Fault Location of Distribution Internet of Things in Electricity Using Ant Colony Optimization Algorithm

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Abstract. To improve the accuracy of fault location for distribution Internet of Things in electricity based on feeder terminal units (FTUs), the ant colony optimization algorithm is used. The basic principle of fault location for distribution Internet of Things in electricity and the ant colony optimization algorithm is introduced, and the programs of fault location for distribution Internet of Things in electricity based on the improved unified matrix algorithm and the ant colony optimization algorithm are written. They are used to locate fault for distribution network with dual power supply. The results reveal that if all FTUs contain correct information, the unified matrix algorithm and the ant colony optimization algorithm can accurately locate fault. If some FTUs contain false information, the improved unified matrix algorithm may get the wrong results. However, the ant colony optimization algorithm can obtain accurate result when only small quantities of FTU information are false. The computation time of the ant colony optimization algorithm is much longer than that of the improved unified matrix algorithm. The ant colony optimization algorithm is more suitable for the case in which FTU information is easily false.

1. Introduction
Overcurrent faults such as ground fault will inevitably occur during the operation of the distribution Internet of Things in electricity. Accurate and timely location of fault feeder sections is of great value for ensuring the normal operation of the power system and improving the reliability of power supply [1]. The feeder terminal units (FTUs) contain switch overcurrent information from which the fault feeder sections can be located [2]. The unified matrix algorithm and the improved ones [3-5] locates faults according to network structure and switch overcurrent information on FTUs. It is a seemingly simple way. However, the switch information on FTUs is easily contains errors, and the algorithm is prone to obtain wrong results at this time. Many artificial intelligence algorithms are used to locate fault for distribution networks [6-8]. Of these, the ant colony optimization algorithm [9-10] has great fault-tolerant ability and has been used in fault location of distribution network. However, the strengths and weaknesses of the ant colony optimization algorithm and the unified matrix algorithm have not been systematically compared.

In order to fix the problem, in this work, the distribution network fault location programs based on the improved unified matrix algorithm and the ant colony optimization algorithm [11] are written. They are used to locate fault for double power supply distribution network when FTUs contain false information or not. From the aspects of computation time, location accuracy and fault-tolerant ability,
the two algorithms are systematically compared. This work provides a reference for the selection of algorithm for distribution Internet of Things in electricity fault location.

2. Distribution network fault location and ant colony optimization algorithm

2.1. Improved unified matrix algorithm

When the fault occurs in the feeder section, there will be an overcurrent on some switches. The fault feeder section can be located according to the overcurrent information about the switches. The unified matrix algorithm mainly uses the distribution network structure to construct the network information matrix, and then constructs the fault information matrix according to the overcurrent state on the switches, and obtains the fault judgment matrix according to Eq. (1).

\[ P = g(DG) \]  

where \( D \), \( G \) and \( P \) are network information matrix, fault information matrix and fault judgment matrix respectively. \( g(P) \) represents the normalized operation on matrix \( P \). The fault feeder section can be located according to \( P \). More details about the algorithm can be found in Ref. [3].

The unified matrix algorithm is easy to implement, but it can't locate the fault when the fault occurs at the end of radiation-shape feeder or tree-shape feeder. In order to solve this problem, Ref. [11] proposes an improved unified matrix algorithm, which artificially adds a virtual switch to the end of the distribution network.

2.2. Ant colony optimization algorithm

The ant colony optimization algorithm is a kind of artificial intelligence algorithm which inspired by the behavior of natural ant colony [12]. Each ant in a colony will release pheromone when they are finding food. Artificial 'ants' can locate the optimal solutions with the help of pheromone-based communication.

Firstly, an ant colony is generated, and each ant is corresponding to a potential fault location solution. The fitness of each ant can be calculated by Eq. (2).

\[ F(I) = \sum_{n=1}^{N} | s_n - s'_n (I) | + \omega \sum_{q=1}^{Q} i_q \]  

where \( I \) is the array of feeder sections state; \( F(I) \) is the fitness corresponding to \( I \); \( N \) is the number of switches in the distribution network; \( s_n \) is the known state of the \( n^{th} \) switch; \( s'_n (I) \) is the state of the \( n^{th} \) switch corresponding to \( I \); \( \omega \) is the weight coefficient for the minimum fault sections set, and it is generally set to 0.5; \( Q \) is the number of feeder sections; \( i_q \) is the state of the \( q^{th} \) feeder section.

The corresponding pheromone of each ant is calculated according to the fitness, and the corresponding solution of ant population is changed according to the pheromone and heuristic quantity. In order to prevent premature falling into the local minimum, it is necessary to generate a second generation population of solutions through mutation. Repeat the above steps, and when the fitness tends to the minimum, the fault can be located.

