grid are relatively fast. But in the actual development process, the protection of the system is more complicated due to the increase of new electronic devices, which causes a greater burden on the relaying protection system. According to relevant data research, the main reason for the operation error of relaying protection device is not the principle error, but the internal setting and external circuit problems. In the past, the evaluation of relaying protection system only stayed in the action judgment, and rarely started from the online diagnosis and quantitative safety performance indicators.

2. State of Relaying Protection System

2.1. Device State

Generally, the state of relaying protection device mainly includes hardware and software states. The work of these two devices is affected by several factors such as design level, manufacturing technology, software version and electronic components, and it is also affected by factors such as operating environment and maintenance level in the process of practical application [1]. For different stages of device state, the two states of commissioning and decommissioning are usually used to distinguish. The main reason is that the structure of relaying protection device is complicated, and it is often difficult to determine the operating state of relaying protection device after entering different working modes. Therefore, when judging the operating state of relaying protection device, it is necessary to first judge its working mode and then analyze its operating state. As most of relaying protection devices are in the preparation stage for a long time, their internal structure will be extremely vulnerable to the influence of external factors, resulting in the aging of the device. Therefore, it is particularly important to judge whether the device is in the normal operation and working state. According to relevant research [2], the relevant research on circuit breakers can distinguish the six working states of relaying protection system. These six working states include judging whether relaying protection device is in normal working state, and the specific probability of the occurrence of events can be determined after calculation. According to the literature [3], there are three main situations in which relaying devices are faulty due to hardware problems: 1) when the fault occurs, the relaying protection device itself does not have any problems, and other related protection actions cannot operate normally due to the fault, 2) the hardware fault will cause the device to fail to complete the normal protection, 3) when there is no fault, the environmental protection will invalidate the protection measures of the relaying protection. As for the software fault at that time, it was mainly caused by the software configuration management problem, but the main reason of the relaying protection error was probably caused by the protection software version problem.

2.2. Circuit State

The circuit of relaying protection system includes two types: On one hand, communication circuit that can self-regulate; On the other hand, the secondary circuit can carry out the DC circuit, working power circuit and DC circuit. In this phase, the communication circuit plays a key important role in whether the relaying protection system can operate normally. According to the literature, the failure mode of communication network includes single and multiple modes. Combining the path to select the appropriate model, through analyzing the reliability of communication protection, the new concept of self-healing transmission of protection information is proposed. The composition of the secondary circuit mainly includes the relaying and the corresponding connecting device cable. The determination of the working state of this circuit needs to be completed by manual inspection and partial self-test work. In this process, there is a certain lack of intelligent diagnosis. Generally speaking, the ground state due to insulation in the actual circuit does not affect the actual secondary circuit operation, but this will cause the secondary circuit to malfunction, thus leading to the failure of the normal action protection work.

2.3. Function State of Relaying Protection System

The composition of the relaying protection system mainly includes four aspects, namely relaying operation box, secondary circuit, protector and transmitter-receiver. The digital relaying protection device is mainly composed of eight parts, including the circuit breaker, the protection part, the transmission part, the synchronization timer, the terminal part, the merged component, the switching device and the sensor. The coordination among these systems can promote the stable operation of relaying protection system. The overall operating states of these links together constitute the overall functional state of the system. According to the literature [4], in the process of judging the hidden fault, the influence between each component is analyzed, and the misoperation caused by the original is classified, and a more practical state model can be obtained.

3. Diagnostic Mode of Relaying Protection System State

Through the online diagnosis of the operation of the relaying protection system, the relevant information of its operation state can be obtained, which is the basic way to maintain the state of the relaying protection system. At present, the primary switch and secondary protection are not timely enough in information transmission, which leads to the lack of information and large amount of uploaded data. Hidden fault diagnosis for relaying protection is the most effective way to detect high-risk state in time. According to relevant literature research, through the introduction of the input of the relaying protection device into the hidden fault monitoring system, the logic module is used to compare the operation of the relaying protection with the monitoring system to know whether the relaying protection device is hidden. The fault condition can further guide the relaying monitoring system. In addition, some scholars have put forward two suggestions [5]. On the one hand, it is easier to implement hidden fault detection by digital protection system; on the other hand, it is not necessary to hide each relaying protection system. The monitoring only needs to be carried out for the system with higher risk. Many scholars at Virginia Tech have studied the hidden fault monitoring methods [6], mainly introducing three structures in the hidden fault monitoring system, namely hidden fault monitoring system, hidden fault control system and misoperation tracking database. In the process of using the monitoring module to monitor the relaying protection system, if abnormal conditions are detected, two protection methods in the control module will be started, namely isolating the abnormal system and changing the tripping logic, so as to constitute the tripping mechanism of simultaneous voting of two or more relay functional units. In addition, similarly, the relaying voting alternate tripping mechanism is introduced in the related literature. This mechanism mainly applies the monitoring module to cover all the relays in the whole substation, thus effectively improving the reliability of the monitoring system.

