Research on fault location of distribution network based on Radar principle

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Abstract. When the distribution network fails, the operation and maintenance personnel need to quickly determine the fault location and minimize the scope of the inspection line so that the fault repair personnel can accurately reach the vicinity of the fault point to carry out work. Whether the fault location method is advanced and reliable directly affects the power failure time of the power supply user, and further affects the social, economic, and life aspects. Therefore, the fault location of the distribution network needs to satisfy both reliability and accuracy. It is the basis and premise for troubleshooting, isolating and restoring the power supply. The automation level of China's distribution network is relatively backward, and the reliability of power supply equipment is relatively low, making it difficult to find fault points. If we find out the intelligent algorithms that can meet the requirements of rapid positioning, accuracy and fault tolerance through theoretical research, we can improve the fault location efficiency very well.

1. Introduction
Whether the fault location of the distribution network can satisfy the rapidity, accuracy and fault tolerance directly affects the reliability, continuity, and security of the user's power supply [1-3]. The existing distribution network fault location methods mainly include the following three categories: one is to use the 95598 complaint telephone dialed by the user when a power failure occurs to determine the fault point; the other is to use the action signals of the recloser and the segmenter to perform fault location; The Supervisory Control And Data Acquisition (SCADA) system is used to analyze and process the overcurrent information uploaded by the Feeder Terminal Unit (FTU) to locate faults [4-7].

2. Fault location of non-measurement control area in distribution network based on fuzzy information fusion
In the non-measurement control area, a small number of demarcation switches or fault indicators are often installed at the load switch in the distribution network main line and some important branch lines. When the fault occurs, the switch can be automatically opened and the alarm information is uploaded to the main station system. Based on this, this chapter first introduces the basic principle of fuzzy set theory. For the non-measurement and control area of the distribution network where the user's electricity data has been collected, the fuzzy integrated telephone complaint information and the alarm information uploaded by a small number of devices in the actual running line (including the demarcation switch information) are
proposed. And fault indicator information, etc.) to locate the fault, use the alarm information to improve the fault weight of the branch line where the alarm device is located, to reduce the uncertainty of the telephone complaint information, and then modify the fault location result by defining the evaluation parameters, thereby reducing the multi-node The misjudgment problem under the fault improves the fault tolerance of fault location.

2.1. Fuzzy set geometric description
There is a certain difference between the fuzzy set and the concept definition of the ordinary set. Here, the fuzzy set is A, and the feature function which takes one in the \([0,1]\) interval is the membership function, which is recorded as \(\mu_A(x)\)The fuzzy set is specifically defined as follows:

\[
\mu_A: U \rightarrow [0,1] \\
\mu_A: x \rightarrow \mu_A(x) \tag{2}
\]

In equations (1) and (2), the fuzzy set A is represented by a real-valued function on the universe U. For \(x \in U\), the function \(A\) is called the membership function of the fuzzy set A, and the function value \(\mu_A(x)\) is the membership degree of the variable x for the fuzzy set A. The value range of \(A(x)\) is \([0,1]\). When \(\mu_A(x)\) approaches 1, it means that the membership of variable x is higher for set A; otherwise, the more representative of variable x for set A low. A value of \(\mu_A(x)\) of 0.5 indicates that the variable x has the most ambiguity for the membership of the set A, or the variable x is called the fuzzy transition point of the set A. The essence of a fuzzy set is a generalized subset of a classical set. Since there is no precise boundary, it is necessary to use a membership function to represent the smoothing process from affiliation to non-dependent.

2.2. Fault location algorithm
Aiming at the telephone complaint information in the non-measurement and control area of the distribution network and the small amount of equipment alarm information existing in the actual operation line, the fuzzy information fusion algorithm can make full use of the collectible information in the line for fault location. For the determined distribution network topology, the power supply path between each power supply station area and the bus line is first represented by an array. Based on the power flow direction, the array equipment is hierarchically classified according to the number of alarm information in different power supply links. Different alarm information in the power supply link defines the membership function to determine the fault membership degree of the equipment and then fuses the fault complaint telephone information to calculate the fault membership degree of the power supply link. Finally, the fault location result is obtained through fuzzy fault evaluation, thereby improving the fault location. Fault tolerance and shortened fault location time.

