Research on Fault Location Method of Distribution Network

Xiangzhen He* 

1 School of Electrical Engineering and Electronic Information, Xihua University, Chengdu, Sichuan, 610000, China
*Corresponding author’s e-mail: 3120180806826@stu.xhu.edu.cn

Abstract. Distribution network is an important part of the power system, is the core link of power distribution, and is also the key node in the process of power grid operation. Once the distribution network fails, it is very important to determine the fault location quickly and accurately for the restoration of normal power supply. Aiming at the problem of distribution network fault location, this paper introduces the research status of distribution network fault location method in detail, introduces the existing distribution network fault location method in detail, expounds its application situation, analyzes the advantages and disadvantages of various methods in detail, so as to provide reference for the future research of distribution network fault location method.

1. Introduction
With the continuous development of social economy, social power consumption has been greatly improved, and higher requirements for power supply reliability are put forward. As an important part of the power system, distribution network is responsible for the safe and reliable power supply, and its safe and stable operation is closely related to people's life. Once the distribution network fails, it will have an adverse impact on the reliability and quality of power supply, directly affect the normal use of users, and bring many difficulties to users. It is of great significance to determine the location of the power grid fault in time, if the power supply fault can be eliminated in time. From this point of view, the research on distribution network fault location has great significance.

At present, the fault location of distribution network is divided into two categories: one is section location method and the other is range location method. The range location method evolved from the transmission network range location method. It is to calculate the position of the fault point according to the speed and time of electromagnetic wave propagation or to find the location of the fault point by using the principle of the ratio of short circuit impedance to the fault location. This method can find the approximate location of the fault, but it is simple in structure of transmission network, mostly two-point one line, which is conducive to the application of distance measurement. However, the distribution network has many branches and complex branches, and the access of distributed energy is not conducive to the application of range location method in distribution network. The section location method is to divide the feeder into several sections according to the position of the switchgear, and collect the fault information by using the communication device on the switchgear, then find out which segment the fault occurred. The range location method mainly includes impedance method, traveling wave method and S-wave injection method. The section location method mainly includes direct algorithm and indirect algorithm. Direct algorithm includes overheated arc search and matrix algorithm. Indirect algorithm is mainly based on intelligent optimization algorithm and artificial intelligence algorithm, such as expert system, genetic algorithm, binary particle swarm optimization.
algorithm, immune algorithm, differential evolution algorithm and improved ant colony algorithm. The classification of fault location method of distribution network is shown in Figure 1. Due to the shortage of range location method and the high efficiency of section location method, this paper mainly studies the related content of section location method [1-3].

2. Section location method

2.1. Direct algorithm

2.1.1. Overheated arc search
The traditional overheated arc search is a method based on graph theory knowledge. The method takes the tie switches and section switches in the distribution network topology as the vertices, and each feeder segment as the arc, and defines the power flow direction of the distribution network as the positive direction of the network. In this way, the distribution network is regarded as a directed graph, and its main feature is one in many out type. The positioning principle is as follows: assuming that each switch is equipped with a device to measure the load in and out of the switch position, the ratio of the difference between the measured load between the two switches and the load dissipated by the feeder section at the actual location multiplied by 100, and the feeder section far greater than 100 is the overheated arc, and the overheated arc is the fault feeder. Figure 2 is the node diagram of the directed distribution network [4].

![Figure 2. The node diagram of the directed distribution network](image)

The transformation formula between the end point of the arc Lab and the arc is

\[ L_{ab} = L_{aa} - L_{bb} \]  

(1)

For example, for a single source distribution network with fault shown in Fig. 3, when feeder L4 fails, the search formula of overheat arc is as follows:

\[ L_h = \frac{L_4 - L_3}{L_m} \]  

(2)

When the obtained Lh exceeds the set threshold, the line section is the overheated arc, that is, the location of the fault.
Figure 3. Single source distribution network with fault

However, the node structure is not so simple in the ordinary distribution network, and there are not only two feeders connected by a switch. Although this location method is simple and can provide fault degree information, in practical application, the method has a large amount of calculation, which is not conducive to rapid location, and requires feeder terminal unit (FTU) to provide specific current value information and direction information, which is difficult to avoid missing and false alarm of reported information. Moreover, for the distortion and false alarm information, the fault area is located at the expense of accurate fault location range, which is not conducive to the practical application of distribution network fault location.

Matrix algorithm

2.1.2. Matrix algorithm
Matrix algorithm is also based on the distribution network topology model for fault location. The basic principle of matrix algorithm is to use the distribution network topology to form a description matrix to represent the distribution network model. At the same time, a fault information matrix is formed according to the fault information detected by the distribution network detection device, and then the description matrix and fault information matrix are calculated according to certain rules. Then fault section can be obtained. The fault location process based on matrix algorithm is as follows [5]:

Firstly, it is assumed that there are FTU devices at each section switch, tie switch and circuit breaker in the distribution network, and the FTU at the node is coded with the section switch, tie switch and circuit breaker as nodes.

Secondly, the coding forms an n-order square matrix, that is, the description matrix. The elements in the square matrix represent the relationship between nodes. If two nodes are adjacent, the element is 1, if not, it is 0. For example, if node i and node j are adjacent, the elements aij and aji in the corresponding matrix are equal to 1. If node i and node j are not adjacent, the elements aij and aji in the corresponding matrix are equal to 0, and aii and ajj are equal to 1.