At this stage, with the rapid development of relaying protection system and diagnostic system, the working characteristics of relaying protection system are gradually divided into static and dynamic modes. The static mode mainly refers to the working characteristics that the protection device is not able to start, and is often used to detect the cable connection condition, the pre-processing of the circuit and the system circuit test in the relaying protection system; and the dynamic mode mainly means that the measured signal meets the protection starting condition, and it is mostly used in the detection of the setting value and the correctness of the action principle [7]. The specific steps of the online setting of the relaying device mainly include the following items: Firstly, construct the fixed value space; secondly, match the topology information in real time; finally, perform the tuning in real time. Although this method has good effects, its disadvantages are also obvious, Topology change belong to the frequent failure period, while the system can only use the traditional offline setting value during the period of incomplete real-time setting. Therefore, it is necessary to improve the real-time setting efficiency and formulate online setting strategy for improvement.

4. State Analysis and Application Overview of Relaying Protection System

4.1. Relaying Protection Risk Assessment Based on State Statistical Analysis on Relaying Protection System

With the wide use of Markov state model and fault tree model, most researchers have constructed risk assessment methods for relaying protection device; they mainly reflect the reliability of the entire relaying protection system by factors such as protection system misoperation rate, normal operation rate, availability, refusal rate, failure frequency and load loss risk. It is mainly used to analyze the basic data, including the test and operation between different modules and the constituent systems; its main sources include two types: one is to collect objective historical statistics; the other is based on the subjective and prior improvement, the historical data is used as a reference basis, and according to the actual operation at the current stage, a certain range is given for the possible value of the current data [8]. In the study of different problems, it is often necessary to solve the curve of data incompleteness; in terms of simulation, the method of neural network usually has certain problems, and Monte Carlo can effectively solve this problem.

At present, the more common methods are applied to the risk assessment by means of historical data statistics. According to the relevant literature, the model can judge the overall situation of the device according to the historical operation of the device. From the perspective of prior probability, the following steps are mainly used to judge: Firstly, it can reflect the grid structure of the grid and connected relation between the switchgear and the electrical components; secondly, according to the current failure parameters and operating parameters.

The judgment is made; finally, according to the historical protection failure data of the relevant scene, the order and scale of the device can be analyzed. According to relevant foreign research, it constructs the model of relaying protection system, which mainly adopts the idea of primary device reliability analysis. It mainly analyzes the reliability of the primary device, distinguishes the mode of the hidden fault, by extending the concept of hidden fault risk parts in each unit to the transmission line measured by length, the results obtained are more intuitive. However, the main shortcoming is the process of data processing, the malfunction rate of circuit breakers caused by hidden faults is taken as a constant. Because of the difference between line protection systems, the occurrence rate of hidden faults is actually a variable. In the related literature research [9], the traditional sampling method is used to obtain the simulation structure with higher confidence, which usually requires more samples and long time calculation. The importance sampling method can facilitate the occurrence of faults with low occurrence rate in the sample. In addition to the fault action due to hidden faults in line protection, the DC power flow algorithm can also effectively make up for the non-convergence of the Niu Lafa after three iterations. Finally, the error rate obtained by sampling method is used to evaluate the weak link of the line. As shown in the model in **Table 1**, due to different modeling methods, indicators contain different directions, but there is still a lack of perfect state evaluation model research. At the same time, a large amount of historical data also plays a very important role in the construction of the state assessment model. The incompleteness of historical data leads to the fact that most cases need to be carried out in a hypothetical way, which also makes the assessment model lack of standards for the status quo of information interface.

Table 1. Comparison of models.

Diagnosis method	Evaluation method	Indicator Used	Indicator Description	Data Sources
None	Semi-Markov process	Preventive maintenance frequency	Consider multiple outage mode	Information management system statistics
None	Markov model	Correct action rate, rejection rate, misoperation rate	Consider the effects of device self-test, online monitoring, configuration redundancy and protection misoperation	Literature hypothesis, historical statistics
Method for transforming from dynamic gate to Markov chain	Dynamic fault tree, Markov model	Accumulated failure probability, protection availability, component probability importance	Consider rejection and misoperation modes of the hardware and software	Historical statistics
None	State space model	Economic loss	Consider dual protection	Historical statistics
None	Markov model	Comprehensive misoperation rate	Consider human error	Literature hypothesis
None	Markov model	System integrity	Consider equipment reliability and functional reliability	Vendor experimental parameters, empirical statistics
None	GO method	System success probability	Considering the N-3 failure mode	Literature hypothesis
Using probability method to identify hidden dangers	Event tree model	Misoperation probability	Consider device hidden fault	Historical statistics

4.2. Safety Measures Based on State Evaluation of Protective Device

In the process of evaluating the state of the relaying protection device, if the hidden fault is diagnosed, the exit separation or function reorganization can be appropriately selected to solve the corresponding fault problem after knowing the actual fault causing device [10]. It is worth noting that for a substation like IEC61850, it not only has certain data platform functions, but also has a wide range of protection devices. If such a device system is used in actual work, it can effectively improve the device protection function. Combined with digital information sharing in the current digital substation, relevant researchers have studied the stability of digital substation relaying protection system, and proposed two ways to solve the problem of transformer failure and protection unit failure.

5. Conclusion

To sum up, with the rapid development of information technology, in order to promote the relaying protection work to obtain the good condition, the relaying protection also carries out the transformation gradually from the theory to the structure hardware, so as to adapt the present stage power system development demand unceasingly. However, according to practical experience, there are still many problems in the operation of the relaying protection system, such as the malfunction of protection actions and the emergence of refusal problems, leading to widespread power outages. Therefore, it is necessary to effectively evaluate the operating state and risks of the relaying protection system, and constantly optimize the research on the theory and technology, so as to improve the safety and stability of the relay protection system.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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