Through the above classification method, the fuzzy information of the fusion device and the fault complaint telephone information are blurred, and the fault weight of the complaint telephone in the power supply link is adjusted according to the maximum number of alarm information of different equipment sections in the power supply link, and the maximum number of alarm information is increased. More, the less the weight of the fault complaint call, the shorter the time required for fault location. Therefore, the method can adopt different strategies to determine the fault weights of different branch lines of the non-measurement control area of the distribution network that cannot collect user meter information and has wide applicability in the continuous popularization of smart meters and further upgrading of the collection equipment. In the background, in some non-measurement and control areas of the distribution network, relying on the two-way communication system, the power enterprise can also obtain various power values of the user through the smart meter in time or in real time. Based on this, for a given distribution network topology, in the non-measurement and control area of the distribution network where the user meter
information has been collected, the user's smart meter information, user telephone complaint information and equipment alarm information are used as the condition attributes of the fault classification to establish a fault. Make a decision table and find the minimum reduction. Then, according to the three types of information, attribute matching is performed on the reduced fault decision table to determine the fault section. Since the user meter collection information and the device alarm information are used as the fault information source, the number of complaint telephones required for fault location is greatly reduced, and the fault location time is shortened.

3. Fault location of non-measurement and control area in distribution network based on rough set theory and data fusion

Under the background of the continuous popularization of smart meters and the further upgrade of collection equipment, in the non-measurement and control area of the distribution network, relying on the two-way communication system, the power enterprise can also obtain the user's various power values through the smart meter in time or in real time. Based on this, this chapter first introduces the basic principle of rough set theory. For a given distribution network topology, in the non-measurement and control area of the distribution network where the user meter information has been collected, the user's smart meter information, user telephone complaint information and the device alarm information is used as a condition attribute of the fault classification to establish a fault decision table and find a minimum reduction. Then, according to the three types of information, attribute matching is performed on the reduced fault decision table to determine the fault section. Since the user meter collection information and the device alarm information are used as the fault information source, the number of complaint telephones required for fault location is greatly reduced, and the fault location time is shortened.

3.1 Fault location step

The implementation of fault location includes the following two steps:

Step 1: Determine the maximum power outage range When the distribution network fails, the power supply department receives the complaint call from a power outage user, determines the user's station area, and then selectively calls the user's power level data of the station area. According to different call results, the fault range can be preliminarily determined: if the power data of the user's smart meter in the same floor of the user is normal, it can be determined that only the user's internal power supply fault occurs, and the maximum power outage range is a single user; The smart meter data of the floor of the user, and the recall data of other floors is normal, it can be determined that the power failure occurs on the floor, the maximum power outage range is a single floor; if the smart meter data of the building where the user is located cannot be recalled, and other buildings If the recall data of the building is normal, it can be determined that there is a power failure in the building. The maximum power outage is a single building; if all the smart meter data in the station cannot be recalled, it means that all power supply abnormalities in the station need to be combined with other The user's electricity data and user complaint information in the station area, and the fault alarm and the device alarm information uploaded by the demarcation switch are integrated for comprehensive analysis. If the smart meter and smart interactive terminal are not installed in the station, the user's power data of other stations will be directly called.

Step 2: Fault location based on rough set theory and camping data fusion

If the maximum power outage range is obtained by calling the user's power data to a single user, floor, building or internal area, the fault range of the low voltage side can be directly determined. Otherwise, the smart meter of the entire distribution line will be collected and matched with the fault decision table after reduction. If the corresponding decision rule can be found in the decision table according to the power data of the user of the station, the fault occurs in the section where the faulty device is located. If the corresponding decision rule cannot be found in the decision table by the user power data, it is necessary to
continue to wait for the user complaint calls of other stations until the corresponding decision rule is found. This chapter combines device alarm information, user power recall information and telephone complaint information. Based on the rough set theory, the fault location decision table is generated according to the situation of all possible faulty devices in the line, and the user power consumption is eliminated by reducing the decision table. The redundancy of the measurement information and the telephone complaint information enables the fault section to be judged based on less user power information and telephone complaint information, which effectively shortens the fault location time and lays a good foundation for fault elimination and power restoration.

4. Fault location based on universal gravitation search algorithm for measurement and control area

The Gravitational Search Algorithm (GSA) is a group intelligence optimization method developed by Professor Esmat Rashedi and based on the gravitational law of gravity and mass interaction between different particles in the physics discipline. The algorithm first calculates its own mass according to the fitness value of the population particles and then generates the interaction force of the population particles based on the law of universal gravitation. Each particle is attracted by other particles, and each attracted particle moves under the gravitational force of other particles. The best position to get the best results. Because the fault location problem of distribution network is an optimization problem with 0 and 1 constraints, this paper applies the improved universal gravitation search algorithm to the problem of fault location in distribution network, avoiding the traditional continuous optimization algorithm. Various problems that arise during discrete data processing to shorten the positioning time and improve the efficiency of positioning.