Thirdly, the connection relationship between each feeder section and the node is constructed, and the fault information matrix is formed according to the status information of each switch reported by FTU device at each node.

Fourth, the description matrix and fault information matrix are calculated according to certain rules, and the fault section can be obtained from the calculation results.

In reference [6], a matrix algorithm for fault location of complex distribution network with multiple power sources is proposed. The algorithm does not need the difficult matrix multiplication operation. When the number of power sources changes, the program does not need to be standardized. This method has strong adaptability to topology, simple and intuitive judgment principle and small amount of calculation. On the basis of [6], reference [7] gives solutions to the unsolved terminal faults and multiple faults in [6]. The method has the advantages of simple principle, small amount of calculation, fast speed, and can be applied online. However, there may be misjudgment in the multi power multiple fault location, because the algorithm only defines the positive direction of the network for one power source. The principle of matrix algorithm is simple and the calculation process is intuitive. It can locate the fault section well under the premise of accurate fault information. However, when the fault information is wrong, it will lead to errors in the location section, and the dependence on the accurate fault information results in its low error tolerance.
2.2. Indirect algorithm
The indirect algorithm of fault section location method in distribution network is mainly based on intelligent optimization algorithm and artificial intelligence algorithm. In recent years, due to the increasingly mature technology of distribution network automation, the research of intelligent optimization algorithm and artificial intelligence algorithm in fault section location of distribution network has also got rapid development.

2.2.1. Intelligent optimization algorithm
The principle of section location method based on intelligent optimization algorithm is as follows: the feeder terminal equipment is configured at each circuit breaker, section switch and contact switch in the distribution network; an effective communication network is established, and the status information of the switch detected by the terminal equipment is encoded and reported to the master station system through the communication network; The master station system will analyze the collected switch status information, and after processing the missing and false alarm information, start the fault section positioning program to find the fault section. In the fault section location method of distribution network based on intelligent optimization algorithm, the fault status information of each switch can be obtained effectively by relying on the distribution automation system, and then the fault feeder can be calculated through the intelligent optimization algorithm program. Figure 4 shows the principle of fault section location in distribution network.

Reference [8] proposed the fault location of distribution network based on genetic algorithm. Genetic algorithm is a mature intelligent algorithm with strong search ability and high robustness. However, the local search ability of the algorithm is poor, the late search efficiency is low, and the search time is long. Therefore, hybrid genetic algorithm is often used to improve the performance. The reference [9] proposed a distribution network fault location method based on binary particle swarm optimization (BPSO). The binary particle swarm optimization algorithm is simple and convenient, and the convergence speed is fast, but the algorithm is easy to fall into local optimization, which affects the accuracy of fault section location. In reference [10-11], the improved ant colony algorithm is used to locate fault sections in multi-source distribution network. This method improves the shortcomings of ant colony algorithm, such as large amount of calculation, low efficiency of solution and easy to fall into local optimum. However, the pheromone update mechanism is required by ant colony algorithm, and the pheromone update strategy is still in the research stage.

2.2.2. Artificial intelligence algorithm
In recent years, the field of artificial intelligence has a rapid development, and it is also widely used in all directions of power system. Compared with the simple topology of the transmission network, the structure of the distribution network is more complex, and the automation level of the distribution network needs to be further improved. For the wrong alarm information, artificial intelligence method can be very good to deal with, so it has a good application in the fault location of distribution network. For example, expert system, artificial neural network, Bayesian network and so on all belong to artificial intelligence algorithm.

Expert system is a kind of expert system knowledge base established between expert experience, protection and circuit breaker by using some rules that have been made [12]. When alarm information appears, fault section can be obtained under the inference function of expert system knowledge base.
The expert system has the following advantages: it has good performance on knowledge, good tolerance for uncertain factors, and good logical interpretation ability. In addition, it does not rely on the knowledge base of human resources to maintain the knowledge base.

Artificial neural network is a method of fault simulation. It trains the test data and fault basis according to the network parameters [13]. After many times of training, the fault characteristics are obtained and the neural network is trained. It can locate the fault section after getting the alarm information. Artificial neural network has excellent generalization, learning, fault tolerance and good applicability, which can achieve accurate section positioning. However, before application, it needs a large number of training sample data, and its model is not simple.

Bayesian network is a mathematical model that uses directed acyclic graph to express the dependence between attributes, and the joint probability distribution of attributes is expressed by conditional probability [14]. It can still achieve fault location in the case of missing alarm information, to a certain extent, alleviate the positioning failure caused by incomplete alarm information, and has high fault tolerance. However, Bayesian network also has its own defects. When the prior probability obtained is not accurate, it will lead to inaccurate fault location. Therefore, when facing multiple faults, the effect of Bayesian network is not good.

3. Conclusion
This paper mainly classifies the existing fault location methods of distribution network, summarizes the existing fault location methods. There are many researches on the fault location methods of distribution network, but each method has its limitations and can not reach the perfect degree. Scholars need to further improve the algorithm to make the method more perfect, the scope of application more extensive and the function more complete. The purpose of this paper is to provide a reference for the research of distribution network fault location method, and try to provide help for the research in related fields.

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