3. Comparisons of two algorithms

3.1. All FTUs with correct information

Distribution network with dual power supply as shown in Figure 1 is used to represent a distribution Internet of Things in electricity. The state of switch overcurrent on FTUs is shown in Table 1, where 0 represents normal and 1 represents overcurrent. Obviously, the 4\( ^{th} \) and 5\( ^{th} \) feeder sections have a fault, while other feeder sections are normal. The improved unified matrix algorithm [11] is used to locate the feeder section fault and the results are presented in Table 2, where 0 represents normal and 1
represents a fault. Obviously, in the case of no false information in FTUs, the improved unified matrix algorithm can accurately locate distribution Internet of Things in electricity faults. At the same time, the ant colony optimization algorithm is also used to locate the distribution network fault. The parameters of the ant colony optimization algorithm are as follows: the information weight is set to 2, the heuristic weight is set to 2, pheromone evaporation coefficient is set to 0.2, the maximum number of iterations varies within the range of 1 to 10, the number of ant is set to 30, and the mutation probability is set to 0.4. In order to better reflect the algorithm performance, the ant colony optimization algorithm is run 100 times for each set of parameters above. The relationship between the mean computation time, the mean fitness, the mean number of misjudged sections, the mean misjudgment rate and the number of iterations is displayed in Figure 2.

![Figure 1. Distribution network with dual power supply.](image)

| No. of switch | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------------|---|---|---|---|---|---|---|---|---|----|
| State         | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0  |

**Table 1.** State of switches, all FTUs with correct information.

| No. of feeder section | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----------------------|---|---|---|---|---|---|---|---|---|----|
| State                 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0  |

**Table 2.** Fault location of improved unified matrix algorithm, all FTUs with correct information.

![Figure 2. Relationship between mean computation time, fitness, number of misjudgment sections and misjudgment rate](image)

**Figure 2.** Relationship between mean computation time, fitness, number of misjudgment sections and misjudgment rate when all FTUs information is correct.

As can be seen from Figure 2, all the mean fitness, number of misjudged sections and misjudgment rate of the ant colony optimization algorithm decrease with the number of iterations. When the number of iterations is 10, the fault location by the ant colony optimization algorithm is exactly right. In addition, the computation time of the ant colony optimization algorithm is proportional to the number of iterations.
The mean computation time of the improved unified matrix algorithm and the ant colony optimization algorithm with an iteration number of 10 for fault location is 69.71μs and 0.34s, respectively. That is to say, the computational burden of the improved matrix algorithm is much less than that of the ant colony optimization algorithm. Obviously, when there is no false information about switch overcurrent state, the fault location accuracy of the improved unified matrix algorithm and the ant colony optimization algorithm with enough iterations is 100%.

3.2. Some FTUs with false information

The object of study is the same as that in Section 3.1. The state of switch overcurrent is shown in Table 3. It is obvious that the FTUs on the first and 6th switches have false information. The most correct result is that the third and 8th feeder sections have a fault. The fault location results using the improved unified matrix algorithm are shown in Table 4. The number of misjudgment sections and the misjudgment rate are 2 and 100%, respectively. The ant colony optimization algorithm is also used for fault location of the above distribution network, and the maximum number of iterations varies from 1 to 40. The other parameters are consistent with those in Section 3.1. The relationship between the mean computation time, the mean fitness, the mean number of misjudged sections, the mean misjudgment rate and the number of iterations is shown in Figure 3.

Table 3. State of switches, some FTUs with false information.

| No. of switch | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--------------|---|---|---|---|---|---|---|---|---|----|
| State        | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1  |

Table 4. Fault location of improved unified matrix algorithm, some FTUs with false information.

| No. of feeder section | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----------------------|---|---|---|---|---|---|---|---|---|----|
| State                 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0  |

Figure 3. Relationship between mean computation time, fitness, number of misjudged sections and misjudgment rate with number of iterations when some FTUs contain false information.

Figure 3 shows that, similar to Section 3.1, all the mean fitness, number of misjudged sections and misjudgment rate of the ant colony optimization algorithm decrease with the number of iterations. When the number of iterations is 29, the mean number of misjudged sections and the mean misjudgment rate are 0 and 0%, respectively. At the same time, these values remain unchanged with the increase of number of iterations. In addition, the computation time is also proportional to the iteration number.

The mean computation time of the improved unified matrix algorithm and the ant colony optimization algorithm with an iteration number of 40 is 81.82μs and 1.32s.
4. Conclusion
In this work, the fault location of distribution Internet of Things in electricity is studied, and the improved unified matrix algorithm and the ant colony optimization algorithm are applied to the fault location for dual power supply distribution network. The results show that the ant colony optimization algorithm can accurately locate the distribution network faults under enough iterations regardless of whether the FTUs contain false information or not, while the improved unified matrix algorithm is prone to obtain wrong location results when FTUs contain false information. The computation time of the ant colony optimization algorithm is much longer than that of the improved unified matrix algorithm. The ant colony optimization algorithm is more suitable for the case in which FTU information is easily false.

Acknowledgments
This work was financially supported by the Research Project of the Jiangsu Frontier Electric Technology Co., Ltd. under Grant KJ201917.

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