The attribute characteristics of the universal gravitation search algorithm are partially similar to the particle swarm optimization algorithm. Each individual in the gravitational search algorithm has its corresponding spatial position and movement speed. The quality of different individuals can be obtained by the degree of fitness value corresponding to the spatial position of the individual. The corresponding fitness of the individual with higher individual quality. The value is better, and the individual's quality is smaller, and the corresponding fitness value is worse. The gravitational search algorithm is significantly different from the particle swarm optimization algorithm and the bee colony algorithm. It is mainly reflected in the fact that the particles in the gravitational search algorithm do not need to perceive the situation in the environment through external factors but through the gravitational interaction between individuals. To pass optimization information. Suppose there are N particles in a D-dimensional search space, and the position of the i-th particle is:

\[
X_n = (x_{n1}, x_{n2}, \ldots, x_{nD}); \quad n = 1, 2, \ldots, N
\]

where \(x_{ni}\) represents the position of the n-th particle in the i-th dimension.

A. Fault Location Algorithm

The universal gravitation search algorithm is applied to the fault location of the distribution network. Firstly, the fault segment vector is regarded as the solution to the optimization function. By establishing a uniform function model, the model is sampled and calculated in turn, and the optimal fault segment vector is gradually improved. The probability in space, and finally the solution that obtains the optimal value of the objective function is the fault segment. In principle, the fault location problem of distribution network is an optimization problem with 0 and 1 constraints. In the process of searching for faulty segments, it is necessary to find the fault section that best meets the given conditions of the algorithm. Therefore, after establishing the switching function and the evaluation function according to the network topology, the final result is that a reliable algorithm is needed to find the optimal fault section. When the circuit breaker fault information sequence is uploaded, the fault section can be located. In the early stage, the universal gravitation search algorithm optimizes the
gravitational effect of the population by multiple action particles in the global scope. With the passage of
time (the number of iterations), the gravitational constant G index decreases, and the population's
gravitational effect due to the decreasing effect of the particles Aggregate into the neighborhood space of
the optimal solution and search within the local scope to find the optimal solution. Therefore, applying the
universal gravitation search algorithm to the fault location of the distribution network can ensure the
accuracy and rapidity of the positioning results.
In order to further test the effect of the universal gravitation search algorithm in the fault location process
of distribution network, the same fault of IEEE-33 node distribution network is repeatedly run 60 times by
genetic algorithm, bee colony algorithm and universal gravitation search algorithm respectively. For
example, as shown in Table 1.

Table 1. Comparison of three algorithms for fault location simulation results.

| Algorithm type         | Genetic algorithm | Bee colony algorithm | Universal gravitation search algorithm |
|------------------------|-------------------|----------------------|---------------------------------------|
| Average number of iterations | 53.6              | 41.8                 | 23.9                                  |
| Result number of false positives | 42                | 26                   | 8                                     |

Figure 1 shows the convergence curve of the gravitational search algorithm and the genetic algorithm and
the bee colony algorithm under the same fault condition. The abscissa is the number of iterations and the
ordinate is the optimal evaluation value of the corresponding iterations.

5. Conclusion
With the large investment of the grid company in the construction of the cooperative management and
control platform and the improvement of the electricity information collection system, the urban area
(including the county) in the non-measurement and control area of the distribution network and some
power supply areas in the township will be able to collect the user's electricity information. The method
of fuzzy fusion fault complaint telephone information and a small amount of equipment alarm
information is used to locate the fault. First, the power supply link is hierarchically based on the maximum
number of alarm information, and the membership function based on the hierarchical model of the power
distribution network is defined by combining two different fault information. The device alarm information is used to improve the fault weight of the branch line where the alarm device is located, and then the evaluation parameter is defined according to the source of the complaint, and the fault location result is corrected, thereby reducing the uncertainty of the telephone complaint information and improving the rapidity of the fault location. Fault tolerance. In the non-measurement and control area of the distribution network that has collected the user's electricity information, based on the rough set theory and the data fusion method, the user's electricity information is taken as one of the fault information, supplemented by the user's telephone complaint information and equipment alarm information for fault location, and the minimum is found. Degenerate fault matching. Priority is given to the user's power information, supplemented by telephone complaint information, which greatly reduces the number of complaint calls required for fault location, further shortens the fault location time, and reduces the subjective factors of fault information. The universal gravitation search algorithm is applied to the reliability and accuracy of fault location in the distribution network and overcomes the shortcomings of common optimization algorithms such as genetic algorithm and bee colony algorithm which are easy to fall into local extremum and slow convergence.

6. References

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